POPULATION DYNAMICS, INTENSITY OF DAMAGE AND MANAGEMENT OF THE COREID BUG, *PARADASYNUS ROSTRATUS* DIST.

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DEDICATED

TO

MY FAMILY

DECLARATION

I hereby declare that this thesis entitled **'Population dynamics, intensity of damage and management of the coreid bug, *Paradasynus rostratus* Dist.'** is a bona fide 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 **'Population dynamics, intensity of damage and management of the coreid bug, *Paradasynus rostratus* Dist.'** is a record of research work done independently by Ambily Paul (2002-21-08) 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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AP

Ambily Paul

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INTRODUCTION

1. INTRODUCTION

The Green revolution ushered a sea change in the philosophy of agriculture in India. The 'begging bowl' status was transferred to that of 'self sufficiency' in food grain production. In due course, the focus shifted to horticulture, which has immense potential in crop diversification, employment generation and foreign exchange earning. During the tenth five year plan, several new initiatives were taken up to achieve a targeted production of 265 million tonnes of horticultural produce. Among the various horticultural crops grown in India, coconut (*Cocos nucifera* L.) occupies an important place.

Coconut is a versatile crop grown in about 93 countries over an area of about 12 million hectares. In India, the palm is raised in 1.89 million hectares distributed in 18 states and three union territories with an annual production of nearly 13,000 million nuts (Apshara, 2005). It provides livelihood to about one crore farm families and about 15,000 families depend on coir based industries.

In Kerala, coconut or 'Kalpavriksha' has often been eulogized as the symbol of prosperity. The crop is interwoven with the ethos and heritage of the people of the state. In Kerala, the crop occupies an area of 0.90 million ha with an annual production of 5484 million nuts (Parthasarathy *et al.*, 2006). However, the productivity of the coconut palm of about 6052 coconuts per ha is low and far below the potential. One of the major reasons attributed to low productivity is the infestation by pests and disease causing organisms.

The coconut palm is prone to infestation by a large number of insects like coccids, diaspidids, pseudococcids, tingids, coreids, thrips, lepidopterans, coleopterans etc and non-insect pests like mites, rodents etc. The control measures currently adopted against these pests are inadequate and improper. The distribution of the palms in the small farms and homesteads compounds the problem of effective and comprehensive plant protection. Of late, the coreid bug has gained notoriety as a major pest of coconut in Kerala. The coreid bug was first observed on coconut in Krishnapuram, Alappuzha district of Kerala in 1959 (Kurian *et al.,* 1972). Later the pest was identified and confirmed as *P. rostratus* (Kurian *et al.,* 1976 and 1979).

The adults and nymphs of the bug feed on the buttons resulting in immature nutfall. They suck the sap from the immature buttons by thrusting the long needle like mouth part just below the perianth which develops necrotic lesions. Later, permanent deep furrows with gummosis are observed on the nut. In case of severe infestation, endosperm fails to develop and rots resulting in complete loss of copra. The damage caused by *P. rostratus* is similar to those caused by *Amblypelta* sp. in the Solomon Islands, South China and Australia and *Pseudotheraptus wayi* Brown in Zanzibar and East Africa in coconut.

The distribution of the coreid bug in Kerala and its intensity of damage on coconut was studied in the eighties by Visalakshi *et al.* (1989). However, information on the extent of damage by the bug in the present decade is lacking. The damage and yield loss especially of copra and coir caused by the coreid bug on coconut in the present scenario has to be understood.

Alternate hosts are known to exert a positive influence on the population dynamics of coreid bug. This assumes significance in a state like Kerala, a land of smallholdings where in the land use system is concentrated around the farm homes. This unique system has evolved as a result of generations of experience and experimentation in response to a plethora of ecological and socio economic pressures. The homestead farms have an array of crops with mainly coconut as the base crop, other perennial trees and seasonal crops. This conglomeration of crops thrive on a minimum or no use of agrochemicals and enhance bio - diversity (Regeena *et al.*, 2004). The very bio diversity which contributes to sustainability creates a congenial ecological niche for a highly polyphagous pest like the coreid bug. A precise study is required to establish the status of alternate hosts in relation to the damage caused by the pest on coconut. This could be the cornerstone for the development of methodologies for the management of the coreid bug in the homestead farming systems of Kerala.

Association between varietal characters and level of coreid bug infestation has been reported (Vanderplank, 1958). However, more insight is needed on the biochemical changes due to the feeding of coreid bug. At times, nuts with different degrees of coreid bug infestation are used as seed nuts. More information on whether the quality of the seedlings has been compromised would be of use in seed nut selection. The control measures currently adopted against the bug includes spraying of endosulfan and carbaryl, are inadequate. Moreover, the damage caused by the pest is often ignored, considering the cost and difficulties involved in applying the insecticides on the coconut palm. The present study was envisaged to address the above issues, which would be of high value for integrated management of the coreid bug on coconut and alternate hosts. Research was undertaken with the following objectives.

1. To assess the extent of damage caused by the coreid bug, *P.rostratus* in Thiruvananthapuram district.
2. To study the influence of alternate hosts on the population dynamics of the coreid bug, *P.rostratus.*
3. To determine the yield loss in coconut due to coreid bug infestation.
4. To study the changes in biochemical constituents of young buttons of coconut due to the infestation of coreid bug.
5. To identify the effective botanicals and chemicals for managing the pest.
6. To evolve an eco-friendly management strategy for the pest.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Eventhough coconut enjoys a prime position as a plantation crop in the country, it is subjected to the vagaries of nature and outbreaks of pests and diseases. Of late, the coreid bug, *Paradasynus rostratus* Dist. has gained notoriety as a major pest of coconut in Kerala. Three genera belonging to the family-Coreidae *viz.*, *Amblypelta* spp. of northern Australia and Solomon Islands, *Pseudotheraptus* spp. of East Africa and Zanzibar Islands and *Paradasynus* sp. have already become infamous as destructive pests of coconut throughout the coconut belts of the world. The type of injury caused by these bugs is identical though they are geographically isolated from one another and systematically distinct. Literature on *P.rostratus* is meagre. Hence, an attempt has been made to review the available literature on the biology, yield loss, population dynamics, influence of alternate hosts and management of coreid bugs on coconut across the world.

2.1 OCCURRENCE AND DISTRIBUTION OF COREID BUGS AND THEIR NATURAL ENEMIES

2.1.1 *Paradasynus rostratus* Dist.

The coreid bug was first collected from Bombay and identified as *Pendulinus rostratus* Dist. Later, it was placed under a new genus *Paradasynus* raised by China (1934). In Kerala, the bug was first observed on coconut in Alappuzha district in 1959 (Kurian *et al.*, 1972). Later the pest was identified and confirmed as *Paradasynus rostratus* Dist. (Kurian *et al.*, 1976). It was reported to be present on coconut in all parts of Kerala along the West Coast and Thirthalli in Karnataka and neighbouring parts of Tamil Nadu (Kurian *et al.*, 1979).

Surveys conducted in Kerala showed that the pest was not restricted to the coastal belt but also reported in high intensity in all the agroclimatic zones of the state. The incidence of coreid bug showed wide variation with the percentage of infested palms being highest in Wyanad district (23.48) followed by Kasaragod and Thiruvananthapuram (Visalakshi *et al.*, 1989). The report from Bombay indicated the possibility of this pest occurring towards North at least along the coastal belt (Mohandas and Remamony, 1993).

2.1.2 *Amblypelta* spp.

In tropical and subtropical tree crops, *Amblypelta* spp. were important and they were distributed widely in the Solomon Islands (Lever, 1935) and in the Western Pacific region including Northern and Eastern Australia (Brown, 1958a; Donaldson, 1983; Ghouri, 1984; Peng *et al.*, 2002).

Amblypelta cocophaga China was first noticed by Lever, who mentioned that an 'undetermined species of *Dasynus*' did considerable injury to the young nuts before the protrusion of the stigma and the male flowers which dropped (Phillips, 1940). *Amblypelta lutescens* Dist. was reported as a pest of coconut in New Guinea and Queensland in Australia (Kurian *et al.*, 1976).

2.1.3 *Pseudotheraptus wayi* Brown

Widespread damage of *P. wayi* to coconuts in British East Africa had been reported by Welsford (1925). The coreid bug infestation resulted in the gumming disease or gummosis of coconut (Way, 1953a). The bug was at first referred to the genus *Theraptus* Stal. (Brown, 1955) and then described as *Pseudotheraptus*. This bug was reported from coastal zones of Tanzania, Kenya and Islands of Zanzibar, Pamba, Mafia, Solomon Islands and Papua New Guinea (Lever, 1969; Mohandas and Remamony, 1993).

2.1.4 Natural Enemies

Most of the research on biological control of coreid bugs had been oriented towards the use of different species of ants, the most prominent being *Pheidole megacephala* (F.), *Iridomyrmex myrmecodiae* Emery and *Oecophylla smaragdina* (F.) In crops that mainly suffer from heteropteran pests, ants could be utilized as a key element in an IPM programme (Peng *et al.*, 1999).

P. rostratus

In India, Nair and Remamony (1964) recorded two species of egg parasitoids *viz.*, *Hadrophanurus* sp. and *Anastatus* sp. as natural enemies of *P. rostratus* from cashew trees. The eggs of this bug were parasitised by two parasitoids *viz.*, *Chrysochalcissa oviceps* Boucek and *Gryon* sp. (Mohan *et al.*, 2001). Mohan and Faizal (2004a) reported that parasitisation by *Gryon* sp. was observed from June to November with maximum parasitisation during October.

Mohan *et al.* (2001) reported that *Metarhizium anisopliae* (Met.) Sorokin caused cent per cent mortality in nymphs of *P. rostratus*. This revealed the potential of *M. anisopliae* as a biocontrol agent against *P. rostratus*.

***Amblypelta* sp.**

A number of natural enemies of *Amblypelta* sp. had been reported by Mann (1919), Phillips (1940), Brown (1958b), Ivany and Catley (1960), Ivany (1961), Stapley (1972), Ironside (1978), Fay and Huwer (1993), Peng *et al.* (1995, 1997, 1998a) and Naumann and Steinbauer (2001).

Phillips (1940) reported that four main species of ants *viz.*, *P. megacephala* (F.), *I. myrmecodiae* Emery, *O. smaragdina* (F.) and *Anaplolepis longipes* (Jerd.) were present in the coconut plantations of the Solomon Islands. Out of these four ant species, *O. smaragdina* gave absolute protection to the palms against *Amblypelta* sp.

Competition between green ants and other species of ants had been considered as a problem influencing the use of green ants as biological control agents (Phillips, 1940; Greenslande, 1971; Way and Khoo, 1992; Peng *et al.*, 1998b; Waite and Huwer, 1998).

Phillips (1940) observed three egg parasites, one predatory bug and four species of ants in addition to an entomogenous fungus. A reduvid bug *Euagoras dorycus* (Boisduval), an egg parasite *Anastatus* sp. and an entomogenous fungus had been found attacking *A. cocophaga*. A hymenopteran parasitoid complex attacked the eggs of *Amblypelta lutescens lutescens* (Distant) in North Queensland. It included *Anastatus* sp. (Euphelmidae), *Oenocyrtus* sp.*nov*. (Encyrtidae) and *Gryon* sp. (Scelionidae) and similar to other complexes previously reported attacking eggs of related coreids in Africa, Indonesia and Papua New Guinea (Fay and Huwer,1993 ; Fay *et al.*, 2001).

***Pseudotheraptus* spp.**

Way (1953b), Douaho (1984), Fataye *et al.* (1989), Rapp and Satum (1995) and Varela (1997) reported the effectiveness of *Oecophylla longinoda* (Latr.) in controlling *Pseudotheraptus devastans* Dist.in East Africa, West Africa and Tanzania. Vanderplank (1959a) and found that *P. wayi* was controlled to a limited extent in Zanzibar by *O. longinoda*.

Oswald (1990) discussed the possibilities of the use of egg parasitoid, *Oenocyrtus albicrus* (Prinsloo) (Hymenoptera: Encyridae) for the management of *P. wayi* in Zanzibar. Schnauder (1993) described the egg parasitism of *P.wayi* by the parasitic wasp, *Oenocyrtus utetheisae* (Risboc). He found out that independent of the age of the host egg, two to nine parasitoids developed in an egg. Nethling and Joubert (1994) reported that two egg parasitoids, *Anastatus* sp. and a scelionoid caused natural mortality of the bug.

Zerhusen and Rashid (1992) and Mwaiko and Mpunami (1997) observed that *O. longinoda* was the major natural enemy of *P.wayi*.

2.2 INFLUENCE OF ALTERNATE HOSTS ON THE EXTENT OF DAMAGE CAUSED BY COREID BUGS

2.2.1 Alternate Hosts

P. rostratus

Several plants had been reported as alternate hosts of *P. rostratus* in Kerala. Cashew (Nair and Remamony, 1964), guava (Nair, 1975; Kurian *et al.*, 1976; Beevi *et al.*, 1989), mango, tapioca, rubber (Kurian *et al.*, 1976), tamarind (Kurian *et al.*, 1979), neem (Sundararaju and Babu, 1999), cocoa (CPCRI, 1999), passion fruit (Mohan and Nair, 2000) and black pepper (Lekha and Mohan, 2004) had been identified as the alternate hosts of the pest.

***Amblypelta* sp.**

Apart from coconut, *A. cocophaga* was found on *Ficus* sp. and Parasol leaf tree *Macaranga tanarius* (Muell). Besides these, a number of other bush shrubs belonging to the families Euphorbiaceae, Leguminosae, Malvaceae, Meliaceae and Vitaceae served as hosts. The bug had also been found feeding on the introduced plants like Physic nut *Jatropha curcas* (L.), Christmas plant *Poinsettia pulcherrima* (Willd. exklotzsch), Chinese burr *Triumfelta bartrami* (L.), cowpea, melon, orange, grandillias, red chillies, sugarcane, manioc and muscatels. The bug fed on papaya and kapoka in North Queensland (Phillips, 1940).

A. cocophaga was reported to feed on 35 species of plants in 23 families predominantly of family Euphorbiaceae. It was found to desap mango and cocoa. *Amblypelta costalis szentivanyi* Brown fed on rubber and cassava (Brown, 1958b). Sixteen species of *Amblypelta* were known to damage a wide range of tree crops of economic importance (Smith, 1984a;

Waite, 1990; Waite and Huwer, 1998). George and Nissen (1985) reported the infestation of *Amblypelta* spp. on persimmons.

***Pseudotheraptus* spp.**

Apart from coconut palm, *Pseudotheraptus* had been found breeding on and damaging guava and certain wild leguminous plants (Wright, 1952; Way, 1953a), cocoa, mango and cinnamon (Kurian *et al.*, 1976), cassava (IITA,1981; Kankolongo *et al.*, 1987), avocado (Dennill and Erasmus, 1991; Dupont,1993; Der *et al.*, 1994) and star fruit (Der *et al.*, 1992).

2.2.2 Population Dynamics of Coreid Bugs

Way (1953a) studied the population dynamics of *Theraptus* in East Africa. He reported that a population density of less than two per palm caused severe damage and one *Theraptus* made more than 200 feeding punctures in its lifetime. Even in severely damaged plantations, the maximum number of *Theraptus* found on a single palm rarely exceeded two and frequently none could be seen. In 1958, Yeo and Foster gave a direct estimation of population of *P. wayi* on the coconut palm. They found that the nymphal population was not distributed at random among the palms. Hence, one fourth of the population present could only be found.

2.2.3 Nut fall due to the Infestation of Coreid Bugs

Froggatt (1911) recorded the immature nut fall due to coreid bugs in the Solomon Islands. Later, Phillips (1940) observed that longer the period of infestation of *Amblypelta* sp., the smaller was the average size of a fallen nut. Over 50 per cent nut fall was observed from spadices between three and four months old, which had a normal nut fall of more than 20 per cent. In an infested garden, 97 per cent of the fallen nuts showed typical damage caused by *Amblypelta* sp. However, Way (1953a) reported that over 70 per cent of five to ten week old nuts fall 'naturally'.

After natural nut fall had ceased, the pest became concentrated on the few remaining nuts, which were susceptible to damage for about four weeks more.

Vanderplank (1958) defined vidaka damage rate (VDR) in Zanzibar as the number of vidaka (young nuts) showing damage by the insect, expressed as a percentage of the total number of fallen vidaka collected. The relationship between VDR and yield was linear and not logarithmic (Brown, 1959a). Seguni *et al.* (2002) reported the premature nut fall due to the damage by *P.wayi* in Tanzania.

In Kerala, an experiment was conducted by Mohan (2001) regarding the infestation of coreid bug in coconut and reported that the mean number of fallen nuts showing symptoms of coreid bug was maximum in November and minimum in June.

Apart from coconut, Brown (1958b) studied the effect of feeding of *Amblypelta* on other crops also.

A. lutescens had the same effect in the case of macadamia nut (Brimblecombe, 1948) and custard apple (Veitch, 1951). In crops like banana, pawpaw and cocoa, the young fruits did not normally fall as a result of coreid bug attack.

2.2.4 Ecology

The influence of weather parameters on coreid bug infestation in coconut was studied as early as in 1958 by Vanderplank in Zanzibar. He reported that the infestation was severe in warm rather than in cooler seasons.

The studies conducted by Reghunath *et al.* (1988) in Kerala from June 1985 to June 1988 revealed that the population of coreid bug increased from June onwards in all the years and declined sharply from November. The percentage of infestation was positively correlated with rainfall (0.44) and humidity (0.41) and negatively correlated with temperature (-0.53).

2.2.5 Biology

P. rostratus

Kurian *et al.* (1979) first studied the biology of *P. rostratus* on coconut. They reported that there were five nymphal instars and the total life period was 82 to 97 days. However, Nair *et al.* (2000) described the life cycle of *P. rostratus* in detail. The female laid eggs in clusters, the numbers varying from 10 to 58 per cluster. Freshly laid egg was oval, brown with an yellowish tinge which later turned reddish with a golden tinge. Eggs were deposited on leaf petiole, spathe, spadix or nuts of coconut. The immature nymphal stage comprised of five instars. The first, second, third, fourth and fifth instars had a duration of four to five, five to seven, four to six, four to six and eight to ten days, respectively. Adult longevity lasted from 49 to 53 days.

The biology of *P. rostratus* was also studied in cashew by Nair and Remamony (1964) and in guava by Nair (1975) and Kurian *et al.* (1976).

***Amblypelta* spp.**

Phillips (1940) studied the life history of *Amblypelta* on coconut in the British Solomon Islands. He reported that the egg and first nymphal stages of the bug were seen on the central leaf spike for a period of 10 days. The duration of the different stadia *viz.*, egg, first, second, third, fourth and fifth nymphal instars took six to seven, three to four, seven, six, seven and seven to eight days, respectively. Thus, the total number of days taken from oviposition to emergence of adult was 37 to 38 days. Smith (1984b) studied the biology of *Amblypelta theobromae* Brown on cocoa in Papua New Guinea.

P. wayi

The biology of *P. wayi* was studied by Way (1953a) in East Africa. The adult bug laid eggs singly and a female laid on an average of 74 eggs. There were five nymphal instars and about nine generations were produced annually. Yeo and Foster (1958) observed the random mortality among the first and second instar nymphs of *P. wayi*.

Kurian *et al.* (1976) reported on the life history of *P. wayi*. They reported that *P. wayi* took 26 to 40 days from egg to adult stage. Adult stage lasted 84 and 73 days for males and female bugs respectively.

2.3 DAMAGE AND YIELD LOSS CAUSED BY COREID BUGS

2.3.1 Nature of Damage in Different Crops

On Coconut

P. rostratus

The pest, *Paradasynus* sp. was one that caused direct damage to the produce. The bug was found to feed on female flowers and immature nuts of coconut (Kurian *et al.*, 1976).

The feeding of nymphs and adults of coreid bug caused immature nut fall and formation of puny or barren nuts with deformities. Infested buttons which escaped shedding developed into undersized or barren nuts (Kurian *et al.*, 1976; Ponnamma *et al.*, 1985; Mohandas and Remamony, 1993).

The nymphs and adults sucked the sap from the immature buttons by thrusting the long needle like mouth parts just below the perianth. The necrotic lesions developed in the infested buttons left permanent deep furrows with gummosis (Visalakshi *et al.*, 1989; Nandakumar *et al.*, 1996; Nair *et al.*, 2000; Mohan and Faizal, 2004b). The infested buttons which mature showed feeding marks as permanent deep depressions resulting in eye like crinkles surrounded by necrotic lesions (Mayilvaganan and Nair, 2002).

The damage caused by *P. rostratus* was identical with those caused by *A. cocophaga* and *P. wayi.*

A. cocophaga

Coconut was a widely favoured food plant of *A. cocophaga* (Brown, 1958b).

Phillips (1940) studied in detail about the damage caused by *A. cocophaga* on coconut in the British Solomon Islands. He reported that *Amblypelta* attacked the male flowers during the first two weeks. They produced the typical tissue shrinkage and root patches. Brown (1958b) reported that in addition to discolouration there was an exudation of gum from the scar. The nut fall of coconut was also referred to as 'gumming disease'. The scars became infected with fungi, *Gloeosporium* sp.

P. wayi

The feeding behaviour and nature of damage caused by *P. wayi* showed similarity with *A. cocophaga* (Lever, 1935; Phillips, 1940; Leach, 1949; O'Connor, 1950; Vanderplank, 1958; Mohandas and Remamony, 1993).

The coreid *P. wayi* formerly known as *Theraptus* sp. caused heavy damage to the fruits of the coconut palm (Way, 1951, 1953a; Vanderplank, 1953, 1958). Female coconut flowers and young nuts were destroyed by a single feeding puncture of *Pseudotheraptus* sp. Damaged 10 to 16 weeks old young nuts reached maturity, but were undersized and often distorted by lesions from which gummy material exuded (Way, 1953a).

The preferred feeding sites for late instars and adults of *P. wayi* were immature female flowers and young nuts. The dead flowers generally remain attached to the spadix for several months. However, nuts older than about five weeks generally abscissed and fell within a week (Way, 1953a; Vanderplank, 1958; Yeo and Foster, 1958; Kurian *et al.*, 1976). The damaged nuts that develop in to mature ones gave low copra yield (Way, 1951; Julia and Mariau, 1978).

On Alternate Hosts

P. rostratus

Beevi *et al.* (1989) in Kerala explained the infestation of *P. rostratus* on guava fruits in detail. They recorded the nymph and adult damage on guava fruits. As a result of feeding, formation of hard areas and suppression of ovule development took place. This resulted in the formation of malformed fruits.

Nair and Remamony (1964) reported that *P. rostratus* was a pest of cashew. They described the damage to tender cashew nuts when the adult bug fed on them. It thrusted its long stylets deep into the tender nuts and sucked out sap. Nuts thus fed upon shrivelled, withered, turned black and eventually dried up.

The nymphs of *P. rostratus* were found feeding on the tender twigs of rooted pepper cuttings, which later wilted due to desapping (Lekha and Mohan, 2004).

***Amblypelta* spp.**

In New Guinea, Brown (1958b) studied the attack of *Amblypelta* sp. on cocoa. He reported that the initial effect of feeding on shoot of cocoa usually resulted in the wilting of the shoot. The infested shoots that did not wilt developed cankerous swelling and cracks. Both the nymphs and adults sucked sap from the cocoa pods also. The most typical result was a sunken brown scar, which developed around the feeding puncture made by the insertion of the rostrum. The scars were normally circular, brown which in severe cases, coalesced and caused malformation and inhibited the growth of the fruit.

The scars developed by the feeding of *A. cocophaga* were elongate rather than round running down the long axis of the cocoa fruit (Phillips, 1940).

The attack of *Amblypelta* sp. on young banana fruits resulted in initial scar formation. Subsequent attack resulted in the formation of splits and cracks (Veitch and Simmonds, 1929).

A. cocophaga fed on potted legumes *viz*., peas and beans, the leaves became blotched, twisted and later withered. The bug puncture on citrus fruit caused only local discolouration. The infestation of *A. cocophaga* in ficus resulted in the discolouration and dropping of fruits. The feeding effect of this bug on *M. tanarius* was confined to small discolourations of the leaf portions around the punctures and slight twisting of the stem. *A. lutescens* was found to feed on stems and shoots of papaya causing lesions and rosetting of crowns (Phillips, 1940).

A. cocophaga fed on petioles of cassava and the result was a pronounced downward drooping of the whole leaf. Cassava plants infested by *Amblypelta* could generally be recognised by this characteristic effect. The same symptom was produced by *Amblypelta manihotis* (Blote.) (Phillips, 1941).

Brown (1958b) and Ryan (1994) studied the nature of damage caused by *Amblypelta* sp. on pawpaw plant in the British Solomon Islands. They explained that the initial effect of feeding was usually the wilting of the shoot. *A. lutescens* rapidly caused the death of young pawpaw plants. If the shoot survived, it developed cankerous swellings and cracks as seen in cassava when attacked by *A. cocophaga*, *Amblypelta costalis costalis* Van Duzee, *Amblypelta costalis szentivanyi* Brown, *Amblypelta cristabulensis* Brown. *A. cocophaga* feeding on the tender shoots of the euphorbiaceous shrub *M. tanarius* produced no apparent external damage. However, this was deceptive because the parenchyma cells were destroyed by the insect saliva and replaced by a resin, which later formed a solid brown mass internally. Die back of *Eucalyptus deglupta* Bl. saplings caused by *A.cocophaga* was observed by Bigger (1985) in the Solomon Islands.

***Pseudotheraptus* sp.**

The injury on cassava due to feeding by adults of *P. devastans* was described by Kankolongo *et al.* (1987). They reported that there was a linear relationship between the number of lesions and the bug population. However, Fokunang *et al.* (2000) opined that *P. devastans* was a potential vector in anthracnose transmission in cassava. The association between *P. devastans* feeding and *Glomerella cingulata* f.sp. *manihotis*, causative organism of anthracnose showed that feeding by *P. devastans* followed by fungal inoculation and vice versa resulted in more severe anthracnose symptoms than either insect feeding or fungal inoculation alone.

2.3.2 Yield Loss in Coconut

P. rostratus

Kurian *et al.* (1979) reported that the extent of losses due to *P. rostratus* was up to 65 per cent during certain years. In India, the quantification of yield loss due to *P. rostratus* was first estimated by Nair *et al.* (1997). The area of pericarp damaged showed significant correlation with the weight of dehusked nut (-0.264), volume of dehusked nut (-0.224), weight of copra (-0.300), weight of oil (-0.350) and percentage of oil (-0.415). The weight and volume of whole coreid bug infested nuts was reduced by 28.80 per cent and 33.50 per cent respectively compared to whole uninfested nuts. The mean area of pericarp damaged per nut was 2387 mm^2. Mayilvaganan and Nair (2002) reported that the volume of nut water and weight of copra showed 52.50 and 28.70 per cent reduction, respectively in infested nuts compared to uninfested nuts.

Amblypelta sp.

Brown (1959b) classified *Amblypelta* sp. infested nuts into six damage categories based on the severity of damage in the Solomon Islands. He explained that *Amblypelta* attack caused yield losses by reducing the amount of copra obtainable from surviving nuts.

P. wayi

Way (1953a) studied the yield loss on coconut due to the infestation of coreid bug *Theraptus* sp. in East Africa. He reported that the bug caused very serious loss to the crop.

Vanderplank (1958) stated on the need for a rapid and reliable method of assessing the damage caused by the coreid bug which could be used to estimate the effectiveness of control methods that were being tested. Vanderplank (1959a) estimated the crop loss due to *P. wayi* and reported that two third of the potential crop in Zanzibar was being lost due to *P. wayi* incidence and the projected loss of revenue was 0.50 to 2.00 million pounds. He also found that there was 20 per cent more copra per nut in the undamaged nut compared to the damaged nut.

Julia and Mariau (1978) observed that coconut bunches severely damaged by *Pseudotheraptus* sp. produced about half as much copra as healthy ones. The division of losses between copra content and premature fruit drop may be varied according to varieties but total losses were comparable for the same rate of attack. They suggested that the percentage of nuts attacked could be estimated based on the percentage of bunches damaged.

Der *et al.* (1992) assessed the damage caused by *P. wayi* on guava and reported 30 per cent of aborted fruits and 26 per cent of ripe fruits of guava were infested by coreid bug in Nelspruit area of South Africa.

Bio-chemical Changes in Coconut due to Coreid Bug Infestation

Mayilvaganan and Nair (2002) studied the changes in chemical properties of oil due to coreid bug infestation. They reported that the iodine value showed a decrease by 0.60 in oil from infested nuts, whereas the acid and peroxide values were higher in the oil from bug infested nuts compared to healthy nuts. However, there was no appreciable change in the saponification value.

Germination and Vigour of Seedlings from Coreid Bug Infested Nuts

Damage caused by *P. rostratus* resulted in small and malformed nuts. Those nuts that were retained in the bunch exhibited different intensities of infestation. Good seed nuts were necessary for producing healthy seedlings. Planting poor quality seedlings would result in the establishment of a plantation giving low yields (Menon and Pandalai, 1958).

The early germination of seed nuts in coconut was associated with early bearing and consequent enhancement of production in terms of nut yield (Jack and Sands, 1929). Liyanage (1953) observed that selection at the stage of seedling alone could effect an increase in nut yield by ten per cent. Hence, seedling selection is an important factor in coconut cultivation. Freedom from pest and disease has also to be given due consideration during seedling selection (Chattopadhyay and Sharangi, 2006).

