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19 INTEGRATED PEST MANAGEMENT IN COCONUT

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TABLE OF CONTENTS

ABSTRACT

In India, the major pests of coconut palm include the rhinoceros beetle, leaf eating caterpillar, red palm weevil and white grubs. There are occasional/sporadic pests such as, the slug caterpillars, coreid bug, lace bug, scale insects, mealy bugs, mites and rodents. Rhinoceros beetle is a ubiquitous pest causing serious damage to the unopened fronds and inflorescences. Integrated pest management of rhinoceros beetle may lead to an increase in yield of 5-8 nuts per palm per year. Biological suppression with the viral pathogen baculovirus of *Oryctes* is an effective tool included in the IPM schedule for this pest. The leaf eating caterpillar is a major pest in the coastal, backwater and certain interior tracts. Peak occurrence of this pest is during summer months. Relative humidity is a key factor favouring the build up of this pest. Technology involving use of parasitoids and predators has been developed for the management of pest outbreaks. The tissue borer-red palm weevil is the most dreaded enemy of coconut. IPM schedule consisting of plant and field sanitation, prophylactic/curative control measures and trapping of adult weevils is effective in the management of the red palm weevil. Root grubs cause severe damage in coastal sandy loam soils. This is a polyphagous pest affecting coconut and its intercrops. A permanent solution for this pest is feasible only by the integration of all known methods of control. For the control of the pest of minor importance, proper monitoring and surveillance are necessary to formulate a suitable biointensive IPM system wherein need based application of pesticides is undertaken.

1. INTRODUCTION

The coconut palm *Cocos nucifera* Linn. is one of the most widely cultivated perennial oilseed crops of the tropics. The palm is subjected to the ravages of several pests (49, 56, 58, 59, 60, 61). Kurian *et al.* (35, 36) listed more than 800 pests infesting the coconut palm. Rajan and Mathen (72, 73) and Sathiamma (78, 79, 80) added to this list nine species of insects and three species of mites as pests. Of the numerous species of insects recorded on coconut the rhinoceros beetle *Oryctes rhinoceros* (L.), the leaf eating caterpillar *Opisina arenosella* Wlk., the red palm weevil *Rhynchophorus ferrugineus* F. and the cockchafer *Leucopholis coneophora* Burm. are the key pests. Among the less serious pests, the eucleid caterpillars like *Contheyla rotunda* H., *Latoia lepida* (Cram.), *Macroplectra nararia* M. etc. appear in epidemic proportions in certain localised tracts and cause untold havoc to the crop. The hesperiid caterpillars such as *Gangara thyrsis* M. and *Suastus gremius* F. often appear as minor pests in nursey seedlings. The lace bug *Stephanitis typica* D. and the coreid bug *Paradasynus rostratus* D. are also responsible for heavy economic loss to the crop. The scale insects and mealy bugs infest the leaves, inflorescence and nuts. Mites, particularly the spider mites and the false spider mites, infest the leaves, inflorescence and immature nuts and cause drying of the affected leaves and fall of nuts. Proper monitoring of the incidence of these pests is quite imperative for resorting to pest management practices against them (70, 87). The system of Integrated Pest Management (IPM) is feasible in coconut and the coconut-based farming system. In this system all the compatible pest management techniques can be adopted in an organised way so as to bring down the pest population below the level of economic injury.

2. MAJOR PESTS

2.1. The rhinoceros beetle, *Oryctes rhinoceros* (L.)

Oryctes rhinoceros is a ubiquitous pest of the coconut palm. The beetle bores through in to the unopened fronds and inflorescences and causes severe cuts and injuries to the leaves (Plate Ia) and drying of the inflorescences. This results in the substantial

reduction in the yield of palms. The rhinoceros beetle is also a pest on palmyra, toddy palm, oil palm, date palm, areca palm, sago palm, nypa palm, sugar palm etc. It has also been reported on sugarcane, pineapple, banana, taro etc. Nirula (57) and Bedford (17) gave a detailed account of the life history, ecology and methods of control of this pest. The beetle lays eggs in the decaying organic matter such as, cow dung, compost, dead wood, decaying stumps etc.

The life cycle is completed in about six months.

Suitable methods have been developed for the control of rhinoceros beetle. Field control operations effect significant reduction in the intensity of pest infestation on palms and consequent increase in yield to the extent of 5-8 nuts per palm per year (76). Integrated management of the beetle by mechanical, cultural and chemical methods has yielded encouraging results (71). The operations include extraction of beetles by means of a beetle hook during the peak period of pest abundance on the crown of the palm (July-September); treatment of all possible breeding sites of the beetle such as cattle dung, farmyard manure, dead coconut logs and stumps and other decaying organic debris in and around the plantations with HCH/carbaryl 0.01% in January, April, July and October; prophylactic crown treatment of the main border palms (two rows) with HCH (225 g HCH/ 10% dust) and equal volume of sand mixed together, during the pre-and post-monsoon periods in April-May and October-November; provision of beetle traps containing decaying organic debris treated with HCH 0.1% suspension; and above all maintenance of field sanitation through disposal of decaying organic matter. Release of the laboratory bred exotic reduviid predator *Platymeris laevicollis* can also be combined with the above pest control operations and in such cases insecticide application to the crown of the palm should be eliminated from the schedule. The microbial pathogens such as the green muscardine fungus *Metarhizium anisopliae* var. *major* (M. & S.) and the baculovirus of *Oryctes* can also be effectively blended in the IPM programme.

An IPM trial laid out at farmers' fields in Thamarakulam, and Alappuzha Districts of Kerala during 1964-1971, with a view to assess the combined efficacy of beetle control operations such as mechanical, cultural, sanitational and chemical methods in bringing down the pest incidence on the crown of the palm, yielded encouraging results (33). The leaf damage came down to 4.80 from 26.25%, spathe damage to one from 38% and fresh incidence to 15 from 45% of the pre-treatment condition. Quicker reduction in pest incidence and crop damage was obtained in the integrated control experiment than that obtained by the individual method of insecticide treatment to the breeding places of the pest (70).

