

PEST MANAGEMENT IN COCONUT GARDENS*

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ABSTRACT

The coconut palm, *Cocos nucifera* L. is attacked by nearly 57 species of insects and 12 species of rodents and other vertebrates in India. Among them the rhinoceros beetle, *Oryctes rhinoceros* L., the leaf eating caterpillar, *Opisina arenosella* Meyr., the red palm weevil, *Rhynchophorus ferrugineus* F., the white grub, *Leucopholis coneophora* Burm., and the black rat, *Rattus rattus* L. are considered to be the major pests. The nature of damage and severity of infestation are discussed. A review has been made on the control aspects including cultural, mechanical, chemical, physiological and biological methods adopted against these pests. An account of the damage and control of other less important pests such as scales, mealy bugs, nut crinklers, termites and bandicoots are also discussed.

INTRODUCTION

Many insect and rodent species have been recorded as pests of coconut palm from all over the world. However, the number of insects and rodents causing economic damage is very few. Some species occur in almost all coconut growing areas and pose a serious threat to the cultivation of the crop. On the other hand there are a few species which are confined to a particular geographical region. For subjugating the pest population several methods viz., cultural, mechanical, chemical, physiological, biological, etc. have been developed by researchers in different countries. For obtaining better results in the control of pests it is imperative to integrate various methods in such a way that there is minimum use of chemicals. Hence, the strategy for the management of various pests should be based on an integrated approach. In this article the work done on the major pests of coconut and their management has been reviewed.

INSECT PESTS

Rhinoceros beetle (*Oryctes rhinoceros* L.)
(Dynastidae : Coleoptera)

This is a serious pest of coconut occurring in most of the coconut growing countries. The black coloured adult beetle bore holes and feed on the unopened fronds and spathes. On opening, the damaged leaves show the geometrical cuts on leaflets. The beetle causes damage to seedlings, young and old palms. Several reports on the severity of its damage are available (Mickie, 1917; Orian, 1959; Ramachandran, Kurian and Mathen, 1963). It has been estimated that the damage caused by this pest was atleast US \$ 1,100,000 in South Pacific countries in 1968 (Catley, 1969).

The eggs are deposited in decaying organic matter, cattle dung, compost, rotting coconut logs, etc. The grubs remain in these materials for about six months. The average longevity of adults was reported as 4.7 months (Nirula, Radha and Menon, 1955a).

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Control:

Since the pest breeds in decomposing organic matter, removal of waste materials from the field should be done regularly and good phytosanitation should be maintained in the gardens. In young palms the beetles are extracted from the feeding holes with the help of long rods hooked at the tip (Cherian and Ananthanarayan, 1939; Gressit, 1953; Sison, 1957; Menon and Pandalai, 1958).

It is necessary to treat the breeding places with chemicals to prevent the multiplications of the beetles. In India the application of 0.01% gamma BHC was found to be effective and became a normal practice (Nirula, Antony and Menon, 1951a). Subsequently 0.01% aldrin was successfully used for the treatment of compost (Kurian and Pillai, 1964). In Fiji and India good results were obtained by applying gamma BHC (W.P. 50%) mixed with damp saw dust at a ratio of 1:9 (O'Connor, 1954; Nirula, 1955a). O'Connor (1957) has advocated the application of diazinon at 32% because of its more rapid action and longer persistence.

Filling the leaf axils of the central leaves with a mixture of BHC 5% and sand in equal proportion during dry season was reported to give adequate protection to the palms from beetle attack (Menon and Pandalai, 1958). The trials in Philippines indicated that leaf axil placement of carbofuran 3G (0.7g.a.i./palm) or diazinon 5G (1.26g.a.i./palm) or pirimiphos ethyl 10G (0.92g.a.i./palm) granules at 4 to 6 weeks intervals prevented the beetle attack. However, these insecticides were not superior to gamma BHC 6G (1.39g.a.i./palm) which, was withdrawn from the market (Abad, Gallego and Aterrado, 1982).

For attracting *O. rhinoceros* adults, ethyl dihydrochrysanthemumate (chrislure) applied

in metal vane traps was found very effective (Barbar et al, 1971). Later on a cheaper and commercially available formulation ethyl chrysanthemumate (rhinoplure) was also reported to be equally effective (Maddison, Beroza and McGovern, 1973). Due to some reasons like the non-entry of beetles into the traps even at high density of traps and the cost of servicing, this method did not gain popularity (Anonymous, 1978). The methoprene, a juvenile hormone analogue was found to be effective when applied topically or injected into the pupae of *O. rhinoceros* (Dhondt, McGovern and Beroza, 1976). However, no further attempts were made to evaluate the efficacy of these products in the field.