Thomas *et al.* (2004) studied the effect of eriophyid infestation on growth and vigour of seedlings. They found out that maximum value for all the growth characters were recorded in seedlings raised from nuts coming under damage category III. However, there is a lack of information on the growth and vigour of coconut seedlings raised from coreid bug infested mature nuts.

Intensity of Coreid Bug Infestation as Influenced by the Colour of Coconut Fruit

Vanderplank (1958) reported that *P. wayi* showed preference for coconuts with dark green, brown and orange background.

2.4 CHEMICAL CONTROL

P. rostratus

In India, Kurian *et al.* (1976) reported the management of *P. rostratus* using pesticides. They recommended the spraying of 0.1 per cent BHC (2 g 50 per cent BHC in 1 litre of water) or 0.05 per cent carbaryl (1 g 50 per cent carbaryl in 1 litre of water) for controlling this pest. Spraying was done at bimonthly intervals on coconut bunches/ inflorescences and leaf axils. However, Ponnamma *et al.* (1985) recommended the use of either carbaryl 0.05 per cent or endosulfan 0.1 per cent for the control of *P. rostratus*.

Nandakumar *et al.*, 1996 conducted an experiment in Chirayinkil taluk of Thiruvananthapuram district to find out the optimum frequency of chemical treatments for the control of coreid bug. The result revealed that the spraying of carbaryl 0.1 per cent four times an year (avoiding the rainy season)was effective in controlling *P. rostratus* in very heavily infested coconut gardens. The income from the above treatment over control was Rs.120 per palm per annum.

***Amblypelta* sp.**

As early as 1940, Phillips conducted several trials in the British Solomon Islands to control *Amblypelta* sp. He reported that insecticidal sprays could be used to control *Amblypelta*. The residual effects of the insecticides like DDT and chlordane persisted sufficiently long enough to kill any nymphs emerging from eggs laid by *Amblypelta*. Smith (1984b) conducted a field trial using gamma HCH as a dust or a liquid formulation against *A. theobromae* in cocoa. He found out that the dust formulation gave better control of *A. theobromae.* In 1996, Huwer tested three neem formulations against *A. lutescens lutescens* on papaya, French beans and banana under laboratory conditions in Australia. The formulations had no ovicidal effect. NeemAzal was the most effective of the products followed by Green Gold and powdered neem seeds, but only significantly in respect of nymphal mortality.

P. wayi

Way (1953a) treated coconut spadices with 0.4 per cent BHC dust once in a fortnight for six and half months against *Theraptus* in East Africa. The rate of application averaged 20 lbs per acre. A ‘guard row' surrounding the block was also treated. The insecticide successfully destroyed the adults and nymphs of *Theraptus* present on the spadices at the time of treatment but did not prevent the damage from adults which inspite of the guard row migrated into the block during the periods between each dusting.

Vanderplank (1959b) tested the formulations containing DDT and various synthetic resins against *P. wayi,* in Zanzibar. Resins were included to prevent DDT from being absorbed by the parts of the coconut palms on which it was deposited. It was found that the proportion of one part resin to ten parts DDT gave optimal effect in terms of the kill of nymphs of *P. wayi* allowed to walk on a treated surface for one minute.

The economy of spraying of chemicals against *P. wayi* was calculated by Julia (1978) in Ivory Coast. He reported that the cost of five to six sprayings was equivalent to the value of 350 to 400 kg copra per hectare. It was also suggested that if the population was 30 insects per hectare, treatment should be given immediately.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The occurrence and intensity of infestation of coreid bug in coconut and other crops were studied through a survey conducted in Thiruvananthapuram district. Trials on the influence of alternate hosts on the extent of damage caused in coconut were conducted in farmers' fields in Kalliyoor panchayat of Thiruvananthapuram district. Studies on quantitative and qualitative losses incurred in nuts and management of the pest were done in the College of Agriculture, Vellayani. The details of materials used and methods followed for the various experiments are briefly described below.

3.1 INCIDENCE OF *P. ROSTRATUS* AND THEIR NATURAL ENEMIES

3.1.1 Extent of Damage on Coconut

Five panchayats each from coastal, midland and upland regions of Thiruvananthapuram district were selected for the study. Ten homesteads having yielding coconut palms and a range of other crops were selected at random from each of the panchayats. In each homestead, the extent of damage caused by *P. rostratus* was assessed in ten coconut palms. The third bunch of the palms was selected (Julia, 1978) and the total number of nuts in the bunch and number of nuts damaged by the pest were recorded. The percentage of infestation was calculated as follows,

$$\text{Percentage of infestation} = \frac{\text{Number of infested nuts in the bunch}}{\text{Total number of nuts in the bunch}} \times 100$$

3.1.2 Alternate Hosts of *P. rostratus*

The crops other than coconut in the homesteads were examined for infestation by coreid bug. The plant species damaged by the pest were recorded as its alternate hosts. The level of infestation in mature bunches of coconut around each alternate host was assessed as heavy (nuts showing heavy damage and splitting), medium (nuts showing medium damage) and low (nuts showing two or three spots) (Visalakshi *et al.*, 1989). The crops around which the palms showed heavy and medium damage were identified as potential alternate hosts.

The potential alternate hosts were further selected for detailed study on the influence of the crops either singly or in combination on the extent of infestation in coconut. Ten palms were selected for each alternate host plant and their combinations at random in the homesteads identified in the coastal panchayats and the effect was assessed in terms of percentage of infestation as described in 3.1.1.

3.1.3 Influence of Palm Characters and Management Operations on Extent of Infestation in Coconut

Age

The coconut palms selected in each homestead were divided into four age groups *viz.*, less than 5 years, 5 to 10 years, 11 to 15 years and more than 15 years. The extent of infestation in the palms coming under these age groups was worked out as described in 3.1.1.

Height

The coconut palms selected in each homestead were divided into three groups *viz.*, less than 5 m, 5 to10 m and more than 10 m. The extent of infestation in the palms coming under these height categories was worked out as mentioned in 3.1.1.

Spacing

Based on the spacing adopted, the palms surveyed were categorised into three groups *viz.*, planted at recommended spacing (7.6 x 7.6 m) (KAU, 2002), less than recommended and more than recommended. The extent of infestation in the palms under each category was worked out as given under in 3.1.1.

Irrigation

The level of infestation in coconut palms under irrigated and unirrigated (rain fed) conditions was determined as described in 3.1.1.

Fertilizers and Manures

The coconut palms to which fertilizers were either applied or not in each homestead were noted and the level of infestation by coreid bug in the palms was worked out as in 3.1.1.

Plant Protection Measures

The extent of infestation of coreid bug in sprayed and unsprayed palms was worked out as given under 3.1.1.

3.1.4 Natural Enemies of *P. rostratus*

The crown of the coconut palms and the alternate host plants were examined for natural enemies of *P. rostratus*. The parasitoids and predators observed were collected and identified by comparing with the reference collections maintained in the Department of Agricultural Entomology, College of Agriculture, Vellayani. A reduvid predator collected from the coconut palms was sent to Dr. Sahayaraj, Director, Crop Protection Research Centre, Palayamkottai, Tamil Nadu for identification.

To study the seasonal occurrence of the egg parasitoids, four guava trees were selected in Kalliyoor panchayat of Thiruvananthapuram district. The plants were monitored at monthly intervals for one year and egg masses were collected. The parasitised egg masses along with plant part were transferred to petri dishes and observed for emergence of parasitoids. The number of parasitoids emerging from each egg mass was recorded.

Prey Consumption Pattern of the Predator

Feeding pattern of the reduvid predator on nymphs and adults of *P. rostratus* was studied in the laboratory. Guava twigs with one tender fruit were selected. The twigs were moistened by placing the cut end in water contained in a conical flask. The conical flask was placed inside a cylindrical glass jar of size (20 x 50 cm). The mouth of the jar was covered with a muslin cloth. Sixteen such experimental jars were maintained in the laboratory. Five adults of the coreid bug were introduced into each of eight jars. Similarly, five nymphs of the coreid bug each were also released into another eight jars. The adults of the reduvid bug were introduced into four jars containing the adults and four jars with nymphs of coreid bug at the rate of one predator per jar. The nymphs of the predator were released in the remaining jars at the rate of one nymph per jar. The number of the pests preyed per day was recorded.

3.2 INFLUENCE OF ALTERNATE HOSTS ON THE EXTENT OF DAMAGE IN COCONUT

The trial was conducted in the homesteads of Kalliyoor panchayat, Thiruvananthapuram district. Coconut – alternate host combinations *viz.,* coconut – guava, coconut – cashew, coconut – cocoa and coconut – neem noted to have a significant influence on the infestation of the pest in coconut during the survey were selected for the study. Four plots were selected for each coconut-alternate host combination and from each plot, ten coconut palms were selected at random within 100 m radius from the alternate hosts. Both the alternate hosts and the coconut palms were monitored for coreid bug infestation at monthly intervals for 12 months from January to December 2004. In each month, the following observations were recorded.

Coconut

The number of egg masses, nymphs and adults of coreid bug, number of healthy and infested nuts in the third and the oldest bunches, number of nuts under each damage category in the oldest bunch and the number of buttons or nuts fallen due to coreid bug infestation were recorded.

Damage category was fixed as per the method of Brown (1959a) as described below with slight modification.

Category I	Nuts without scars (Uninfested)
Category II	Nuts with 1 to 5 scars (Negligible damage)
Category III	Nuts with 6 to 20 scars (Mild damage)
Category IV	Nuts with greater than 20 scars in a single ring round the nut (Moderate damage)
Category V	Nuts with greater than 20 scars distributed more or less all over the nut (Heavy damage)
Category VI	Nuts heavily scarred in which the endosperm failed to develop (Severe damage)

The difference between classes IV and V depends on whether the nut has been attacked during its development only once (Class IV) or repeatedly (Class V) resulting in lesser and greater reduction of kernel respectively.

The percentage of infestation in the third and oldest bunches was calculated as detailed under 3.1.1.

Mean Intensity Score (MIS) of each harvested bunch was calculated as follows,

$$MIS = \frac{\text{Number of nuts belonging to category 1 x 1 (score of nuts) + ... + Number of nuts belonging to category 6 x 6 (score of nuts)}}{\text{Total number of nuts}}$$

The MIS indicated the damage as follows,

MIS	Indications of damage
1.0	No damage
1.1 to 2.0	1-10 per cent damage
2.1 to 3.0	11-25 per cent damage
3.1 to 4.0	26-50 per cent damage
4.1 to 5.0	51-75 per cent damage
5.1 to 6.0	76-100 per cent damage

Alternate Hosts

The number of egg masses, nymphs and adults of coreid bug on the alternate hosts were recorded from leaves, twigs and fruits.

3.2.1 Correlation and Regression Studies Between Population of Coreid Bug in Alternate Hosts and Extent of Infestation in Coconut

The number of egg masses, nymphs and adults of coreid bug in guava, cashew, cocoa and neem in a particular month were correlated with the percentage of infestation in coconut palms in the next three successive months.

3.2.2 Correlation Studies Between the Meteorological Parameters and Population of Coreid Bug in Coconut

The data on various weather parameters *viz.*, maximum temperature, relative humidity, rainfall and number of rainy days during the period of observation were collected from the Department of Meteorology, College of

Agriculture, Vellayani. The number of egg masses, nymphs and adults of coreid bug in coconut around the alternate hosts *viz.*, guava, cashew, cocoa and neem were correlated with the maximum temperature, relative humidity, rainfall and number of rainy days during the period of observation.

3.2.3 Biology of Coreid Bug

Studies on the life cycle of *P. rostratus* on coconut and alternate hosts *viz.*, guava, cashew and neem were conducted in the Department of Entomology, College of Agriculture, Vellayani. The adult bugs collected from the field were confined in cylindrical glass jars (20 x 50 cm). The observations on mating, egg laying and egg period were noted. Four cylindrical glass jars (20 x 50 cm) were selected. Coconut buttons collected from third bunch along with rachis, guava twigs with tender fruits, twigs of cashew with young nuts and tender twigs of neem were moistened by placing the cut end into conical flasks containing water. These conical flasks were placed inside cylindrical glass jars and the mouths of jars were covered with muslin cloth. A set of five first instar nymphs were introduced into each glass jar. The number of instars, duration of each instar and adult longevity were observed and recorded.

3.3 ASSESSMENT OF YIELD LOSS

3. 3.1 Quantitative Loss

The experiment was laid out in Complete Randomised Design (CRD). Four coconut palms of West Coast Tall (WCT) variety were randomly selected and the mature bunches were labelled. At harvest, the nuts of each observational palm were divided into six damage categories as described in 3.2. One nut from each damage category was taken from each palm and the following parameters were estimated in the laboratory. The estimation was done during four consecutive harvests and the data were pooled and analysed.

Morphological Changes of Nut

Circumference at the upper, middle and lower portions of the nuts under each category was measured using a twine and scale.

Weight of Nut

Weight of unhusked and dehusked nuts was taken using a pan balance.

Weight of Nut Without Water

The dehusked nuts were split into two halves, coconut water drained and weighed.

Weight of Nut Water

Coconut water was drained into a measuring cylinder after splitting the dehusked nut and weighed.

Weight of Husk

Weight of husk was determined by subtracting the weight of dehusked nut from unhusked whole nut.

Weight of Shell

The kernels were removed from shell and the weight of shell was taken.

Weight of Kernel

Kernels were excised out of the shell of healthy and infested nuts and weighed.

Weight of Copra

Kernels were excised out of the shell of healthy and infested nuts and sun dried for four to five consecutive days. The moisture content was brought down from 50 to 55 per cent to five to six per cent and weighed.

Weight of Oil

Oil was extracted from copra of nuts coming under five damage categories (endosperm is absent in category-VI nut) using Soxhlet extraction procedure of AOAC (1996) and weighed.

3.3.2 Qualitative Loss

Quality of Coir

The husks of twenty nuts in each damage category (category 1 to VI) were subjected to natural retting practices by submerging them in the Vellayani lake. After six months, the husks were taken out from water, washed and the fibre extracted. Length and breadth of the fibre in each category were measured. Coir yarn was spun from fibre obtained from the nuts in each damage category. The tensile strength was determined using 'Autograph', a tensile strength testing machine at the Central Coir Research Institute, Kalavoor, Alappuzha, Kerala.

Bio-chemical Changes

Healthy and infested young nuts were collected from the third and fourth bunches of WCT palms. The damaged tissues of the nuts with high, medium and low infestation were excised and the starch, phenol and fibre content were estimated as per the procedure of Sadasivam and Manickam (1996).

The acid value and peroxide value of the oil extracted from the nuts in the five damage categories were estimated as per AOAC standards (AOAC, 1996).

Histological Changes

Hand sections were taken from the surface of young nuts (third bunch) of coreid bug infested tissues of different damage intensities *viz*., high, medium and low. Sections were stained, mounted on glass slides and covered with a cover slip without any air bubble. The histological changes of the tissues were recorded.

Seedling Vigour

An experiment was conducted to compare the vigour of seedlings produced from healthy as well as nuts of different damage intensities. It was laid out in randomized block design with five replications. A nursery bed of 1.5 x 2 m size was prepared. Nuts in the six damage categories were planted at a spacing of 30 x 30 cm in trenches 30 cm deep and covered with soil. The seedlings were maintained as per the package of practices recommendations of KAU (2002). Observations on the number of nuts germinated, height of seedling, girth at collar, number of leaves and total leaf area were recorded 6, 9 and 12 months after planting. Total leaf area was calculated by an equation, $Y = a + bx$ where Y is the leaf area, a = 27.3861, b = 0.6139 and x is the product of length and breadth of lamina in case of unsplit leaves.

3.3.3 Influence of Nut Colour and Shape

Five palms (WCT) each yielding green, red, greenish orange and orange nuts were selected at the College of Agriculture, Vellayani to study the influence of colour of nuts on the infestation of *P. rostratus*. Similarly, four palms (WCT) each bearing round and elongated nuts were selected to study the influence of nut shape on the infestation. Nuts with mean circumference/length (C/L) ratio less than 1.90 were considered as elongated nuts and those with C/L ratio above 1.90 as round nuts (Paul *et al.*, 2005). The nuts of the palms from four consecutive harvests were grouped into the six damage categories as detailed in 3.2. and the MIS of each harvested bunch was calculated as in 3.2.

3.4 MANAGEMENT

3.4.1 Laboratory Evaluation of Botanicals and Chemicals

3.4.1.1 Botanicals

An experiment was conducted in the laboratory to test the efficacy of botanicals against fourth instar nymphs of coreid bug.

Design - CRD

Replications - 3

Treatments - 13

1	Achook	0.15 per cent	2 ml/l
2	Achook	0.15 per cent	4 ml/l
3	Nimbecidine	0.03 per cent	2 ml/l
4	Nimbecidine	0.03 per cent	4 ml/l
5	Econeem	1 per cent	2 ml/l
6	Econeem	1 per cent	4 ml/l
7	NeemAzal T/S	1 per cent	2 ml/l
8	NeemAzal T/S	1 per cent	4 ml/l
9	Neem oil	2 per cent	20ml/l
10	Neem oil	4 per cent	40 ml/l
11	Neem oil-garlic emulsion	2 per cent	20 ml neem oil + 20 g garlic /l
12	Neem oil-garlic emulsion	4 per cent	40 ml neem oil + 40 g garlic /l
13	Control		

Preparation of Spray Solutions of Botanicals

The desired concentration of botanicals except neem oil-garlic emulsion was prepared by mixing the required quantities of the botanicals with water.

Preparation of Neem Oil – Garlic Emulsion (2 per cent)

Five grams of ordinary bar soap was dissolved in 30 ml of luke warm water. To this 20 ml of neem oil was added and stirred well. 20 g of garlic was crushed and made into a paste by mixing with 50 ml of water. The garlic extract was filtered and added to neem oil – soap solution and made upto one litre with water.

3.4.1.2 Chemicals

The following five insecticides were tested at two doses in the laboratory against fourth instar nymphs of coreid bug.

Design	-	CRD
Replications	-	4
Treatments	-	11

T_1 – Quinalphos	(Ekalux 25 % EC)	0.05 per cent
T_2 – Quinalphos	(Ekalux 25 % EC)	0.10 per cent
T_3 – Chlorpyriphos	(Dursban 20% EC)	0.05 per cent
T_4 – Chlorpyriphos	(Dursban 20% EC)	0.10 per cent
T_5 – Acephate	(Asataf 75 SP)	0.05 per cent
T_6 – Acephate	(Asataf 75 SP)	0.10 per cent
T_7 – Profenophos	(Curacron 50 %EC)	0.05 per cent
T_8 – Profenophos	(Curacron 50 %EC)	0.10 per cent
T_9 – Triazophos	(Hostathion 40 %EC)	0.05 per cent
T_{10} – Triazophos	(Hostathion 40 %EC)	0.1 per cent
T_{11} – Untreated control (Water spray)		

Preparation of Spray Solutions of Chemicals

The insecticide solutions were prepared from the proprietary formulations by mixing with water to get the required concentration.

3.4.1.3 Application of Botanicals and Chemicals

Guava twigs with one tender fruit were selected and the twigs were maintained as mentioned in 3.2.3. The prepared spray solutions were strained through a muslin cloth and sprayed on guava fruits using an atomizer. Guava fruits sprayed with water alone served as control. The fruits were dried under a fan and five fourth instar nymphs of coreid bug were released on each treated fruit.

The botanicals were tested for their antifeedant effect. The number of feeding punctures on treated guava fruits was noted 12 and 24 hours after treatment and mortality was recorded 48 hrs after treatment. The mortality of nymphs was recorded in insecticide treated fruits 24, 48 and 72 hours after treatment.

3.4.2 Field Evaluation

The efficacy of applying pesticides on alternate hosts to reduce the infestation of coreid bug in the surrounding coconut palms was evaluated by spraying the most effective botanical and chemical insecticides identified in the laboratory trial on guava, cashew, cocoa and neem.

Design : CRD

Replications : 4

Treatments : 4

1. Neem oil - garlic emulsion 2 per cent
2. Profenophos 0.05 per cent
3. Neem oil – garlic emulsion 2 per cent + profenophos 0.025 per cent
4. Control (Alternate hosts - not sprayed)

Preparation of Spray Solutions and Application

The desired concentrations of spray solutions of botanical and insecticide were prepared as described in 3.4.1.1 and 3.4.1.2, respectively. An anionic wetting agent 'wet well' was added to the prepared spray solutions at the rate of 2 ml l^{-1} for better wetting, dispersing and penetration of insecticides on treated surface. The prepared spray solutions were strained through muslin cloth.

The spray fluid required for each alternate host tree was calculated by 'quartering method'. The canopy of each tree was divided into four parts visually. The volume of fluid required for spraying one fourth of the canopy was estimated. This was multiplied by four to get the required quantity of spray fluid for the entire tree. The fluid was sprayed on guava, cashew, cocoa and neem with the help of a rocker sprayer.

Assessment of Coreid Bug Infestation

Four palms around each treated alternate host were selected for taking observations. The first six bunches of the selected palms were tagged with 'sunpac' labels and numbered serially from the sixth bunch onwards to the top, so that the emerging bunches could be serially tagged. The infestation of coreid bug on the third bunches was assessed as described in 3.1.1. The nuts in the third bunch were harvested as and when it matured. The total number of nuts and number of nuts in the different damage categories were recorded and the percentage of nuts in the various categories was worked out.

The price of harvested nuts in each damage category was calculated based on prevailing market rate (Appendix II). The total price of nuts obtained from four coconut palms around each treated alternate host was found out and the increase in income consequent to treatment of alternate hosts over control was calculated.

Statistical analysis

Data relating to each character were analysed by applying the analysis of variance technique as applied to CRD described by Cochran and Cox (1965) and the significance was tested by F test (Snedecor and Cochran, 1967). In cases where the effects were found to be significant CD values were calculated by using standard technique.

RESULTS

4. RESULTS

4.1 INCIDENCE OF *P. ROSTRATUS* AND THEIR NATURAL ENEMIES

Results of the study conducted on the incidence of coreid bug in coconut and other crops and influence of alternate hosts, palm characters, farmers' cultivation practices and plant protection measures on the intensity of infestation in the coastal, midland and upland regions of Thiruvananthapuram district are presented in Tables 1 to 4.

4.1.1 Extent of Damage on Coconut

Studies on the extent of damage caused by *P. rostratus* on coconut in Thiruvananthapuram district indicated that infestation of the pest was the highest in the coastal panchayats (25.36 to 54.67 per cent). The incidence was lower in the upland (1.11 to 30.93 per cent) and midland (5.71 to 23.18 per cent) panchayats (Table 1).

Higher infestation in the coastal region was recorded in Kalliyoor (54.67 per cent) and Vizhinjam (41.59 per cent) panchayats followed by Kulathoor panchayat (36.10 per cent). No significant difference was observed in the extent of infestation in Vizhinjam and Kulathoor panchayats. Lower infestation was recorded in Poovar (25.76 per cent) and Thirupuram panchayats (25.36 per cent).

In the midland region, higher infestation was observed in Vamanapuram (23.18 per cent) and Vilavoorkal (16.71 per cent) panchayats. A significantly lower level of infestation was seen in Malayinkil (14.68 per cent) and Kilimanoor (7.33 per cent) panchayats followed by Parassala (5.71 per cent).

The highest infestation in the upland region was recorded in Kattakada panchayat (30.93 per cent). The extent of infestation observed in the panchayat differed significantly from that recorded in Poovachal (23.56 per cent) and Kallikadu (13.18 per cent) panchayats. Only very low infestation was seen in Amboori (3.89 per cent) and Pangode (1.11 per cent) panchayats.

Table 1. Infestation of *Paradasynus rostratus* on coconut in Thiruvananthapuram district

Panchayats	Extent of infestation (per cent)
Coastal	
Vizhinjam	41.59
Thirupuram	25.36
Kalliyoor	54.67
Kulathoor	36.10
Poovar	25.76
CD (0.05)	14.17
Midland	
Parassala	5.71
Kilimanoor	7.33
Vamanapuram	23.18
Vilavoorkal	16.71
Malayinkil	14.68
CD (0.05)	7.64
Upland	
Poovachal	23.56
Kallikadu	13.18
Kattakada	30.93
Amboori	3.89
Pangode	1.11
CD (0.05)	5.89

4.1.2 Alternate Hosts of *P. rostratus*

Guava (*Psidium guajava* Linn.), cashew (*Anacardium occidentale* Linn.), cocoa (*Theobroma cacao* Linn.), neem (*Azadirachta indica* Linn.), mango (*Mangifera indica* Linn.), pepper (*Piper nigrum* Linn.), curry leaf (*Murraya koenigii* Spreng.) and tamarind (*Tamarindus indica* Linn.) were observed to be damaged by *P. rostratus* and were recorded as alternate hosts of the pest (Table 2). The plant parts infested in the different crops varied. While the bug damaged the fruits of guava, cocoa and curry leaf, it preferred the tender twigs of neem, pepper and tamarind for feeding and oviposition. In cashew and mango, the pest attacked both the fruits and tender twigs.

Black necrotic lesions developed on the surface of guava fruits consequent to the feeding of coreid bug. The lesions extended up to the endocarp. Dark brown hard areas were seen in the pericarp. However, in cocoa, a sunken brown scar developed around the feeding punctures on the pods. The infestation extended towards the inner side of the pods, resulting in the rotting of the beans. The fruits of curry leaf turned black and rotted due to the feeding of coreid bug.

In neem, pepper and tamarind, the twigs dried from tip downwards, exhibiting typical die back symptoms. Small, brown necrotic patches developed on tender cashew nuts infested by the pest, which subsequently shrivelled and turned black. The tender twigs when attacked dried from tip downwards. Similarly, tender mango fruits rotted and dropped due to infestation by the pest and typical die back symptoms were observed on the twigs.

Considering the impact of the alternate crops on the infestation of coreid bug in coconut, guava, cashew, neem and cocoa exerted a profound effect as evidenced by the level of damage on coconuts around these crops (Table 2). Infestation was high on coconuts around guava and cashew, medium in the palms around neem and cocoa, and low on coconuts around mango, pepper, curry leaf and tamarind.

Table 2. Alternate hosts of *Paradasynus rostratus* and level of infestation of the pest in the surrounding coconut palms

Alternate host				Level of infestation in coconut
Common Name	Scientific Name	Family	Parts infested	
Guava	*Psidium guajava* Linn.	Myrtaceae	Fruits	High
Cashew	*Anacardium occidentale* Linn.	Anacardiaceae	Fruits, tender twig	High
Cacao	*Theobroma cacao* Linn.	Sterculiaceae	Fruits	Medium
Neem	*Azadirachta indica* Linn.	Meliaceae	Tender twig	Medium
Mango	*Mangifera indica* Linn.	Anacardiaceae	Fruits, tender twig	Low
Pepper	*Piper nigrum* Linn.	Piperaceae	Tender twig	Low
Curry leaf	*Murraya koenigii* Spreng.	Rutaceae	Fruits	Low
Tamarind	*Tamarindus indica* Linn.	Caesalpiniaceae	Tender twig	Low

Table 3. Influence of alternate hosts on the extent of infestation of *Paradasynus rostratus*

Alternate hosts	Extent of infestation in coconut (per cent)
Guava	32.44
Cashew	34.99
Cocoa	6.10
Neem	2.93
Guava + Cashew	36.74
Guava + Cocoa	6.57
Guava + Neem	16.73
Cashew + Cocoa	19.69
Cashew + Neem	11.21
Cocoa + Neem	6.59
Guava + Cashew + Cocoa	39.36
Guava + Cashew + Neem	33.66
Guava + Cocoa + Neem	11.88
Cashew + Cocoa + Neem	9.20
Guava + Cocoa + Neem + Cashew	25.45
Other alternate crops	4.20
No alternate crops	1.92
CD (0.05)	1.98

Further studies on the extent of infestation on coconut in homesteads having the crop alone and the palm + the potential alternate crops (guava, cashew, neem and cocoa) indicated that the highest infestation on coconuts (39.36 per cent) was in homesteads having coconut + guava + cashew + cocoa (Table 3). The extent of infestation differed significantly from that of all other coconut - alternate host combinations. The palms in homesteads with coconut + guava + cashew showed 36.74 per cent infestation. The extent of infestation on coconuts in the vicinity of cashew (34.99 per cent), guava + cashew + neem (33.66 per cent) and guava (32.44 per cent) did not differ significantly. The crop combinations like coconut + guava + cocoa + neem + cashew (25.45 per cent), coconut + cashew + cocoa (19.69 per cent) and coconut + guava + neem (16.73 per cent) showed significant difference in the extent of infestation on coconut. On the other hand, infestation on coconuts around cashew + neem (11.21 per cent), guava + cocoa + neem (11.88 per cent) was on par. The extent of infestation on coconuts around cashew + cocoa + neem was 9.20 per cent. The coconuts in homesteads around cocoa + neem, guava + cocoa, cocoa and other alternate hosts showed only 6.59, 6.57, 6.10 and 4.20 per cent infestation respectively. Very low infestation was recorded on coconuts in homesteads having neem (2.93 per cent) and also no alternate hosts (1.92 per cent).

4.1.3 Influence of Palm Characters and Management Operations on Extent of Infestation

The results of the study are presented in Table 4.