Predators and parasites are found associated with the breeding grounds of rhinoceros beetle and they exert some degree of suppression to *Oryctes* population, particularly the immature stages. *Santalus parallelus* P. (Histeridae), *Scarites* sp., *Harpalus* sp. and *Pheropsophus* sp. (Carabidae) and *Agrypnus* sp. nr. *bifoveatus* (Candeze) (Elateridae) are some of the important indigenous predators recorded. The extent of pest suppression effected by them is very meagre and as such, their mass multiplication and release has yet not been attempted. However, conservation of these indigenous predatory fauna is extremely important and care should be taken to use only less hazardous insecticides for treating the breeding sites of rhinoceros beetle.

The exotic predator *Platymeris laevicollis* Dist. (Reduvidae) from Zanzibar was introduced for the control of rhinoceros beetle in India. The predator was mass multiplied and released in heavily infested coconut plantations in Kerala and Karnataka States (13). The released sites revealed 13.06% leaf damage, nil spathe damage and 1% fresh infestation on spindle as compared to 59.2%, 2.5% and 37.0%, respectively, recorded during pre- release observations. The incidence was also reduced considerably. However, no build up of the predator population was observed in and around the released sites. The technique was found to be very effective as a result of which filling of leaf axil with insecticides has been eliminated from the schedule.

The entomopathogen *Metarhizium anisopliae* M. & Z. causes epizootics in the population of *O. rhinoceros,* particularly on the west coast of India. The incidence of the disease is very much prevalent when the climatic factors such as low temperature and high relative humidity prevail in nature (92). High degree of infection by the fungus has been observed during the monsoon (64). Methods have been developed for mass culturing of the fungus under laboratory conditions for large scale field application. Mass culturing can be done on cheaper substrates like cassava chips and rice bran supplemented with waste fish meal extract or urea as a source of nitrogen, in specially designed large aluminium vessels (52). Coconut water medium is still another cheaper and easily available agricultural waste material from copra making industry, for mass production of the fungus. Better mycelial growth and sporulation of the fungus occur in this medium as compared to the conventional potato dextrose broth. Moreover, farmers themselves can adopt this method with easily available local resources. Cattle dung pits or farmyard organic refuse heaps in farmers' homesteads can be inoculated with the fungal preparation at approximately 5×10^{11} spores per m^3 of the heap as a result of which the grubs get infected.

Baculovirus of *Oryctes* (Plate I b) is one of the most successful microbial control agents available for the biological suppression of rhinoceros beetle. This viral pathogen has been proved to be very effective in several countries such as the South Pacific Islands, Fiji, Mauritius, Seychelles and Papua New Guinea (19). Mohan *et al.* (50) recorded its occurrence in the natural population of beetles in Kerala, India. The viral infection leads to reduction in longevity of the beetles by 40% and total reduction in fecundity. Whenever, the virus is introduced into the pest habitat, an initial epizootic decimates the larval and beetle populations resulting in drastic reduction in larval population at breeding sites.

The baculovirus was successfully introduced during April, 1983 to Minicoy, Lakshadweep, where natural incidence of baculovirus disease was not observed in the pest population. The pathogen established in the natural population of the pest and exerted considerable degree of pest suppression (Table 1). 62% of the beetle population collected from different parts of the island showed incidence of baculovirus disease as compared to none during the pre-release observations (51). Baculovirus of *Oryctes* was also introduced to Androth, Lakshadweep, where the disease was not existing before, in April, 1988. Post-release observations recorded during January, 1990 showed that the viral pathogen had established in the natural population of the beetle and exerted considerable degree of pest suppression and the consequent reduction in crop damage. The leaf damage had come down to 14 from 55%, spathe damage to 3 from 7% and fresh incidence on spindle

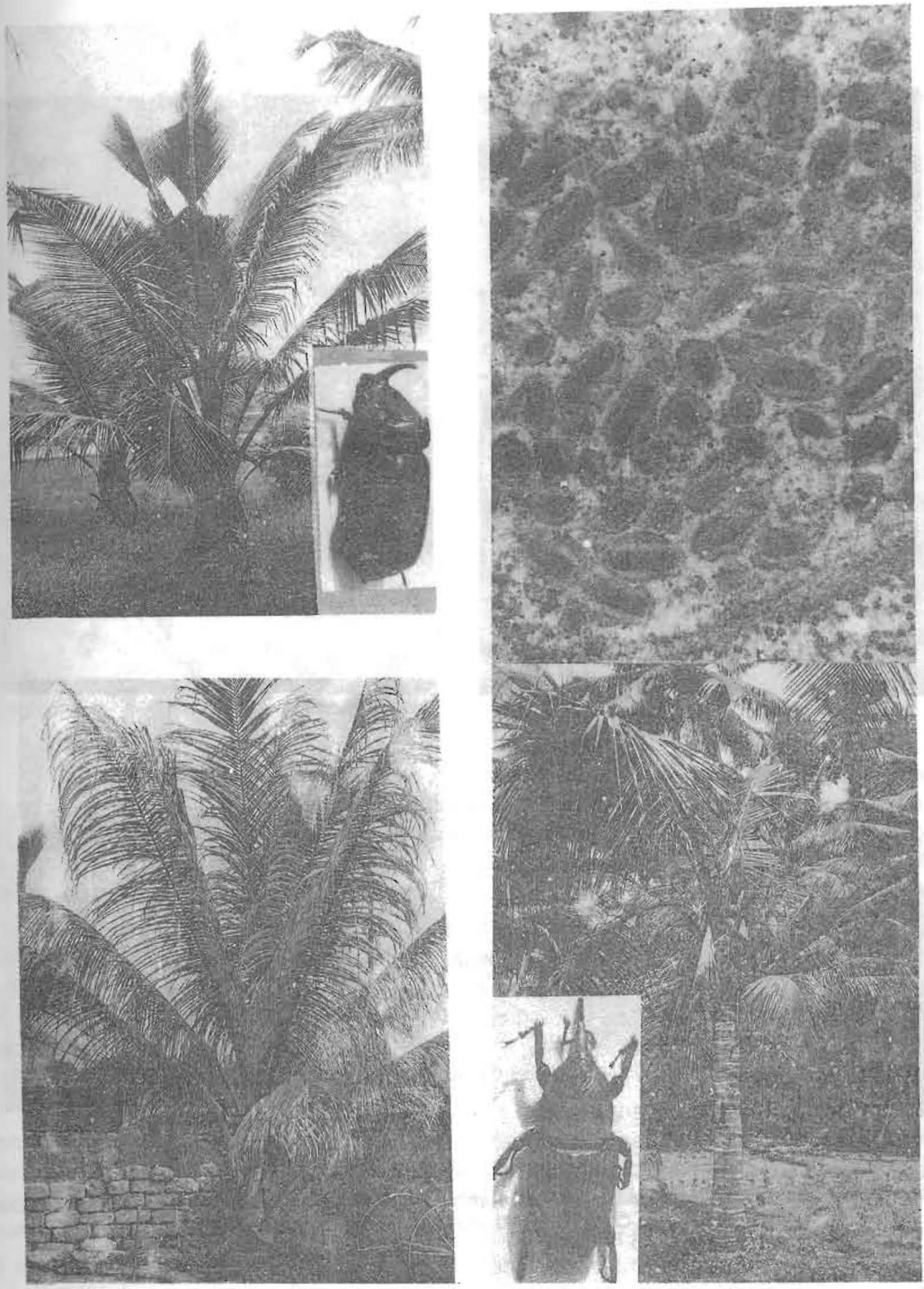
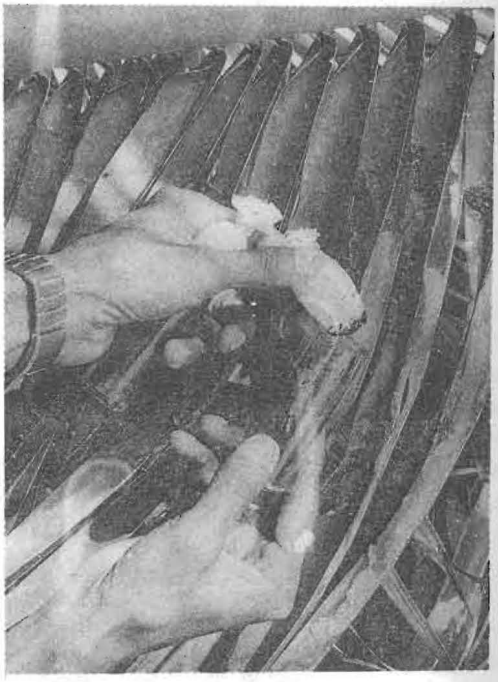


