# Biological Control of Insect Pests of Coconut—A Review

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**Abstract**

*Oryctes rhinoceros* L , *Nephantis serinopa* M., *Rhynchophorus ferrugineus* F., and *Leucopholis coneophora* B. are the major pests of coconut in India. These insects are attacked by a number of parasites, predators, and microorganisms including nematodes. The most important biological control agents for the control of the black beetle are the indigenous predators *Sntalus parallelus* P.,*Agrypnus* (near *bifoveatus* C.), and the exotic reduviid bug *Platymeris laevicollis* G. The pathogens *Metarrhizium anisopliae* (M.) S., *Rhabdionvirus oryctes* and a nematode *Neoaplectana carpocapsae* D. (DD-136) also show promise. The establishment of the above agents depends very much on the ecological conditions and biotic factors.

No biological agent other than *Chelisoches moris* F. has been reported on red palm weevil in India. The scope of utilizing parasites, predators, and pathogens for the control of the cockchafer is also discussed. The leaf eating slug caterpillars *Contheyla rotunda* H., *Macroplectra nararia* M., and *Parasa lepida* C. are attacked by bacterial, fungal and insect parasites. *Stephanitis typicus* D., the suspected vector of the root (wilt) disease of coconut, has a predator in *Stethoconus paraefectus* D.

Mention is made also of parasites obtained on these pests from other countries. A few such examples of *Aspidiotus destructor* S. (found in India as well), *Artona catoscantha* H., *Levuana irridiscens* B-B, and *Promecotheca reichii* B. are given. Some of the main problems encountered in their utilization are also pointed out.

The phenomenon of an insect preying upon another and being dependent upon it for food was known ever since the early days of entomology. Almost all insects are subject to this natural restraint placed on their increase in population by parasites and predators. By taking measures calculated to favour the parasites and predators, we can help to sway the balance between the pest and their natural enemies in a direction favourable to man. The organisms responsible for insect control, while common in the field and occurring sporadically and causing natural controls have so far proved to be rather unreliable and generally not very effective when artificially introduced. The vertebrate predaotrs, the most important of

which are birds and rodents, destroy large number of noxious insects. But opinion is divided on their efficacy. The chief enemies of insect pests are insects themselves, because their number and rate of reproduction are not less than that of the pest itself and also their extreme specificity.

Two methods are used in biological control. One is the artificial increase of the natural enemies that already exist in the locality and the other is the introduction of a new species into the existing natural enemy complex. The latter is done mostly in cases where effective indigenous parasites or predators are not observed, as in the case of the rhinceros beetle of coconut where effective biological control agents had to be imported from abroad. The introduced parasite/predator should not only be able to survive in the new environment, but must also adapt itself advantageously to the stages in the life-history of the pest, i.e., the correct host stage must be available at the appropriate time.

Coconut palm is attacked by a number of insect pests at all stages of its growth. In India, more than 100 species of insect pests have been reported to damage the coconut palms. These pests get an abundant supply of food and multiply uninterruptedly all the year round with the result that the coconut plantations are often seriously damaged. The major pests are the rhinoceros beetle, *Oryctes rhinoceros* Linn., the leaf eating caterpillar, *Nephantis serinopa* Meyr., the red palm weevil, *Rhynchophorus ferrugineus* Fab., and the cockchafer beetle, *Leucopholis coneophora* Burn. Among the less serious enemies, the important ones are the slug caterpillars, *Contheyla rotunda* H., *Macroplectra nararia* Moore and *Parasa lepida* Cram., the coconut scale *Aspidiotus destructor* Sign., the lace wing bug *Stephantis typicus* Dist., and the nut crinkler *Paradasynus* sp. near *rostratus* Dist.

### The Rhinoceros Beetle (*Oryctes rhinoceros* L.) (Coleoptera : Scarabaeidae)

This is the most ubiquitous pest of the coconut palm. The adult beetle bores through into the unopened fronds and spathes. The infestation damages the leaves and quite often, attacked inflorescence is totally destroyed.