Age

Significant difference could not be observed in the infestation of coreid bug on coconuts among the different age groups. The extent of infestation on palms in the age groups, less than 5 years, 5 to 10 years, 11 to 15 years and more than 15 years was to the tune of 20.06, 18.25, 18.98 and 15.55 per cent, respectively.

Table 4. Influence of palm characters and management practices on infestation by *Paradasynus rostratus*

Characters of palm/management practices	Extent of infestation on coconut (per cent)
Age group (yr)	
<5	20.06
5-10	18.25
11-15	18.98
>15	15.55
CD(0.05)	NS
Height of palm (m)	
<5	16.94
5-10	40.16
>10	5.15
CD(0.05)	9.67
Spacing of palm (m)	
7.6X7.6	21.86
<7.6X7.6	19.33
CD(0.05)	NS
Irrigation	
Irrigated	13.80
Unirrigated	24.50
CD(0.05)	6.12
Fertilisers	
Applied	17.30
Not applied	16.38
CD(0.05)	NS
Plant protection	
Sprayed (with wrong chemical)	20.49
Unsprayed	21.20
CD(0.05)	NS

Height

Height of the palms had a significant influence on the infestation of the pest. The highest infestation was observed in palms having height in between 5 to 10 m (40.16 per cent) and this was significantly higher compared to palms of other height categories. The damage by the bug was the lowest (5.15 per cent) in palms having height more than 10 m. The palms having height less than 5 m showed 16.94 per cent infestation.

Spacing

The spacing between palms in all the panchayats surveyed was either as per the recommended spacing (7.6 X 7.6 m) or less than the recommended spacing. The extent of infestation in the palms planted in recommended (21.86 per cent) and less than recommended spacing (19.33 per cent) did not differ significantly.

Irrigation

The infestation by coreid bug was significantly lower in irrigated palms (13.80 per cent), than in unirrigated coconut (24.50 per cent) palms.

Application of Manures and Fertilizers

None of the farmers surveyed applied fertilizers and manures at the recommended doses as per the POP of KAU, 2002. The infestation in coconut palms did not differ significantly between those receiving fertilizers (17.30 per cent) and not receiving (16.38 per cent) fertilizers.

Plant Protection Measures

Only 32.00, 32.00, 18.00 per cent of the farmers in the coastal, midland and upland panchayats, respectively adopted plant protection measures (Fig.1). Dicofol and neem seed oil- garlic emulsion 2 per cent were applied against both coreid bug and eriophyid mite. The percentage of farmers in coastal, midland and upland panchayats who sprayed dicofol alone was 16.00 20.00 and 8.00

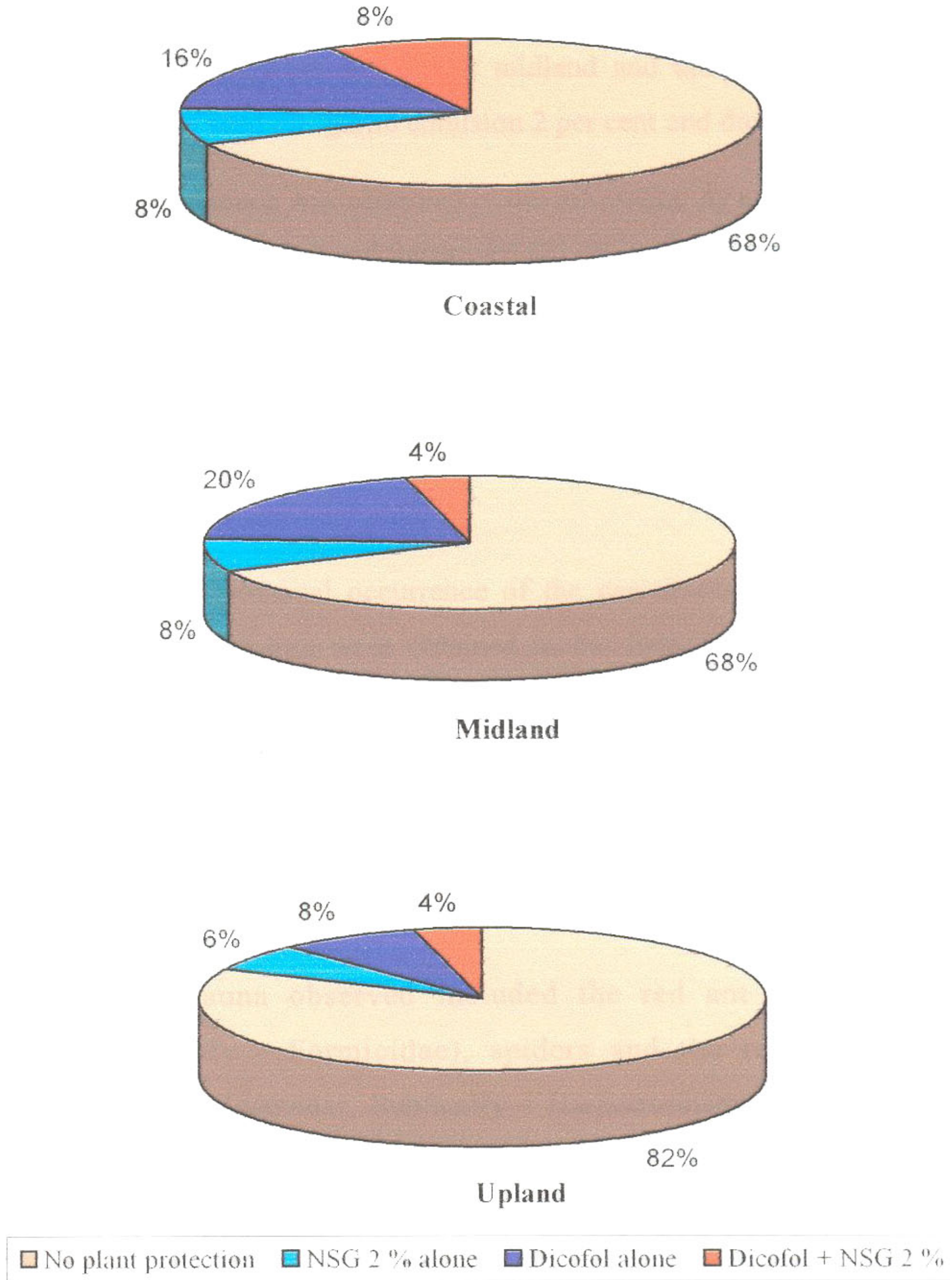


Fig. 1. Insecticide use pattern of coconut farmers

respectively. Only 8.00, 8.00 and 6.00 per cent of farmers in coastal, midland and upland panchayats sprayed neem seed oil garlic -emulsion 2 per cent alone. 8.00, 4.00 and 4.00 per cent of farmers in coastal, midland and upland panchayats respectively sprayed neem seed oil -garlic emulsion 2 per cent and dicofol.

No significant difference was observed in the infestation by coreid bug on coconuts in sprayed (20.49 per cent) and unsprayed (21.20 per cent) homesteads

4.1.4 Natural Enemies

The hymenopteran parasitoids, *Chrysochalcissa oviceps* Boucek (Family - Torymidae) and *Gryon* sp. (Family - Scelionidae) were recorded to parasitize the eggs of *P. rostratus.*

Further studies on seasonal occurrence of the parasitoids revealed that though egg masses of coreid bug were obtained in the field during February, March and June to October (Table 5), parasitisation was recorded only in March, July, August and September. The total number of parasitoids *viz. C. oviceps* and *Gryon* sp. that emerged per egg mass ranged from 33 to 67. The number of parasitoids that emerged per egg mass was more during August (67.00) followed by September (55.00), March (51.00) and July (33.00).

The predatory fauna observed included the red ant *Oecophyla smaragdina* (F.) (Family - Formicidae), spiders and the reduvid bug *Sycanus* sp. (Family – Reduvidae, Subfamily – Harpectorinae). The reduvid bug predated on both the adults and nymphs of *P. rostratus.* While the nymphs of the predator consumed 2.00 nymphs of coreid bug per day, they predated only 1.00 adult bug in a day (Table 6). The adult reduvid consumed 3.00 nymphs and 2.00 adults of coreid bugs per day (Plate 1).

4.2 INFLUENCE OF ALTERNATE HOSTS ON THE EXTENT OF DAMAGE IN COCONUT

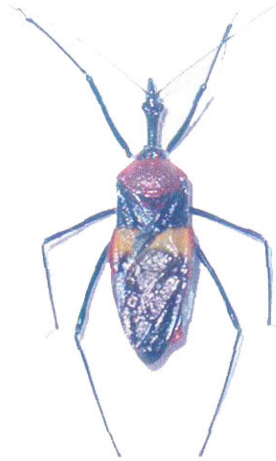
The results of the study are presented in Tables 7 to 10.

Table 5. Seasonal occurrence of egg parasitoids of *Paradasynus rostratus*

Month	Number of egg masses		Number of parasites emerged/egg mass	Name of parasitoids
	Total	Parasitised		
January-2004	0	0	0	
February	1	0	0	
March	2	1	51	*C.oviceps*
April	0	0	0	
May	0	0	0	
June	1	0	0	
July	2	1	33	*C.oviceps* and *Gryon* sp.
August	3	2	67	*Gryon* sp.
September	2	1	55	*C.oviceps* and *Gryon* sp.
October	1	0	0	
November	0	0	0	
December -2004	0	0	0	

Table 6. Prey consumption pattern of *Sycanus* sp. on *Paradasynus rostratus*

Stages of Predator	Mean number of different stages of prey consumed/day	
	Third instar	Adult
Nymph	2	1
Adult	3	2



Adult

Late instar nymph

Early instar nymphs

Predation by reduvid bug

Plate 1. The reduvid predator, *Sycanus* sp.

4.2.1 Influence of Guava

4.2.1.1 Population Dynamics of P. rostratus in Guava

Egg Mass

Egg masses of *P. rostratus* were observed on guava during March, April, July, August and September, the number per tree being 1.00, 1.50, 0.50 1.25 and 1.00 respectively. No egg masses were observed during the other months. There was no significant variation in the number of egg masses among the different months.

Nymph

Nymphs of *P.rostratus* were observed on guava tree from February to October. Population of nymphs per tree was significantly higher during March (9.25), September (9.00) and April (8.75). Comparatively, during August (3.00 per tree), February (2.75 per tree), July (1.00 per tree), May (0.75 per tree), June (0.50 per tree) and October (0.50 per tree), the population of nymphs was significantly lower. Nymphs were not observed during November, December and January.

Adult

Adults of coreid bug were recorded from February to April and July to October. Significantly higher population of adults was observed during September (5.50 per tree) and August (4.75 per tree). Comparatively, lower population of the adult bugs per tree was seen during July (1.25), April (0.75) October (0.50) and February (0.25). No adults were observed in guava during January, May, June November and December.

4.2.1.2 Population Dynamics of P. rostratus in Coconuts Around Guava

Egg Mass

Egg masses were observed on the coconut palms throughout the year. However, no significant variation in the number of egg masses was observed

Table 7. Seasonal abundance of *Paradasynus rostratus* in guava and coconut and extent of damage in coconut

Month	Population of *P.rostratus* (number per plant)						Damage in coconut			
	Guava			Coconut			Infestation (per cent)			Nut fall*** (number/palm)
	Egg mass	Nymph	Adult	Egg mass	Nymph	Adult	Young nuts**	Mature nuts**	MIS	
January-04	0.00*	0.00*	0.00*	0.63	1.23	0.90	0.50 (4.31)	26.50 (30.94)	2.54	0.00*
February	0.00*	2.75	0.25	0.68	2.38	1.08	0.00*	42.10 (40.48)	2.54	0.00*
March	1.00	9.25	2.50	0.50	3.13	1.05	35.33 (36.44)	27.50 (31.61)	2.29	0.75(1.29)
April	1.50	8.75	0.75	0.93	2.53	1.13	57.67 (49.51)	84.60 (66.90)	2.71	4.75(2.38)
May	0.00*	0.75	0.00*	0.78	4.75	1.18	78.80 (62.57)	97.30 (80.68)	3.36	4.25(2.28)
June	0.00*	0.50	0.00*	0.88	4.08	1.35	55.33 (48.46)	93.50 (75.24)	3.93	3.25(2.06)
July	0.50	1.00	1.25	0.80	4.00	1.65	38.00 (37.86)	99.43 (85.69)	4.16	0.25(1.10)
August	1.25	3.00	4.75	1.13	3.68	1.63	64.00 (53.99)	97.33 (80.45)	4.45	0.00*
September	1.00	9.00	5.50	0.98	5.23	1.80	62.13 (52.10)	90.10 (71.69)	3.33	1.50(1.57)
October	0.00*	0.50	0.50	0.60	6.45	1.33	59.00 (50.19)	89.60 (71.15)	2.19	3.00(1.98)
November	0.00*	0.00*	0.00*	0.55	2.23	1.35	1.15 (6.15)	1.15 (6.15)	1.53	4.50(2.32)
December-04	0.00*	0.00*	0.00*	0.65	3.10	1.08	5.20 (13.16)	1.75 (7.60)	1.66	1.25(1.49)
CD (0.05)	NS	4.21	1.48	NS	1.63	NS	(22.48)	(25.91)	0.92	(0.37)***

**- Figures in parentheses of the entire column are angular transformed values
***- Figures in parentheses of the entire column are $\sqrt{x+1}$ transformed values
* - Values not included for statistical analysis

among the different months. The number of egg masses recorded ranged from 0.50 to 1.13 during the period of study.

Nymph

Nymphs too were observed throughout the year on the coconut palms. The population of nymphs per coconut palm was significantly higher during October (6.45) and September (5.23). During March, May, June, July, August and December the population of nymphs was 3.13, 4.75, 4.08, 4.00, 3.68 and 3.10 per palm, respectively and there was no significant difference among them. Lower population of nymphs was observed during April (2.53), February (2.38), November (2.23) and January (1.23).

Adult

Adult coreid bugs were seen throughout the year. No significant variation in the population of adult coreid bugs was observed in coconut palms surrounding guava among the different months. The number of adult bugs ranged from 0.90 to 1.80 per palm.

4.2.1.3 Infestation in Young Nuts

Notable infestation of coreid bug was recorded in young nuts of coconut from March to October. The infestation was significantly the highest during May (78.80 per cent). The extent of infestation recorded during the month was statistically similar to that observed during August (64.00 per cent), September (62.13 per cent), October (59.00 per cent), April (57.67 per cent) and June (55.33 per cent). The infestation recorded during July (38.00 per cent) and March (35.33 per cent) had no significant difference. Significantly lower infestation was observed during January (0.50 per cent), November (1.15 per cent) and December (5.20 per cent). No infestation was recorded during February.

4.2.1.4 Infestation in Mature Nuts

Nuts harvested during January to October showed appreciable damage by the pest. The extent of infestation was severe from April to October, the percentage of nuts infested being 84.60 (April), 97.30 (May), 93.50 (June), 99.43

(July), 97.33 (August), 90.10 (September) and 89.60 (October). The infestation was significantly lower during November (1.15 per cent) and December (1.75 per cent). No significant variation was observed in the infestation of nuts harvested during February (42.10 per cent), March (27.50 per cent) and January (26.50 per cent).

The intensity of damage was significantly higher in bunches harvested during June, July and August as evidenced by the MIS recorded during the period, being 3.93, 4.16 and 4.45, respectively. The MIS of the bunches harvested during January, February, April and September were 2.54, 2.54, 2.71 and 3.33 respectively. However, there was no significant difference in the intensity of damage among the months. Similarly, medium damage was observed in the bunches harvested in March and May, the MIS recorded being 2.29 and 3.36 respectively. Lower damage was recorded in bunches harvested during October (2.19), November (1.53) and December (1.66).

4.2.1.5 Nut Fall

Maximum number of fallen nuts per palm (4.75) was recorded in coconuts around guava during April. No significant difference was observed in the nut fall during November (4.50), May (4.25), June (3.25) and October (3.00). The number of fallen nuts observed during September, December, March and July were 1.50, 1.25 0.75 and 0.25 per palm respectively. However, coreid bug induced nutfall was not observed during January, February and August.

4.2.2 Influence of Cashew

4.2.2.1 Population Dynamics of P. rostratus in Cashew

Egg Mass

Egg masses of *P. rostratus* were observed in cashew during January to May and October to December. Significantly higher number of egg masses was collected during January (1.50 per tree), February (1.50 per tree) and March (2.50 per tree). The number of egg masses observed during May (0.25 per tree), October

Table 8. Seasonal abundance of *Paradasynus rostratus* in cashew and coconut and extent of damage in coconut

Month	Population of *P.rostratus* (number per plant)						Damage in coconut			
	Cashew			Coconut			Infestation (per cent)			Nut fall***
	Egg mass	Nymph	Adult	Egg mass	Nymph	Adult	Young nuts**	Mature nuts**	MIS	(number/palm)
January-04	1.50	5.25	4.75	2.80	4.60	4.43	100.00(90.00)	23.60(29.09)	3.03	3.75(2.18)
February	1.50	7.50	7.50	2.78	6.30	4.73	100.00(90.00)	23.80(29.22)	3.18	5.25(2.46)
March	2.50	15.25	15.25	2.20	6.80	6.65	96.30(78.93)	0.00*	2.41	2.50(1.87)
April	1.25	2.50	5.00	2.13	7.93	5.90	100.00(90.00)	1.15 (6.15)	1.99	1.25(1.49)
May	0.25	0.75	0.50	1.75	3.78	4.58	52.52(46.44)	0.00*	1.00	2.00(1.72)
June	0.00*	0.00*	0.00*	1.25	3.81	3.40	29.40(32.85)	0.00*	1.00	0.25(1.10)
July	0.00*	0.00*	0.00*	1.15	1.95	2.88	1.15 (6.15)	0.00*	1.00	0.00*
August	0.00*	0.00*	0.00*	0.75	1.00	1.10	0.00*	33.80(35.54)	2.60	0.00*
September	0.00*	0.00*	0.50	0.73	0.75	0.55	0.00*	32.90(35.00)	4.59	0.00*
October	0.25	1.00	0.25	0.80	1.15	0.88	0.57 (4.31)	100.00(90.01)	4.98	0.00*
November	0.50	3.50	2.25	1.23	2.35	1.70	39.50(38.98)	100.00(90.01)	2.41	0.00*
December-04	0.75	1.25	1.50	1.28	2.90	2.28	35.90(34.40)	69.80 (56.69)	1.75	0.00*
CD (0.05)	1.03	5.74	2.43	1.00	1.94	1.43	(16.32)	(24.38)	0.77	(0.43)

** - Figures in parentheses of the entire column are angular transformed values
***- Figures in parentheses of the entire column are $\sqrt{x+1}$ transformed values
* - Values not included for statistical analysis

(0.25 per tree), November (0.50 per tree) and December (0.75 per tree) had no significant difference. No egg masses were recorded during June to September.

Nymph

The nymphs were also seen during January to May and October to December. The population was significantly the highest during March (15.25 per tree). No significant difference was observed in the population of nymphs during January (5.25 per tree), February (7.50 per tree) and November (3.50 per tree). Lower population was collected during April, May, October and December being 2.50, 0.75, 1.00 and 1.25 per tree respectively. No nymphs were observed from June to September.

Adult

Adults of coreid bug were recorded from January to May and September to December. The population of adults per cashew tree was the highest during March (15.25) followed by that in February (7.50). No significant difference was observed between the population in April (5.00 per tree) and January (4.75 per tree). The population recorded during May (0.50 per tree), September (0.50 per tree), October (0.25 per tree), November (2.25 per tree) and December (1.50 per tree) was found to be on par. No adults were recorded during June to August.

4.2.2.2 Population Dynamics of P. rostratus in Coconuts Around Cashew

Egg Mass

Egg masses of *P. rostratus* were observed throughout the year on coconut palms. Higher number of egg masses per palm was present during January (2.80), February (2.78), March (2.20), April (2.13), May (1.75), June (1.25), November (1.23) and December (1.28). However, significantly lower number was observed during July (1.15 per palm) which was on par with the number of egg masses during October (0.80 per palm), August (0.75 per palm) and September (0.73 per palm).

Nymph

Nymphs too were observed throughout the year on the coconut palms around cashew. Significantly higher population of nymphs per palm was observed during April (7.93 per palm) which was similar to the population in March (6.80) and February (6.30). The population recorded during January (4.60), June (3.81) May, (3.78) and December (2.90) did not differ significantly. Lower population was noticed in July (1.95 per palm), October (1.15 per palm), August (1.00 per palm) and September (0.75 per palm) which were on par

Adult

Adult bugs too were seen throughout the year. Significantly higher population was recorded in March (6.65 per palm) and April (5.90 per palm). The population observed in January, February, May, June, July and December were 4.43, 4.73, 4.58, 3.40, 2.88 and 2.28 per palm respectively. Comparatively, a lower population was observed during November (1.70 per palm), August (1.10 per palm), October (0.88 per palm) and September (0.55 per palm).

4.2.2.3 Infestation in Young Nuts

The coreid bug infestation was observed in young nuts of coconut palms around cashew during January to July and October to December. The infestation was 100 per cent during January, February and April and 96.30 per cent in March. The extent of infestation was lower during May (52.52 per cent) and June (29.40 per cent) and very low during July (0.57 per cent). Infestation was not observed during August and September. During October, again light infestation of the pest was observed. Subsequently, the extent of infestation increased to 39.50 and 35.90 per cent during November and December, respectively.

4.2.2.4 Infestation in Mature Nuts

The bunches harvested during January, February, April and August to December were damaged by coreid bug. All the nuts in the bunches harvested during October and November were infested by the pest. However, the infestation in nuts harvested during August (33.80 per cent), September (32.90 per cent) and

December (69.80 per cent) had no significant difference. The infestation during January (23.60 per cent), February (23.80 per cent) and April (1.15 per cent) were found to be on par. Infestation by coreid bug was not observed during March and May to July.

Analysis of the intensity of damage on the nuts of coconut palms around cashew revealed that the harvested nuts recorded significantly higher damage in October and September, the MIS during the period being 4.98 and 4.59, respectively. The damage was statistically similar in bunches harvested during January, February, March, August and November, the MIS being 3.03, 3.18, 2.41, 2.60 and 2.41, respectively. The MIS observed in April (1.99) and December (1.75) were on par. The harvested nuts had no coreid bug attack symptoms during May to July.

4.2.2.5 Nut Fall

Studies on the nutfall due to coreid bug in coconut palms around cashew revealed that nutfall was high during January and February, the number of fallen nuts per palm being 3.75 and 5.25, respectively. Lower number of fallen nuts was observed during March (2.50), April (1.20).and May (2.00). The nut fall was negligible during June (0.25 nuts per palm). Subsequently no nut fall was observed from July to December.

4.2.3 Influence of Cocoa

4.2.3.1 Population Dynamics of P. rostratus in Cocoa

Egg Mass

Egg masses of *P. rostratus* were observed on cocoa from January to February, September and November to December (Table 8). Egg masses were not observed during the other months. Analysis of the data revealed no significant variation in the number of egg masses collected among the different months. The number of egg masses collected per cocoa tree during January, February, September, November and December was 1.75, 2.00, 1.00, 1.00 and 1.75, respectively.

Table 9. Seasonal abundance of *Paradasynus rostratus* in cocoa and coconut and extent of damage in coconut

Month	Population of *P.rostratus* (number per plant)						Damage in coconut			
	Cocoa			Coconut			Infestation (per cent)			Nut fall*** (number/palm)
	Egg mass	Nymph	Adult	Egg mass	Nymph	Adult	Young nuts**	Mature nuts**	MIS	
January-04	1.75	3.25	2.00	0.13	3.78	0.68	16.30(23.82)	78.33(62.29)	3.48	1.75(1.64)
February	2.00	4.00	2.00	1.13	6.30	0.80	93.30(75.00)	57.90(49.54)	2.62	4.25(2.28)
March	0.00*	1.00	0.00*	0.85	7.25	1.28	100.00(90.00)	92.40(74.04)	1.52	6.00(2.64)
April	0.00*	0.00*	0.00*	0.75	4.53	1.13	74.70(59.80)	38.55(38.37)	1.57	2.50(1.87)
May	0.00*	0.00*	0.00*	0.85	3.80	0.93	51.30(45.73)	52.50(46.45)	1.96	4.25(2.22)
June	0.00*	0.25	0.00*	0.95	3.38	1.28	35.60(36.64)	34.70(36.07)	1.61	2.25(1.72)
July	0.00*	0.00*	0.50	0.53	3.10	1.05	33.88(35.54)	1.15 (6.15)	1.67	2.50(1.75)
August	0.00*	0.75	0.00*	0.68	2.80	1.25	34.00(35.66)	0.00*	1.00	0.00*
September	1.00	0.25	0.75	0.98	4.13	1.33	1.15 (6.15)	44.20(41.69)	2.00	0.00*
October	0.00*	1.00	0.50	0.75	3.55	0.53	0.57 (4.31)	58.70(50.00)	2.84	0.00*
November	1.00	1.25	0.00*	0.65	1.98	0.45	0.57 (4.31)	79.40(63.00)	4.49	0.00*
December-04	1.75	3.75	0.00*	0.53	2.05	0.58	1.15 (6.15)	91.40(72.99)	4.52	0.00*
CD (0.05)	NS	1.70	NS	NS	2.22	NS	(17.55)	(24.34)	0.91	NS

**- Figures in parentheses of the entire column are angular transformed values
***- Figures in parentheses of the entire column are $\sqrt{x+1}$ transformed values
*- Values not included for statistical analysis

Nymph

The nymphs of coreid bug were recorded on cocoa from January to March, June and August to December. Among the different months, significantly higher population of nymphs per cocoa tree was observed during February (4.00), December (3.75) and January (3.25).Very low population was observed during March (1.00 per tree), June (0.25 per tree), August (0.75 per tree), September (0.25 per tree), October (1.00 per tree) and November (1.25 per tree). No nymphs could be collected during April, May and July.

Adult

Adults were seen in cocoa during January to February, July and September to October. No significant variation in population of adult bugs was noticed around cocoa among the different months.

4.2.3.2 Population Dynamics of P. rostratus in Coconuts Around Cocoa

Egg Mass

Egg masses of *P. rostratus* were recorded throughout the year in coconut palms around cocoa. However, there was no significant difference among the number of egg masses observed in the different months, the number of egg masses per palm ranging from 0.13 to 1.13.

Nymph

Nymphs too were seen throughout the year on the coconut palms around cocoa. The population of nymphs per coconut palm was significantly higher during March (7.25 per tree) and February (6.30 per tree). The population of nymphs in the other months *viz.*, January (3.78 per tree), April (4.53 per tree), May (3.80 per tree), June (3.38 per tree), July (3.10 per tree), August (2.80 per tree), September (4.13 per tree), October (3.55 per tree), November (1.98 per tree) and December (2.05 per tree) were statistically similar.

Adult

Though adult coreid bugs were seen throughout the year, no significant variation was observed in their population. The number of adult coreid bugs per palm ranged from 0.45 to 1.33.

4.2.3.3 Infestation in Young Nuts

The infestation in young nuts of coconut palm was observed throughout the year. The infestation was substantially high during March, February and April and the number of infested nuts in the third bunch being 100.00, 93.30, and 74.70 per cent respectively. The infestation was significantly lower during May (51.30 per cent), June (35.60 per cent), July (33.88 per cent) and August (34.00 per cent). The extent of damage in September and December (1.15 per cent each) and October and November (0.57 per cent each) was negligible.

4.2.3.4 Infestation in Mature Nuts

Observations taken from harvested nuts of coconut palms around cocoa during January to December showed that the infestation was seen in mature nuts throughout the year except August. Significantly higher infestation in harvested nuts was observed during January (78.33 per cent), March (92.40 per cent), October (58.70 per cent), November (79.40 per cent) and December (91.40 per cent). The infestation noticed during February (57.90 per cent), April (38.55 per cent), May (52.50 per cent), June (34.70 per cent) and September (44.20 per cent) were statistically on par. No infestation was recorded during August, whereas a lower infestation was observed during July (1.15 per cent)

Significantly higher damage was obtained in bunches harvested during November which was statistically similar with that of bunches harvested during December as evidenced by the MIS recorded during the period being 4.49 and 4.52 respectively. However, the intensity of damage of bunches obtained during January, February and October were statistically on par, the MIS being 3.48, 2.62 and 2.84 respectively. A lower damage was recorded in the months of March, April, May, June, July and September which were statistically similar, the MIS being 1.52, 1.57, 1.96, 1.61, 1.67 and 2.00. No damage symptom was observed in nuts harvested during August.

4.2.3.5 Nut Fall

The number of fallen nuts with coreid bug infestation in palms around cocoa was higher during March (6.00 per palm). This was statistically similar to the number recorded during February and May (4.25 each). Significantly lower nutfall was observed during January (1.75), June (2.25), April (2.50), and July (2.25) which were statistically similar. Nutfall due to coreid bug did not occur during August to December.

4.2.4 Influence of Neem

4.2.4.1 Population Dynamics of P. rostratus in Neem

Egg Mass

There was no significant variation in the number of egg masses observed among the different months. Egg masses of *P. rostratus* were seen in neem from January to February and from September to November, the number ranging from 0.25 to 0.75 per neem tree. Egg masses were not observed during the other months.