Plate I. (a) Palm infested by *Oryctes rhinoceros* L., (b) Electronmicroscopic photograph of Baculovirus of *Oryctes*, (c) Palm infested by *Opisina arenosella* Wlk., (d) Palm infested by *Rhynchophorus ferrugineus*



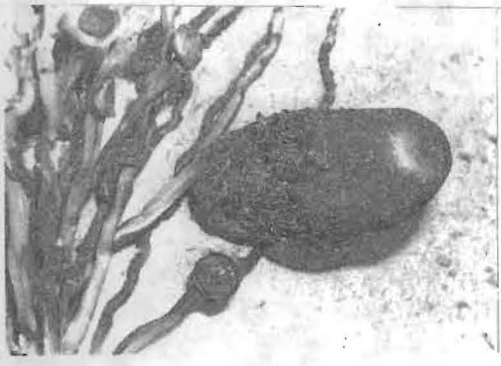


Plate II. (a) Laboratory reared parasitoids of *Opisina arenosella*, (b) Release of parasitoids on *Opisina* infested palms, (c) Coreid bug, *Paradasynus rostratus*, (d) White spider mide, *Oligonychus iseilemae* (H).

leaves to 6 from 24% of the pre-release condition. Baculovirus infected grubs with typical visual symptoms of the disease also had increased from zero to 11.4 per breeding site. Similar observations were made in Andamans in May 1987 (26).

TABLE 1 : PERFORMANCE OF BACULOVIRUS OF *ORYCTES* AT MINICOY, LAKSHADWEEP

Date of survey	% infestation			Baculovirus disease incidence (%)
	Leaf	Spathe	Spindle	
Pre-release				
April, 1993	56.6	31.1	39.2	0.0
Post-release				
January 1984	44.9	6.4	5.0	50.0
November 1984	20.4	2.3	5.1	25.9
September 1985	17.5	1.6	9.2	43.3
May 1986	10.0	0.5	1.2	50.0
December 1988	7.0	*	*	62.0

* Negligible, only 4-5 cases recored per 2000 palms.

In Maldives, the virus was totally absent. Introduction of the pathogen to the islands during 1984/1985 resulted in significant reduction in the population of *O. rhinoceros* (97). Young and Longworth (96) reported successful control of *O. rhinoceros* in Tonga for seven years after its first and only release in 1970. Similarly, substantial reduction in the population of the pest and crop damage (39) was effected in Western Samoa.

The most economical, effective and simple method adopted for dissemination of *Oryctes* baculovirus in to the natural population of beetles is to release the infected beetles. The biggest singular advantage of this pathogen offers over the other microbial control agents is that this is an autotransmissible pathogen capable of passing from one generation to another. It can be used as one of the effective components in the integrated pest management programme against rhinoceros beetle.

Trapping and killing the adult beetle is an effective means for the management of rhinoceros beetle (37). Use of attractants such as, metal vane traps or coconut cap traps treated with ethyl dihydro-chrysanthemumate (chrislure)or commercially available ethyl chrysanthemumate (rhinolure) are very effective in the south Pacific (15, 16, 38).

Vegetative barriers such as the cover crop, *Pueraria javanica* restricts the feeding of the adult beetle on the crowns of palms, conceal the breeding grounds and act as physical barriers to impede flight of the beetle from their breeding grounds. This is one of the effective and inexpensive methods to check the pest damage on young palms in Malaysia and Ivory Coast (66, 95, 29).

Maintenance of field sanitation, extraction of beetles during the peak period of incidence, mass multiplication and release of the reduvid predator *P. laevicollis*, mass culturing of *M. anisopliae* and their application to the breeding places of the beetle particularly during moist weather conditions, release/re-release of baculovirus infected rhinoceros beetle, provision of attractant traps etc. are some of the components envisaged under the IPM programme of the management of coconut rhinoceros beetle.

2.2. The leaf eating caterpillar, *Opisina arenosella* Wlk.

O. arenosella is another key pest of the coconut palm which assumes severe proportion resulting in serious depredations to the palms in certain tracts. The caterpillars live in silken galleries on the lower surface of the leaflets and while hiding in these galleries they scrape and feed on the chlorophyll containing parenchymatous tissues leaving the upper epidermis intact. The affected foliage dries and presents a scorched appearance (Plate I c). Very severe damage results in drooping of the leaves and even the bunches. *O. arenosella* is a pest on coconut palm in Bangladesh, India, Myanmar and Sri Lanka. In India, the pest has been recorded from Andhra Pradesh, Gujarat, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu and West Bengal. Though coconut is the principal host plant of the caterpillars, palmyra, talipot, wild date and some ornamental palms are also reported hosts of the caterpillar (58, 82).