The pest is attacked in nature by certain pathogenic fungi, bacteria, viruses, mites, nematodes, insect parasites and predators and vertebrate predators like the squirrel, mongoose, rats, and pig (Kurian *et al.*, 1969; Kurian and Antony, 1973). The fungus *Metarrhizium anisopliae* (Metch.) Sorokin, which is the causative organism of green muscardine disease, has been under investigation in India for more than forty years now. The fungus infects all stages of the pest except eggs (Nirula, Radha, and Menon, 1955; Nirula, 1957). The practical utility of this fungus in controlling the pest was studied in our Station. The disease is more prevalent during the south-west monsoon period when high relative humidity and low temperature are prevalent. Under such conditions, it can take the

role of a virulent pathogen and cause epidemics particularly in the larval population (Elizabeth and Kurian, 1970, 1971). But considerable variations have been reported in the virulence and efficacy of this fungus as an agent for the biological control of the pest. This fungus was also recorded from Samoa and Fiji (Simmonds, 1941) and Palaus (Steinhaus, 1951). Cumber (1957) reported heavy mortality of the pest in Samoa as a result of natural or artificial infection by *Metarrhizium*. Venkataraman (1956) isolated the fungus *Beauveria bassiana* (Bals.) Vuill. from diseased grubs collected from Trivandrum. The second instar larvae were more susceptible. Steinhaus (1951) carried out experiments in the Palau Islands on *Oryctes* using *Bacillus popilliae* Dutky., *B. lentimorbus* D., and *B. thuringiensis* Berl. with no conclusive results. Cumber (1955, 1957) also tested *B. lentimorbus* var. *australis* Beard and *B. eulomarahae* B. Neither of these showed marked pathogenicity. Several types of Rickettsiae are known to be associated with insects. Surany (1960) reported that rickettsial diseases might play an important role in the biological control of *Oryctes*. In majority of cases the rickettsial infections have been found in association with other diseases. He also recorded Heidenreiche' disease, Mayas' disease and a combination of both. It was presumed that these diseases were caused possibly by viruses. A high percentage of mortality of late last instar larvae and prepupae was observed, due to the combined effect of the two diseases.

A virus disease that appears to have great potentialities of practical utility is caused by *Rhabdionvirus oryctes*. Investigations on *R. oryctes* are in progress in Fiji, W. Samoa, and India. The virus appears highly specific to *Oryctes* and has not proved infectious in laboratory tests to any of the Coleoptera introduced earlier into Samoa as biological control agents. In field tests, the virus disease has spread and there was a marked improvement of coconut plantations (Huger, 1969a). Beetles visiting breeding sites containing larvae freshly killed by virus infection can become infected (Zelazny, 1972; 1973a; 1976) In Fiji, a marked reduction in the incidence of the beetle on palms was obtained 12-18 months after introduction of the virus in the beetle population (Bedford, 1976).

Nematode infections in Oryctes seem to be rather common in Africa. Surany (1960) reported that the genus of nematode commonly met with on *Oryctes* larvae is *Rhabdites*. Attempts have been made to rear and infest these nematodes on *Oryctes* larvae in Fiji and Seychelles with limited success. All stages of the pest from egg to adult are prone to the attack of nematodes. Isolations of nematodes were made from the third instar grubs of Oryctes collected from Agathi Island in the Lakshadweep. Suspensions made from the material, when injected into healthy grubs, produced mortality (Kurian *et al.*, 1969). The nematode *cum* bacterium culture DD-136 (*Neoaplectana carpocapsae* and *Achromobacter nematophilus*) was effective against the larval stages of *Oryctes*.

Surany (1960) observed mortality among eggs and freshly hatched first instar grubs as a result of the feeding activities of certain mites. In India, Mesostigmata : Ascidae are found associated with the eggs and early instar grubs of *Oryctes* in the breeding materials. During latter part of summer with the onset of monsoon, they are found to congregate on the eggs and just hatched grubs of *Oryctes* and in August-September, nearly 60% of eggs are damaged by mites (Kurian *et al.*, 1969).