Oryctes species has been reported to be attacked by a number of parasitoids and predators. Thompson (1943) has listed five scoliid parasites viz; *Campsomeris luctuosa* Smith, *Scolia procer* Ill. *Scolia azurea* Chr, *Scolia oryctophaga* Coq, and *Scolia ruficeps* Smith. *Scolia patricialis* Burm Var. *Plebeja* Girb was reported to parasitize *Oryctes* larvae in Malaya (Bryan Jr, 1949). The wasps indigenous to eastern Africa and Madagascar belonging to the family scoliidae viz., *S. oryctophaga* coq., *Scolia ruficornis* F, *Elis romandi* Saussure were introduced to some Pacific ocean islands for the parasitization of *Oryctes* but they failed to establish in the field (Lever, 1979). In India, however, no scoliid parasite has been found to parasitize *O. rhinoceros*.

Several predatory beetles were tried against *Oryctes* without much success. They were *Catascopus*, *Neochryopus*, *Mecopus*, *Mecadema spinifer* Lev. (Carabidae), *Pyrophorus*, *Lanelater* and *Alans* (Elateridae) and *Hololeptis*, (Menon and Pandalai, 1958; Lever, 1979). In an attempt to reduce the pest population, a predatory bug *Platymiris laevicollis* was introduced into

Fiji and New Caledonia from Zanzibar. Each predator can destroy one adult beetle per day (Vanderplank, 1958). However, the initial success was not sustained in the field for longer duration. The release of *P. laevicollis* was attempted on a small scale in India also for the control of *O. rhinoceros*. As the impact on the pest was for a limited period the trials were discontinued (Antony et al, 1979).

Although the first attempt to control the rhinoceros beetle by biological means was made as early as in 1913 in Samoa (Friedrichs, 1913) by an introduction of a culture of the green muscardine fungus, *Metarhizium anisopliae*, its efficacy remained a mystery because of various factors. Attempts were continued unsuccessfully in many countries like India, Sri Lanka, Mauritius and Malay peninsula. This fungus attacks larvae and adults. In India, the humid conditions with moderate temperatures prevailing during monsoon season in the South West Coast appear to be more suitable for a large scale multiplication of the fungus (Nirula, Radha and Menon, 1955b).

Among less known pathogens certain bacteria from United States of America (Cumber, 1957) and other microorganisms from Sumatra, Sri Lanka, Pemba and Africa (Surany, 1960) have been used in Western Samoa to infect larvae.

A virus disease recorded on *O. rhinoceros* from Malaysia (Huger, 1966) was introduced into several South Pacific islands as baculo-virus to control the pest population (Marschall, 1970; Hammes, 1971; Zelazny, 1973, 1977a, 1979; Young, 1974; Bedford, 1976). After the introduction, this has rapidly spread and established thereby drastically reducing the population of *O. rhinoceros* below the threshold levels (Hammes and Monsarrat, 1974; Zelazny, 1977b; Bedford, 1980). Caltagirone (1981)

claimed the success with baculovirus as one of the most successful examples of microbial control in recent years. The occurrence of baculovirus in the natural population of the beetles was reported from the Philippines and Indonesia (Zelazny, 1977b) and India (Mohan, Jayapal and Pillai, 1983). Within one year of release of *Baculovirus* sp. against the *O. rhinoceros* in the Maldives in 1984, the number of beetle attacks on palms fell to one quarter, the number of virus infected beetles increased to about 50% and coconut yields increased by about 10% (Anonymous, 1986). It was also reported that the disease could easily spread 1-2 km over sea.

The pest population has been substantially reduced in Minicoy island, Lakshadweep, India, through the release of baculovirus infected beetles (Mohan, Jayapal and Pillai, 1989). The leaf and spathe damage as well as fresh incidence of spindle damage which was 56.6%, 31.1% and 39.2% respectively got reduced to just 7% leaf damage only. On the other hand the disease incidence in beetles enhanced to 60% from zero level (Anonymous, 1989).

A study was conducted to see the possibility of resistance to baculovirus in populations of the coconut rhinoceros beetle (Zelazny, Alfiler and Lolong, 1989). Trials with larvae showed no evidence for resistance but confirmed that baculovirus isolates can differ significantly in their virulence. Hence, for the successful and economic control of *O. rhinoceros* more attempts should be made to introduce the right type of baculovirus isolate in areas where it is completely absent or present in negligible levels.

Leaf eating caterpillar (*Opisina arenosella* Wilk = *Nephantis serinopa* Meyr.)
(Oecophoridae: Lepidoptera)

This pest is serious in India, Sri Lanka, and Myanmar (Burma) where the caterpillars feed on the lower surface of the older leaves (Nirula, 1956; Child, 1974). The pale pink coloured caterpillars with a black head make galleries on the underside of the leaflet with silken threads and their faecal matter. They remain inside these galleries and feed on the leaf tissues. During severe cases of infestation all older leaves become dried up and only a few young leaves remain green (Jayaratnam, 1941). The crop yields have been reduced to half in the years following severe outbreak of pest (Lever, 1979). In India, the summer months are reported to be highly favourable for the development of the pest. The larvae pass through 8 stages in about 5–8 weeks and the pupal stage is completed in 9–14 days. (Santhosh Babu and Prabhu, 1987). George, Sathiamma and Vijayakumar (1984) have developed a method to estimate field populations of this pest.