Nymph

Nymphs of *P. rostratus* were observed on neem during January to May, September and November to December. The higher number of nymphs per tree was noticed during March (2.75) followed by January (1.50). No significant difference was observed in the population during the months of February (0.75 per tree), April (0.25 per tree), May (0.75 per tree), September (0.75 per tree), November (0.25 per tree) and December (1.00 per tree). No nymphs of the pest could be observed during June, July, August and October.

Adult

The population of adult bugs was seen from January to April and September to December. Adult bugs were absent during May to August. The

Table 10. Seasonal abundance of *Paradasynus rostratus* in neem and coconut and extent of damage in coconut

Month	Population of *P.rostratus* (number per plant)						Damage in coconut			
	Neem			Coconut			Infestation (per cent)			Nut fall***
	Egg mass	Nymph	Adult	Egg mass	Nymph	Adult	Young nuts**	Mature nuts**	MIS	(Number/palm)
January-04	0.50	1.50	0.50	1.70	3.53	1.70	100.00(90.00)	73.90(59.23)	1.88	4.50(2.33)
February	0.25	0.75	0.75	1.70	4.85	1.88	97.65(81.15)	74.00(59.43)	1.73	1.75(1.65)
March	0.00*	2.75	1.25	2.18	5.68	1.88	95.15(77.31)	65.80(54.20)	1.77	3.00(1.95)
April	0.00*	0.25	1.00	2.23	5.30	1.60	79.90(63.31)	0.00*	1.00	2.25(1.79)
May	0.00*	0.75	0.00*	1.60	4.18	1.90	40.00(39.24)	0.00*	1.00	2.25(1.72)
June	0.00*	0.00*	0.00*	1.65	3.48	1.98	29.00 (32.60)	2.10 (8.37)	1.09	0.00*
July	0.00*	0.00*	0.00*	0.95	2.60	1.43	0.56 (4.31)	0.57 (4.31)	1.14	0.00*
August	0.00*	0.00*	0.00*	0.45	1.70	0.73	26.40(30.90)	62.90(52.49)	1.69	0.00*
September	0.75	0.75	0.50	0.98	1.10	0.78	0.00*	95.45(77.71)	2.32	0.00*
October	0.25	0.00*	0.25	0.90	2.15	0.58	0.00*	100.00(90.00)	2.57	0.00*
November	0.75	0.25	1.50	1.03	2.00	0.88	0.56(4.31)	98.85(83.85)	3.29	2.75(1.88)
December-04	0.00*	1.00	3.50	1.30	2.75	0.88	0.00*	88.90(70.51)	2.63	5.00(2.40)
CD (0.05)	NS	1.41	1.28	0.92	1.83	NS	(25.23)	(18.99)	0.58	NS

**- Figures in parentheses of the entire column are angular transformed values
***- Figures in parentheses of the entire column are $\sqrt{x+1}$ transformed values
* - Values not included for statistical analysis

population was significantly the highest during December (3.50 per tree) compared to other months. The adult population of bug per neem tree was observed in January (0.50), February (0.75), March (1.25), April (1.00), September (0.50), October (0.25) and November (1.50) did not vary significantly.

4.2.4.2 Population Dynamics of P. rostratus in Coconuts Around Neem

Egg Mass

Egg masses of coreid bug were seen on coconut palms around neem throughout the year. Significantly higher number of egg masses per coconut palm was observed during January (1.70), February (1.70), March (2.18) and April (2.23). The number of egg masses collected during May, June, July, September, October, November and December was 1.60, 1.65, 0.95, 0.98, 0.90, 1.03 and 1.30 per palm respectively which had no significant difference. The lowest number of egg masses was collected during August (0.45 per palm).

Nymph

Nymphs of the bug were observed throughout the year on the coconut palms. The population of nymphs per coconut palm around neem was significantly higher during March (5.68) followed by the population in April (5.30), February (4.85) and May (4.18) and were statistically similar among themselves. Lower population was observed during September (1.10 per palm) which was significantly similar to the population in July (2.60 per palm), August (1.70 per palm), October (2.15 per palm), November (2.00 per palm) and December (2.75 per palm). The nymphal populations collected during January and June were 3.53 and 3.48 per palm respectively and were found to be on par.

Adult

Adults of *P. rostratus* were seen on the coconut palm throughout the year. However, no significant variation was noticed in population of the adult bugs on coconut palms around neem among the different months. The population ranged from 0.58 to 1.98 per palm.

4.2.4.3 Infestation in Young Nuts

The infestation of coreid bug in young nuts of coconut was recorded from January to August and in November. The infestation was significantly higher in young nuts sampled during January (100.00 per cent) , February (97.65 per cent), March (95.15 per cent) and April (79.90 per cent) and the extent of infestation was on par. The infestation in young nuts during May (40.00 per cent), June (29.00 per cent) and August (26.40 per cent) had no significant difference. Only negligible infestation was observed during July and November (0.56 per cent each). No infestation was recorded during September, October and December.

4.2.4.4 Infestation in Mature Nuts

Notable infestation in mature nuts was observed in the bunches harvested during January to March and June to December. Significantly higher infestation was observed in the bunches harvested during October (100.00 per cent), November (98.85 per cent), September (95.45 per cent) which were found to be on par. The infestation noticed during January (73.90 per cent), February (74.00 per cent), March (65.80 per cent), August (62.90 per cent) and December (88.90 per cent) had no significant difference. The percentage of infestation was significantly lower during June and July, recording 2.10 and 0.57 per cent infested nuts respectively. No infestation was recorded in the bunches harvested during April and May.

The intensity of damage was the highest in harvested bunches of coconut around neem in November, the MIS being 3.29 which was significantly different from all the other months. The intensity of damage of bunches harvested during September, October and December also did not differ significantly, the MIS during the period being 2.32, 2.57 and 2.63 respectively. The damage as indicated by the MIS in bunches observed during January (1.88), February (1.73), March (1.77) and August (1.69) was statistically similar. The intensity of damage of nuts harvested during June and July had no statistical difference, the MIS being 1.09 and 1.14 respectively.

4.2.4.5 Nut Fall

Nut fall due to coreid bug was observed from January to May (1.75 to 4.50 nuts per palm) and in November and December (2.75 to 5.00 nuts per palm). However, no significant variation was observed in nut fall among the different months.

4.2.5 Correlation and Regression Studies Between Population of Coreid Bug in Alternate Hosts and Extent of Infestation in Coconuts After Different Months

The results of the correlation and regression studies between population of coreid bug in alternate hosts and extent of infestation in coconut in subsequent months are presented in Tables 11, 12 and 13.

After One Month

The population of adult bugs (0.6369), nymphs (0.6937) and egg masses (0.7200) in guava was significantly and positively correlated with percentage of infested young buttons in coconut around guava in the following month. A similar trend was observed in cashew and cocoa too. The positive correlation coefficients between the percentage of infested young nuts of coconut palms in a month and the population of adults, nymphs and egg masses of coreid bug in cashew in the preceding month were 0.7215, 0.7305, 0.8391 respectively. In cocoa, the corresponding correlation coefficients were 0.8462, 0.9003, 0.8005 respectively. Similarly, significantly high positive correlation was obtained between the population of adults (0.8170), nymphs (0.3287) and egg masses (0.6294) in neem in a particular month with the percentage of infested young buttons of coconut around the plant in the following month.

After Two Months

After two months too, the population of adults (0.4495), nymphs (0.0.4658) and egg masses (0. 6339) of *P. rostratus* in guava was significantly and positively correlated with percentage of infested young buttons of coconut around guava. Similar significant and positive correlation was also seen in cashew

Table 11. Correlation and regression equations between the population of *Paradasynus rostratus* in alternate hosts in a particular month and percentage infestation in coconut palms around alternate hosts after one month

	Guava	Coeficient of correlation
Y11	-1.0490 + 0.0640 X11	0.6369**
Y12	-1.4391 + 0.1071 X11	0.6937**
Y13	-0.2838 + 0.0198 X11	0.7200**
	Cashew	
Y21	-0.3344 + 0.0726 X12	0.7215**
Y22	-0.3240 + 0.6727 X12	0.7305**
Y23	-0.0456 + 0.0155 X12	0.8391**
	Cocoa	
Y31	0.1373 + 0.0214 X13	0.8462**
Y32	0.1776 + 0.0371 X13	0.9003**
Y33	0.2416 + 0.0259 X13	0.8005**
	Neem	
Y41	0.0258 + 0.0201 X14	0.8170**
Y42	0.1129 + 0.0026 X14	0.3287*
Y43	0.3482 + 0.0676 X14	0.6294**

X11_ Per cent infestation in young nuts of coconut palm around guava after one month
Y11 – Population of adult coreid bugs on guava
Y12 – Population of nymphs of coreid bug on guava
Y13 – Population of egg masses of coreid bug on guava

X12 - Per cent infestation in young nuts of coconut palm around cashew after one month
Y21 – Population of adult coreid bugs on cashew
Y22 – Population of nymphs of coreid bug on cashew
Y23 – Population of egg masses of coreid bug on cashew

X13 - Per cent infestation in young nuts of coconut palm around cocoa after one month
Y31 – Population of adult coreid bugs on cocoa
Y32 – Population of nymphs of coreid bug on cocoa
Y33 – Population of egg masses of coreid bug on cocoa

X14 - Per cent infestation in young nuts of coconut palm around neem after one month
Y41 – Population of adult coreid bugs on neem
Y42 – Population of nymphs of coreid bug on neem
Y43 – Population of egg masses of coreid bug on neem

* -Significance at 5% level
**-Significance at 1% level

Table 12. Correlation and regression equations between the population of *Paradasynus rostratus* in alternate hosts of a particular month and percentage infestation in coconut palms around alternate hosts after two months

	Guava	Coeficient of correlation
Y11	0.1146 + 0.0446 X21	0.4495*
Y12	0.7367 + 0.0706 X21	0.4658*
Y13	-0.0888 + 0.0171 X21	0.6339**
	Cashew	
Y21	0.7211 + 0.0421 X22	0.4151*
Y22	0.5938 + 0.0442 X22	0.4427*
Y23	0.1499 + 0.0100 X22	0.5345**
	Cocoa	
Y31	0.1985 + 0.0196 X23	0.7749**
Y32	0.5714 + 0.0256 X23	0.6195**
Y33	0.3104 + 0.0246 X23	0.7546**
	Neem	
Y41	0.2023 + 0.0139 X24	0.5665**
Y42	0.0701 + 0.0030 X24	0.4271*
Y43	1.0719 + 0.0390 X24	0.3635*

X21 _ Per cent infestation in young nuts of coconut palm around guava after two months
Y11 – Population of adult coreid bugs on guava
Y12 – Population of nymphs of coreid bug on guava
Y13 – Population of egg masses of coreid bug on guava

X22 - Per cent infestation in young nuts of coconut palm around cashew after two months
Y21 – Population of adult coreid bugs on cashew
Y22 – Population of nymphs of coreid bug on cashew
Y23 – Population of egg masses of coreid bug on cashew

X23 - Per cent infestation in young nuts of coconut palm around cocoa after two months
Y31 – Population of adult coreid bugs on cocoa
Y32 – Population of nymphs of coreid bug on cocoa
Y33 – Population of egg masses of coreid bug on cocoa

X24 - Per cent infestation in young nuts of coconut palm around neem after two months
Y41 – Population of adult coreid bugs on neem
Y42 – Population of nymphs of coreid bug on neem
Y43 – Population of egg masses of coreid bug on neem

* -Significance at 5% level
**-Significance at 1% level

Table 13. Correlation and regression equations between the population of *Paradasynus rostratus* in alternate hosts in a particular month and percentage infestation in coconut palms around alternate hosts after three months

	Guava	Coeficient of correlation
Y11	1.5573 + 0.0193 X31	0.1898
Y12	3.0141 + 0.0318 X31	0.2062
Y13	0.3874 + 0.0090 X31	0.3325
	Cashew	
Y21	1.8570 + 0.0097 X32	0.0095
Y22	1.6014 + 0.0141X32	0.1385
Y23	0.3600 + 0.0037 X32	0.1934
	Cocoa	
Y31	0.3934 + 0.0142 X33	0.5626*
Y32	0.6864 + 0.0231 X33	0.5576*
Y33	0.4043 + 0.0241 X33	0.7586**
	Neem	
Y41	0.3477 + 0.0091 X34	0.3703*
Y42	0.0791 + 0.0023 X34	0.3213
Y43	1.9197 + 0.0099 X34	0.9150**

* -Significance at 5% level
**-Significance at 1% level

X31 _ Per cent infestation in young nuts of coconut palm around guava after three months
Y11 – Population of adult coreid bugs on guava
Y12 – Population of nymphs of coreid bug on guava
Y13 – Population of egg masses of coreid bug on guava

X32 -Per cent infestation in young nuts of coconut palm around cashew after three months
Y21 – Population of adult coreid bugs on cashew
Y22 – Population of nymphs of coreid bug on cashew
Y23 – Population of egg masses of coreid bug on cashew

X33 - Per cent infestation in young nuts of coconut palm around cocoa after three months
Y31 – Population of adult coreid bugs on cocoa
Y32 – Population of nymphs of coreid bug on cocoa
Y33 – Population of egg masses of coreid bug on cocoa

X34 - Per cent infestation in young nuts of coconut palm around neem after three months
Y41 – Population of adult coreid bugs on neem
Y42 – Population of nymphs of coreid bug on neem
Y43 – Population of egg masses of coreid bug on neem

(adults = 0.4151; nymphs = 0.4427 and egg masses = 0. 5345) and cocoa (adults = 0.7749; nymphs = 0.6195 and egg masses = 0.7546). In neem too, high positive correlations were obtained between the population of adults (0.5665), nymphs (0.4271), and egg masses (0.3635) of pest in the plant in a particular month and the percentage of infested young nuts of surrounding palms after two months.

After Three Months

The population of coreid bug (adults and nymphs) on guava had no significant correlation with the percentage infestation in young nuts of coconut palms around guava after three months. However, the population of egg masses was positively correlated (0.3325) with the percentage of infestation in young nuts of coconut. Likewise, no correlation was observed between the percentage infestation in young nuts of coconut palms with the population of adults, nymphs and egg masses in cashew. Whereas, in cocoa, significantly high positive correlation was obtained between the population of adults (0.5626), nymphs (0.5576) and egg masses (0.7586) with the percentage infestation in young nuts of surrounding coconut palms. Similarly, positive correlation was seen in neem (adults = 0.3703; nymphs = 0.3213 and egg masses = 0.9150)

4.2.6 Correlation Between Meteorological Parameters and the Population of Coreid Bug in Coconut

The results on the correlation between the population of adult, nymph and egg masses of *P. rostratus* in coconut and meteorological parameters during January to December 2004 are presented in Table 14.

The population of adult coreid bugs in coconut was significantly and positively correlated with average maximum temperature (0.6500). The nymphal population too was positively and significantly correlated with maximum temperature (0.8284). However, negative correlation was observed between the population of nymphs and rainfall (-0.3386) and number of rainy days (-0.3749). Similarly, though positive correlation was obtained between number of egg

Table 14. Correlation between the meteorological parameters and the population of *Paradasynus rostratus* in coconut from January 2004 to December 2004

Parameters	Adults	Nymphs	Egg masses
Average humidity (per cent)	-0.2911	-0.5642*	-0.4432*
Max Temp (°C)	0.6500**	0.8284**	0.6773**
Rainfall (mm)	-0.1601	-0.3386*	-0.2549
Number of rainy days	-0.2049	-0.3749*	-0.3581*

* -Significance at 5 % level
**-Significance at 1 % level

masses and maximum temperature (0.6773), negative correlations were observed between number of egg masses and average humidity (-0.4432) and number of rainy days (0.3581).

4.2.7 Biology

The adult female laid eggs in clusters containing an average of 43 yellowish oval shaped eggs per cluster. The eggs were 1.65 mm long and 0.85 mm wide at the middle. At maturity (hatching), the eggs turned dark red with a golden tinge. A crescent shaped black marking was present at the cephalic end of the egg. The egg period was 8.20, 8.40, 7.60 and 8.40 days when reared in guava, neem, cashew and coconut respectively. The pest completed five nymphal instars when reared on the alternate hosts (Table 15 and Plate 2). The mean egg period took 8.15 days.

First Instar

The first instar nymphs were ant like, reddish orange in colour and measured 2.50 x 0.70 mm. After hatching, they congregated near the eggshells. Antenna had 4 segments and was 2.50 mm long. The third segment of antenna was laterally compressed. The nymphs took 3.60, 4.60, 3.80 and 3.60 days to moult into second instar when reared in guava, neem, cashew and coconut respectively. The mean number of days taken by the first instar nymphs was 3.90.

Second Instar

The second instar nymphs were 4.50 mm long and 1.00 mm wide. The abdomen was dark reddish and slightly shorter than the thorax. The second instar nymphal period recorded in the different hosts guava, neem, cashew and coconut were 4.20, 4.00, 3.80, 4.20 respectively. The antenna was 6.51 mm in length and reddish brown in colour. The third joint of the antenna was lighter in colour compared to the other parts of antenna. The second instar nymphs took a mean of 5.85 days to moult into the third instar.

Table 15. Developmental duration and biometrics of *Paradasynus rostratus* in different hosts

Life stages	Duration (days)					Size (mm) Length x Breadth
	Guava	Neem	Cashew	Coconut	Mean	
Egg period	8.2	8.4	7.6	8.4	8.15	1.65 x 0.85
I instar	3.6	4.6	3.8	3.6	3.90	2.50 x 0.70
II instar	6.8	5.6	6.4	4.6	5.85	4.50 x 1.00
III instar	4.2	4.0	3.8	4.2	4.05	6.70 x 1.50
IV instar	5.6	5.0	6.4	5.2	5.55	8.50 x 2.00
V instar	4.8	5.6	5.4	5.4	5.30	13.00x 2.50
Adult longevity						
Male	55	50	62	68	58.75	16.50 x 5.00
Female	60	52	65	68	61.25	17.50 x 6.00

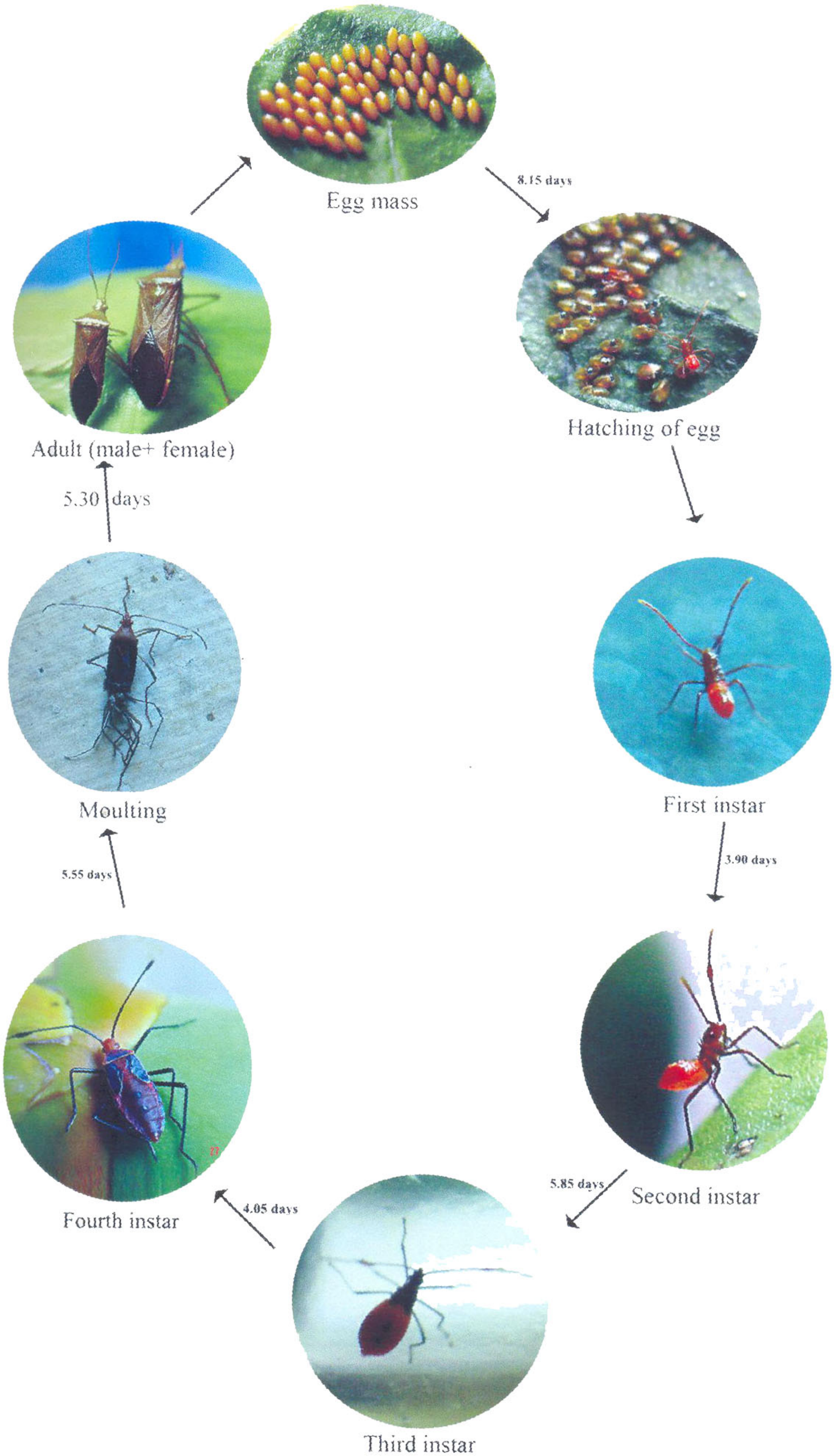


Plate 2. Life cycle of *Paradasynus rostratus*

Third Instar

The third instar nymphs measured 6.70 x 1.50 mm. The head was as long as the thorax. The antenna was 9.00 mm in length and reddish brown in colour. The instar took 4.20, 4.00, 3.80 and 4.20 days in guava, neem, cashew and coconut respectively to moult into the next instar. The mean number of days taken by the fourth instar nymphs was 4.05 days. From the third instar onwards, the nymphs moved through the foliage and tender branches for feeding.

Fourth Instar

The fourth instar nymphs were 8.50 mm long, 2.00 mm wide and dark reddish brown in colour. Small wing buds were visible. The duration of the fourth instar nymph was 5.60, 5.00, 6.40 and 5.20 in guava, neem, cashew and coconut respectively. The fourth instar nymphs took a mean of 5.55 days to moult into the next instar.

Fifth Instar

The fifth instar nymphs were dark reddish brown in colour and measured 13.00 x 2.50 mm in size. Wing buds were prominent, 4.00 mm in length and covered the meso and metathorax. Antenna measured 14.50 mm in length. The fifth instar became adult in 4.80, 5.60, 5.40, and 5.40 days in guava, neem, cashew and coconut respectively. The fourth and fifth instar nymphs caused severe damage to the crops they infest. The symptoms of damage caused by the bug on young buttons of coconut are depicted in Plate 3. The instar was completed in 39.00, 40.20, 39.40 and 28.00 days in guava, neem, cashew and coconut respectively. This instar took a mean of 5.30 days to complete the fifth instar.

Adult

The female adult coreid bug was slightly bigger than male with broader abdomen. Female measured 17.50 mm in length and 6.00 mm in width across the prothorax. However the male measured 16.50 x 5.00 mm. The other characters were similar in both male and female coreid bugs. Antenna was reddish brown in

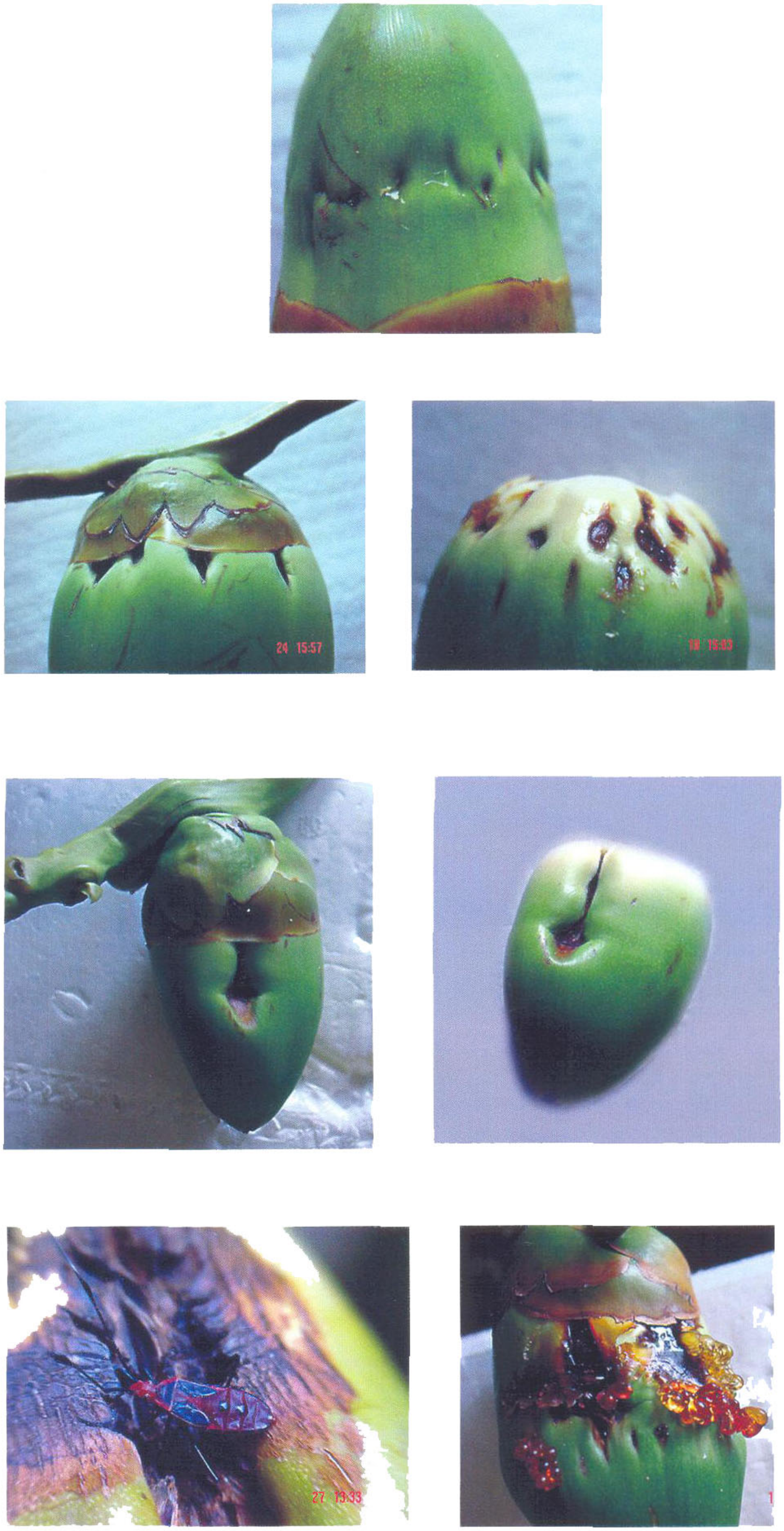


Plate 3. Symptoms of damage caused by *Paradasynus rostratus* on young buttons of coconut

colour and nearly as long as the body. The basal one fourth portion of the fourth segment of antenna was whitish. The longevity of male bugs was 55, 50, 62 and 68 days in guava, neem, cashew and coconut respectively. The female had a life span of 60, 52, 65 and 68 days on guava, neem, cashew and coconut respectively. The average lifespan of the male and female coreid bug was 58.75 and 61.25 days respectively. The longevity of the male bug was shorter compared to females.

4.3 YIELD LOSS

4.3.1 Quantitative Loss

The data on the size and weight of fresh nut (unhusked and dehusked), nut without water, nut water, husk, shell, kernel, copra and oil in different damage categories are depicted in Table 16.

Size of Nut

The upper circumference of nuts under category II was 32.00 cm and was on par with that of the healthy nuts (32.00 cm). No significant difference was observed in the upper circumference of nuts in category III (26.84 cm) and IV (23.25 cm). Comparatively, the measure of category V nuts was lower, being 18.88 cm. The lowest circumference was observed in nuts under category VI (14.02 cm).

Similarly, circumference of the middle region of the nuts under category II (40.94 cm) was comparable to that of the uninfested nuts (43.13 cm). Lower measure was recorded in the circumference of nuts under categories III, IV and V, being 34.57, 28.31 and 21.81 cm respectively. The lowest circumference was observed in nuts under category VI (16.28 cm), which was statistically inferior compared to the nuts in the other damage categories.

Circumference of the lower region of the nuts in damage category II (24.13 cm), III (21.75 cm), IV (18.43 cm) and V (14.86 cm) differed significantly from that of uninfested nuts (27.06 cm). Again, nuts of category VI (10.38 cm) recorded the lowest circumference.