On the west coast of India, the pest occurs almost throughout the year, but with high incidence from February to May. Climatic factors cause significant population fluctuation of the pest in the field. Relative humidity favours the population build up which may be the reason of the greater prevalence of the pest in the coastal, backwater and river belts and also in certain interior tracts adjacent to open paddy fields. On the east coast also maximum population occurs during April, May and June and minimum during north-east monsoon season. The pest completes its egg to adult period in about 2 months (63).

During pest outbreaks, an integrated approach can be adopted for bringing down the pest incidence (34, 75). Cutting and burning of the badly affected leaves/leaflets followed by an initial spray with dichlorvos 0.02% suspension are the effective management practices in the begining. Release of an appropriate species of parasitoids depending on the target stages of the pest, at fortnightly intervals, is done till the pest population is suppressed. Care should be taken to use only those insecticides which are less toxic to the natural enemies and the parasitoids are released only after three weeks of insecticidal spraying.

An epidemic of *O. arenosella* at Badagara, Kozhikode, Kerala in an area of nearly 600 ha during 1970, was brought under control by inundative release of parasitoids. The bethylid *Goniozus nephantidis,* braconid *Bracon brevicornis,* elasmid *Elasmus nephantidis* and the eulophid *Trichospilus pupivorus* were released in the infested gardens. Pre-release observations on the population revealed that the pest population ranged from 2-3 pests per infested leaflets and the natural parasitism was 3-5 %. Post-release observations after two months of parasitoid release revealed 99.97% reduction in pest population and an increased percentage of parasitism ranging from 37.3 to 68.3. In addition to the parasitoids, 16-30% microbial infection was also observed.

Biological suppression of *O. arenosella* occurs in nature by a number of parasites and predators. Pathogens also effect significant control of the caterpillars particularly during the rainy season. Investigations on this line led to the record of effective parasitoids affecting the larval, pre-pupal and pupal stages of the pest (69, 70). So far, no egg parasitoids are known except laboratory reared *Trichogramma chilonis* Ishii (75, 56). Predators, both insectan and on-insectan, consume all the stages of *O. arenosella*. The important indigenous parasitoids are *Apanteles taragamae* Wlk. parasitising the early instar caterpillars, *Bracon hebetor* Say (Braconidae) and *Goniozus nephantidis* (Bethylidae) parasitising the middle and late instar caterpillars and *Elasmus nephantidis* Rohw. (Elasmidae) parasitising the late larval/prepupal stage of the pest. *Brachymeria nosatoi* Habu, *B. nephantidis* Gahan, *B. atteviae* Joseph *et. al.*, *B. lasus* Walker, *Antrocephanlus hakonensis* (Ashmead) (Chalcididae), *Xanthopimpla punctata* F., *X. nana nana* Schulz. and *Brachycoryphus nursei* (Ichneumonidae) and *Trichospilus pupivorus* F. (Eulophidae) are some of the important pupal parasitoids of the pest. In addition, there are a number of predators such as *Parena nigrolineata* (Chaudoir) and *Calleida splendidula* (F.) (Carabidae), *Sphedanolestes aurescens* (Reduvidae), *Triphleps* sp. (Anthocoreidae) and many species of spiders (69, 90). During rainy season, heavy mortality of the pest occurs, because of infection by bacterial pathogens like *Serratia marcescens.*

Among the parasitoids studied, the larval parasitoid *G. nephantidis*, the pre-pupal parasitoid *E. nephantidis* and the pupal parasitoid *B. nosatoi* play a significant role in the biological suppression of this pest. These bioagents have all the desirable attributes of a successful parasitoid. They possess good searching ability, capacity to withstand high temperature, preponderance of female progeny, persistent occurrence, abundance during the peak period of the host and distribution in all the pest infested areas. Techniques have been standardised for the laboratory multiplication of these dominant parasitoids so as to use them for large scale release in *Opisina* infested coconut gardens (67).

The laboratory reared parasitoids can be effectively used for biosuppression of *Opisina* population in the field (Plate II a). Arbitrary release of the parasitoids often fail to effectively check the pest population and sometimes the parasitoids do not even reach the proper target stage of the host. Hence, norms have been fixed for the release of the three effective parasitoids viz., *G. nephantidis, E. nephantidis* and *B. nosatoi* in *Opisina* infested coconut garden.

A special technique has been developed for the estimation of field poulation of *O. arenosella* and its natural enemies (24, 88). The doses of parasitoides to be released is fixed based on the stages of the target pest present at the time of observation which have been worked out to be 20.5% for *G. nephantidis*, 49.4% for *E. nephantidis* and 31.9% for *B. nosatoi*, when the parasitoids were released individually (91). Release of *G. nephantidis* effected 83% and *E. nephantidis* 81% reduction in population of *Opisina* (Table 2). When the host appears in a multistage condition in the field, all the three parasitoids are released at a dose of 40.4% of each stage of the pest population. The parasitoids are released, at fortnightly intervals, on the infested palm leaves (Plate II b) with live larvae/pupae, so the parasitoids get direct access to their host, preferably during morning hours. Repeated releases of appropriate species of parasitoids at the right doses and at the right stage of the host are essential for achieving maximum efficiency of the parasitoid releases.

TABLE 2 : OPTIMUM DOSES FOR PARASITOID RELEASE AND REDUCTION IN POPULATION OF *OPISINA ARENOSELLA*

Parasitoid	Optimum dose (%)	Reduction in pest population (%)
Goniozus nephantidis	20.5	82.9
Elasmus nephantidis	49.4	81.0
Brachymeria nosatoi	31.9	29.0
Combination of the three parasitoids	40.4	35.5

It is always advisable to liberate *G. nephantidis,* when the host larva is around the third instar stage, *E. nephantidis* at the late larval (pre-pupal) instar and *B. nosatoi* at the early pupal phase.