Several species of Scoliid wasps parasitise different species of *Oryctes* in Zanzibar, Malagasay, and Mauritius. They are *Scolia azurea* Chr., *S. oryctophaga* Cog., *S. ruficornis* F., *S. ruficeps* Smith, *S. erratica* Smith, and *S. patricialis* Burm. Biology of all these parasites is known (Gressitt, 1953). Consideration has been given to the control of *Oryctes* by employing some of the scoliid wasps. One instance of satisfactory biological control of an *Oryctes* sp. is that of *Oryctes tarandus* ol. in Mauritius by *S. oryctophaga* introduced from Madagascar. Simmonds (1949) observes that *S. ruficornis* may be playing an important role in keeping *Oryctes bosa* Fe. and *O. monoceros* ol. under control in Zanzibar and neighbouring parts of eastern Africa. Simmonds introduced *S. oryctophaya* Cog. into Western Samoa from Madagascar in 1939, but it failed to establish. However, with *S. ruficornis* it was more successful in 1945. In Western Samoa, *S. ruficornis* has established and spread at least 40 km in one direction. In India, attempts were made without success to establish *S. ruficornis* and *S. oryctophaga* (Kurian and Antony, 1973). More than 100 species of Scoliidae are present in India, including *S. procer* III., which is stated to be a parasite of *Oryctes*. But so far, no evidence is available to prove their efficacy. In general, the results of introductions of scoliid wasps have been disappointing. It is too early however to attempt a final assessment of them (Lever, 1969).

Gater (1924) mentions two cases of Sarcophagid flies reared from *Oryctes larvae*, but indicated that parasitism was uncertain. Venkataraman *et al.* (1954) have also reported a Sarcophagid fly infesting rhinoceros beetle. Since these Sarcophagids are generally seen on dead grubs, they are to be considered saprophytic forms.

Scorpions and the centipede *Scolopendra* sp. are also reported to attack *Oryctes* grubs. There are several indigenous predators of *Oryctes* belonging to families Carabidae, Elateridae, Cetonidae and Histeridae among Coleoptera and Reduviidae among Hemiptera (Kurian *et al.*, 1965). Some of the important predatory insects of *Oryctes* reported from various countries are *Mecodema spinifer* Brown, *Neochryopus sauvagei* Hope, *Catascopus whithilli* Hope, *Morion cucujoides* Walk. and *Pheropsophus* sp. (Carabidae), *Agrypnus fuscipes* Fabs. and *Alaus speciosus* Linn. (Elateridae), *Oxycetonia versicolor* Fab. (Cetonidae), *Pachylister chinensis* Quensel (Histeridae), and *Platymeris laevicollis* Distant. (Reduviidae). (Venkataraman, 1958.) In India, the promising species are *Santalus parallelus* Payk., *Agrypnus* sp. near *bifoveatus* Candeze, *Scarites* spp. and

*Harpalus* spp. *S. parallelus* is frequently found in Kerala and Tamil Nadu. Larvae and adults predate on eggs and grubs of *Oryctes* singly or collectively (Antony and Kurian, 1966; Kurian *et al.*, 1969). In *Agrypnus*, only grubs are predaceious. *Scarites* sp., during its larval and adult stages, feed on the eggs and early instar grubs of the pest. *Harpalus* spp., which are very common in the breeding material of *Oryctes*, are also predaceous on eggs and early instar grubs.

The reduviid bug *P. laevicollis* Distant., an efficient predator on the adults of *Oryctes monoceros* ol., was imported from Zanzibar through CIBC, Bangalore and tried against *Oryctes* at CPCRI. This is being mass bred and liberated at two centres.