Control:

The spraying of DDT (0.2%) to the lower surface of the leaflets gave good control of caterpillar in two weeks (Nirula, Antony and Menon, 1951b). Since the DDT persists for two weeks, its deleterious effects on the beneficial parasitoids were far greater. But the toxicity of BHC 0.2% persisted only for 6–10 days reducing the adverse effects on parasitoids. By increasing the dosage of dieldrin from 0.05% to 0.2% mortality was enhanced to 82% from 77% (Pillai and Kurian, 1960).

Nadarajan and Channabasavanna (1981) recommended trunk injection of either monocrotophos or dicrotophos @7 ml a.i./palm to control *O. arenosella*. In Sri Lanka

trunk injection with monocrotophos 60% @ 3 ml and 6 ml/palm resulted in persistence of the insecticide in the leaves for about 4–6 months giving adequate control over a long period (Kanagarathnam and Pinto, 1985). In order to minimise the adverse effects of trunk injection, a better method known as root feeding or root absorption technique was tried against *O. arenosella* (Rao et al, 1980). Recently the application of systemic insecticide through a cavity in the base of a petiole "Petiolar wells" has been demonstrated to be useful in the control of *O. arenosella* in Sri Lanka (Perera, Mahindapala and Pethiyagoda, 1989).

Nadarajan and Channabasavanna (1981) reported that the residues in palms treated with a lower dose of 5 ml a.i./palm fell below the tolerance limit after three weeks. According to Rao and Murthy (1985) the residue level in coconut water and meat of tender and mature nuts was 0.50, 0.60, 0.44 and 0.45 ppm respectively after 45 days of root feeding with monocrotophos which was much above the FAO/WHO prescribed tolerance limit of 0.2 ppm. In view of high oral and dermal toxicity of monocrotophos care must be exercised in recommending such insecticides for general use.

Though the bacteria *Serratia marcescens* Bizio causes septicaemia in *O. arenosella* (Antony and Kurian, 1961) it was reported to be equally dangerous to the silk worms (Steinhaus, 1949). Among the microbial insecticides *Bacillus thuringiensis* HD strain preparations were successfully tested against the caterpillar without any adverse effect on beneficial insects (Kurian., 1983). Mathen, Sathiamma and Kurian (1968) reported a predatory mite *Pyemotes venticosus* Newport occurring on *O. arenosella*.

Several species of predatory beetles have been recorded on *O. arenosella*. The

carabid beetles, *Parena nigrolineata* and *Calleida splendidula* are recognized as the most potential predators. In laboratory studies it was found that *P. nigrolineata* consumed about 0.34 to 1.32 host larvae/day (Pillai and Bhat, 1987). A detailed investigation on the comparative feeding potential and biology of *C. splendidula* and *P. nigrolineata* has also been made (Pillai and Nair, 1990). However, the population build up was limited due to egg parasitoids like *Xenomermis* in the case of *P. nigrolineata*. Out of 18 species of predatory spiders of *O. arenosella* larvae, *Sparassus* sp., *Cheiracanthium* sp., *Rhene khandalaensis*, and *Rhene indicus* were the most voracious, consuming 0.7 to 1.5 larvae/day (Sathiamma, Jayapal and Pillai, 1987).

A more economical and safer method for the effective control of *O. arenosella* is to release parasitoids. Some of the common and useful parasitoids are given in Table I. The intensive colonization of the parasitoids for over two years saved the palms in the worst affected tracts (Rao, Cherian and

Ananthanarayan, 1948). During 1950, heavy infestation of the pest observed along the coastal area of Quilon district in Kerala was controlled by the liberation of parasitoids in large numbers (Nirula, 1956). Similarly another serious outbreak in the deltaic areas of East Godavari district of Andhra Pradesh was brought under control by intensive colonization of parasitoids for a period of two years (Dharmaraju, 1952). A serious outbreak with 2-3 insects/leaflet with low parasitization (3-5%) was controlled by the release of parasitoids. After the release of parasitoids the pest population declined by 99.97% and the parasitoids reached 37-68% (Anonymous, 1972).

The combined parasitism by various species of *Brachymeria* was 22% with parasitism by *B. nosatoi* reaching 19.3% in southern Kerala and 2.2% in northern Kerala. Though the mass multiplication of *Brachymeria* spp. was found to be difficult (Joy, 1975), Pillai and Nair (1982) have standardized the laboratory multiplication technique.

Table I. Parasitoids of *O. arenosella* in India

Parasitoid	Family	Host stage
<i>Apanteles taragamae</i>	Vipionidae	Larva
<i>Bracon brevicornis</i>	Braconidae	Larva
<i>Bracon hebetor</i>	Braconidae	Larva
<i>Goniozus nephantidis</i> (<i>Perisierola nephantidis</i>)	Bethylidae	Larva
<i>Elasmus nephantidis</i>	Elasmidae	Prepupa
<i>Brachymeria nosatoi</i>	Chalcidae	Pupa
<i>Brachymeria nephantidis</i>	Chalcidae	Pupa
<i>Trichospilus pupivorus</i>	Eulophidae	Pupa
<i>Xanthopimpla punctata</i>	Ichneumonidae	Pupa
<i>Xanthopimpla nana nana</i>	Ichneumonidae	Pupa

Sathiamma et al. (1987) worked out the norms for release of larval, prepupal and pupal parasitoids of *O. arenosella*. The doses worked out were 20.5 % for *G. nephantidis*, 49.4 % for *E. nephantidis* and 31.9 % for *B. nosatoi* when the parasitoids were released individually and 40.4 % when a combined release was made.