The endoparasitoid *Apanteles taragamae* Wilkinson (Braconidae) parasitises the early instar, preferably, the second instar caterpillars of *O. arenosella.* This is one of the most important parasitoids occurring in *Opisina* infested tracts of Kerala and Karnataka. *Bracon hebetor* is another larval parasitoid, which occurs in different intensities in several tracts in southern Kerala. Parasitism has been observed through out the year, with a mean natural parasitism of 31% (91). These parasitoids can be mass multipied under laboratory conditions using caterpillars of *O. arenosella* and *C. cephalonica.*

2.3. The red palm weevil, *Rhynchophorus ferrugineus* F.

The red palm weevil is the most dreaded enemy of coconut palm in India. This pest or its related species are found in other coconut growing countries also. This is a tissue borer pest and is found in the internal tissues of trunk, leaf stalks or crown of palms. Besides India the pest is reported from Indonesia, Kampuchea, Malaysia, Myanmar, New Caledonia, Papua New Guinea, The Philippines, Solomon islands, Sri Lanka and Thailand. In India it occurs in Maharashtra, Karnataka, Kerala and Tamil Nadu. Red palm weevil is also reported as one of the major pests of the date palm and the oil palm. Other hosts are sago palm, toddy palm, palmyrah palm, oil palm, talipot palm, sugar palm, serdang palm, nibong palm, the royal palm and certain ornamental palms.

The destructive stages of the pest are the grubs. They tunnel in to the palm trunk or crown and feed on the soft tissues of the growing parts which ultimately results in the death of the palm. Adult is prolific breeder and the pest completes its entire life cycle inside the palm. Usually young palms below 20 years of age are affected by this pest. If timely detection of the pest infestation is not made and curative control measures are not resorted to, the death of the palm is certain. Early detection often becomes difficult as the infestation is only inside the palm. Abraham *et al.* (12) described the symptoms of infestation, of which the major symptoms are presence of frass on the palm trunk, extrusion of frass and fibres through holes, oozing out of a brown viscous fluid, yellowing of middle leaves,

wilting and drooping of central spindle leaf, gnawing sound produced by the feeding grubs inside and toppling of the crown (Plate I d). These symptoms are not invariably associated with all cases of infestation. It is also possible that the palm may lodge the pest without giving any symptoms from outside. Hence, sustained surveillance for infestation by the pest is absolutely necessary.

The females lay 200 eggs in its entire life time on any part of the palm especially the cracks, crevices and wounds on the stem, leaf axils, diseased/rotten leaves, holes made by rhinoceros beetle on the spindle leaves etc. The eggs are about 2.6 mm long and 1.2 mm broad and hatch in 2 to 3 days. The emerging grubs tunnel towards the interior of the palm, take the sap in to the alimentary canal and push back the fibrous materials, closing the tunnels. Grub period lasts for about 60 to 75 days, followed by cocoon formation and pupating. The pupal period lasts for about a month. The adult weevils are more active during morning and evening and are active fliers. Weevils live for 76-113 days.

As the pest is a hidden tissue borer, infestation remains unnoticed, particularly, when it occurs on tall palm and by the time it is detected, the palm reaches beyond recovery stage resulting in the death. An IPM model has been prepared by integrating all the proven methods of red palm weevil control, based on the findings of operational research and test conducted in farmers' fields at Kurathicadu, Alappuzha Dt., Kerala consist (7, 11). The IPM model consists of the following steps :

(a) Surveillance : Periodic examination of palms under the susceptible age group (5-20 years) helps in detecting the infestation in its early stage.

(b) Sanitation : Dead and infested palms beyond recovery may harbour various stages of the pest which may serve as a potential source of inoculum for further spread of the pest. These palms are cut, split open exposing different stages of the pest present inside, and burnt.

(c) Prophylactic/cultural methods : Green coconut leaves are in great demand for various domestic uses and hence cutting of such leaves is very common. The plant sap oozing out from the cut surface attracts weevils for egg laying and subsequent entry of the hatching grubs into the stem. To avoid such entry, the leaves are cut, at a distance of one metre from the leaf base. The remaining petiole may dry up before the grubs reach the stem, if at all the eggs are laid by the female weevil in the injured portion (1)

Similarly injury caused on the stem due to cutting of steps for climbing over the crown or wounds caused by implements while cultural operations are done are also favourable sites of oviposition. Treatment of such wounds with HCH or coal tar+HCH is an effective measure to prevent red palm weevil entry into the palm through wounds (2). Holes made by rhinoceros beetle may be filled with HCH + sand mixture (@125 g HCH 10% dust + equal volume of sand) to prevent oviposition by the red weevil through such holes.

Adult weevils hide in the leaf axils and sometimes lay eggs also. Filling of leaf axils of young palms with HCH/chlordane 5% dust + sand mixture is recommended as a prophylactic measure (42). Treating the leaf rot/bud rot disease affected palms with Indofil

M-45 (Dithane M-45) and insecticide to prevent pest entry through decayed tissue is another preventive measure.

(d) Trapping the adult weevils : Trapping and destruction of adult weevils is another method by which pest population can be brought down. Trapping also helps in detection of the presence of the pest in a garden. To make trap, logs of tender coconut palm are cut to 50 cm length and split longitudinally into two equal halves. Coconut toddy, macerated grapes, cashew apple, pineapple, crushed suagrcane and molasses singly or in combination with yeast or acetic acid are used as attractants and are smeared on the cut surface of the split log. The split halves are put one over the other. Such log traps are kept 200 m apart in cultivators' fields having medium level of red palm weevil infestation (32, 37). The best combination of attractants is coconut toddy, yeast and acetic acid. Pealed fresh coconut petioles arranged in trays and mixed with the above attractant can also be used as a trap (3).

(e) Biological control : An earwig predator *Chelisoches moris* has been observed to feed on the eggs and early instar larvae of red palm weevil under laboratory conditions. These earwigs are seen on crowns of red palm weevil infested palms (6). Pathogenic bacterium and nuclear polyhedrosis virus have been isolated from diseased grubs of red palm weevil collected from the field (21).

(f) Curative chemical control : Once the infestation is detected in a palm, curative measures are undertaken using 1% pyrethrins piperonyl 1-butoxide in the field (60). After cleaning the crown of the infested palm, the holes on the stem are plugged with cement or clay. A new hole, above the original holes is made for pouring insecticides which percolate into the tunnells and come in contact with the immature stages of the pest and is plugged thereafter with cement or clay. Carbaryl 1%, trichlorphon 0.2% and endosulfan 0.1% have been also effective in controlling the pest (10, 43).