Among the vertebrate predators, the giant toad *Bufo marinus*, the tree lizard, *Hemidactylus brooki* (Geckonidae), the monitor lizard, *Veranus monitor*, the large Geoko, *Gekko* sp. the Pacific Iguanid *Brachylophus fasciatus*, owls kingfishers, chickens, ducks, the Indian crow, the bulbul *Molpastes bengalensis*, the golden backed woodpecker *Brachypternus aurantius*, the Indian hoopy *Upupa epops indica*, the hawk-cuckoo *Hierococcyx varius*, the tree sprew *Tupaia* sp., palm squirrels, rats, pigs, lemurs, the mongoose *Herpestes* sq., some marsupials etc. have also been reported preying upon the various stages of *Oryctes* in different coconut growing tracts of the world.

**The Leaf-eating caterpillar (*Nephantis serinopa* M.) (Lepidoptera : Cryptophasidae)**

The leaf-eating caterpillar is another serious pest of the coconut palm in India, Sri Lanka, and Burma. It is distributed along the coastal and backwater areas. The larvae live on the under surface of leaves in galleries and feed on green tissues. Infestation results in reduced yield.

The larvae and pupae of *Nephantis* are often killed by fungal and bacterial parasites during the monsoons. The bacterium causing septicaemia is *Serratia marcescens* Bizio. (Antony and Kurian, 1961). According to Steinhaus (1949), the silk worms and a number of other insects are susceptible to *S. marcescens*.

Several brands of microbial "Insecticides" like *Bacillus thuringiensis* preparations have been tested for the control of the pest. These meet to a considerable degree of criteria like consistent virulence, persistence, speed of action, specificity, safety of use, and ease of production. To the present, there is no evidence to indicate that the toxin adversely affects any of the beneficial insects. *B. thuringiensis* HD strain along with surfactant fundal was successfully tried against the caterpillar.

The mite *Pyemotes venticosus* Newport is parasitic on caterpillars during rainy season. It is amenable to laboratory breeding and capable of quick dispersal (Mathen *et al.*, 1968).

The most important parasites of *Nephantis* belong to Hymenoptera and

Diptera. The indigenous parasites are the Vipionid, *Apanteles taragamae* Vier., the Braconid *Bracon brevicornis* Wesm., the Bethylid *Perisierola nephantidis* Mues., the Elasmid *Elasmus nephantidis* Roh., the Eulophid *Trichospilus pupivora* Ferr., the Chalcids *Brachymeria nephantidis* Gahan, *B. nosatoi Habu* and *Antrocephalus* (*Stomatoceras*) *sulcatiscutellum* (Girault), the Ichneumonids, *Xanthopimpla punctata* F. and *Goryphus nursei* Cameroon, and the Tachinid *Winthemia* sp. (Kurian, 1964). Joy (1975) added *Brachymeria lasus* Walker, *B. excarinata* Gahan, *B. himeattevae* J. N.N.J., *B. hearseyi* var. *Xanthosterus* W., *Antrocephalus* sp. near *denticollis* C., *A. phaeosoma* W., and *Anastatoidea brachartonae* G. to the list. A Tachinid, *Spoggosia bezzinna* Bar. and an Ichneumonid, *Erioborus trochanteratus*, introduced from Sri Lanka, are also under trial in India.