Some growth regulators have been tried against the leaf eating caterpillar for control. When the last instar larvae of *O. arenosella* were fed on the coconut leaves treated with diflubenzuron (4g/l suspension), a chitin synthesis inhibitor, only 5 % of the larvae survived to become adults as against 97.5 % in untreated larvae (Sundaramurthy and Santhanakrishnan, 1979). In a field trial the entire field population of larvae was eliminated by treating the diflubenzuron within 14–18 days depending upon the dose (Sundaramurthy, 1980). However, the compound directly or indirectly affected the development of the parasitoid *G. nephantidis*.

In an attempt to develop newer methods of control, the female sex pheromones of *O. arenosella* were isolated, identified and synthesized by Coconut Research Institute, Sri Lanka in collaboration with the Overseas Development and Natural Resources Institute, U. K. (Anonymous, 1987). Although the initial laboratory studies were encouraging the subsequent field studies showed no significant difference between blank traps and the pheromone loaded traps. More studies on these lines are required to identify the reasons for the failure of the synthetic pheromones in the field.

Red palm weevil (*Rhynchophorus ferrugineus* F) (Curculionidae : Coleoptera)

This is also one of the important pests of coconut. The entire damage is caused by the larvae which feed on the inner tissues of crown and upper portion of trunk. The

external symptoms produced by the pest include the presence of small holes on the stem, oozing out of brown viscous liquid, extrusion of chewed up fibres and longitudinal splitting of leaf bases. In severe cases the crown of the palm topples. Palms in the age group of 5–20 years are more susceptible to this pest attack. In Kerala it is reported that nearly 5 % palms below the age of 10 years are killed annually by this pest (Lever, 1979). Quite frequently the feeding activities of *Oryctes* facilitate the egg laying by red palm weevil. The legless larvae are yellowish, stout and make galleries inside the tree for about 2–4 months. The adult weevils live for 3–4 months. The females are known to be attracted strongly to the fermenting sap oozing out of wounds in the trunk or the leaf bases.

Control:

As a prophylactic measure Copeland (1931) and Ayyar (1940) suggested that all scars, wounds and exposure of soft part of palm should be avoided. They also prescribed the removal of grubs and dressing the wounds with tar, lime, etc. In cases of severe infestation the affected palm should be cut and burnt to prevent the spread to healthy palms (Vestal, 1956). Cutting the trunk for making footholds for climbing the palm or any other activity which provides sites for egg laying by weevils should be avoided (Child, 1974).

Out of several insecticides tried Pyrocon E 1 % when injected into infested trees gave the best results (Nirula, Antony and Menon, 1953a). As a prophylactic measure, the leaf axils of young palms may be filled with sand and BHC 5 % or chlordane dust in equal proportion as in the case of *Oryctes* damage. An adult mortality of 92 % at 0.5 % and 100 per cent at 1.0 % concentration of endrin was reported by Mathen and Kurian (1962).

By injecting the infested trees with carbaryl 1.0% nearly 93% palms were cured (Mathen and Kurian, 1967). Subsequently Rao, Subramanian and Abraham (1973) achieved good success by placing aluminium phosphide tablets inside the damaged portion. Among several insecticides tested trichlorophon 0.2% gave the best results with 92% recovery of infested palms (Abraham, Koya and Kurian, 1975).

A trap for the collection of *Rhynchophorus palmarum* was developed by Maharaj (1965) in Trinidad. When this method consisting of traps with split fresh coconut petioles was tested in one estate in Sri Lanka 302 red palm weevils (*R. ferrugineus*) were recovered from 10 traps in 141 days (Ekanayake, 1970.) The trapping method was modified with the addition of sugarcane and yeast to the split petioles. By mixing the traps with BHC 50WP (2g/trap) the trapped weevils could also be killed (Anonymous, 1988).

Attempts have been made to develop control measures against red palm weevil making use of the sterile insect technique with radioisotopes (Kloft et al., 1986; Kloft, Koerner and Wolfram, 1986). However, the results on the application of this technique in the field and its success are not available from any country. As the early detection of the damage in palms is difficult some attempts have been made to develop simple electronic device for detecting infestation (Anonymous, 1990).

White grubs (*Leucopholis coneophora* Burm) (Melolonthinae : Coleoptera)

The white grubs (root grubs) are a major threat to the coconut gardens in sandy and sandy loam soils. They cause damage to the roots by direct feeding resulting in yield loss as well as reduced vigour. Though several species of white grubs are reported

to damage coconut, *Leucopholis coneophora* has been considered the most predominant species in the coastal areas of Kerala and Karnataka (Nirula, Antony and Menon, 1952). In the plains *Holotrichia serrata* was reported to be the main root feeder of coconut (Veeresh, 1983). The most common symptoms associated with white grub attack in coconut are yellowing of leaves, immature nut fall, delayed flowering, stunted growth, reduction in yield, etc.