2.4. The coconut root grub, *Leucopholis coneophora Burm.*

The root grub *L. coneophora* is a serious pest of coconut palm in Kerala and southern part of Karnataka. They are well adapted to heavy rainfall tracts with sandy loam soils. They are found in isolated pockets. The grubs of this melolonthid beetles feed on the roots of coconut palm and also that of the intercrops (62). They feed on the soft tender apical portion of fresh coconut roots and affects the intake of nutrients from the soil. Continuous infestation by grubs in a garden results in general weakness of palms, yellowing of leaves and delayed production of inflorescence, shedding of young buttons/nuts and reduction in yield. Young palms of three to five year age show retarded growth. In nursery the seedlings turn weak and sometimes dry up. The grubs feed on other vegetations available in coconut gardens. Intercrops raised in coconut gardens are affected badly. The grubs also feed on cassava, sweet potato, yam, colocasia, banana etc. They feed on the edible tubers and roots of these crops and make them unacceptable for consumption. When cassava sets are planted the grubs feed on the rind and also the fresh roots causing death of the plants. In banana the grubs bore into the rhizome and pseudostem and sometimes kill the plant (4).

Adult beetles emerge *en masse* from soil during June-August at dusk, fly for

sometimes, locate the opposite sex, mate on the soil surface and then go deep into the soil. Eggs are laid in earthen chambers which hatch in 23 days. Just hatched grubs are about 2 mm long, feed on organic matter and gradually start feeding on rootlets of young plants. After 40-45 days, they enter into second instar, during which period they start feeding on coconut roots and after about 50 days they enter into the third instar. Third instar grubs feed on coconut roots and this stage lasts for about 168-178 days. Pupation takes place in an earthen chamber in soil. Total life period from egg to adult emergence is 295-317 days for males and 304-333 days for females. Beetles, eggs, grubs and pupae are found in the soil at 30-100 cm depth. Seasonal distribution of different stages of the pest has been illustrated in Fig. 1.

Management of this pest is very difficult as all stages are found in the soil and also due to peculiar nature of the damage caused by the pest. Any single method of control may not give a long lasting control and hence an integrated pest management approach is applied.

Adult beetle while active for mating at dusk above the soil is hand picked during emergence season (June-August) and killed. Large scale collection continuously for three years from a heavily infested field helps in briging down the population to a low level. Deep ploughing or digging soil after the onset of monsoon helps in exposing different stages of the insect above the soil for predation by crow, mynah, dogs, pig etc. It is a common sight that predatory birds assemble in large numbers behind the plough picking the pest from the opened furrows. Some insects may die while ploughing or digging due to crushing or injury caused to them. Cassava plants are grown in coconut gardens in patches as a trap crop. Planting may be done from November when third instar grubs are prevalent in the field. Grubs when congregate around the plants can be dug out and killed.

Augmentation of natural enemies of white grubs is an important tool in keeping this pest under suppression. A scoliid wasp *Campsomeriella collaris* is recorded as a natural enemy of the grubs. The wasp paralyses the grubs and lay eggs vertically on the body of the host. The larva of the parasite on emergence punctures the host skin by inserting its head inside, sucks the body fluid completely and then pupates in silken cocoon. A nematode *Caenorhabditis* sp. is found inside the body of the grubs. Mummified, hard, dead grubs having pink colour harbour a bacterium, *Serratia marsescens*. An obligate gregarine protozoan has also been recorded from the field collected grubs of *L. coneophora* (20). It produces at an average of 37 milky white, mebraneous cysts measuring 2.6 x 1.2 mm in the fat body of the host, each containing about 4 x 10^5 mucilaginous elliptical spores (26 x 2.6 mm). The grubs are also susceptible to infection by *Bacillus popilliae*.

Single treatment with 5% heptachlor dust @ 28 kg/ha in June or with two treatments with 5% HCH dust @ 100 kg/ha in June and again in September (8) have been recommended for the control of the pests. During the period from June to September first and second instar grubs are seen in the field which are the right stages of the pest for chemical control. Any application beyond this is of no use as the grubs enter third instar. Timely application is highly essential for the success of insecticidal control. Integration of all these components of control measures is necessary for bringing down the pest population below the economic level.

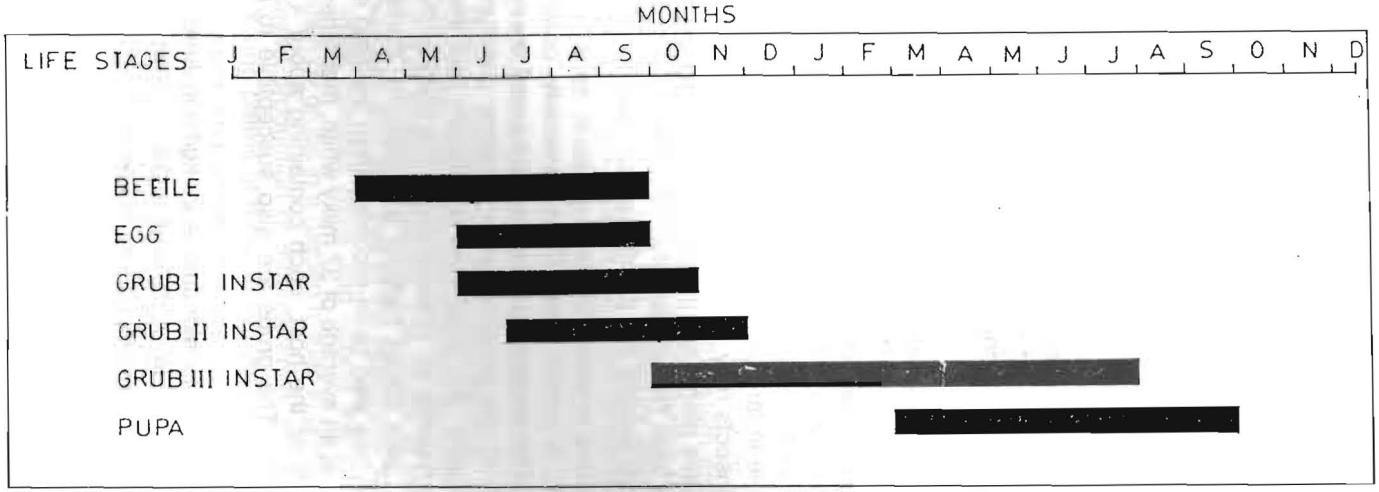


Fig. 1. Seasonal distribution of *Leucopholis coneophora*.