Table 16. Effect of infestation of *Paradasynus rostratus* on nut characters of coconut

Damage categories	Circumference of unhusked nut (cm)*			Weight of nut characters (g)*								
	Upper	Middle	Lower	Unhusked nut	Dehusked nut	Nut without water	Nut water	Husk	Shell	Kernel	Copra	Oil
Category – I (No damage)	32.69	43.13	27.06	1501.25	817.50	435.00	240.00	812.81	166.34	243.35	185.07	153.79
Category-II (Negligible damage)	32.00	40.94	24.13	1438.75	725.00	414.69	188.44	784.69	151.93	201.03	142.73	143.25
Category-III (Mild damage)	26.84	34.57	21.75	1052.50	411.56	300.94	141.88	637.19	108.64	166.23	113.68	92.63
Category-IV (Moderate damage)	23.25	28.31	18.43	814.38	279.69	195.31	98.75	553.44	68.83	111.68	70.27	47.16
Category-V (Heavy damage)	18.88	21.81	14.86	598.13	165.63	126.25	63.69	443.75	33.87	49.13	35.39	26.10
Category-VI (Severe damage)	14.02	16.28	10.38	341.25	15.50	15.19	0.00	298.88	8.18	0.00	0.00	0.00
CD(0.05)	4.06	3.83	2.91	144.03	325.31	27.31	53.22	58.51	27.97	26.40	10.14	23.42

*- Values per nut

Weight of Nut

The weight of nuts in category II did not differ significantly from that of nuts in damage category I (uninfested nuts), the weight recorded being 1438.75 and 1501.25 g per nut respectively. However, significant reduction was observed in the weight of nuts in the other categories. While the weight of nuts in categories III and IV was 1052.50 and 814.38 g per nut respectively, it was 598.13 g per nut in category V. The lowest weight was recorded in nuts coming under damage category VI (341.25 g per nut) which was significantly lower than the weight of nuts in other categories (Plate 4).

Weight of Dehusked Nut

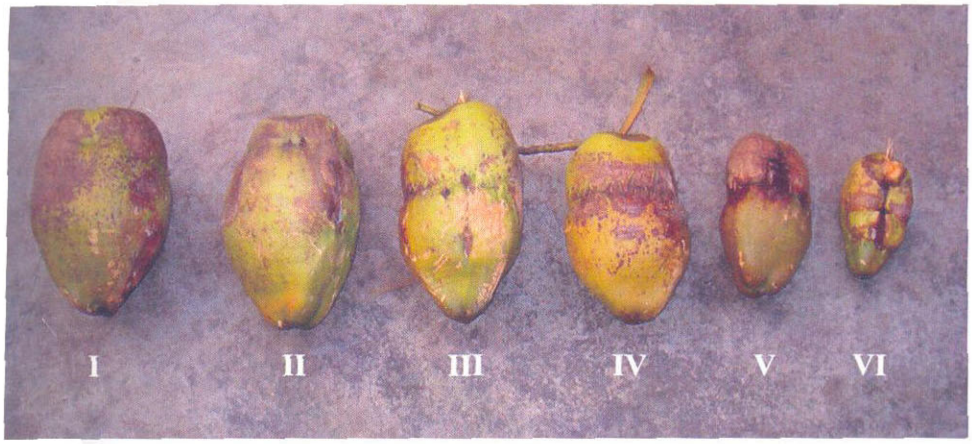
The weight of dehusked nuts in category II (725.00g per nut) too was on par with the weight of uninfested nuts (817.50 g per nut). The weight of a dehusked nut in category III was 411.56 g. Lower weight was recorded for nuts in category VI (15.50 g per nut) which was on par with the weight of nuts in category V (165.63 g per nut) and IV (279.69 g per nut) (Plate 4).

Weight of Nut Without Water

Similarly, the weight of nuts without water in category II (414.69 g per nut) did not differ significantly from that of uninfested nuts (435.00 g per nut). However, significant reduction was observed in the weight of nut without water in damage categories III (300.94 g per nut), IV (195.31 g per nut) and V (126.25 g per nut). The nuts from damage category VI recorded the lowest weight (15.19 g per nut) (Plate 4).

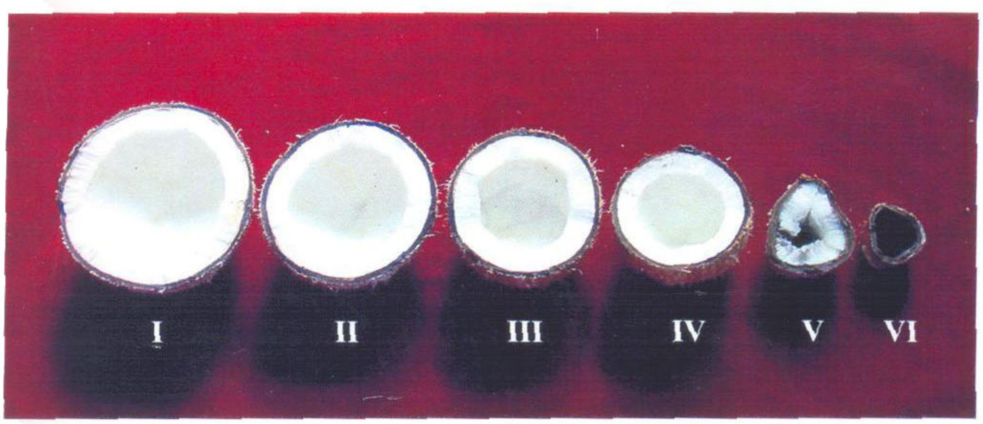
Weight of Nut Water

The quantity of nut water in category II (188.44 g per nut) was on par with that of the healthy nuts (240.00 g per nut). However, significant reduction was seen in the quantity of water in the nuts of other damage categories. The quantity of water in nuts of category III (141.88 g per nut) and IV (98.75 g per nut) were statistically similar. The quantity of nut water in nuts of category V was 63.69 g per nut. The nuts from category VI had no water.



Unhusked nuts

Dehusked nuts



Nuts without water

Plate 4. Nuts of different damage categories

Weight of Husk

The weight of husk of nuts from category II (784.69 g per nut) did not differ significantly from that of healthy nuts (812.81 g per nut). However, significant difference was observed among the weight of husks in category III (637.19 g per nut), category IV (553.44 g per nut) and category V (443.75 g per nut). The lowest weight of husk was recorded from category VI nuts (298.88 g per nut).

Weight of Shell

No significant difference was observed in the weight of shells of nuts in category II (151.93 g per nut) and healthy (166.34 g per nut). The weight of shell from damage categories III and IV were 108.64 and 68.83 g per nut respectively. Lower weight was recorded for shell of nuts in damage category V (33.87 g per nut) and VI (8.18 g per nut) and they were on par. The weight of shell from category III and IV were 108.64 and 68.83 g per nut respectively.

Weight of Kernel

The weight of kernel obtained from the nuts of the different categories was significantly lower than that of the uninfested nuts (243.35 g per nut). Significant difference was also observed among the different damage categories. The weight of kernel recorded from nuts of damage categories II, III and IV were 201.03, 166.23 and 111.68 g per nut respectively. The weight of kernel from nuts of category V was still lower (49.13 g per nut). The nuts in category VI were devoid of kernel.

Weight of Copra

Compared to the healthy nuts (185.07 g per nut), significant reduction was observed in the weight of copra from nuts of damage categories II to V. Among the different categories too, the weight of copra was significantly reduced, the weight of copra from nuts of categories II, III, IV and V being 142.73, 113.68, 70.27, and 35.39 g per nut respectively. The nuts from category VI were devoid of copra.

Weight of Oil

No significant difference was observed in the weight of oil from nuts of category II (143.25 g per nut) with that of uninfested nuts (153.79 g per nut). However, only lower quantity of oil was obtained from other damage categories. Compared to the weight of oil from nuts of category IV (47.16 g per nut) and V (26.10 g per nut), the weight of oil from nuts of category III (92.63 g per nut) was significantly higher. However, the weight of oil from nuts of category IV and V did not differ significantly. Since the nuts from category VI were devoid of copra, no oil was recorded from the category.

4.3.2 Qualitative Loss

Quality of Coir

No significant reduction was seen in the length of fibres obtained from husks under category II (23.70 cm per fibre) and III (21.50 cm per fibre) compared to that in healthy nuts (23.64 cm per fibre) (Table 17). Similarly, no significant difference was observed in the length of fibre obtained from nuts in damage categories IV (18.40 cm per fibre), V (18.00 cm per fibre) and VI (15.80 cm per fibre) (Plate 5).

The thickness of fibres from category II (0.184 cm per fibre) and III (0.172 cm per fibre) had no significant difference from that of the uninfested husk (0.186 cm per fibre). Compared to fibres in these categories, the thickness of the fibres from category IV (0.148 cm per fibre) and V (0.104 cm per fibre) was reduced significantly. The least thickness (0.078 cm per fibre) was recorded from fibres obtained from category VI nuts.

The break load of coir yarn spun from husks of category II to V did not differ significantly from that of the healthy nuts (78.89 Kgf per coir yarn). The break loads of coir yarn of husks of category II, category III, category IV and category V were 79.49, 75.88, 73.84 and 71.79 Kgf per coir yarn respectively. Break load was found to be lowest in yarn obtained from category VI nuts (17.38 Kgf per coir yarn).

Table 17. Effect of infestation of *Paradasynus rostratus* on quality of fibre and coir yarn obtained from husks under different damage categories

Damage category	Quality of fibre (cm)		Coir yarn
	Length	Thickness	Break load (Kgf)
Category – I (No damage)	23.64	0.186	78.89
Category-II (Negligible damage)	23.70	0.184	79.49
Category-III (Mild damage)	21.50	0.172	75.88
Category-IV (Moderate damage)	18.40	0.148	73.84
Category-V (Heavy damage)	18.00	0.104	71.79
Category-VI (Severe damage)	15.80	0.078	17.38
CD (0.05)	3.45	0.030	10.40

I II III IV V VI

Coir fibre obtained from different damage categories

I II III IV V VI

Coir yarn obtained from different damage categories

Plate 5. Effect of infestation of *Paradasynus rostratus* on quality of coir

Bio-chemical Changes

The results of the biochemical analysis of starch, phenol and fibre content of young buttons (third and fourth bunches) are presented in Table 18.

Starch

The starch content in young nuts having low infestation (1.61 mg/g) was on par with those in uninfested nuts in the third bunch (1.51mg/g). However, in medium and highly infested buttons the starch content was significantly less being 0.90 mg/g and 0.65 mg/g respectively.

The analysis of starch content in the young nuts from fourth bunch too revealed that the starch content in nuts having low infestation (2.56 mg/g) was comparable to that in uninfested nuts (2.08 mg/g). While, the starch content was 1.39 mg/g in nuts having medium infestation, it was significantly lower in highly infested nuts (0.71 mg/g).

Phenol

Phenol is usually seen in low quantities in uninfested nuts (3.03 mg/g). However, the content of phenol was significantly higher in the bug infested nuts. The quantity of the chemical in nuts having low (6.19 mg/g) and medium (6.49 mg/g) infestation was on par. The highest phenol content was recorded from nuts having high infestation (7.75 mg/g)

A similar trend was observed in the nuts from the fourth bunch. The lowest phenol content was recorded from uninfested nuts (2.95 mg/g). The phenol content in nuts having low (6.45 mg/g) and medium (6.85 mg/g) infestation did not differ significantly. The highest phenol content was observed from the nuts having high infestation (7.78 mg/g).

Fibre

The fibre content was significantly greater in uninfested nuts of third bunch (9.38 per cent). While the fibre content of nuts having low infestation was 8.25

Table 18. Effect of infestation of *Paradasynus rostratus* on bio - chemical constituents of coconut buttons

Category	Starch (mg/g)		Phenol (mg/g)		Fibre (per cent)	
	3rd bunch	4th bunch	3rd bunch	4th bunch	3rd bunch	4th bunch
Low	1.61	2.56	6.19	6.45	8.25	13.00
Medium	0.90	1.39	6.49	6.85	5.25	9.38
High	0.65	0.71	7.75	7.78	3.25	6.13
Control	1.51	2.08	3.03	2.95	9.38	13.75
CD(0.05)	0.40	0.42	0.71	0.72	0.91	2.03

Table 19. Effect of infestation of *Paradasynus rostratus* on chemical properties of oil

Damage category	Peroxide value (per cent)	Acid value (per cent)
Category – I (No damage)	0.64	0.73
Category-II (Negligible damage)	0.65	0.80
Category-III (Mild damage)	1.73	2.90
Category-IV (Moderate damage)	2.27	5.40
Category-V (Heavy damage)	2.17	5.60
CD(0.05)	0.26	0.42

per cent, it was 5.25 per cent in nuts with medium infestation. The lowest fibre content was recorded from highly infested nuts (3.25 per cent).

In the fourth bunch, the fibre content of nuts having low infestation (13.00 per cent) did not differ significantly from that in the uninfested nuts (13.75 per cent). The fibre content of nuts with medium infestation was 9.38 per cent. Significantly lowest fibre content was recorded from highly infested nuts (6.13 per cent).

Peroxide Value of Oil

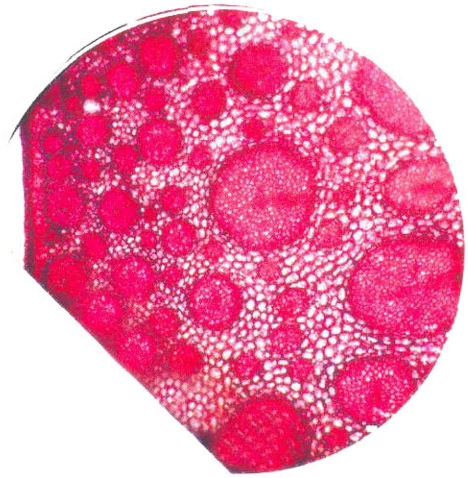
The peroxide value of oil obtained from nuts in category II (0.65 per cent) was comparable to that of the oil of healthy nuts (0.64 per cent). However, a significant increase was observed in the peroxide value of oil with increase in the intensity of infestation by coreid bug (Table 19). The peroxide value of oil of nuts in category III was 1.73 per cent. Higher value was obtained for oil from category IV nuts (2.27 per cent) followed by category V (2.17 per cent) which were significantly similar. The category VI nuts were devoid of copra.

Acid Value of Oil

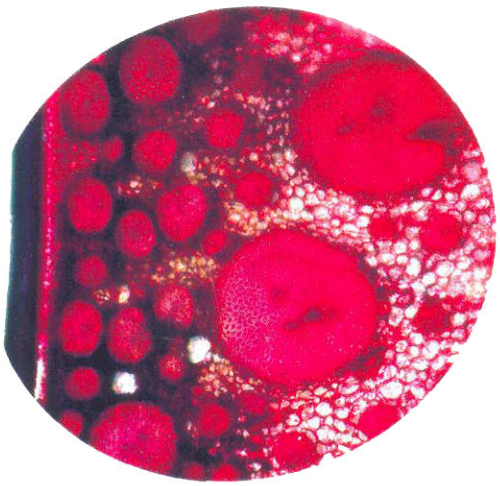
A similar trend was observed in the case of acid value of oil also. The acid value of oil was low in healthy nuts (0.73 per cent) and category II nuts (0.80 per cent), which were on par. The acid value of oil from category III was 2.90 per cent. Higher acid value was reported from category V nuts (5.60 per cent), which had no statistical difference with that of category IV nuts (5.40 per cent).

Histological Changes

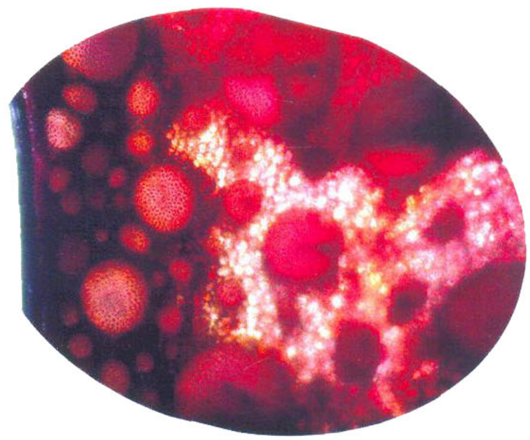
In the healthy young buttons, the epidermis is composed of small, compactly arranged thin walled parenchymatous cells. On the inner side of epidermis, a few layers are sclerenchymatous and this region is called the hypodermis. The region inner to the hypodermis consists of thin walled parenchymatous tissues with a large number of intercellular spaces. Vascular bundles are found irregularly scattered in the parenchymatous tissues (Plate 6).



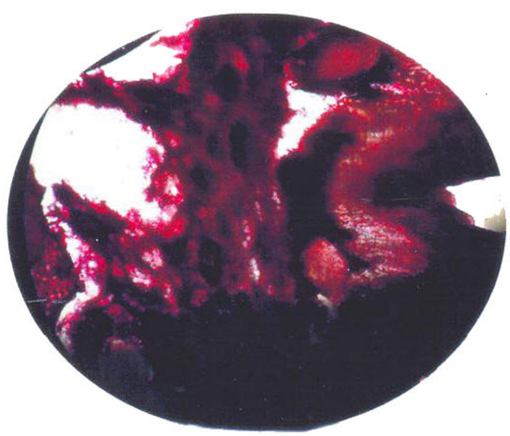
Healthy



Low



Medium



High

Plate 6. Histological changes due to the infestation of *Paradasynus rostratus* on coconut

The coreid bug was observed to probe in the parenchyma cells seen outside the vascular bundles. The styles were inserted intracellularly and the cellular contents were lacerated which underwent plasmolysis. When infestation was low, the discolouration of parenchymatous cells was seen just below epidermis around the vascular bundles. The discolouration of the parenchymatous cells increased and extended downwards when infestation was medium. In highly infested nuts, the parenchyma cells disintegrated and were destroyed. The cells could not be differentiated.

Germination and Seedling Vigour of Coconuts

The extent of germination of the nuts in damage category II was similar to that of the uninfested nuts (Table 20). Sixty per cent of the nuts germinated three months after sowing. By the fourth month, all the seed nuts germinated.

Only 20 per cent germination was seen in the nuts from damage category III when observed three months after sowing. During the fourth month, 60 per cent of the nuts germinated and by the fifth month all the nuts germinated.

Similarly, only 20 per cent of nuts in damage category IV germinated three months after sowing. The extent of germination increased to 40 and 80 per cent four and five months after sowing respectively. By the end of sixth month, all the seed nuts germinated.

The nuts repeatedly attacked by coreid bug (category V) started germinating four months after sowing (20 per cent). Five and six months after sowing, 60 and 80 per cent nuts germinated respectively. None of the severely infested nuts (category VI) germinated up to six months after sowing.

The data on height, collar girth, number of leaves and leaf area of seedlings from different damage categories 6, 9 and 12 months after sowing are presented in Table 21.

Height of Seedling

Six months after sowing, the height in seedlings produced from nuts of damage category II (48.20 cm per seedling) was statistically on par with the height of

Table 20. Extent of germination of nuts infested by *Paradasynus rostratus*

Damage category	Percentage of germination			
	Months after sowing			
	3	4	5	6
Category – I (No damage)	60	100	100	100
Category-II (Negligible damage)	60	100	100	100
Category-III (Mild damage)	20	60	100	100
Category-IV (Moderate damage)	20	40	80	100
Category-V (Heavy damage)	0	20	60	80
Category-VI (Severe damage)	0	0	0	0

seedlings from healthy nuts (48.80 cm per seedling) and significantly superior to the other categories. The height of seedlings of nuts from category III, IV and V were 37.60, 22.40 and 18.60 cm per seedling respectively.

A similar trend was observed in the height of seedlings nine and twelve months after sowing. Among the nuts of different damage categories, the maximum height was observed in seedlings raised from nuts in category II (107.60 cm per seedling) nine months after sowing. The height of the seedlings was on par with that of healthy nuts (109.60 cm per seedling). The height of seedlings raised from nuts under category III and IV were 74.20 cm per seedling and 55.00 cm per seedling respectively. The lowest height (37.60 cm per seedling) was recorded in seedlings from nuts of category V which was significantly lower compared to the other categories. Similarly 12 months after sowing, the height of seedlings was recorded in nuts from category II (152.00 cm per seedling) was on par to that of seedlings from healthy nuts (155.60 cm per seedling). The height of seedlings in category III, IV and V was 107.80, 66.40 and 49.00 cm per seedling respectively (Plate 7).

Collar Girth

Six months after sowing, maximum girth at collar was observed in seedlings raised from nuts under category II (6.56 cm per seedling) and it did not differ significantly from that of uninfested nuts (6.74 cm per seedling). The collar girth of seedlings from nuts of category III (5.96 cm per seedling), IV (5.16 cm per seedling) and V (4.24 cm per seedling) differed significantly from one another.

Nine months after sowing, higher collar girth was recorded in seedlings produced from nuts of category II (10.28 cm per seedling) which was statistically similar to that of healthy seedlings (10.26 cm per seedling) (Table 21). The collar girth recorded in seedlings from nuts of category III (9.02 cm per seedling), category IV (5.86 cm per seedling) and category V (5.38 cm per seedling) differed significantly. Twelve months after sowing too, significantly higher collar girth was recorded in seedlings from healthy nuts and category II nuts (15.40 cm each per seedling) compared to the other categories. The collar girth of seedlings from

Table 21. Biometric characters of coconut seedlings raised from nuts damaged by *Paradasynus rostratus*

Damage category	Height (cm)			Collar girth (cm)			Number of leaves			Leaf area (cm^2)	
	6 MAS	9 MAS	12 MAS	6 MAS	9 MAS	12 MAS	6 MAS	9 MAS	12 MAS	9 MAS	12 MAS
Category – I (No damage)	48.80	109.60	155.60	6.74	10.26	15.40	3.20	4.80	6.60	1364.58	1586.48
Category-II (Negligible damage)	48.20	107.60	152.00	6.56	10.28	15.40	3.00	5.00	5.80	1093.12	1303.67
Category-III (Mild damage)	37.60	74.20	107.80	5.96	9.02	10.80	2.40	4.60	5.80	667.97	815.98
Category-IV (Moderate damage)	22.40	55.00	66.40	5.16	5.86	10.00	2.00	2.80	5.20	295.54	361.52
Category-V (Heavy damage)	18.60	37.60	49.00	4.24	5.38	7.60	1.40	2.20	3.80	151.76	182.05
CD(0.05)	3.91	5.25	10.72	0.49	0.38	0.91	0.52	0.58	0.69	97.48	109.60

MAS- Months after sowing

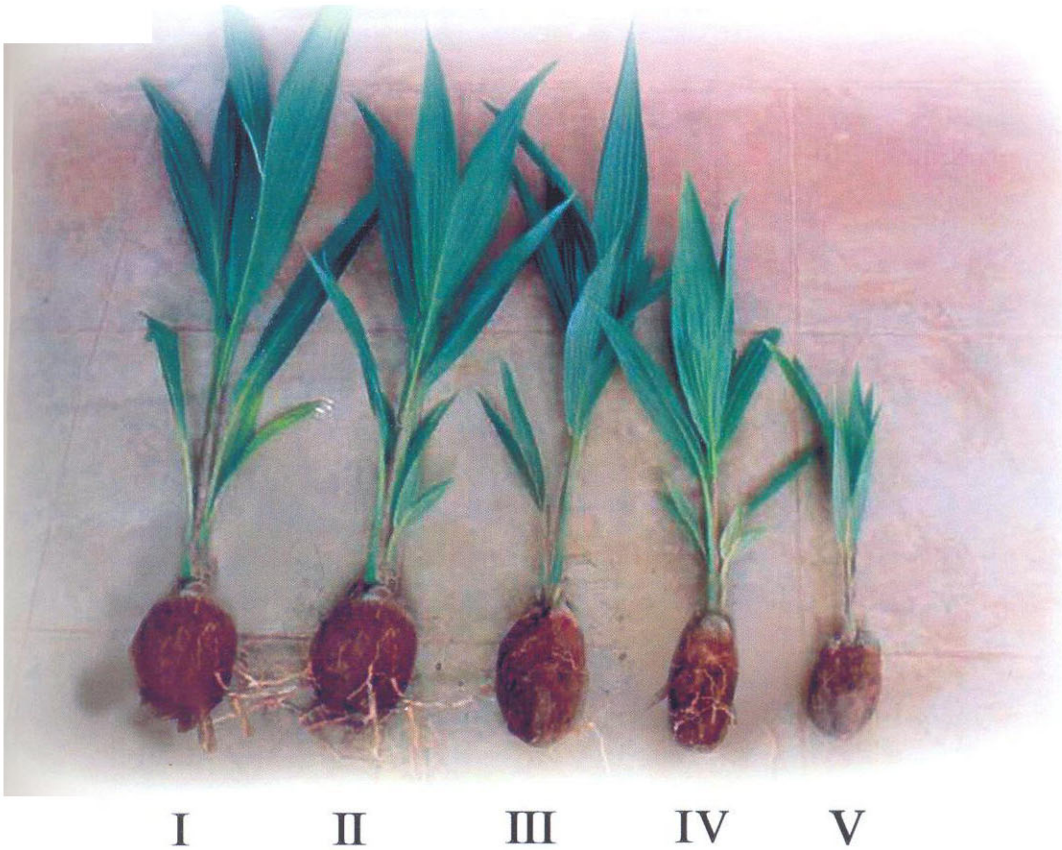


Plate 7. Coconut seedlings from *Paradasynus rostratus* infested nuts of different damage categories

category III and IV were 10.80 and 10.00 cm per seedling respectively which were statistically similar. The lowest girth was observed in seedlings from nuts of category V (7.60 cm per seedling).

Number of Leaves

Six months after sowing, no significant difference was observed in the number of leaves in seedlings of category II (3.00 per seedling) and healthy seedling (3.20 per seedling). The seedlings from category III (2.40 per seedling) and IV (2.00 per seedling) had lesser number of leaves. The lowest number of leaves was seen in seedlings of category V (1.40 per seedling) which was significantly inferior compared to the other categories.

Nine months after sowing, significantly higher number of leaves was recorded in seedlings from damage category II nuts (5.00 per seedling) which was statistically similar to those in healthy seedlings (4.80 per seedling) and category III (4.60 per seedling). Seedlings of category V (2.20 per seedling) had only lower number of leaves and it was significantly similar to that in category IV (2.80 per seedling). Similarly, 12 months after sowing, the higher number of leaves per seedling was observed in category II and III (5.80 each). However, the number of leaves in these categories differed significantly from that of healthy seedlings (6.60 per seedling). The number of leaves of seedlings from category IV nuts was 5.20. The lowest number of leaves was observed in seedlings of category V (3.80) nuts.

Leaf Area

Among the seedlings raised from different damage categories, the highest leaf area was recorded in seedlings from nuts of category II (1093.12 cm^2) nine months after sowing. However, the leaf area of the seedlings was significantly lower than that of the seedlings of uninfested nuts (1364.58 cm^2). The leaf area of seedlings from nuts of category III (667.97cm^2), IV (295.54 cm^2) and V (151.76 cm^2) was low and differed significantly from each other.

A similar trend was observed 12 months after sowing. Leaf area of seedlings from nuts of category II (1303.67cm^2) was significantly less than that of seedlings from healthy nuts (1586.48cm^2). Still lesser leaf area was recorded for seedlings from nuts of category III and IV and were 815.98 cm^2 and 361.52 cm^2 respectively. The lowest leaf area of seedlings was recorded in nuts from damage category V (182.05 cm^2).

4.3.3 Influence of Nut Colour and Shape

The Mean Intensity Score (MIS) of coreid bug infested bunches of coconut palms bearing nuts of different colours *viz*., green, red, greenish -orange and orange and shape is presented in Table 22. The lowest damage was recorded in bunches with green coloured nuts, the MIS being 3.10. The damage observed in the nuts was significantly lesser than that in the other bunches. The intensity of damage on bunches with greenish orange (4.55), orange (4.50) and red (4.00) coloured nuts did not differ significantly.

Damage of the pest was significantly higher in elongated nuts (MIS = 4.10) compared to palms having round shaped nuts (MIS = 3.30).

4.4 MANAGEMENT

4.4.1 Laboratory Evaluation of Botanicals and Chemicals

4.4.1.1 Botanicals

Antifeedant Effect

Twelve hours after release of coreid bug nymphs, all the treatments showed significantly lower number of punctures when compared to the untreated fruits. While no feeding punctures were observed in neem seed oil - garlic emulsion 2 per cent and 4 per cent and neem seed oil 4 per cent treated fruits. (Table 23), negligible number of punctures (0.67 per fruit) was recorded on fruits treated with neem seed oil 2 per cent. The number of feeding punctures in NeemAzal 2ml/l, Nimbecidine 2 ml/l, Econeem 2ml/l and 4 ml/l, and NeemAzal 4 ml/l treated fruits was 1.33,1.67,1.67,1.67 and 2.00 per fruit respectively. Higher number of feeding punctures were recorded in Achook 2ml/l (2.67 per

Table 22. Influence of nut colour and shape on the extent of damage by *Paradasynus rostratus* in coconut

Characters	Mean Intensity Score
Colour of nut	
Green	3.10
Red	4.00
Greenish orange	4.55
Orange	4.50
CD (0.05)	0.85
Shape of nuts	
Round	3.30
Elongate	4.10
CD (0.05)	0.44

fruit), Nimbecidine 4ml/l (3.00 per fruit) and Achook 4 ml/l (3.00 per fruit) treated fruits which were on par.

Twenty four hours after release of coreid bug nymphs, no feeding punctures were recorded from neem seed oil - garlic emulsion 4 per cent. The number of feeding punctures in neem seed oil- garlic emulsion 2 per cent (0.33), neem seed oil 4 per cent (0.33) and neem seed oil 2 per cent (0.67) treated fruits was negligible. However, more number of feeding punctures was observed in NeemAzal 2 ml/l (2.33), NeemAzal 4ml/l (2.67) and Econeem 2 ml/l (3.00) treated fruits and they were on par. No significant difference was observed in the number of feeding punctures in Nimbecidine 2ml/l (3.67), Achook 2ml/l (4.00), Achook 4ml/l (4.33) and Econeem 4ml/l (4.33) treated fruits.