Control:

Repeated ploughings once a week, for 4-5 times after the first rains in summer reduce the population to non-pest level (Veeresh, 1975).

Several chemicals were recommended for the control of white grubs. The soil application of BHC 5% dust (Nirula, 1955 b; Anonymous, 1984a) BHC 10% dust (Nirula, 1958), aldrin 5% (Mathen, Kurian and Mathew, 1964; Johnson and Nair, 1966) and Chlordane (Mathen, Kurian and Mathew, 1964), heptachlor (Anonymous, 1976; 1984a) were recommended for the control of white grubs. Menon and Pandalai (1958) recommended the dusting of soil with 66 kg of 10% BHC or 33 kg of 5% chlordane per hectare and then ploughing to a depth of 15 cm for the destruction of the early stages of the pest. Aldrin, dieldrin, heptachlor and malathion were also found effective for nursery. Covering the germinating seeds in the nursery beds with a layer of sand also gives protection (Lever, 1979). Veeresh (1983) reported that application of chlorpyrifos 20 EC (10 ml/palm), Counter 5G, and phorate 10G (20g/palm) with irrigation gave good control of *H. serrata*. Subsequently for the effective control of root grubs two applications of BHC 5% @ 2 kg a.i./ha or one round of heptachlor 5% @ 1.4 kg a.i./ha were recommended (Anonymous, 1985).

Kurian et al, (1983) were of the opinion that *Bacillus popilliae* D. isolated from *H. serrata* could be used against the white grub species attacking coconut. The mortality among the prepupae of *L. coneophora* was also attributed to nematodes but no further investigations on this aspect were carried out (Sekhar, 1958). A scoliid wasp, *Campsomeriella collaris* was observed parasitizing grubs of *Leucopholis* sp. in Kerala (Anonymous, 1969). A carabid *Pheropsophus sordidus* was reported to be predacious both on larvae and adults of white grubs (Veeresh, 1983). Besides crow which preys to a large extent, striped squirrel also predate on this pest. Even dogs, cats and bats have been found feeding on the adult beetles during emergence time (Menon and Pandalai, 1958). Several intercrops viz., tapioca, yam, cacao, etc., serve as host plants for the white grubs. Hence, the control measures should be applied to intercrops also for the effective and long lasting control of the pest.

Minor pests

Scales:

Although scale insects are considered to be minor pests of coconut in India, they are assuming the status of major pests due to the close planting, poor management practices and scarce rainfall. Several species are associated with coconut of which coconut scale *Aspidiotus destructor* is universally distributed. The insects form a continuous crust and suck the sap from the leaves, flower spikes and young nuts resulting in loss of vigour (Lever, 1979; Jalaluddin and Mohana Sundaram, 1989, Vidyasagar, 1989).

In Fiji, young palms were sprayed with malathion 0.1% or Diazinon 0.25% to control the pest (Hinckley, 1961). It has been found that biological control of this

pest is more economical and practical. Successful biological control of *A. destructor* has been achieved by the introduction of a predator *Cryptognatha nodiceps* Marshall in Fiji (Taylor and Paine, 1935) and Principe Island (Simmonds, 1960). Similarly, two coccinellid beetles *Chilocorus nigrinus* F. from Sri Lanka and *Chilocorus politus* from Java were successfully introduced in Mauritius (Moutia and Mamet, 1946). Another coccinellid *Lindorus lophanthae* Blaisdell was also used to control *A. destructor* in some Pacific Ocean islands (Cochereau, 1965).

Mealy bugs:

The mealy bug, a sucking pest occurs in small colonies at the bases of spear leaf, spadix, inflorescence and perianth of tender nuts (Vidyasagar, 1989). There are several species of mealy bugs reported from coconut palm. Among them *Palmicoccus palmarum* and *Pseudococcus cocotis*, are commonly found in India (Anonymous, 1988). As a result of mealy bug infestation, the tender unopened fronds remain stunted, deformed and suppressed and in severe cases immature nut fall occurs. The ant species found in association with mealy bugs were *Oecophylla smaragdina*, *Technomyremex* sp. and *Selenopsis oeminata* (Anonymous, 1988). For the control of the pest spraying with fenthion (0.1%) or monocrotophos (0.1%) was found effective (Anonymous, 1989; Vidyasagar, 1989).

Nut crinklers:

Many coreid bugs were recorded in association with coconut (Lever, 1935; Kurian et al., 1972). Among them *Paradasynus rostratus* recorded from India causes damage by feeding on the developing nuts (Kurian et al., 1972). The symptoms of damage are easily identified by the cracks and gummosis on the nuts. Spraying of the tender nut

bunches with carbaryl 0.1% or BHC 0.2% was reported to give good control of this pest (Visalakshi et al., 1987).