2.5. Slug caterpillars

Slug caterpillars are minor pests of coconut palm. Sporadic outbreaks of these slug caterpillars cause serious damage to the crop on the west coast of India. When the infestation is severe, caterpillars completely defoliate the palm and voraciously feed on all green parts of the crown. In case of outbreaks, when the larval population is very high, in addition to the leaves, the larvae feed on green petioles, spathes and nuts. The gardens show a scorched appearance resulting in premature leaf and nut fall. Yield loss up to 75% is also reported as a result of heavy infestation (54). The following slug caterpillars are observed on coconut palm in India.

2.5.1. *Contheyla rotunda* H. : Ayyar(14) and Nirula *et al.* (66) recorded this pest on coconut palm from Kerala. The pest is more common in the coastal tract. *C. rotunda* mainly feeds on the coconut palm and areca nut. However, banana, wild arrowroot and tea are some of the alternate host plants recorded The female moth lays eggs on the lower side of the leaflets in groups of 4 to 15 and fecundity ranges from 120-420 eggs per female (54). The egg to adult period is completed in 40-68 days. Cutting and burning of heavily infested fronds and application of carbaryl 0.05% spray are effective operations in the management of the pest (85, 86). During monsoon season, bacterial and fungal pathogens reduce the population in the field. *Rogas* sp. (Braconidae), *Antrocephalus* sp. (Chalcididae) and *Chrysis* sp. (Chrysididae) are some of the natural enemies recorded (65, 50).

2.5.2. *Latoia lepida* Cram. : This pest is more common in the coastal and backwater regions of Kerala. Usually young palms are severely damaged and the caterpillars devour the entire leaf lamina leaving only the midrib. Other host plants are castor, mango, banana, cacao, rose and palmyra. The pest complets its life cycle in about 76-86 days. Initial stages of population build up can be prevented by clipping the infested leaflets lodging the pest and the cocoons and destroying them. Carbaryl at 1.2 kg. a. i. per ha can be used for the control of the pest. The caterpillars of *L. lepida* are parasitised by *Chinocentrus* sp., *Stomatoceras ayyari, Eurytoma parasae* and *E. monemae, Stilbum splendidum* and *Apanteles parasae.* A predatory caterpillar *Phycita dentilinella* has also been found associated with the pupal cocoons.

2.5.3. *Macroplectra nararia* Moore : Fletcher (23) recorded this from several locations in south India and Nirula (57) reported its severe incidence on coconut in the east coast of India. Besides coconut, the pest is found on coffee, tea and *Zizyphus.* The life cycle is completed in about 50-52 days. *Eurytoma tatipakensis, Euplectromorpha natadae, Secodes nararariae* and *Euderus natadae* are some of the larval parasites recorded on this pest.

2.6. Leaf rollers

2.6.1. *Gangara thyrsis* M. : The caterpillars have been recorded as pests on nursery seedlings. The caterpillars construct tubular leaf rolls and feed within them. The fully grown larvae are pale green with red markings, but the colour is generally concealed by white waxy filaments. The larval period is about 35 days and the pupal period 10 days. The larval population is seen through out the year. Clipping of the affected leaf area or hand collections and destruction of the larvae are suggested as control measures.

2.6.2. *Suastus gremius* Fab. : Nirula (57) reported this pest on coconut palm from west coast of India. Besides coconut, the pest infests date and palmyra palms. The life cycle is completed in about 36 to 47 days (87). Though the pest is seen through out the year, the population is maximum during the months of July to September. Clipping the infested leaf rolls and destruction of the larvae is the best method of control. Split application of 0.05% carbaryl is also recommended for the control (54).

2.7. Nut borer - *Cyclodes omma* Van der Hoeven

The caterpillars bore deeply into the young developing nuts and cause them to fall. Though of rare occurrence, this pest causes shedding of the immature nuts. The pest is controlled by spraying endosulfan or carbaryl at 0.1% to the developing nuts just after pollination.

2.8. Nut crinkler - *Paradasynus rostratus D.*

The notorious coreid bug infests the developing buttons, sucks the sap just below the perianth portion. These infested nuts develop warts when mature, or they are rendered barren (Plate II c) or may fall off. The eggs are laid in clusters on soft portions like spadix, young nuts, leaf petiole etc. The life cycle is completed in about 33 to 45 days. The adults and nymphs feed on developing nuts by piercing its long stylet into the tender nuts. The feeding points are mainly the perianth region and these parts develop into necrotic lesions, finally taking the form of furrows and crinkles. Gummosis may also occur in the damaged portion. In most cases the infested nuts are shed, however, sometimes, may remain attached with the rachis, show retarded growth and become barren nuts. The pest is seen in the field during most parts of the year, but is active during post monsoon and early summer months.

For the control of the pest, spraying of crown with 0.1% carbaryl or 0.05% endosulfan has been recommended. Spraying is to be done at monthly interval and care is taken to avoid spraying on just opened flower bunches or buttons in the receptive phase. Afternoon hours are preferred for spraying the bunches (31, 94). Monitoring the coreid bug population on collateral hosts such as, cashew, cacao, tamarind, guava etc. and tackling them at the appropriate time is an important management practice. Two egg parasitoids have been recorded on *Hadrophanurus* sp. (Scelionidae) and *Anastatus* sp. (Eupelmidae) (54). Applied biocontrol is not known for this pest.

2.9. The lace bug - *Stephanitis typica* (D.)

Commonly known as the banana lace bug, it infests the lower surface of the coconut leaflets in colonies. This is a pest on sixteen other host plants, in addition to coconut (47). Both adults and nymphs suck sap from the lower surface of the leaf reuslting in yellow marks on the adaxial surface. The lace bug completes its life cycle on coconut in about 25 days (40). In the field this pest occurs through out the year, but March-May and September-October are the two distinct peak periods of its abundance (45). In addition to the role of the lace bugs as pest, it has been suspected to be the vectors of coconut root (wilt) disease that cause an annual loss in yield of 34 crore nuts in south and central

Kerala (46). Foliar application of carbaryl 0.01% spray is recommended for the contral of lace bugs (49). A mirid bug *Stethoconus pralfectus* is an effective predator of *S. typica* (43, 48). In addition, a chrysopid, anthocorid and spider predators have also been recorded as predators on the immature and adult stages of the pest.