Toxic Effect

The mortality of coreid bug nymphs was high when released on neem seed oil -garlic emulsion 2 and 4 per cent (46.67 per cent each) treated fruits and it was statistically on par with the treatments, Econeem 4ml/l (30.00 per cent), Achook 4ml/l (30.00 per cent) and Nimbecidine 4ml/l (23.33). Lower percentage mortality was recorded from neem seed oil 2 per cent (20.00), Neem Azal 4ml/l (6.67) and Econeem 2ml/l (3.33) treatments, which were on par in their effect. No mortality was recorded when the nymphs were released on guava fruits treated with Nimbecidine 2 ml/l and Achook 2 ml/l.

4.4.1.2 Chemical Insecticides

Twelve hours after release of nymphs of coreid bug on insecticide treated fruits, no mortality was observed in acephate 0.05 per cent, triazophos 0.05 per cent and triazophos 0.1 per cent treatments (Table 24). The treatments came on par with chlorpyriphos 0.05 per cent, acephate 0.1 per cent (3.33 per cent mortality each) and quinalphos 0.05 per cent (6.67 per cent). Significantly, higher mortality of nymphs was recorded in profenophos 0.1 per cent (30.01 per cent) treatment which was statistically similar to chlorpyriphos 0.1 per cent (20.01 per cent), profenophos 0.05 per cent and quinalphos 0.1 per cent (16.67 per cent each).

Table 23. Antifeedant effect and toxicity of neem based botanicals on *Paradasynus rostratus*

Treatments	Antifeedant action: Number of feeding punctures on guava fruits hours after release		Toxicity: Mortality (per cent) 48 h after release
	12	24	
Achook 0.15 per cent 2 ml/l	2.67 (1.91)	4.00 (2.24)	0.00 (1.00)
Achook 0.15 per cent 4 ml/l	3.00 (2.00)	4.33 (2.31)	30.00 (5.56)
Nimbecidine 0.15 per cent 2 ml/l	1.67 (1.63)	3.67 (2.16)	0.00 (1.00)
Nimbecidine 0.15 per cent 4 ml/l	3.00 (2.00)	1.67 (1.63)	23.33 (4.93)
Econeem 1 per cent EC 2 ml/l	1.67 (1.63)	3.00 (2.00)	3.33 (2.08)
Econeem 1 per cent EC 4 ml/l	1.67 (1.63)	4.33 (2.31)	30.00 (5.57)
NeemAzal T/S 1 per cent 2ml/l	1.33 (1.53)	2.33 (1.99)	0.00 (1.00)
NeemAzal T/S 1 per cent 4 ml/l	2.00 (1.73)	2.67 (1.91)	6.67 (2.19)
Neem seed oil 2 per cent	0.67 (1.28)	0.67 (1.28)	20.00 (4.58)
Neem seed oil 4 per cent	0.00 (1.00)	0.33 (1.14)	23.33 (4.93)
Neem seed oil-garlic 2 per cent	0.00 (1.00)	0.33 (1.14)	46.67 (6.87)
Neem seed oil-garlic 4 per cent	0.00 (1.00)	0.00 (1.00)	46.67 (6.87)
CD (0.05)	**(0.22)**	**(0.31)**	**(3.07)**

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

Table 24. Effect of synthetic insecticides on *Paradasynus rostratus*

Treatments	Percentage mortality observed after various intervals (h)			
	12	24	48	72
Triazophos 0.05 per cent	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	13.33 (3.39)
Triazophos 0.10 per cent	0.00 (1.00)	3.33 (1.77)	33.33 (6.01)	66.67 (8.11)
Quinalphos 0.05 per cent	6.67 (2.54)	13.33 (3.39)	26.67 (5.24)	43.33 (6.65)
Quinalphos 0.10 per cent	16.67(3.72)	20.21 (4.01)	36.67 (6.04)	46.67 (6.90)
Chlorpyriphos 0.05 per cent	3.33(1.77)	6.66 (2.19)	16.67 (3.72)	26.67 (5.24)
Chlorpyriphos 0.10 per cent	20.01 (4.49)	26.67 (5.24)	36.67 (6.13)	56.67 (7.59)
Profenophos 0.05 per cent	16.67(3.72)	20.67 (4.24)	50.01 (7.08)	79.46(8.97)
Profenophos 0.10 per cent	30.01(5.52)	46.67 (6.90)	63.33 (7.94)	86.42(9.35)
Acephate 0.05 per cent	0.00(1.00)	6.67 (2.54)	16.67 (4.16)	43.33 (6.62)
Acephate 0.10 per cent	3.33(1.77)	13.33 (3.39)	16.67 (4.16)	50.01 (7.08)
CD(0.05)	**(2.02)**	**(2.27)**	**(1.80)**	**(2.08)**

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

Twenty four hours after release of nymphs, no mortality was observed in triazophos 0.05 per cent treatment. Profenophos 0.1 per cent (46.67 per cent) recorded significantly higher percentage of mortality than the others but was statistically similar to chlorpyriphos 0.1 per cent (26.67 per cent) treatment. The mortality of nymphs recorded in profenophos 0.05 per cent, quinalphos 0.1 and 0.05 per cent, acephate 0.1 and 0.05 per cent and chlorpyriphos 0.05 per cent was 20.67, 20.21, 13.33, 13.33, 6.66 and 6.66 per cent respectively. Only 3.33 per cent mortality of the nymphs was recorded in triazophos 0.1 per cent treatment.

Similarly, no mortality of nymphs was observed in triazophos 0.05 per cent treatment when observed after forty eight hours. However, higher percentage mortality was recorded in profenophos 0.1 per cent (63.33) and profenophos 0.05 per cent (50.01) which were on par. No significant difference was observed in the mortality of nymphs released on guava fruits treated with chlorpyriphos 0.1 per cent (36.67 per cent), quinalphos 0.1 per cent (36.67 per cent) and triazophos 0.1 per cent (33.33 per cent).

Seventy two hours after treatment, significantly higher mortality was observed in profenophos 0.1 per cent (86.42 per cent) followed by profenophos 0.05 per cent (79.46 per cent), triazophos 0.1 per cent (66.67 per cent), chlorpyriphos 0.1 per cent (56.67 per cent). The mortality of nymphs recorded in quinalphos 0.1 per cent (46.67 per cent), acephate 0.1 per cent (50.01 per cent), quinalphos 0.05 per cent, acephate 0.05 per cent (43.33 per cent each) and chlorpyriphos 0.05 per cent (26.67 per cent) treatments was on par. The lowest mortality was observed in triazophos 0.05 per cent treatment (13.33 per cent).

4.4.2 Field Evaluation

The results of the investigation on infestation of coreid bug in young buttons (third bunch) of coconuts around alternate host plants *viz*., guava, cashew, cocoa and neem treated with the most effective botanical, neem seed oil - garlic emulsion 2 per cent and the most effective chemical pesticide, profenophos 0.05 per cent and their combinations are presented in Table 25.

Table 25. Extent of infestation of *Paradasynus rostratus* on coconuts around pesticide treated alternate hosts

Treatments	Extent of infestation recorded at different months after spraying (per cent)											
	Guava			Cashew			Cocoa			Neem		
	1	2	3	1	2	3	1	2	3	1	2	3
Neem seed oil – garlic 2 per cent	44.93 (6.78)	44.01 (6.71)	63.92 (8.06)	50.43 (7.17)	54.26 (7.43)	42.66 (6.61)	60.18 (7.82)	65.97 (8.18)	75.97 (8.77)	49.09 (7.08)	60.53 (7.84)	67.59 (8.28)
Profenophos 0.05 per cent	15.93 (4.11)	17.17 (4.26)	18.56 (4.42)	20.89 (4.68)	23.74 (4.97)	22.38 (4.84)	27.43 (5.33)	36.89 (6.16)	38.61 (6.29)	24.80 (5.08)	30.46 (5.61)	28.66 (5.45)
Neem seed oil - garlic 2 per cent + Profenophos 0.025 per cent	20.11 (4.60)	21.55 (4.75)	27.38 (5.33)	17.11 (4.25)	18.55 (4.42)	16.74 (4.21)	34.59 (5.97)	31.98 (5.74)	23.65 (4.96)	14.83 (3.98)	26.61 (5.25)	34.95 (6.00)
Control	52.17 (7.29)	47.94 (6.90)	87.40 (9.40)	64.04 (8.07)	65.04 (8.13)	65.99 (8.19)	58.34 (7.70)	73.72 (8.64)	55.14 (7.49)	54.84 (7.47)	61.85 (7.93)	65.05 (8.13)
CD(0.05)	(1.53)	(0.93)	(1.26)	(1.33)	(1.34)	(1.53)	(1.43)	(1.28)	(1.99)	(1.79)	(1.79)	(1.71)

Values in parentheses are adjusted means transformed to their square roots

4.4.2.1 Guava

One month after application of the pesticides, significantly lower infestation was observed in coconut palms around guava trees treated with profenophos 0.05 per cent (15.93 per cent) followed by coconut palms around plants treated with neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent (20.11 per cent). The extent of infestation in palms around guava treated with neem seed oil - garlic emulsion 2 per cent (44.93 per cent) was similar to that of the palms around untreated guava (52.17 per cent). A similar trend prevailed when the coconut palms were observed two months after treatment. Significantly, lower infestation was noticed in coconut palms around profenophos 0.05 per cent treated guava (17.17 per cent) and neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent sprayed guava (21.55 per cent). The infestation in palms around neem seed oil - garlic emulsion 2 per cent treated guava trees (44.01 per cent) and untreated guava (47.94 per cent) did not differ significantly. Three months after spraying, again lower infestation was recorded from palms around profenophos 0.05 per cent treated guava (18.56 per cent) and in palms surrounding neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent treated guava (27.38 per cent). The infestation in palms around neem seed oil -garlic emulsion 2 per cent treated guava trees (63.92 per cent) was similar to that in control palms (87.40 per cent).

4.4.2.2 Cashew

One month after spraying, lower infestation of the coreid bug was recorded in neem seed oil -garlic emulsion 2 per cent + profenophos 0.025 per cent treatment (17.11 per cent) followed by profenophos 0.05 per cent (20.89 per cent).. Higher infestation was observed in palms around cashew trees treated with neem seed oil - garlic emulsion 2 per cent (50.43 per cent) and palms around untreated cashew (64.04 per cent). A similar trend was observed two months after spraying. Significantly lower infestation was observed in the treatment neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent (18.55 per cent) followed by profenophos 0.05 per cent (23.74 per cent) compared to 65.04 per cent infestation in control. When sprayed with neem seed oil- garlic emulsion 2 per cent, the extent of infestation was 54.26 per cent which was on par with the infestation in control palms. Three months after spraying, lower infestation was recorded in neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent (16.74 per cent) followed by profenophos 0.05 per cent (22.38 per cent). The extent of damage recorded in neem seed oil - garlic emulsion 2 per cent (42.66 per cent) was higher and did not differ significantly from the damage recorded in palms around untreated cashew (65.99).

4.4.2.3 Cocoa

Profenophos 0.05 per cent (27.43 per cent) and neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent (34.59 per cent) significantly reduced the infestation one month after treatment in coconut around treated cocoa trees. The treatments were statistically on par. The infestation noticed in palms around neem seed oil - garlic emulsion 2 per cent treated cocoa (60.18 per cent) was statistically similar to those in coconut around untreated cocoa (58.34 per cent). Significantly lower infestation was observed in coconut palms around cocoa trees treated with neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent (31.98 per cent) followed by profenophos 0.05 per cent treated cocoa (36.89 per cent) two months after spraying. However, the infestation was higher in palms around neem seed oil - garlic emulsion 2 per cent treated (65.97 per cent) and untreated cocoa trees (73.72 per cent).

A similar trend was observed three months after spraying. The infestation in palms around neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent and profenophos 0.05 per cent treated cocoa were 23.65 and 38.61 per cent respectively. Higher infestation was observed in coconut around neem seed oil- garlic emulsion 2 per cent treated cocoa (75.97 per cent) and untreated cocoa trees (55.14 per cent).

4.4.2.4 Neem

One month after spraying, lower infestation was observed in coconut palms near neem trees treated with neem seed oil -garlic emulsion 2 per cent + profenophos 0.025 per cent (14.83 per cent) and profenophos 0.05 per cent (24.80 per cent). However, the infestation in coconut palms around neem treated with neem seed oil - garlic emulsion 2 per cent (49.09 per cent) was significantly higher and similar to those around untreated trees (54.84 per cent). A similar trend was recorded two months after spraying. The infestation was the least in palms around neem treated with neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent (26.61 per cent) closely followed by profenophos 0.05 per cent (30.46 per cent). The infestation in coconut around neem seed oil - garlic emulsion 2 per cent treated neem plants were 60.53 per cent which was statistically on par with control palms (61.85 per cent). Three months after treatment too, statistically lower infestation was observed in coconut palms around profenophos 0.05 per cent treated neem (28.66 per cent) and neem seed oil - garlic 2 emulsion per cent + profenophos 0.025 per cent (34.95 per cent). The infestation in coconut palms around neem treated with neem seed oil - garlic emulsion 2 per cent (67.59 per cent) was significantly similar to those in control palms around untreated neem (65.05 per cent).

4.4.3 Effect of Adoption of Control Measures on Alternate Hosts and Their Impact on Yield of Coconut

4.4.3.1 Guava

Adoption of control measures on the alternate hosts had an appreciable impact on the extent of damage and subsequently yield of coconut (Table 26). Categorization of the harvested nuts into different damage classes revealed that coreid bug caused only negligible to mild damage on coconut palms around guava sprayed with profenophos 0.05 per cent and neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent as indicated by the percentage of nuts in the different damage categories at harvest. 66.67 and 50.00 per cent of the nuts obtained from the treatments respectively were uninfested (category I). While

Table 26. Extent of infestation of Paradasynus rostratus in mature nuts of coconut palms around treated alternate hosts

Treatments	Total number of nuts	Nuts under each damage category (per cent)					
		I	II	III	IV	V	VI
Guava							
1.NSG – 2 per cent	13	15.39	15.39	7.70	30.77	23.08	7.70
2.Profenophos - 0.05 per cent	12	66.67	25.00	8.33	0.00	0.00	0.00
3.NSG-2 per cent + profenophos 0.025 per cent	14	50.00	28.57	21.43	0.00	0.00	0.00
4. Control	11	9.00	9.00	18.00	9.00	27.00	27.00
Cashew							
1.NSG – 2 per cent	8	0.00	0.00	50.00	0.00	25.00	25.00
2.Profenophos - 0.05 per cent	6	83.33	16.67	0.00	0.00	0.00	0.00
3.NSG-2 per cent + profenophos 0.025 per cent	10	80.80	0.00	20.00	0.00	0.00	0.00
4. Control	4	0.00	25.00	0.00	0.00	0.00	75.00
Cocoa							
1.NSG – 2 per cent	9	0.00	44.44	0.00	22.22	33.33	0.00
2.Profenophos - 0.05 per cent	10	20.00	80.00	0.00	0.00	0.00	0.00
3.NSG-2 per cent + profenophos 0.025 per cent	8	100.00	0.00	0.00	0.00	0.00	0.00
4. Control	5	0.00	0.00	0.00	40.00	60.00	0.00
Neem							
1.NSG – 2 per cent	9	0.00	22.22	0.00	0.00	22.22	55.56
2.Profenophos - 0.05 per cent	11	72.72	18.18	0.00	9.00	0.00	0.00
3.NSG-2 per cent + profenophos 0.025 per cent	12	75.00	8.33	0.00	16.67	0.00	0.00
4. Control	8	0.00	0.00	25.00	50.00	25.00	0.00
NSG- Neem seed oil –garlic emulsion							

25.00 and 28.57 per cent nuts had only negligible damage (category II), 8.33 and 21.43 per cent nuts showed mild damage (category III) in the treatments respectively. When guava was sprayed with neem seed oil 2 per cent, only 15.39 per cent undamaged nuts were obtained from the surrounding palms. 15.39, 7.70, 30.77, 23.08 and 7.70 per cent of nuts recorded negligible (category II), mild (category III), moderate (category IV), heavy (category V) and severe (category VI) damages respectively. The percentage of undamaged nuts (category I) was very low in palms around untreated guava (9.00). The percentage of nuts with negligible, mild and moderate damage was 9.00, 9.00 and 18.00 respectively. Higher percentage of nuts recorded heavy (27.00) and severe (27.00) damage.

4.4.3.2 Cashew

A similar trend was seen in nuts harvested from palms around cashew tree treated with insecticides. When profenophos 0.05 per cent was sprayed on cashew trees, 83.33 per cent of nuts in the surrounding palms were undamaged (category I) and 16.67 per cent had negligible damage (category II). In neem seed oil- garlic emulsion 2 per cent + profenophos 0.025 per cent treatment too, 80.00 and 20.00 per cent nuts were recorded in category I and category III(mild damage) respectively. In palms around neem seed oil garlic 2 per cent treated cashew, though 50.00 per cent of the nuts showed mild damage (category III), 50 per cent nuts were heavily (category V-25 per cent) and severely damaged (category VI-25 per cent). Contrarily, all the nuts in palms around untreated cashew trees were damaged by coreid bug. Seventy five per cent of the nuts were severely damaged (category VI). Only 25.00 per cent nuts showed negligible damage (category III).

4.4.3.3 Cocoa

In coconut palms around cocoa, 20.00 per cent of the nuts were undamaged and 80.00 per cent showed negligible damage (category II) when treated with profenophos 0.05 per cent and neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent. When treated with neem seed oil - garlic emulsion 2 per cent, 44.44 per cent of nuts had negligible damage (category II), 22.22 per cent moderate damage (category IV) and 33.33 per cent heavy damage (category V). Heavy damage was observed in the palms around untreated plants. 40.00 per cent nuts were distributed in category IV while 60.00 per cent were seen in category V.

4.4.3.4 Neem

In coconut - neem combination, 72.72 per cent of undamaged nuts were obtained when the alternate hosts were sprayed with profenophos 0.05 per cent. 18.18 and 9.00 per cent of nuts were in categories II and IV respectively. Similarly, 75.00 per cent undamaged nuts were obtained in neem seed oil- garlic emulsion 2 per cent + profenophos 0.025 per cent treatment. While 8.33 per cent nuts harvested were in category II, 16.67 per cent nuts were in category IV. The nuts in neem seed oil- garlic emulsion 2 per cent treatment showed negligible to severe damage. 22.22 per cent nuts were in category II and V respectively. 55.55 per cent nuts showed severe damage (category VI). In the control palms, 25.00, 50.00 and 25.00 per cent nuts were in category III, IV and V respectively.

Considering the impact of the treatments in terms of income from the palms, an increase of Rupees 22.79, 17.15, 29.32 and 23.92 was obtained from the harvested nuts of the marked third bunch of palms around profenophos treated guava, cashew, cocoa and neem respectively (Table 27). Similarly, in coconut around neem seed oil -garlic emulsion 2 per cent + profenophos 0.025 per cent treated guava, cashew, cocoa and neem, the increase in income was Rupees 28.39, 31.07, 22.60 and 26.34 per coconut bunch respectively. Even after spraying with neem seed oil -garlic emulsion 2 per cent on alternate hosts like guava, cashew and cocoa, an increase of Rupees 9.78, 10.01 and 15.36 per coconut bunch was obtained.

Table 27. Increase in income of coconut by the application of treatments on alternate hosts

Treatments	Increase in income per coconut bunch (in terms of rupees)			
	Guava	Cashew	Cocoa	Neem
Neem seed oil – garlic emulsion 2 per cent	9.78	10.01	15.36	0.00
Profenophos 0.05 per cent	22.79	17.15	29.32	23.92
Neem seed oil – garlic emulsion 2 per cent + profenophos 0.025 per cent	28.39	31.07	22.60	26.34

DISCUSSION

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5. DISCUSSION

An 'agro ecosystem' is a fragile system characterized by a much simpler composition with regard to the number of species including crops and their pests residing in the system and the relative simplicity of energy flows than a natural and stable ecosystem. Any strategy directed at the pests, which limit the productivity of crops, has to be dealt in the context of the whole production system rather than as separate individual problems. Thus, Integrated Pest Management (IPM) approaches rather than unilateral measures are best suited for tackling pests in agrarian systems. IPM can succeed only through an understanding of the complexity of ecosystem interactions followed by the application of this knowledge to achieve relative stability of pest populations below damaging levels without resorting to exclusive use of interventive and disruptive techniques. Otherwise the quality of the environment would be compromised.

Coconut is essentially a small holder's plantation crop in Kerala. The production systems of the crop range from monoculture to single and multispecies cropping systems, homestead farming being the more popular mode of cultivation. Homestead farms are important agro ecological systems, which not only provide income and subsistence to the farmers but also act as a repository of biodiversity. Farmers have evolved these through generations of experience and experimentation for domestication of several plant varieties. The coconut based farming system is the most common farming system occupying more than 90 per cent of the homestead farms in the state (Regeena *et al.,* 2004). In these farms, coconut is the base crop and its growth characteristics and planting geometry facilitate the successful growing of other trees, shrubs and herbs between or under the crop. Trees like jack, mango, drumstick, guava, tamarind, cashew, neem, cocoa, curry leaf and seasonals like colocasia, cassava, elephant foot yam, vegetables and ornamental plants are some of the common intercrops. Studies by

Regeena *et al.* (2004) under the National Agricultural Technology Programme revealed a cropping intensity ranging from 62 to 172 per cent in these farms. In the former case, under utilization of land and solar energy was evident whereas in the latter, overcrowding resulted in low infiltration of solar energy and unhealthy competition between plants. Lack of proper and scientific management of the coconut based homestead farms was also visible. The low productivity of the base crop, coconut could be attributed to several reasons, one being the onslaught of pests. Among the complex of pests associated with the crop, the coreid bug, *Paradasynus rostratus* Dist. assumes importance in the multiple cropping scenario as it is polyphagous, infesting coconut as well as a number of other plant species. The availability of food and habitat from the various hosts fuel the growth and development of the pest and consequent infestation.

Information on food and habitat requirements as well as population dynamics of the coreid bug is vital for the development of tactics for an ecofriendly pest management strategy. With this view, the study was taken up to determine the present status of the pest, locate its alternate hosts in the homesteads and explore the possibility of exploiting these crops to contain the pest.

5.1 INCIDENCE OF *P. ROSTRATUS* AND THEIR NATURAL ENEMIES

The coreid bug has gained infamy as a major pest of coconut in Kerala. Surveys had been conducted in 1986 on the incidence of the bug on coconut in the state (Visalakshi *et al.*, 1989). However, information on the extent of infestation by the pest on coconut in the homestead farming system is lacking. In this context, a survey was conducted in Thiruvananthapuram district of Kerala to study the intensity of infestation by the pest in coconut. The survey encompassed 150 farmers' plots in 15 selected panchayats representing the coastal, midland and upland regions of the district. Infestation of the pest was observed to be the highest in the coastal regions (36.69 per cent). Lower incidence was recorded in upland

(14.53 per cent) and midland (13.52 per cent) regions (Fig. 2). Dense cropping of coconut palms is a characteristic feature of the homestead farming in coastal regions. About 215 palms are there in a hectare of land, though the recommendation is only 175 palms in pure plantations (Alexander and Peter, 2005). This high density of palms with closer spacing in the coastal regions might have contributed to higher percentage of infestation. Positive correlation of the infestation in coconut with relative humidity had been observed earlier (Reghunath *et al.*, 1988). In this study, the mean percentage incidence of the pest in Thiruvananthapuram district was 21.58. In 1986, the extent of infestation by the pest was 4.80 per cent in this district (Visalakshi *et al.*, 1989). The study indicated an increasing trend in the incidence of the bug.

Critical analysis of the data on the extent of infestation among the panchayats in the midland and upland regions revealed that the damage was higher in Vamanapuram (23.18 per cent) of midland, Kattakada (30.93 per cent) and Poovachal (23.56 per cent) panchayats of upland too. Kattakada and Poovachal panchayats lie geographically in the beginning of the upland region and had been developed much earlier by demographic settlements, compared to other panchayats situated deeper in the upland. In these areas too, high density of palms with close spacing is prevalent as in the coastal regions. Presumably, the high density of coconut palms per unit area providing copious food could have been the major factor contributing to heavy infestation in the regions.

Alternate hosts are known to exert a positive influence on the population build up of coreid bug in coconut (Nair and Remamony, 1964; Nair, 1975; Kurian *et al.,* 1976; Beevi *et al.*, 1989; CPCRI, 1999). In Kerala, the average size of holding is only 0.20 ha and 98 per cent of the holdings are less than 0.20 ha (Alexander and Peter, 2005). In the coconut based homestead farms, coconut is the base crop with other perennials, annuals and seasonal crops grown in between or below coconut. Some of

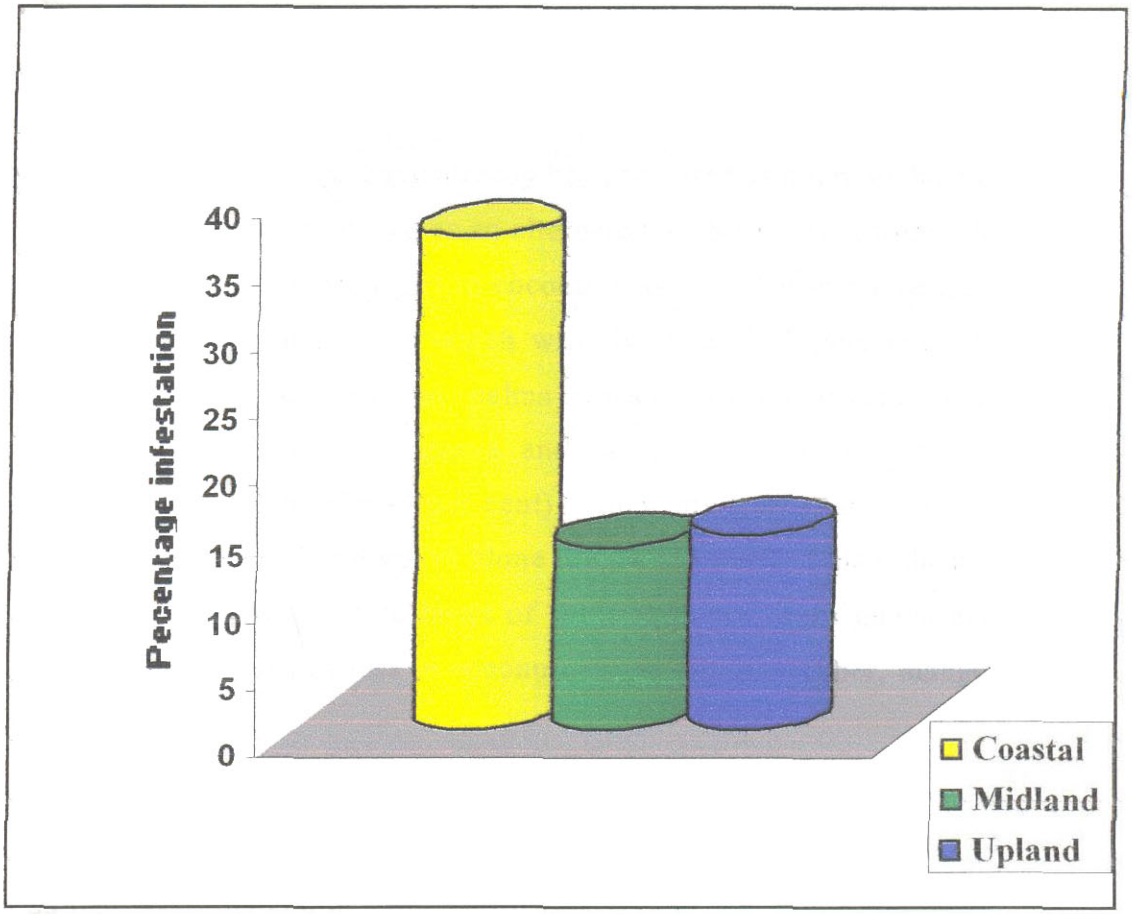

Fig. 2.Extent of infestation by *Paradasynus rostratus* in coconut in Thiruvananthapuram district

the intercrops are recognized as alternate hosts of the coreid bug. The multiple cropping in the coconut holdings thus, increases the possibility of infestation on coconut. In view of the above, the crops other than coconut in the homesteads were examined for coreid bug infestation during the survey. Guava, neem, cashew, cocoa, pepper, rubber, tamarind, mango and curry leaf were recorded as alternate hosts of the pest. With the exception of curry leaf, all the other crops have already been reported as alternate host of the pest. Curry leaf was identified as an alternate host for the first time. The highest infestation (39.36 per cent) in coconut was recorded in homesteads having guava, cashew and cocoa which was significantly higher than the other combinations. The coconut palms infested in homesteads with alternate host combinations of guava and cashew was 36.74 per cent followed by cashew alone (34.99 per cent), combination of guava, cashew and neem (33.66 per cent) and guava alone (32.44 per cent). This indicated that the most favoured alternate hosts of the coreid bug were guava and cashew. The infestation was less in coconut around pepper, rubber, mango, tamarind and curry leaf.