Termites:

The termite is an important pest of the coconut seedlings. The common species that attacks coconut in India is *Odontotermes obesus* Ramb. The coconut seedlings are either attacked through the base of the seednut or at the collar portion resulting in wilting of the central shoot and ultimate death of the seedling. It has been found that about 20% of the seedlings in laterite areas were infected by termites (Nirula, Antony and Menon, 1953b).

Several chemicals found effective against termites were parathion, pentachlorophenol, sodium pentachlorophenate and chlordane (Nirula, Antony and Menon, 1953b). For the chemical control of this pest, Harris (1961) recommended the use of BHC, dieldrin, aldrin or chlordane, while Child

(1974) found the application of BHC 10% dust or dieldrin 2% dust @ 56 kg and 112 kg respectively per hectare as suitable. It is important to treat the nursery and young palms as and when necessary to ensure healthy growth in the initial years (Lever, 1970).

RODENT AND OTHER VERTEBRATE PESTS

Rodent pests

Several species of rodents including rats, squirrels, bandicoots, gerbils and porcupines are known to damage coconut in India (Table II) and other countries. The damage to tender nuts is mostly caused by several subspecies of *Rattus rattus*. Other species of *Rattus* that damage tender nuts are *R. pulliventer* in Andaman islands, *Rattus exulans* in south pacific and *Rattus tiomanicus* in Indonesia. Among the rodents that damage coconut seedlings, bandicoots (*Bandicota bengalensis*, *B. indica*) gerbils (*Tatera*

Table II. Rodent pests of coconut in India

Region	Species	Reference
Mainland	<i>Rattus rattus wroughtoni</i>	Advani, 1985
	<i>Rattus rattus rufescens</i>	Rajasekharan and Dharmaraju, 1975
	<i>Tatera indica</i>	Natarajan, Koya and Kurian, 1976
	<i>Bandicota indica</i>	"
	<i>Bandicota bengalensis</i>	"
	<i>Hystrix indica</i>	(Bhat, unpublished)
	<i>Sciurus vulgaris</i>	Sarkar, 1986
	<i>Sciurus carolinensis</i>	"
Laccadive islands	<i>Rattus rattus</i>	Advani, 1984 b
Andaman islands	<i>Rattus rattus andamanensis</i>	Advani, 1985
	<i>Rattus rattus holechu</i>	"
	<i>Rattus pulliventer</i>	"

indica) and porcupines (*Hystrix indica* and *Acanthyon brachyurum*) are important.

Rattus rattus Linn. :

The black rat, *Rattus rattus* is a medium sized rodent weighing around 100 g and the tail is always longer than the head and body. It is an active climber capable of climbing very tall palms (Smith, 1967a). The subspecies responsible for most of the damage to tender coconut in India is *R. r. wroughtoni* (Advani, 1985). In coconut plantations this rat lives mostly on the crown of the palms (Natarajan, Koya and Kurian, 1976) and seldom comes to the ground (Advani, 1984a; Bhat and Sujatha, 1986).

Rattus exulans Peale:

The Polynesian rat, *Rattus exulans* is found mainly in Southeast Asia and Pacific islands (Rowe, 1975). It is smaller than *R. rattus*, weighing around 50 to 80 g and the length of the tail is equal to the length of the head and body. Unlike *R. rattus*, the *R. exulans* is less arboreal and mostly damages nuts on palms less than 10 m height (Williams, 1974b).

Bandicota bengalensis Gray:

The lesser bandicoot, *B. bengalensis* is a robust animal weighing around 300 g and the tail is shorter than the head and body. It is endemic to India, Nepal, Sri Lanka and south east Asia. It is highly fossorial and its presence can be felt by the presence of heaps of excavated soil concealing the entrance of the burrow system. It is a major pest of coconut seedlings (Urs, 1979; Guruprasad and Srihari, 1983) and tuber crops (Lal and Pillai, 1981).

Nature of damage

R. rattus makes a small hole of about 5 cm diameter near the perianth region of the

tender nut and feeds on the inner contents (Smith, 1967a). The damaged nuts fall from the bunch 2 to 6 days after attack (Rowe, 1975). In Lakshadweep, Shamsuddin and Koya (1985) found 53 rat damaged nuts remaining on the bunches while 107 had already fallen. The rats prefer 3 to 6 months old nuts though damage to buttons and mature nuts are not uncommon. Wodzicki (1972) found 86.5 % of the damage was at the tender nut stage, 12.7 % at the button stage and 0.8 % at the mature nut stage. In severe cases of infestation the damages to leaf stalks, unopened spathes, female flowers etc., was also noticed (Paine, 1934). Sadanandan (1974) reported damage to stored nuts by this pest. Rats were observed to prefer tender nuts of certain palms to others (Wodzicki, 1972; Williams, 1974b; Rao and Subiah, 1982). The holes gnawed by *R. exulans* were smaller in size (2 to 3 cm diameter) than those of *R. rattus*.

The burrowing rodents, especially *B. bengalensis*, *B. indica* and *T. indica* were reported to damage coconut seedlings (Natarajan, Koya and Kurian, 1976). Maximum damage by *B. bengalensis* was noticed when the seedlings were 13 to 15 months old (Urs, 1979). This bandicoot was also reported to damage young palms (Sarkar, 1986).