*Apanteles taragamae* V. is an internal parasite of early instar larvae. Only one parasite emerges from each host and duration of life cycle is 10-14 days. This is distributed on the coastal regions of Tamil Nadu, Andhra Pradesh, and Orissa. *Bracon brevicornis* W. is an external larval parasite with a life cycle of 8-11 days on the West Coast and 7-9 days on the East Coast (Nirula, 1956). *Perisierola nephantidis* M. is an effective ectoparasite on larvae with a life-cycle of 8-14 days on full grown caterpillars (Antony and Kurian, 1960). Kurian and Antony (1961) studied its systematic position, host preference, and distribution. In nature, this is hyperparasitised by certain Chalcids. *Elasmus nephantidis* R. is another ectoparasite on full grown *Nephantis larvae* (prepupae). The female lays 20-70 eggs on the host. Life cycle is completed in 9-12 days. The pupae of *Elasmus* are also subject to attacks of certain hyperparasites. *Trichospilus pupivora* is an important internal pupal parasite which is quite amenable to laboratory breeding (Ananthanarayanan, 1934). The life cycle is completed in about 14 days and 45-250 parasites emerge from each host pupa (Nirula, 1956). For *Brachymeria nephantidis* G., the total life cycle lasts 10-14 days during summer. It is slightly prolonged during rainy season. The combined parasitism by various species of *Brachymeria* is 22% with parasitism by *B. nosatoi* reaching 19.3% in southern Kerala and 2.2% in northern Kerala. The absence of *B. nosatoi* is noted in all areas with heavy incidence of the pest. The desirable qualities that make *Brachymeria* important are their long life span and adaptability to hot season and short developmental period as compared to the pest. However, mass multiplication of *Brachymeria* is difficult (Joy, 1975).

The Ichenumonid, *Xanthopimpla punctala* F. is another pupal parasite (Kurian, 1964) Only a single parasite emerges from each host pupa. It has a life cycle of about 20 days. *Goryphus nursei* C. is yet another Ichneumonid. Only one parasite matures from each hot pupa. It has a life cycle of 12-16 days (Nirula *et al.*, 1954). The Tachinid *Winthemia* sp. infests the grown up caterpillar at the time of pupation. It has a life-cycle of 16-25 days. Generally, one or two parasites emerge from each host.

A comprehensive programme for establishing *Spoggosia bezziana*, the exotic tachinid parasite of *Nephantis* is under way in India (Annual Report, 1974, 1976; Kurian, 1976). Jayaratnam (1941) reported that *Trichospilus pupivora* F. acts as a hyperparasite on *S. bezziana* in eastern Sri Lanka, the natural home of the fly. In spite of this adverse interaction, this Tachinid could be of benefit during summer months, when the *T. pupivora* population will be very low. *Erioborus trochanteratus* is under trial at the Tamil Nadu Agricultural University, Coimbatore (Jayaraj, Unpublished, 1976).

Attempts have been made from time to time to multiply some of the parasites of *Nephantis* and liberate them in pest infested tracts. In 1924-25 25, the then Madras Government set up parasite breeding laboratories at Mangalore, Kozhikode, and Ponnani, all on the west-coast of India. At a later stage, a boat laboratory was set up to reach the interior parts by canals. During 1947, parasite breeding laboratories were set up in East and West Godavari to fight the pest. The intensive colonization of the parasites for over two years saved the palms in the worst affected tracts (Rao *et al.*, 1948). During 1950, heavy infestation of *Nephantis* was observed along the coastal area of Quilon District in Kerala. Parasites liberated in large numbers controlled the incidence (Nirula, 1956). There was an epidemic outbreak of the pest in and around Badagara, Kozhikode district, Kerala in 1970. The outbreak was brought under control by employing parasites. The pest population before parasite liberation was 2-3 pests per infested leaflet with a natural parasitization of 3-5%. Two months later, the pest population was reduced by 99.97% with a field parasitization of 37-68% (Annual Report, 1972).

For mass rearing of the parasites, certain alternate host materials are used. *T. pupivora* is considered to be effective because of its short life cycle, prolific breeding habits, and ability to parasitize more than one pupae. Its host range is also very wide. It has little tendency to super-parasitism. It is not observed to be attacked by any hyperparasite, whereas Elasmids and Bethylids are heavily hyperparasitised in nature (Dharmaraju, 1952, 1962). The wasp has active habits and is capable of wide dispersal. But the greatest drawback is its susceptibility to heat. During the hot months of March-June on the West Coast, the parasite almost disappears (Kurian and Pillai, 1964). With a view to supplementing the popluation of beneficial parasites in nature, zonal parasite breeding stations are functioning in major coconut growing tracts where *Nephantis* is a problem. However some workers hold different views as to the utilization of indigenous parasites. They point out the limitations of the present efforts of the biological control of *Nephantis* and emphasize implementation of a pest management programme in line with modern concepts (Nagarkatti, 1973).