Plant characters and farmer interventions are known to influence incidence of pests in agro ecosystems. Exploratory studies along the line revealed that age of the palm had no influence on the infestation by coreid bug. Irrespective of the age of palm, the pest attacked the young nuts which were in the susceptible stage (third, fourth and fifth bunch). However, the height of palm had a significant role in the infestation. The palms, which had a height of 5 to 10 m suffered more damage compared to palms with less than 5 m and more than 10 m height. The crown of palms with more than 10 m height is more exposed to the abiotic elements like sunlight and wind. This could be uncomfortable to the bug for movement and feeding compared to the shorter palms. Similar relations between height of plants and pest incidence had been observed earlier. When the height of palm increased, the infestation level of rhinoceros beetle decreased in coconut (Patel, 1988). The spacing of palms had no influence on infestation in coconut by coreid bug. This could be due to the fact that adults are active fliers. Similar observations were made on the movement of *Amblypelta* in coconut plantations (Phillips, 1940).

Irrigation plays a crucial role in maintaining the productivity of crops. Infestation by coreid bug in coconut was significantly lower in irrigated fields than in unirrigated. Irrigation results in a significant increase in production of female flowers and button setting. More buttons per unit area would probably result in the coreid bug attack being distributed and reduction in the overall percentage of infestation. The result concurs with the findings of Beevi *et al.* (2004) who reported that the eriophyid mite damage was considerably lesser in irrigated palms compared to unirrigated ones. No significant variation in infestation in coconut was reported from sprayed (dicofol and neem seed oil - garlic emulsion 2 per cent) and unsprayed plots. The ineffectiveness of the plant protection operations was evident due to the erroneous measures adopted consequent to the inability of farmers to differentiate the symptoms of attack by eriophyid mite and coreid bug in coconut. Dicofol and neem seed oil - garlic emulsion 2 per cent were invariably sprayed against both these pests. While these were effective against the eriophyid mite, the coreid bug was not controlled. As a result, the coreid bug had multiplied and infested the coconut palms. The study established the need for creating awareness among farmers and organizing training programmes to enable them to identify the symptoms of attack by the various pests. Manuring of the palms did not have any significant bearing on the extent of infestation.

During the survey, two egg parasitoids, *C. oviceps, Gryon* sp. were recorded. The parasitisation of the egg masses of the coreid bug was observed during March and July to September, 2004 and it was ranged from 50.00 to 66.67 per cent (Fig. 3). These observations concurred with the findings of Mohan *et al.*, (2001) and Mohan and Faizal, (2004a). They reported the occurrence of both the parasitoids in the field from April to

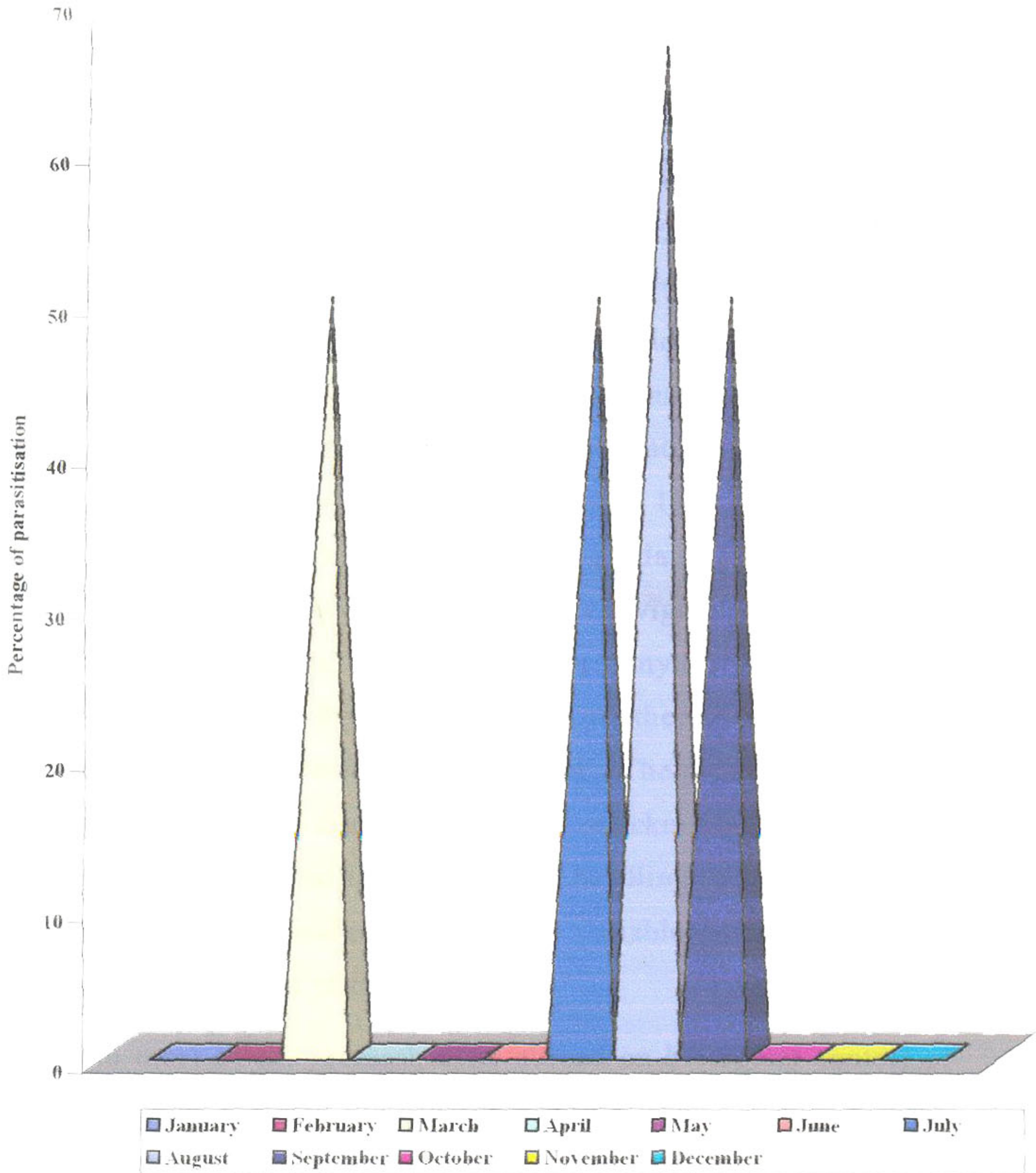

Fig. 3. Parasitisation of egg masses of *Paradasynus rostratus*

October. In 1940 itself, Phillips reported an egg parasitoid, *Anastatus* sp. which hatched from eggs of coreid bug, *Amblypelta* sp. No parasitoid of the nymphs or adult stages had been observed. The potential of these parasitoids has largely remained untapped and underexploited.

Three predators *viz.*, a reduvid bug, red ant and spiders too were recorded. The reduvid predator was identified as *Sycanus* sp. This is the first report of *Sycanus* sp. feeding on *P.rostratus*. Reduvidae, the largest family of predaceous land heteroptera occur world wide and are voracious predators (Schaefer, 1988). *Sycanus* spp. have been identified as predators of various pests like *Spirama retorta* Clerck. (Sajap *et al.*, 1997), *Clostera* spp. (Singh, 1998) from acacia and mangium plantations and *Spodoptera litura* (F.) of different crops (George *et al.,* 1998). In 1999, CPCRI reported on a reduvid bug *Endochus inornatus* Stal. as a predator of nymphs of the bug. Nymphs and adults of the reduvid are active, vigorous and have high prey searching capacity. At times, two to three nymphs of coreid bug would be killed and sucked dry within 24 h. On other occasions, most of the bugs would be left unharmed for over a week. The predatory behaviour of this reduvid is similar to that of *E. doryeus* attacking both nymphs and adults of *Amblypelta* sp. (Phillips, 1940). The handling of this predator is difficult and its predatory behaviour is highly variable which are the two bottlenecks in the utilization of the predator.

Hitherto most of the research done abroad on biological control of coreid bugs had been oriented towards the use of different species of ants. Lever (1935) in the British Solomon Islands, Way (1953b) in East Africa and Peng *et al.* (1995) in Australia were the pioneer workers in the studies on biological control of coreid bugs using different species of ants. However, in this study it was observed that red ant population was very low in coconut and they could not have played a worthwhile role in the control of coreid bug. Still, the possibility of exploiting the ants could be explored since they have been effectively utilized elsewhere.

Though many biocontrol agents have been reported for tackling the coreid, their efficacy at field level are not impressive. Effective predators for tackling *P. rostratus* have not yet been identified. More research is required on population dynamics of the newly identified reduvid and the egg parasitoids of coreid bug. Their role in natural suppression of the bug in relation to biotic and abiotic factors operating within the agro ecosystem has to be analysed. There are several factors interacting among the components of the biotic system and their relationship with abiotic elements. These interactions are dynamic and are bound to change from season to season and one component may mask the effect of the other. IPM strategies that cause not only the least damage but also conserve the natural enemies have to be developed.

5.2 INFLUENCE OF ALTERNATE HOSTS ON THE EXTENT OF DAMAGE IN COCONUT

An alternate host is a species of plant other than the principal host on which a pest can survive (Hoffmann and Frodsham, 1993). Coconut being the base crop of the homestead farming system of Kerala is considered as the principal host of *P. rostratus* and other plant species on which the pest thrives are considered as alternate hosts. The reported alternate hosts of *P. rostratus* are cashew (Nair and Remamony, 1964), guava (Nair, 1975; Kurian *et al.*, 1976; Beevi *et al.*, 1989), mango, tapioca, rubber (Kurian *et al.*, 1979), neem (Sundararaju and Babu, 1999), cocoa (CPCRI, 1999), passion fruit (Mohan and Nair, 2000) and black pepper (Lekha and Mohan, 2004). The related genera of coreid bug, *Amblypelta* reported from Northern Australia and Solomon Islands is a major pest of coconut. Apart from coconut, *Amblypelta* attacks *Ficus* sp., *M.tanarius, J. curcas, P. pulcherrima, T. bartrami,* cowpea, melon, orange, grandillias, red chillies, sugarcane, manioc, mucarels, papaya, kapoka (Phillips, 1940), cocoa, mango, rubber, cassava and perssimons (Brown, 1958b). The third important coreid bug, *P. wayi* of coconut reported from East Africa and

Zanzibar attacked the crops like guava (Wright, 1952; Way 1953a), cocoa, mango, cinnamon (Kurian *et al.*, 1976), cassava (IITA, 1981; Kankolongo *et al.*, 1987), avocado (Dennill and Erasmus, 1991; Dupont, 1993; Der *et al.*, 1994) and star fruit (Der *et al.*, 1992). This reveals the wide host range of the various species of coreid bugs in the coconut growing regions of India and other countries. However, the influence of these host plants on population build up of coreid bugs in coconut has not been clearly understood. Studies are yet to be conducted on the comparative role of these alternate hosts during a particular period or season on the population build up of the pest. In 1989, Visalakshi *et al.* conducted a survey in all the districts of Kerala and they found out a positive significant relationship between alternate host species of coreid bug and infested coconut palms in Pathanamthitta, Alappuzha and Palghat districts. In other districts, no relationship could be established. In this context, they raised the necessity for a more precise study to establish the status of the alternate hosts as a factor with regard to coreid bug damage on coconut. An experiment was undertaken to study these aspects in detail.

Survey on the incidence of the coried bug in Thiruvananthapuram district had revealed that guava, cashew, cocoa and neem were the favoured alternate hosts of the pest. Hence four combinations of coconut and these alternate hosts (guava, cashew, cocoa and neem,) were selected for the study. The population of coreid bug in guava was higher during March to May and August to October. Usually guava flowers twice a year, in April to May and August to September (Gupta and Nijjur, 1978) and the high population of the pest coincided with this period. The population of coreid bug in coconut palms around guava was higher during May to October (Fig.4). Apparently, the coreid bug multiplied and built a strong population in guava plants during the fruiting period and later moved to coconut. Higher Mean Intensity Score (MIS) was recorded in the nuts harvested during March to September.

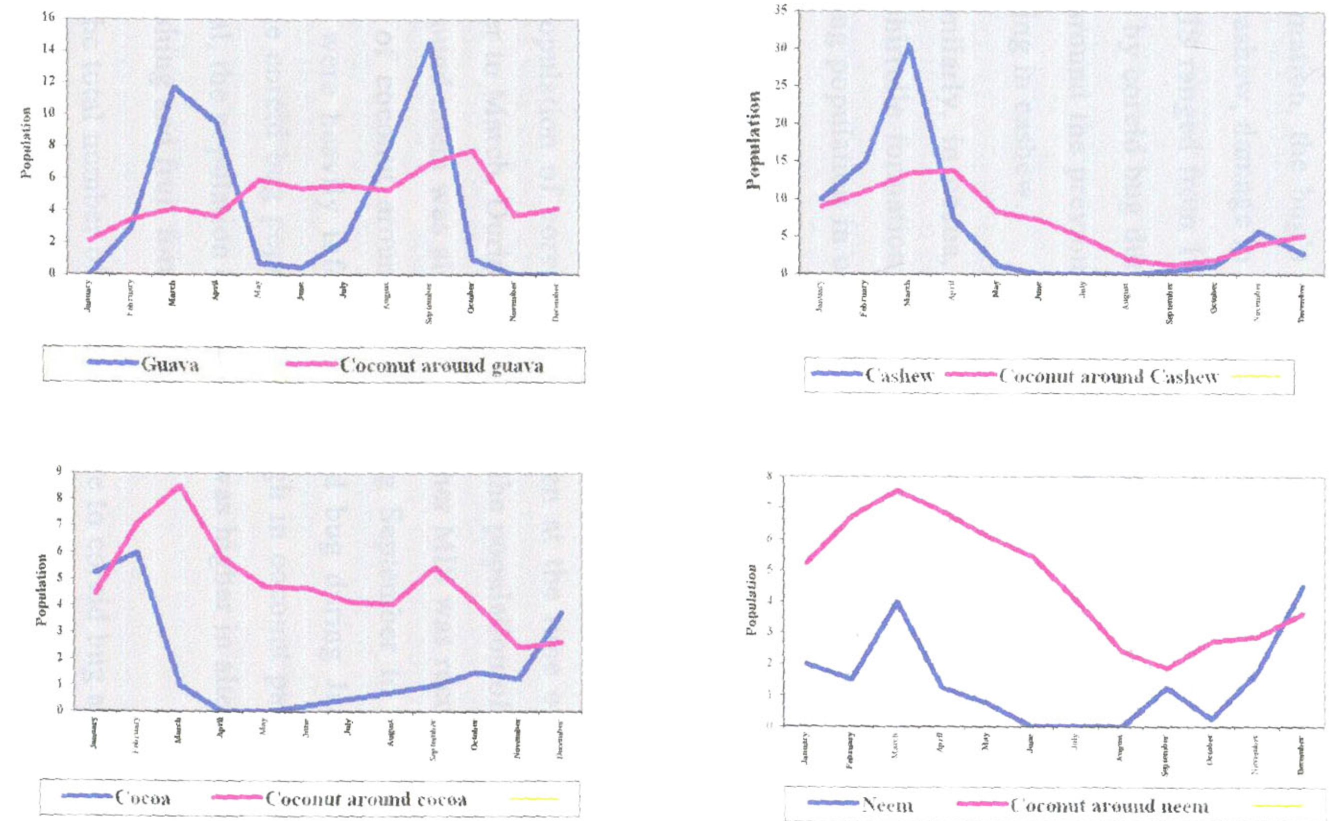

Fig. 4. Population of *Paradasynus rostratus* in alternate hosts and coconut around the alternate hosts

The population of coreid bug in cashew was higher during January to April when the young green cashew nuts were plentiful and provided food. The population was also higher in the coconut palms around cashew during February to May. As in guava, the pest would have shifted to the nearby coconut palms after the fruiting season in cashew registering higher populations of the pest. By January to March during the active flushing and fruit formation, the bug's population began to increase. In coconut palms around cashew, damage in young and mature nuts was not seen from May to July. MIS ranged from 1.75 to 4.98 in the other months. These nuts were attacked by coreid bug during their susceptible stage (third, fourth and fifth bunch) around the previous February to May months which coincided with the fruiting in cashew.

Similarly, in cocoa, higher population of coreid bug was observed during chirrelle formation stage *viz*., December to February. Whereas the coreid bug population in coconut around cocoa was higher during February to April. This again revealed a vivid picture of a population of coreid bug moving from alternate hosts to coconut. Similarly in cocoa, higher MIS was obtained in bunches harvested during November, December and January.

However, in neem, flowering and fruiting is rare in Kerala. The higher population of coreid bug was seen at the time of flushing around December to March. During this period, the population of coreid bug in the palms around neem was also higher. Higher MIS was recorded in harvested bunches of coconut around neem during September to December. These bunches were heavily infested by coreid bug during January to April in which the coreid bug population was high in coconut palms around neem. In general, the population of coreid bug was higher in alternate hosts during their flushing and fruit formation stages.

The total number of fallen nuts due to coreid bug attack was higher during April to May, January to May, February to May and December to March in coconut around guava, cashew, cocoa and neem respectively.

The population of coreid bug was higher during May to October and February to May, February to April and December to March in coconut around guava, cashew, cocoa and neem respectively. This indicated the fact that abundant food supply in the alternate hosts at different periods resulted in population build up of the coreid bug and consequent damage to the buttons at susceptible stage of the coconut palms in the vicinity. This resulted in the fall of severely infested buttons.

The correlation-regression studies strongly supported the previous observations on the role of alternate hosts in population build up of coreid bug and their migration to coconut palms in the vicinity. A high positive correlation was obtained between the population of egg masses, nymphs and adults of coreid bug in alternate hosts in a particular month and percentage infestation in coconut after the succeeding months.

Apart from the influence of alternate hosts, climate also played a role in the fluctuation of coreid bug population. The number of adults (0.6500), nymphs (0.8284) and egg masses (0.6773) had a significantly positive correlation with maximum temperature. Negative correlation was observed between the population of nymphs and number of egg masses with relative humidity (-0.5642 and -0.4432 respectively). The nymphal population was negatively correlated with rainfall (-0.3386). Thus high temperature, low relative humidity and rainfall favoured the multiplication of the coreid bug. The results are in confirmation with those of Vanderplank, (1958) who observed that infestation of *P.wayi* on coconut was severe in warm rather than in cooler seasons.

Knowledge of the biology of the bug on different host plants is essential to determine the population buildup of the bug in an area with a heterogenous mix of crops susceptible to bug infestation and also to predict the number of generations completed per year. No significant difference was observed in the life cycle of the pest when reared on the host crop and alternate hosts. The egg period and the nymphal period ranged from 7.60 to

8.40 and 28.00 to 40.20 days among the different hosts *viz.,* guava, cashew, neem and coconut. The adult longevity of male bugs and female bugs ranged from 50 to 68 days and 52 to 68 days respectively in the different hosts. The mean egg period of *P. rostratus* was 8.15 days in the different hosts. The nymphs passed through five instars and took an average of 24.65 days to reach adult hood. The observations concurred with the findings of Nair and Remamony (1964), Nair (1975), Kurian *et al.* (1976 and 1979), Ponnamma *et al.* (1985), Beevi *et al.* (1989) and Nair *et al.* (2000).

Thus, it could be surmised that there was a carry over of population of coreid bug from alternate hosts to coconut. This may be due to the orientation of the bugs to adequate food source in the proximity provided by the principal as well as alternate hosts at different seasons of the year. From the above studies, it is clear that the establishment of coconut based agrarian systems with inter crops of perennial nature serving as alternate hosts favours the population build up of the coreid bug. The uninterrupted supply of food and habitat throughout the year relative to the seasonal cycle of the coreid bug was the most important factor in the coreid bug becoming a major pest. This is perhaps the most important factor to be considered in the process of developing tactics for ecological management of the coreid bug.

5.3 YIELD LOSS

Assessment of the level of infestation and yield loss due to pest incidence are important for research prioritization in crops to develop appropriate technology interventions. Various factors are involved in the yield loss due to pest incidence.

Unlike most crops wherein a mere damage by pest on the fruit results in its rejection in the market, the intensity of damage determines the economic value of coconut. Taking the fact into consideration, the harvested nuts were grouped into different damage categories and the loss in yield parameters under different categories was studied (Fig. 5). An

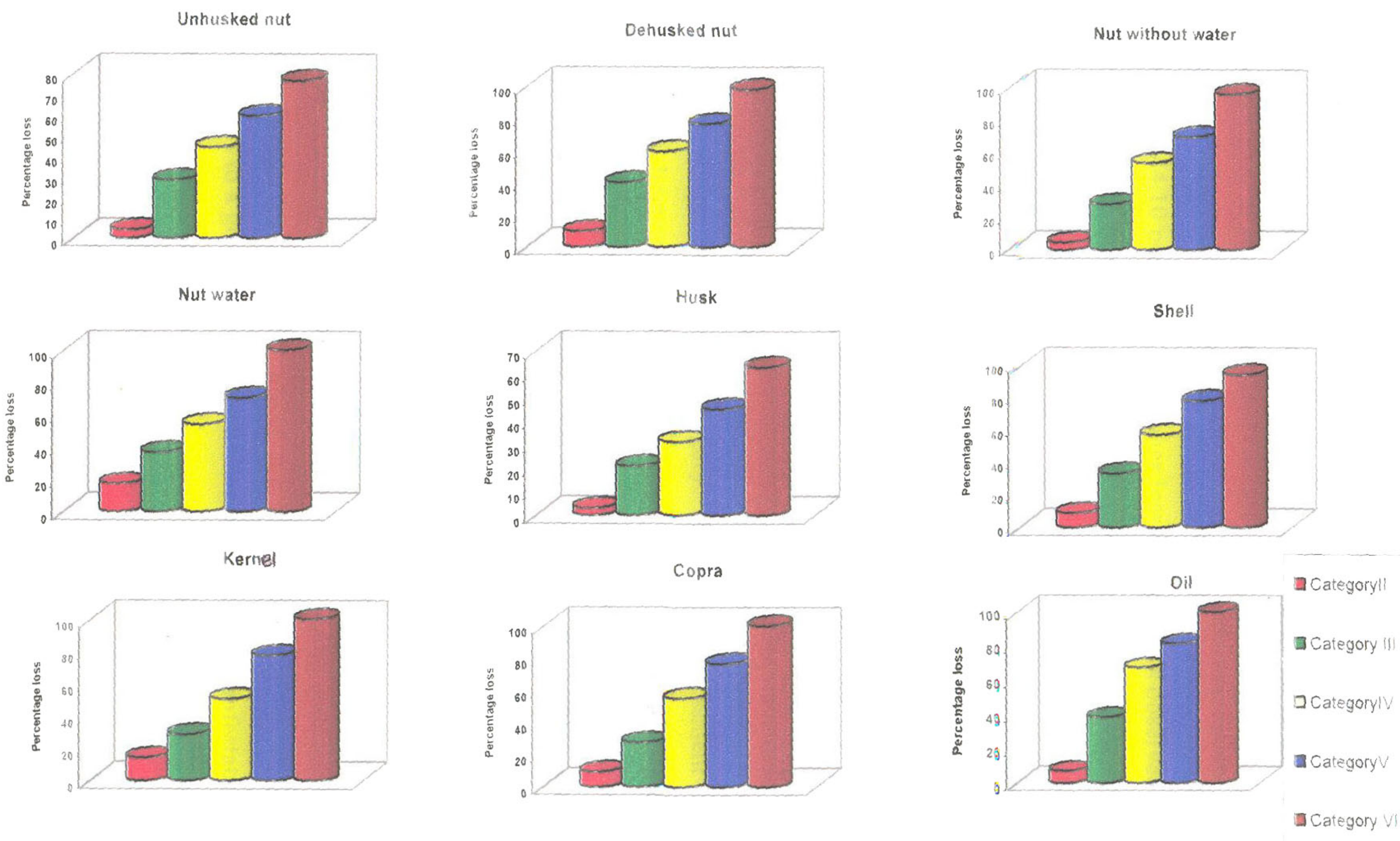

Fig. 5. **Loss in yield parameters in coconut due to the infestation of *Paradasynus rostratus***

important finding was that only the nuts falling in the damage category IV, V and VI showed appreciable loss in the yield parameters. The reduction in weight was negligible in category II nuts (3.95 per cent). The reduction in mildly damaged category III nuts was 28.11 per cent. Whereas, the reduction was higher in severely damaged category VI nuts (76.25 per cent) heavily damaged category V nuts (59.20 per cent) and moderately damaged category IV nuts (44.10 per cent). The higher loss in copra was observed in category V (76.65 per cent) and category IV (55.09 per cent) nuts. The endosperm was not at all formed in category VI nuts. Significant reduction was also seen in the oil content of category V (81.73 per cent) and category IV nuts (67.56 per cent). Obviously, heavily and severely damaged nuts (category V and VI) will be rejected in the market. The nuts coming under category III (mild damage) and IV (moderate damage) will get only a lesser price compared to healthy nuts. Category II (negligible damage) nuts will fetch the same price of a healthy nut. Thus, the economic loss to a coconut farmer due to coreid bug attack on coconut can be calculated from the total number of nuts falling under each category. Hence, an assessment of economic loss in homesteads should be made before adopting control measures. Observations on yield loss due to coreid bug were made by Brown (1959a); Julia and Mariau (1978); Nair *et al.* (1997) and Mayilvaganan and Nair (2002). However, they didn't conduct such category wise yield loss studies.

Kerala has a long coastal belt of about 600 km with approximately 190 million coconut palms. About half a million people are engaged in collection and processing of husk and coir industries. Any menace to coconut will directly or indirectly affect the life of the people whose livelihood depends to a great extent on coir. Hence, the effect of infestation of coreid bug on quality of coir was also studied. The fibre obtained from severely damaged nuts had 33.16 per cent reduction in length and 58.06 per cent reduction in thickness as compared to healthy nuts (Fig. 6). The coir yarn made from the fibre had the lowest break load (17.38 Kgf). The break

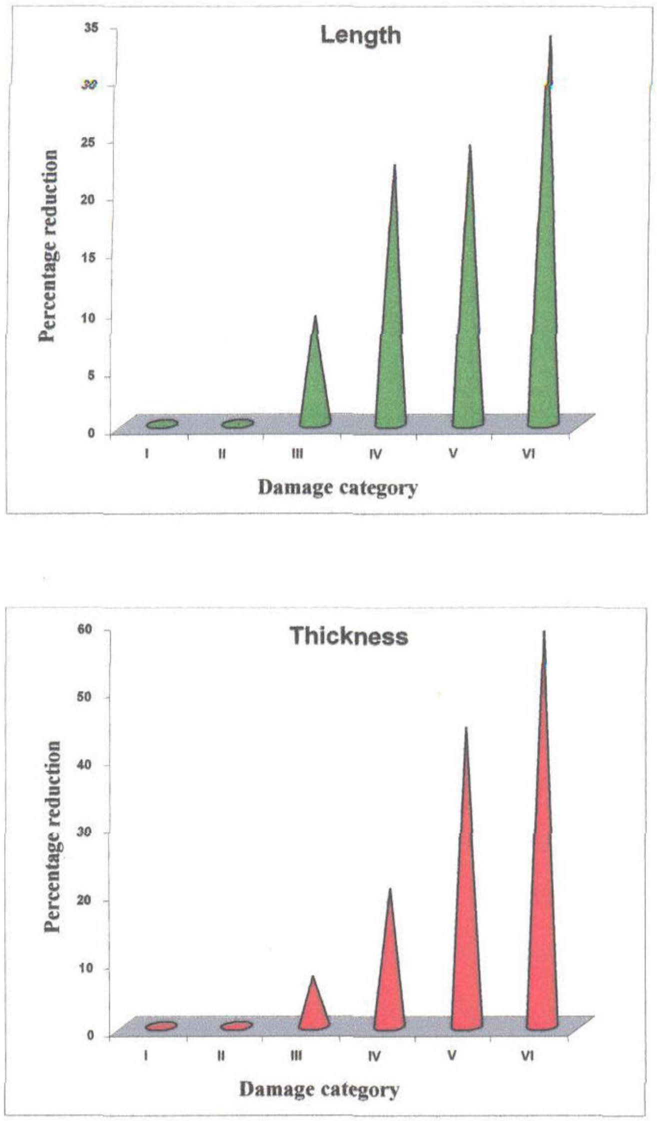

Fig. 6. Reduction in quality parameters of coir fibre due to the infestation of *Paradasynus rostratus*

loads of coir yarn prepared from fibres of nuts with negligible to moderate damage were not affected despite the reduction in length and thickness. Tensile elongation and modulus are the most important indications of strength in a fibre. Evidently, the yarn spun from nuts with heavy damage is neither strong nor usable. A study of similar nature was conducted by Paul and Mathew (2002) on loss of husk, quality of fibre and coir due to the infestation of coconut eriophyid mite, *A. guerreronis*. They reported that the coir fibre obtained from nuts coming under damage categories IV (Nuts with significant mite damage and smaller) and V (Nuts very heavily damaged and with some distortion) was very short and fragile and it was very difficult to spin the coir.