Assessment of damage

Rodent damage in coconut has been assessed as 15 to 50 % in India and its islands (Kidavukoya, 1955; Rao and Subiah, 1982; Sarkar, 1986), 30 % in Fiji (Williams, 1972), 23 % in Philippines (Gallego, Aterrado and Abad, 1981), 5 to 36 % in Jamaica (Smith, 1967a) and 30 to 40 % in Pacific islands (Wodzicki, 1972).

Monthly observations carried out on rat damage in coconut at Fiji (Williams, 1974b) and India (Anonymous, 1990) revealed considerable variation in damage

from month to month. Williams (1974a) was of the opinion that in coconut nearly 50 % of the nuts lost during their early stages of development were being compensated either by increased female flower production or by increased copra content and hence, there would not be a clear one to one relationship between the number of damaged nuts and reduction in yield. Williams (1972) reported that in Fiji coconut meat was not an important food item for rats. But in Lakshadweep islands the rats thrived mostly on coconut meat (Advani, 1984b).

In certain areas *R. rattus*, *B. bengalensis* and *B. indica* were observed to damage mature shed nuts (Mathai 1978; Sarkar, 1986). However, informations on the intensity of such damage are not available.

Control measures

An integrated method of approach consisting of habitat manipulation, trapping, use of barriers, chemical control and biological methods is generally followed for the control of rodents in coconut gardens.

Habitat alteration:

In coconut plantations the population build up of rats on the crown can be discouraged by keeping the crowns clean of dried leaflets, spathes, and matrix regularly. In the fields, by keeping the garden free of weeds and other harbourage spots, the population of burrowing rodents can be minimized.

Trapping:

Trapping is probably the safest but labour intensive method of controlling rodents. Among several types of traps the wooden 'live' traps were found better than the others to capture *R. rattus* (Mathew, 1986; Bhat and Sujatha, 1987). Advani (1985) has achieved 76 % control of *R. rattus* in coconut

gardens by using such traps. Kurian, Natarajan and Koya (1977) found bamboo snap back-cum-noose traps as the best for trapping *B. bengalensis* and plank traps for *B. indica*.

Trunk banding:

In older plantations banding the coconut trunk with 23 to 30 cm wide G. I. sheet at a height of 1.5 to 2.0 m above the ground level proved effective in controlling rats that damage tender coconuts in some countries (Yelf, 1966). Strips of less than 18 cm width were found less effective (Montenegro, 1962). In Philippines Gallego, Aterrado and Abad (1981) found trunk banding highly effective whereas Hoque (1973) reported crown baiting with anticoagulants as the most effective and profitable. In India, trunk banding without controlling the rats on the crown gave only 53.8 % success (Guruprasad and Srihari, 1983). Child (1974) reported that trunk banding was more expensive than poison baiting.

Chemical control:

Acute poisons and fumigants: The burrowing rodents such as bandicoots and gerbils can be effectively controlled by using the acute poison zinc phosphide. The poison baits can be prepared by mixing 2 parts of zinc phosphide with 95 parts of rice and 3 parts of edible oil (Prakash and Mathur, 1987). Fresh tubers of cassava can also be used as the bait. To achieve better results poison baiting with this poison should be carried out after 2 to 3 days of pre-baiting (Guruprasad and Srihari, 1983).

Aluminium phosphide is a fumigant widely used against burrowing rodents (Barnett and Prakash, 1975). It is suggested to apply 0.6g pellets of aluminium phosphide per burrow in wet lands and 1.2 g pellets in dry lands (Sridhara and Srihari, 1979).

The cost involved in aluminium phosphide treatment was much more than with zinc phosphide (Advani and Mathur, 1981). In order to reduce the cost it was suggested to use zinc phosphide baits prior to aluminium phosphide fumigation (Fitzwater and Prakash, 1978). By this approach Gurusasad and Srihari (1983) has achieved 80% control of *B. bengalensis* in coconut fields.

Anticoagulants (slow poisons):

MULTIPLE DOSE: Warfarin, fumarin, to-marin, racumin, etc. belong to this group of anticoagulants. These are used at 0.01% to 0.05% (Prakash and Mathur, 1987). The poison baits are generally prepared in wax cake forms. The baits using warfarin/fumarin could be prepared by mixing broken rice, jaggery, paraffin wax and poison (having 5% a.i.) in the ratio of 8 : 5 : 6 : 1 (Bhat and Sujatha, 1988). The bait base could be changed depending on the preferences of each species. In Jamaica oatmeal was used as the bait (Smith, 1967b) whereas, in Ivory coast cornflour was preferred (Mariau, 1967).

Multiple dose anticoagulants have to be consumed by rodents for several days for mortality (Bhat and Sujatha, 1989a). Hence, while using such poisons it is recommended to replenish the bait points 2 to 3 times at an interval of 2 to 3 days (Rowe, 1975).