The main insect predators of *Nephantis* are the carabid beetle *Parena laticincta* Bates. and *Phalaecdronius nigrolinatus*, the Reduviid bug

*Sphedanolestes aurescens*, and species of ants (Kurian and Pillai, 1964). The Reduviid *P. laevicollis* D. is found to be feeding on *Nephantis* caterpillars, particularly in the nymphal stages. The Anthocorid bug *Triphleps* sp. and certain species of spiders also feed on various stages of the pest. The house lizard, garded lizard, and some birds are the common vertebrate predators.

**Red Palm Weevil (*Rhynchophorus ferrugineus* F.) (Coleoptera: Curculionidae)**

Red palm weevil is the most destructive pest of young coconut palms. The damage caused by the grubs is often fatal.

In India, the pupae are often killed by mites. In the western tropics *Rhynchophorus palmarus* has been reported to be attacked by *Tetrapolypus rhynchophori* Ewing, a mite belonging to a family allied to Pyemotidae (Nirula, 1956).

Friderichs (1919) described *Scolia erratica* Smith as parasitizing the larvae of red palm weevil. Burkill (1912) also has recorded *S. erratica* S. as a parasite of red weevil grubs in Singapore. According to Clausen 1940), Scoliids have host preference to grubs of Curculionids, particularly *Rhynchophorus*. In India, a calliphorid fly *Sarcophaga fuscicauda* Botcher has been observed (Lepesme, 1947). Leefmans (1920) in Indonesia, Hutson (1933) in Sri Lanka, and Copeland (1931) in the Philippines could not detect any parasite on the pest.

Abraham and Kurian (1973) observed an earwig *Chelisoches moris* F. feeding on the eggs and early instar grubs of the weevil in Kerala. They found it to be a very effective predator. Recently, a species of predatory thrips has been observed in the cocoon fibres of the pupae at Kayangulam. Some mammalian predators like the mongoose and squirrels have also been observed predating on the various stages of the pest, particularly the grubs. Man is also a predator. Red weevil grub is said to be considered as a delicacy in some parts of Burma.

**Cockchafer Beetle (*Leucopholisd coneophora* Burm.) (Coleoptera: Melolonthidae)**

*Leucopholis* and other related species of cockchafers attack roots of coconut and other intercrops adversely affecting the vigour of the palms and yields.

The milky disease, *Bacillus popilliae* Dutky, developed by Dutky (White and Dutky, 1940; Dutky, 1942) is still sold and effectively used to control cockchafer grubs in lawns and golf greens under various trade names including Japidemic or Doom. *B. popilliae* D., isolated from *Holotrichia serrata* and other cockchafers in India, could be used against the species that attack coconut.

Sekhar (1958) reported mortality among the prepupae of *L. coneophora*. Dissected specimen revealed the presence of nematodes. Nematodes have been reported to cause mortality among grubs of the Japanese beetle in the USA. No further work on the relationship of this nematode with the pest appears to have been done.

In Kerala, a scoliid wasp *Campsomeriella collaris* is common and parasitises cockchafer grubs. Its biology has also been studied. This can be introduced into areas where it does not exist (Annual Report, 1969). Some Tachinid and Tiphiid parasites have been recorded on European chafers. *Harpalus pennsylvanicus* (Carabidae) is a predator on grubs (Tashiro *et al.*, 1969).

Birds are an important predator of this pest. The common crow is the most useful bird in this respect. The striped squirrel also predates on grubs. During the peak period of emergence of adults, dogs, cats, and bats are also found feeding on beetles (Menon and Pandalai, 1960). Mammals listed as predators in the USA are skunk, mole, and short tailed shrew and birds, starling, robin, crow, black birds, sparrow, grackle, and pheasant (Tashiro *et al.*, 1969).