The biochemical constituents of coconut buttons too were affected due to the feeding of coreid bug. The phenol content in young infested nuts from third and fourth bunches registered an increase compared to healthy ones, the increase in the infested nuts being 60.00 and 62.00 per cent respectively. Phenolic compounds are secondary metabolites which are induced as a response to biotic stress. The accumulation of phenols in response to coreid bug infestation is one of the major reasons for the development of the symptoms on infested nuts. There was a progressive reduction in the starch content of young nuts with increase in degree of infestation. The highly infested nuts in the third and fourth bunches had 21.50 and 65.86 per cent reduction in starch content respectively compared to the uninfested nuts. These observations indicated a feeding induced alteration in the carbohydrate metabolism of young nuts in coreid bug infested parts. Sucrose is the principal form of carbohydrate that is translocated from the source leaves to the developing young nuts and where it is converted to starch and stored. The coreid bug feeds on the translocated sucrose thus reducing the supply of carbohydrate for starch biosynthesis in young nuts.

The fibre content of young nuts was also reduced due to infestation by the pest. The feeding by coreid bug caused a reduction in the sucrose that was available for conversion to glucose for cellulose bio-synthesis. According to Taiz and Zeiger (2003) any reduction in the carbohydrate supply decreased the total fibre production in young nuts also. The observations on starch content of young nuts infested by coreid bug also supported this result.

The peroxide and acid values of oil were estimated in nuts coming under five damage categories. In severely infested nuts (category VI), no endosperm was present. The peroxide value of oil increased from 0.64 per cent in healthy nuts to 2.17 per cent in heavily damaged (category V) nuts due to feeding of coreid bug. Biotic and abiotic pressure causes oxidative stress at the cellular level because of the accumulation of reactive oxygen species including superoxide, hydroxyl radicals and hydrogen peroxide. The peroxide value increased in response to infestation by coreid bug, which explained the intensity of oxidative stress caused by the feeding. Mayilvaganan and Nair first studied the changes in chemical properties of oil due to coreid bug infestation in 2002. The result of this study was in line with their findings. However, they did not conduct damage category wise analysis. The acid value of oil was significantly higher in category IV and V nuts and the least in category II (negligible damage).

Histological changes due to the infestation of coreid bug in young nuts were studied. The intensity of discoloration of parenchymatous cells around vascular bundles increased with increase in the level of infestation in young nuts (Plate 6). Feeding of coreid bug from phloem causes a reduction in the availability of carbohydrate for biosynthesis of starch, which will normally be stored in the vascular bundles. As the degree of infestation increased, the extent of filling of starch in parenchymatous cells decreased. The feeding of coreid bug also caused accumulation of phenols, which on oxidation resulted in change in colour of parenchymatous cells (Taiz and Zeiger, 2003).

The effect of coreid bug infestation on germination and vigour of seedlings was studied.The results indicated that all the nuts under categories II to IV germinated within six months after sowing as in healthy nuts. No nuts in category VI germinated. However, 80.00 per cent of nuts under category V germinated within six months. Early germination is an important factor in the vigour of seedlings (Thampan, 1981). Early germinated nuts produce seedlings having faster rate of leaf production. Seedlings that germinate late are inferior to those that have germinated early. The intensity of coreid bug attack on seed nuts significantly affected their germination. Considering the seedling characters, significant reduction was observed in the seedlings obtained from category III to V nuts. No remarkable difference could be recorded in the characters of seedlings from category II nuts as compared to healthy (Fig. 7). According to the package of practices recommendations of KAU (2002), good quality seedlings should have 6 to 8 number of leaves, 10-12 cm collar girth and early splitting of leaves 10 to 12 month after sowing. Considering these factors, nuts from category II (negligible damage) can be selected along with uninfested nuts for good quality seedling production. Seedling vigour is highly correlated with adult palm characters such as early flowering, nut yield and copra production (Liyanage and Abeywardena, 1957). If the seedlings happen to be of poor quality, the new plantation will prove to be uneconomic causing considerable loss of time and money to the grower.

5.4. MANAGEMENT OF COREID BUG

Among the botanicals screened in the laboratory, neem seed oil – garlic emulsion 2 per cent proved to be the best antifeedant. The mortality of the nymphs was also the highest in the treatment. Similarly, among the synthetic insecticides, profenophos 0.05 per cent was effective against the coreid bug. Both the insecticides when applied alone and in combination

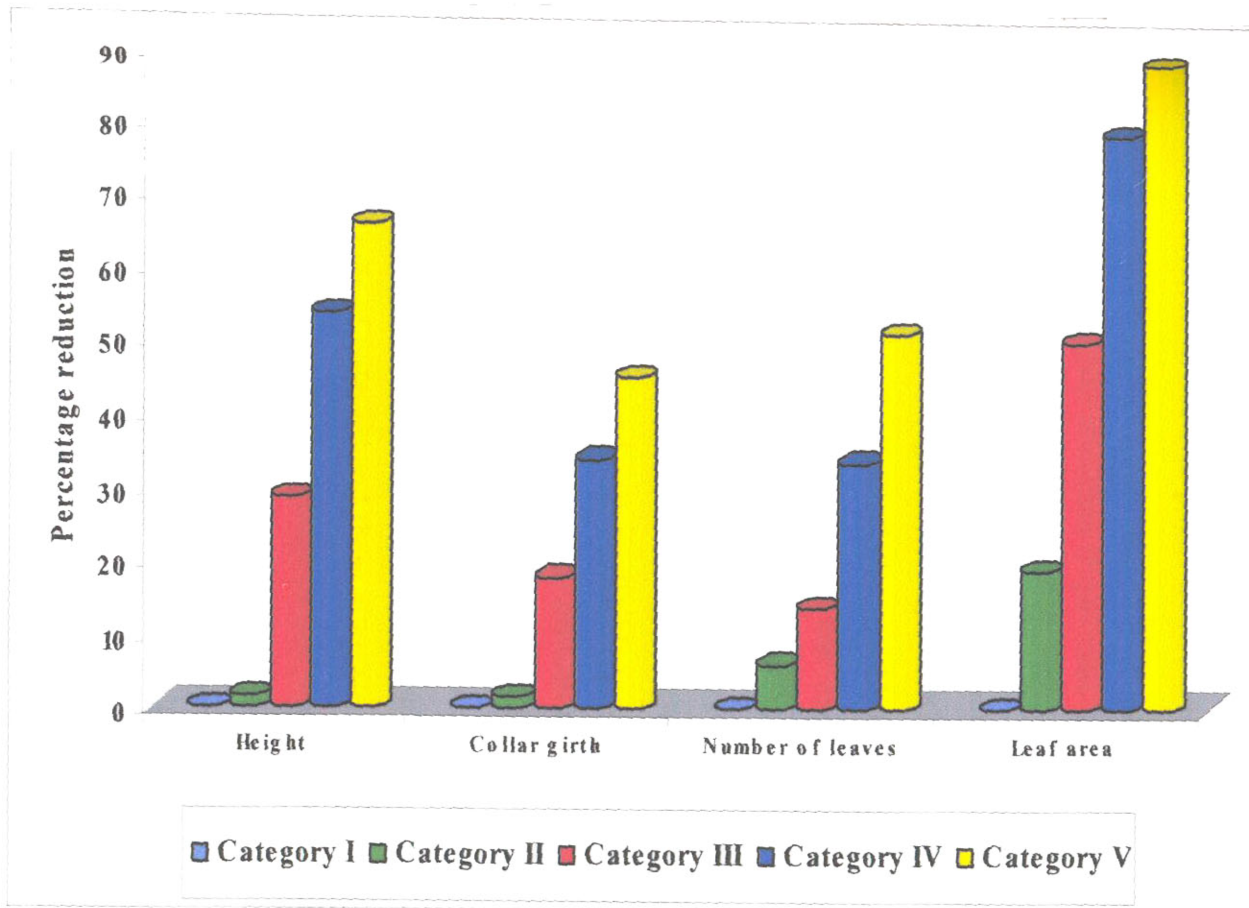

Fig. 7. Reduction in biometric characters of seedling due to the infestation of *Paradasynus rostratus*

on the alternate hosts reduced the infestation of the pest in the surrounding palms. An overall perusal of the results revealed that the application of combination of neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent on the alternate hosts was most effective in reducing the extent of coreid bug infestation (Fig. 8). The present study is in confirmation with the observations made by Mohan (2001). She observed lower infestation in coconut palms treated with neem seed oil - garlic 2 per cent + endosulfan 0.1 per cent compared to the other treatments. Efficacy of neem seed oil- garlic emulsion 2 per cent against the coconut eriophyid mite had been reported earlier (KAU, 2002). The combination of both botanical and chemical was effective as neem has a potentiating effect on chemical pesticides (Singh and Singh, 1987). The antifeedant action of neem inhibited the feeding of the coreid bug which rendered it more susceptible to the toxic action of the chemical. Adoption of control measures on the alternate hosts against the coreid bug had an appreciable impact on the extent of damage and subsequently yields of mature nuts. Categorization of the harvested nuts into different damage classes revealed that the coreid bug caused only negligible to mild damage on coconut palms around alternate host sprayed with profenophos 0.05 per cent and neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent. When the alternate host was either not sprayed or sprayed with neem seed oil - garlic emulsion 2 per cent only, heavy to severe damage was recorded in harvested nuts of palm around these alternate hosts. The increase in income obtained from the harvested nuts of the marked third bunch of coconut palms around the alternate hosts treated with neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent was Rs. 22.60 to 31.07 compared to control and it was Rupees 17.15 to 29.32 for palms around alternate hosts treated with profenophos 0.05 per cent. However, the increase in income from coconut around neem seed oil - garlic emulsion 2 per cent treated alternate hosts was in the range of Rs. 9.78 to 15.36 per palm only.

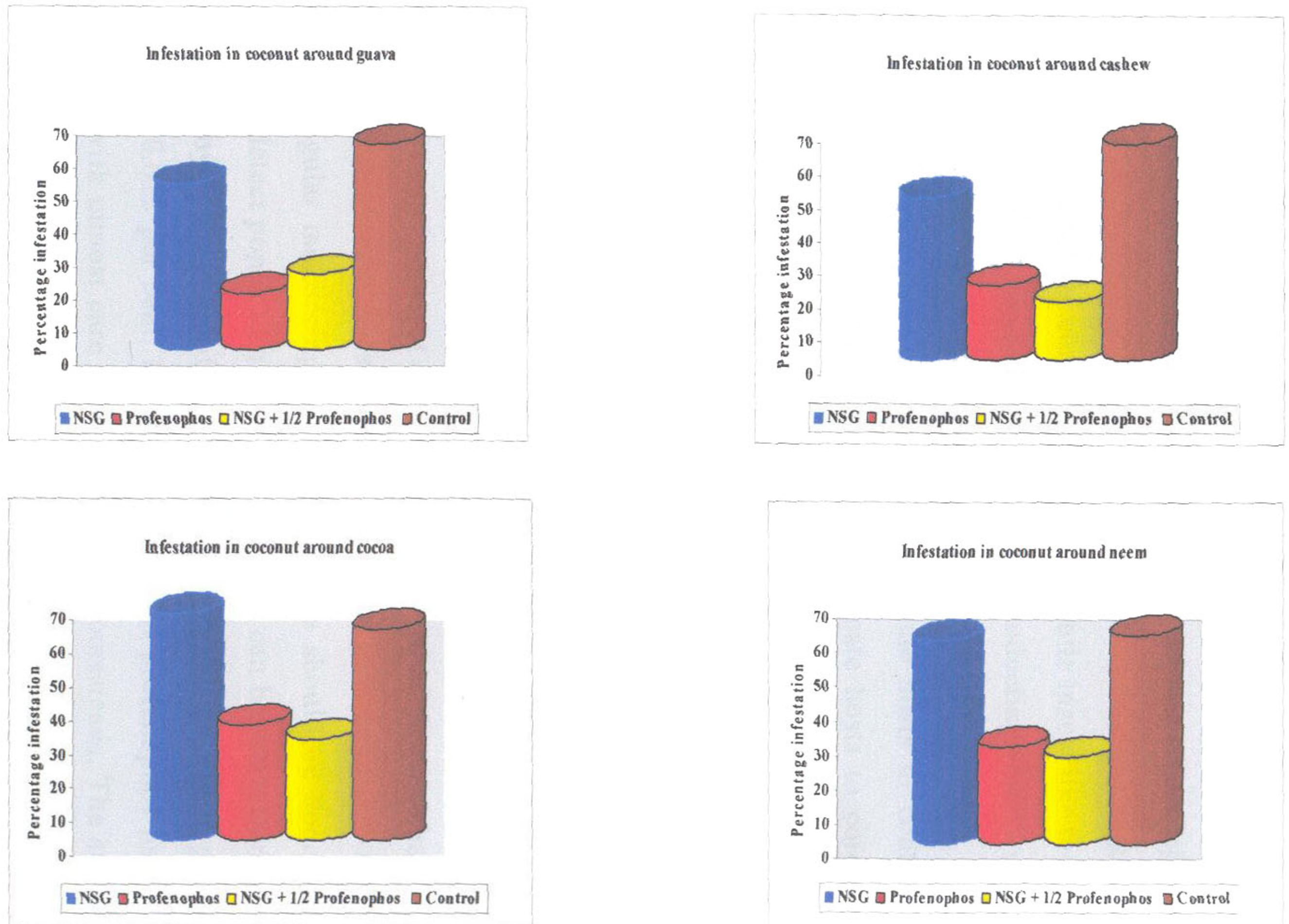

Fig. 8. Extent of infestation of *Paradasynus rotratus* in coconut around treated alternate hosts

The investigations thus revealed the role played by alternate hosts in the population dynamics of the coreid bug in the homestead based cropping systems. The stratification of the coconut palm and other alternate hosts in the multiple cropping system greatly influence the nature and distribution of the bug. This was perhaps the most important factor in the development and establishment of an ecological niche for the coreid bug. Hitherto, spraying of insecticides on coconut is the measure adopted for managing the pest when infestation is severe. However, the single stem stand of the palm makes the control of a highly mobile insect like the coreid bug a difficult task. Lack of skilled climbers for conducting plant protection operations in coconut too makes this an expensive proposition. In this context, a viable strategy is to utilize the alternate hosts to contain the coreid bug. Moreover, the susceptibility of alternate hosts to coreid bug indicated their propensity as trap crops. Thus, the destruction of the coreid bug from one alternate host should save 10-15 surrounding coconut palms from coreid bug attack.

The effective implementation of the technology is dependent on a thorough knowledge of the phenology of the alternate hosts *viz*., flushing, flowering and fruiting, which synchronize with the infesting stages in the coreid bug's life cycle. The life cycle of the pest, damage symptoms caused on alternate hosts and coconut as well as migration of the pest has to be studied and knowledge disseminated among the coconut farming community. Regular monitoring of alternate hosts should be done in the homesteads to detect population build up. The pest can be controlled on the alternate hosts by application of neem seed oil - garlic emulsion 2 per cent + profenophos 0.025 per cent. However, the use of profenophos has to be recommended with utmost care especially in the homesteads. The schedule of insecticide application need not be stressed as the alternate hosts vary in their phenology. Whenever the pest population is active on the alternate host (flushing or fruiting stage), a spray of neem seed oil – garlic emulsion 2 per cent + profenophos 0.025 per cent is to be applied (Plate 8).

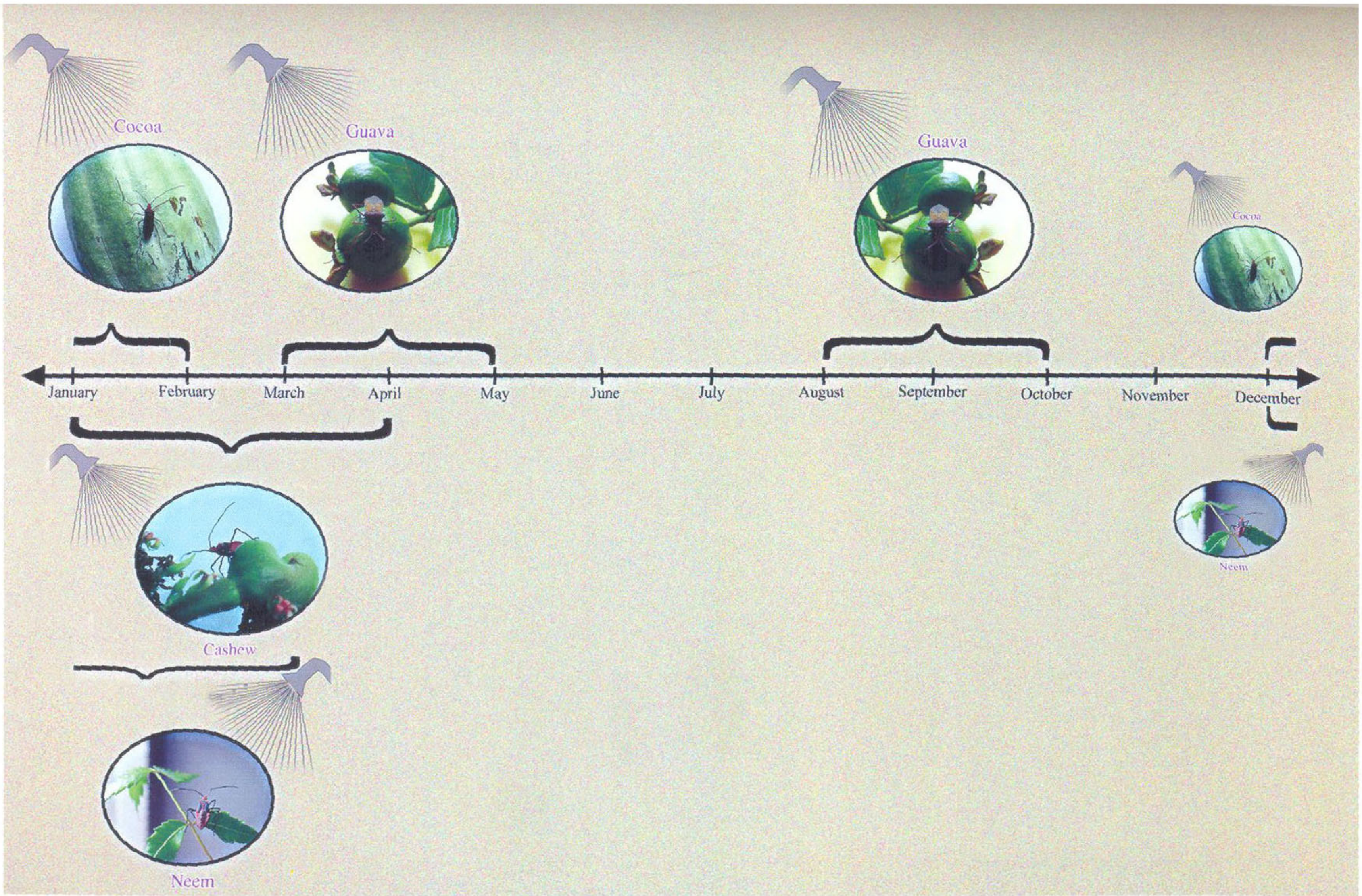

Plate 8. Susceptible stages of alternate hosts of *Paradasynus rostratus*

Integrated pest management, seeks to integrate strategies that are practical, effective, economical and protective of both public health and the environment. The present study could establish plant protection operations on alternate hosts against coreid bug as a cost effective and viable option compared to those in coconut. This strategy would be an invaluable component for integrated management of the pest on coconut palms in sustainable crop production.

SUMMARY

6. SUMMARY

Homestead farms are important agro ecological systems, which provide income and subsistence to the farmers. The homesteads in Kerala present a tree based farming system with coconut forming the major component. Seasonal and annual agricultural crops are intercropped in the coconut based farming system in combination with a diverse but compatible group of trees and shrubs. This agrarian system is considered economically efficient, biologically sustainable and ecologically sound. Of late, there has been a decline in farm income especially from coconut due to the attack of a complex of pests, the coreid bug *Paradasynus rostratus* Dist. being one among them.

A survey was conducted to study the incidence and extent of damage caused by the coreid bug. Studies were conducted to assess the influence of alternate hosts on the population dynamics of the bug in coconut. Quantitative and qualitative losses incurred in nuts and management of the pest were studied. The salient findings of the investigations are summarized below,

- Infestation of the coreid bug, *P.rostratus* was the highest in the homesteads in the coastal region (36.69 per cent) where density of the palms was high. Lower incidence of the pest was recorded in the upland (14.53 per cent) and midland (13.52 per cent) regions.
- In the upland and midland regions too, higher infestation of the pest was recorded from the homesteads with high density of palms.
- Among the cafeteria of crops ranging from annuals to perennial trees cultivated in the coconut based homesteads, guava, cashew, cocoa, neem, mango, pepper, tamarind and curry leaf were recorded as alternate hosts of the pest. Susceptibility of curry leaf to *P.rostratus* was recorded for the first time.

- Palms in the homesteads where alternate hosts of the pest prevailed recorded a higher level of infestation than in monoculture.
- Based on the level of infestation (high and medium) guava, cashew, cocoa and neem were documented as favoured alternate hosts of *P.rostratus*.
- Age of the palms and spacing adopted did not influence the extent of infestation. Irrespective of the age, *P.rostratus* attacked the young nuts in the susceptible stage.
- Height of the palms had a significant bearing on the extent of infestation. Palms of 5 to10 m height were more damaged than palms with less than 5 m and more than 10 m height.
- Lesser damage was recorded in irrigated palms.
- Manuring did not influence the extent of infestation. Similarly, spraying against the pest did not reduce infestation. This was observed to be due to the inability of farmers to differentiate between the symptoms of attack of different pests on coconut bunches and consequent adoption of erroneous measures.
- Two egg parasitoids *viz.*, *Chrysochalcissa oviceps* Boucek and *Gryon* sp. were recorded. Parasitisation of the egg masses ranged from 50.00 to 66.67 per cent.
- The reduvid bug *Sycanus* sp., the red ant *Oecophylla smaragdina* (F.) and spiders were observed to predate on the coreid bug. *Sycanus* sp. was recorded for the first time. Both the nymphs and adults of the predator preyed on adults and nymphs of *P.rostratus.*
- Higher infestation in coconut palms synchronized with the multiplication of the pest on the alternate hosts in their susceptible stage.

  Population of *P.rostratus* on guava was high in the fruiting stage during March to May and August to October. High infestation of the pest was recorded in the surrounding palms during May to October.

In cashew, the pest multiplied during January to April. The infestation in coconut around the crop was high during February to May.

Higher population of *P.rostratus* was recorded in the chirrelle formation stage of cocoa from December to February. In coconut the population was higher during February to May.

Similarly, population of the pest was high in neem during the flushing stage *viz*., December to March and in coconut during January to May.

- Apart from the influence of alternate hosts, climate too played a significant role in the fluctuation of coreid bug population. High temperature, low relative humidity and low rainfall favoured the multiplication of the pest.
- Life cycle of the pest when reared on the base crop coconut and the alternate hosts did not show any remarkable difference. The total life cycle was completed in 83.2 to 99.4 days. The adult longevity of male bugs and female bugs ranged form 50 to 68 days and 52 to 68 days respectively in the different hosts.
- Nut colour and shape influenced the extent of infestation. Green coloured round nuts manifested lesser damage. Elongate, red and orange coloured nuts were more susceptible to the pest.
- Nuts with negligible damage (category II) did not show any significant difference compared to healthy (category I) nuts in nut shape, nut characters, copra and oil content. Significant reduction in copra and oil was observed in moderately (category IV) and heavily (category V) damaged nuts. The endosperm was not at all formed in severely damaged (category VI) nuts.
- Length and thickness of fibre from nuts heavily and severely damaged were reduced significantly.

- Break load of coir yarn prepared from the severely damaged nuts was significantly reduced. The yarn was neither strong nor usable.
- Significant changes were observed in the biochemical constituents of coconut buttons due to feeding of *P.rostratus*. The phenol content in young infested nuts recorded an increase compared to healthy nuts. A progressive reduction in starch and fibre content of young nuts was obtained with increase in degree of infestation.
- Peroxide and acid values of oils obtained from nuts with moderate, heavy and severe damage were higher compared to healthy nuts.
- The extent of filling of carbohydrate in parenchymatous cells decreased with increase in degree of infestation.
- Though all the nuts in damage category II (negligible damage) to IV (moderate damage) germinated within six months, only seedlings from nuts with negligible damage had the qualities of good seedlings.
- Among the four commercial formulations of neem (Achook, Nimbecidine, Econeem and NeemAzal), neem oil and neem oil – garlic emulsion screened at two doses for antifeedant and toxic effect, neem oil – garlic emulsion 2 per cent was superior to other formulations.
- Of the chemical insecticides *viz.,* triazophos, quinalphos, chlorpyriphos, profenophos and acephate tested, profenophos 0.05 per cent was the most effective against coreid bug.
- Evaluation of the efficacy of applying neem oil - garlic emulsion 2 per cent , profenophos 0.05 per cent and neem oil - garlic emulsion 2 per cent + profenophos 0.025 per cent on alternate hosts revealed that spraying of neem oil- garlic emulsion 2 per cent + profenophos 0.025 per cent was the most effective in reducing the extent of coreid bug infestation in the surrounding coconut palms.

The investigations revealed the extent of loss caused by coreid bug in coconut and established the role of alternate hosts on the population dynamics of the pest in the homestead based cropping systems. Based on the results of the study, a package involving regular monitoring of the alternate hosts in the homesteads, removal and destruction of the egg masses and early instars of the pest and giving a need based spray with an insecticide formulation like neem oil - garlic emulsion 2 per cent + profenophos 0.025 per cent on the alternate host would be a practical and cost effective approach in reducing the damage of *P.rostratus* on coconut in the homesteads.

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7. REFERENCES

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* Original not seen

APPENDIX

APPENDIX – I

Weather parameters during January to December 2004

Month	Average humidity, %	Maximum temperature, ^0C	Rain fall, mm	Number of rainy days
January	76.93	33.10	6.80	1
February	75.25	31.50	0.40	1
March	76.70	32.20 33.10	1.20	1
April	78.30	33.33	126.90	10
May	83.05	31.00	447.60	19
June	83.70	30.20	243.00	17
July	85.20	29.80	321.40	20
August	80.60	30.20	89.50	9
September	83.95	30.00	201.40	17
October	82.70	30.60	326.80	22
November	83.64	30.58	167.10	16
December	76.20	30.80	10.00	1

APPENDIX – II

Price of nuts in different damage categories

Damage category	Price/nut
Category I	4.00
Category II	3.84
Category III	2.88
Category IV	2.24
Category V	1.64
Category VI	0.95

POPULATION DYNAMICS, INTENSITY OF DAMAGE AND MANAGEMENT OF THE COREID BUG, *PARADASYNUS ROSTRATUS* DIST.

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Abstract of the thesis submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

Experiments were conducted to study the influence of alternate hosts on the population dynamics of the coreid bug, *Paradasynus rostratus* Dist. and consequent damage to coconut and to evolve an eco-friendly management strategy to the pest. An abstract of the work done and the results are given below.

A survey conducted in Thiruvananthapuram district to study the incidence and intensity of coreid bug infestation on coconut revealed that the infestation was the highest in the coastal region. The incidence was lower in the upland and midland regions. Among the variety of crops seen in the coconut based homesteads, guava, cashew, cocoa and neem were recorded as potential hosts of the pest.

Studies on the influence of alternate hosts on the population build up of coreid bug revealed that the alternate hosts were a major determinant in the extent of infestation of coreid bug on coconut. The pest multiplied on the alternate hosts during flushing, flowering and fruit formation stages of the crops and subsequently shifted to the base crop, coconut in multiple cropping systems.

The changes in size and yield parameters of nut due to the infestation of *P.rostratus* were assessed. Nuts with negligible damage (category II) did not show any significant difference in nut shape, nut characters, copra and oil content. Significant reduction in copra and oil was observed in moderately (category IV) and heavily (category V) damaged nuts. The endosperm was not at all formed in severely damaged (category VI) nuts.

The changes in the biochemical constituents of coconut buttons due to feeding of coreid bug were studied. The phenol content in young infested nuts recorded an increase compared to healthy nuts. A progressive reduction in starch and fibre content of young nuts was obtained with increase in degree of infestation

The study on the effect of infestation of *P.rostratus* on germination and vigour of seedlings revealed that though all the nuts in damage category II (negligible

damage) to IV (moderate damage) germinated within six months, only seedlings from nuts with negligible damage (category II) had the qualities of good seedlings.

The antifeedant effect of neem based botanicals and efficacy of synthetic chemical pesticides were evaluated against coreid bug. Among the botanical and chemical pesticides, neem seed oil- garlic emulsion 2 per cent and profenophos 0.05 per cent proved most effective against the coreid bug.

A field experiment was conducted to evaluate the effect of selected treatments on alternate hosts for control of coreid bug in coconut. The study revealed that the combined application of neem seed oil- garlic emulsion 2 per cent + profenophos 0.025 per cent was the most effective in reducing the extent of coreid bug infestation in the surrounding coconut palms.

The present study could establish the role of alternate hosts on the population buildup of coreid bug. Plant protection operations in alternate hosts against coreid bug are more effective, economical and viable options compared to those in coconut. Based on the results of the study, a package involving regular monitoring of the alternate hosts in the homesteads, removal and destruction of the egg masses and early instars of the pest and giving a need based spray with an insecticide formulation like neem oil- garlic emulsion 2 per cent + profenophos 0.025 per cent on the alternate host would be a practical and cost effective approach for reducing the damage of *P.rostratus* on coconut in the homesteads.