For the effective control of rat damage to tender coconut it was suggested to keep the baits on the crown (Hoque, 1973; Williams, 1975). The infestation of *R. r. wroughtoni* was successfully controlled by applying warfarin/fumarin wax cakes on the crown three times at an interval of 2 to 3 days @ 105 g, 70 g, and 35 g baits, per palm on 30 palms/ha during first, second and third baitings, respectively (Bhat and Sujatha, 1988). In Philippines application of 375 g warfarin baits on the crown of the coconut

palm @ one palm for every five palms gave good results against both *R. r. mindanensis* and *R. exulans* (Reidinger and Libay, 1981). In Jamaica, Smith (1967b) suggested to keep 227 g warfarin baits on every sixth palm to reduce the damage by *R. rattus*.

SINGLE DOSE: Difenacoum, brodifacoum, bromadiolone, etc. belong to this group of anticoagulants. In the comparative studies on the effectiveness of multiple dose and single dose anticoagulants against *R. rattus* infesting tender coconuts the latter was found more effective than the former (Rao et al., 1984; Advani, 1985). In coconut plantations it was possible to achieve full control over the infestations of *R. r. wroughtoni* by applying 10 g bromadiolone (0.005%) wax baits two times at an interval of 12 days on the crowns of coconut palms @ one palm for every 5 to 6 palms (Bhat and Sujatha, 1989b).

Biological control:

Predation, introduction of pathogens, use of antifertility agents are some of the possible means of biocontrol of rodents (Jackson, 1972). Kites, owls, mongoose, palm civets, monitor lizards and snakes are the established predators of rodents in coconut fields. Most of these predators are opportunistic and prey upon whatever is easily available. For example, when barn owls were introduced for the control of rats in Seychelles, they killed all native birds which were easier to locate and eat (Anonymous, 1984b). The use of pathogens for the control of rodents has got very limited practical value as they also pose danger to public health (Jackson, 1972).

Minor rodent pests

Among other rodents, certain species of squirrels were reported to damage tender coconuts in Tripura. Trapping

or covering the bunches with wire mesh was suggested for the control of these pests (Sarkar, 1986). Porcupines (*H. indica*, *A. brachyurum*) were reported to be the pests of coconut in India, Indonesia and Sri Lanka. They were observed to attack the seedlings as well as young palms. In some parts of India they were also observed to break open and feed on the mature shed nuts. Protecting the seedlings with wire mesh, painting the basal portion of the seedlings with coal tar + zinc phosphide and the use of death fall traps or stockade traps were the control methods suggested.

Other vertebrate pests

Birds:

Instances of bird damage to tender coconuts were reported from several countries. The woodpecker, *Centurus radiolatus* was reported to damage tender nuts in Jamaica (Child, 1974) and *Dinopium* sp. in India (Bhat, 1989). However, Bhat and Vidyasagar (1989) felt that the damage by such birds to tender coconuts was too less to warrant any control measures. In New Guinea and Solomon islands the birds of the genus *Cacatua* were reported to strip off the husk of the young nuts causing them to fall prematurely (Child, 1974).

Mammals :

Fruit eating bats were reported to damage tender nuts in several countries. Most important among them were *Pteropus edwardsii* in South India (Nirula, Antony and Menon, 1954), *Pteropus vampyrus* and *Pteropus edulis* in Malaysia, *Pteropus scapulatus* in Melanesia and *Pteropus tonganus* in Polynesia (Lever, 1979). The damage was mostly sporadic and localised. In Tanzania the straw-coloured fruit bat, *Eidolon helvum* was reported to damage the frond and leaflets of coconut by roosting on them in

large numbers (Feare, Manyanza and Mbisc, 1984). Shooting bats at their roosting places or covering the bunches with wire nets or thorny bushes were the possible control methods.

Wild boars (*Sus* sp.) were reported to attack seedlings as well as mature shed nuts. They dig up the soil and extract the nuts to eat the haustorium (Benigno and Soewarno, 1985). The fallen nuts were also cracked and the kernel eaten. Lever (1979) suggested poison baiting with zinc phosphide using cassava as the bait whereas Liaw (1983) suggested erection of stockade traps to control these animals.

Monkeys (*Maccaca* spp) were known to damage tender nuts in several parts of India. The control was mainly by shooting or trapping.

CONCLUSION

A number of advances have been made in management of various coconut pests. Apart from the chemical control, several attempts have been made to introduce newer pathogens, parasitoids and predators for the control of rhinoceros beetle, leaf eating caterpillar, red palm weevil, white grubs etc. Still there are many gaps in the understanding of certain basic aspects of these natural enemies. Hence, more attention has to be paid to the basic research so as to solve some of these problems:

1. The trials with baculovirus for the control of rhinoceros beetle have to be intensified on the mainland. Efforts have to be made to identify more virulent strains of baculovirus.

2. The feasibility of using sex pheromones for the control of *O. arenosella* have to be explored further.
3. More attention has to be paid to investigate the pesticide residues in coconut and its component crops.
4. Introduction of single dose anticoagulants for the control of rodents has eliminated the disadvantages of acute poisons. As very little is known about the development of resistance to these compounds, investigations have to be carried out on these aspects.

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