### *Contheyla rotunda* H. (Lepidoptera: Eucleidae)

This slug caterpillar, though generally considered a minor pest, is capable of assuming serious proportions. The defoliation caused by it can cause reductions in yield.

During the rainy season, quite often, severe outbreaks are brought under control by bacterial and fungus pathogens. The pest is heavily parasitized by some natural enemies. They are the Braconid, *Rogas* sp., Ichneunonid *Goryphus* sp., Chalcidid, *Antrocephalus* sp., and Chrysidid *Chrysis* sp. (Lever, 1969). The incidence of attack by this Chrysidid reaches as high as 20% (Nirula *et al.*, 1954).

### *Macroplectra nararia* Moore (Lepidoptera: Eucleidae)

On the east coast of India, this "spiny slug caterpillar" occasionally attacks the coconut palms and causes extensive damage to leaves.

During the rainy season, this pest is attacked in nature by fungi like *Aspergillus flavus* Link. and *A. niger* Tieg. (Kurian, 1963). In Sri Lanka, a suspension of a granulosis virus has been applied in an attempt to suppress the pest (Lever, 1969). Gadd *et al.* (1948) have recorded few species of Euplectrine Eulophids on it in Sri Lanka. Of these, the commonest and most effective is *Neoplectrus maculatus* Ferr. Kurian (1954) has recorded four new species of chalcid parasites from this pest from Tatipaka, Andhra Pradesh. They are *Eurytoma tatipakensis* Kurian, *Euplectromorpha natadae* Kurian, *Secodes nararíae* Kurian, and *Euderus natadae* Kurian. Their potentialities for control of the pest are yet to be studied.

*Parasa lepida* **Cram. (Lepidoptera: Eucleidae)**

The larvae defoliate the palms and severe infestations occur sporadically.

The larvae are heavily parasitized. The parasites involved are *Clinocentrus* sp., *Stomatoceras ayyari* G., and *Pediobius* sp. (Chalcididae), *Eupelmus catoxanthae* Ferriere (Eupelmidae), *Stilbum splendidum* Fab. and *Chrysis shanghaiensis* Smith (Chrysididae), *Eurytoma monema* Ruschka (Eurytomidae), *Goryphus oxymorus* Tosquinet (Ichneumonidae), *Apanteles parasae* Rohwer (Vipionidae), *Chaetexorista javana* Brawer and *Bergenstamm* (Tachinidae) and *Sarcophaga antilope* Botcher (Calliphoridae). Studies on their utilization are yet to be made. An interesting predatory caterpillar *Phycita dentilinella* Hps. (Phycitidae) has been recorded inside the cocoon of the pest destroying the pupae (Lepesme, 1947; Menon and Pandalai, 1960; and Lever, 1969).

*Stephanitis typicus* **Dist. (Heteroptera : Tingidae)**

This lace wing bug is important because of its dual role as a pest of coconut and as a possible carrier of the pathogenic principle involved in the root (wilt) disease of coconut in Kerala.

A Mirid bug *Stethocomes praefectus* (Dist.) is predaceous on the nymphs and adults of *Stephanitis*. Its life history has been worked out (Mathen and Kurian, 1972).

*Paradasynus* **sp. near** *rostratus* **(Dist.) (Heteroptera: Coreidae)**

It sucks sap from the female flowers and immature nuts and causes their shedding. In an identical species recorded as a pest of cashew, eggs are heavily parasitized in the field by *Hadrophanurus* sp. (Scelionidae) and *Anastatus* sp. (Eupelmidae) (Nair and Remamony, 1964).

**Successful Examples of Biological Control Work done Outside India**

Outstanding successes refer to biological control projects against a major pest of a major crop over a fairly extensive area, so that other control measures become rarely necessary.