2.10. Scale insects

2.10.1 Coconut scale - *Aspidiotus destructor* S. : *A. destructor* is one of the most serious pests of coconut palm in many countires. During severe outbreaks, the scale colony forms a crust over the lower surface of leaves, resulting in yellowing of leaves due to sucking of sap and blocking of stomata. Under severe infestation all the tender parts of the palm are damaged. Besides coconut, the pest is found on a variety of crop plants like oil plam, arecanut palm, date palm, cacao, banana, citrus, sugarcane etc. The life cycle is completed in 30-35 days. They are controlled in nature by a number of predators and parasitoids. Species of *Chilocorus* are the dominant predators observed. Systemic insecticides such as monocrotophos and dimethoate have been recommended for the control of *A. destructor* (27). Nair (54) has suggested the use of only those insecticides which are safe to the natural enemies as well as leave no long term residue.

2.10.2. Leaf and nut scale - *Lepidosaphes mcgregori* Banks : The pink coloured, elongated hard scale infests the upper lamina and surface of tender nuts. Leaves also sometimes get infested. Spraying with dimethoate or carbaryl has been suggested for the control of these scales (95).

2.11. Mealy bugs

The mealy bugs congregate and infest the spindle leaves, mature leaflets, inflorescences and unopened spathes. Infestation on young seedlings results in stunted growth and deformation of leaves. Feeding on floral parts causes shedding of flowers and nuts. Infestation of *Pseudococcus longispinus, Palmicultor* sp. and *Pseudococcus citriculus* on the spathe and inflorescence, and *Palmicultor palmarum* on the spindle has been recorded from Kerala and Tami. Nadu (5, 28, 54). Nair (54) suggested the use of non residual phosphatic insecticides such as, monocrotophos and fenthion for the control of these pests. In nature, though several natural enemies like *Pullus* sp. and *Spalgis epius* exert limited check on the mealy bug population, an effective biocontrol agent is yet to be identified.

2.12. Termites

Usually nursery plants and seedlings transplanted from the nursery are infested with the termites. Termites also infest grown up palms but the damge is not serious. In the lateritic coconut areas of west coast, up to 20% damage has been reported (64). *Odontotermes obesus* and *Termes obesus* are the termites reported on coconut from India. Chlorinated hydrocarbons such as, Heptachlor, HCH and chlordane are recommended for the control of the termites in nurseries (44, 50). However, in the context of the restricted use of the insecticides, other methods of control become more important. Sevral cultural practices such as avoidance of mechanical injury to palms, timely treatment of wounds

on palm trunk with coal tar, addition of river sand on nursery soil, periodical shifting of the nursery sites, heat therapy of nursery beds by long exposure to sunlight after ploughing etc. have been suggested for reducing the chances of termites build up (30).

2.13. Mites

Mites are usually minor pests on coconut palm. Sporadic outbreaks have been recorded which often lead to economic damage to the crop, particularly to the seedlings in the nursery. The recorded list of phytophagous mites comprises twelve species of tetranychid, six tenuipalpid and one eriophyid mites (25, 35, 36, 78, 82). The chief among them are *Eriophyes guerreronis*, *Oligonychus iseilemae* (Plate IId), *Raoiella indica* and *Tetranychus ludeni. O. iseilemae, R. indica* and *T. ludeni* inhabit the lower surface of the leaflets along the midrib suck the sap resulting in drying of the leaf/leaflets (80, 81). *E. guerreronis* inhabits the immature nuts and renders them either abnormal/barren or causes nut fall. *O. iseilemae* occurs in the field in abundance during May, *T. ludeni* in January - February and *R. indica* in March. High temperature, low relative humidity and long hours of bright sunshine favour the increase in population of *O. iseilemae,* whereas, rainfall and the associated mite predators play a dominant role in checking the population. The chief among the predators are *Amblyseius paraaerialis, A. eucalypticus, Cunaxa setirostris* and species of *Agistemus* (84). Temperature and bright sunshine favour the abundance of *R. india* (55).

2.14. Rodents

The black rat*Rattus rattus* Linn. is the most common rodent found throughout the coconut growing belt causing considerable damage to the crop. They make holes on the tender coconuts by gnawing the husk and consume the inner contents and the soft shell. Within a few days the affected nuts drop to the ground. The extent of damage by this particular rodent varies from 8.7 to 50% in different parts of the country. Maximum damage is reported from Lakshadweep (18). Apart from tender nuts the species is reported to damage leaf stalk, unopened spathe and mature nuts. They generally dwell on the crown of palms in nests. Hence, regular cleaning of crown is helful in minimising the population. An effective chemical method of control of this rodent pest is the use of multiple dose of anticoagulants like warfarin or cumarin. By use of a single dose anticoagulant rodenticide bromadiolone 0.005% in wax cake formulation, this pest can be more effectively controlled in the field (18).

The bandicoot rat *Bandicota bengalensis* causes serious damage to young seedlins. The Indian gerbil *Tatera indica* is another species damaging coconut seedlings. The bandicoots and gerbils can be effectively controlled by poison baiting with zinc phosphide. It is suggested that in order to overcome the problem of bait shyness, free baits (baits without poison) are kept in the above burrows for 2-3 days before putting poison baits.

The other vertebrate pests that cause occasional damage on coconut palm are the palm civet *Paradoxurus hermaphroditus,* the wood pecker *Dinopium* sp. and the monkeys.

3. CONCLUSION

With the available technologies on hand, an IPM system for coconut plantations in the country can be made very much feasible for adoption. An IPM system in coconut has definite advantages because coconut is grown as a main crop lodging under it a variety of intercrops. Under an intensified farming system existing in coconut gardens, IPM approach can be adopted with emphasis on the wider use of biocontrol agents and biopesticides.

As far as the major pests of coconut are concerned, workable IPM systems have been developed at the Central Plantation Crops Research Institute, Kasaragod. A constraint in its adoption is the lack of public awareness for which sufficient efforts are yet to be made by the extension and developmental agencies. A successful result oriented IPM can be achieved only with the total involvement of farmers, researchers, extension and developmental officials, particularly under a co-operative or group farming system. Hence, concerted efforts are required to gear up the IPM programme implementation in coconut so as to have a real impact in the coconut production in the country.

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