*Aspidiotus destructor* Sign. (Hemiptera : Coccidae). The coconut scale is a well known pest of several crops in the Tropics. Attempts have been made outside India for controlling this pest by the introduction of Coccinellid beetles. Successful control was obtained in Fiji by the introduction of *Cryptognatha nodiceps* Mohl. from Trinidad (Taylor, 1935). In Mauritius, several parasites and predators were introduced from Java (Indonesia) and Sri Lanka to control it. Of these, the most successful have been the Coccinellid *Chilocorus politus* Mulsant and *C. nigritus* Fabricius. *C. nodiceps* gave successful control within two years in Principle Island in the Gulf of Guinea, where it was released in 1955

(Simmonds, 1960). In Efate Island, in the new Hebrides, another Coccinellid *Lindorus lophanthae* Blaisdell was used with immediate success (Cochereau, 1965).

*Levuena iridisuns* B-Bak. (Lepidoptera : Zygaenidae). Caterpillars feed on the foliage of the coconut palm and cause heavy damage in Fiji. In 1925, there was a very severe incidence. Tothill *et al.* (1930) reported on a regular compaign made for the control of the pest. The Tachinid *Bessa remota* Ald. was introduced from Malaysia and effective control was obtained (Lever, 1969). This is regarded as one of the classic examples of successful biological control.

*Promecotheca cocruleipennis* Blanchard (Coleoptera : Hispidae). The larvae feed by mining the tissues of the basal half of the leaflets, whereas the adults feed by making narrow grooves on the lower surface of the distal half of the leaflets. Severe infestations result in the reduction of upto 75% of the functional leaf surface.

Taylor (1937) studied the natural enemies already present in Fiji prior to 1933. Some indigenous parasites seem to have kept the pest under control until the unintentional introduction into Fiji of the mite *P. ventricosus*. The mite reaches the pest to "one stage condition" at a time (Evans, 1952). In this condition, the indigenous parasites are ineffective. Taylor (1937) introduced the Entedontid *Pediobius parvulus* Ferr. from Java. It soon established in Fiji and the pest was brought under control.

*Promecotheca cumingi* Baly. This is one of the most important pests in the Philippines and neighbouring countries. The damage is greater because of the involvement of a fungus. In 1970, the pest was reported from Sri Lanka. Many egg and larval parasites were introduced and it is reported that *Dimmockia javanica* is responsible for the control (Bannerjee, S.N., Personal communication, 1976).

## Problems of Biological Control

The ability of a parasite to control the pest depends mostly on the higher rate of reproductive capacity of the parasite as compared to that of the pest (Taylor, 1937). So also the stages of the pest at which they are attacked by the parasite must be present all through the year lest the parasite should miss them and be consequently displaced. The ideal parasite is one which attacks most of the stages of the pest and which can live on alternate hosts to ensure its uniform distribution. Competitions among parasites and hyperparasitism are also problems which hamper the efficacy of parasites.

A fully effective parasite is always easily and quickly established, ideally even from a single pair. A parasite which takes long to get established may not be very effective later on For this reason, the colonization of an imported parasite or predator may well be discontinued after three or four years of unsuccessful attempts.

Extensive use of modern synthetic insecticides also causes serious problems. Some of them are more toxic to beneficial insects than to the pests. The phytophagous mites appearing in enormous proportions subsequent to insecticidal application is an example. This should be avoided.

For a realistic understanding of the problem, work has to be based on actual observation and experiments on the changes of population in nature. Work should be directed along lines which appear to be most suitable both biologically and ecologically. On a careful scrutiny it may be seen that the number of success attained will be proportional to the amount of research and importation of suitable exotic material.

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## Discussion

Sane : In your talk you gave the impression that in the sterile male technique programme, almost 75% of the males were only partially sterile. This conclusion was based on the observation that about 75% of the eggs hatched in the area where the sterile males were released. This conclusion is not correct. Another possibility could be that the number of sterile males released was too few in numbers. Possibly, the number of females present in the area was far more than predicted from the samples. The methods for sterilizing males have been worked out. It is most likely that all the males released were induced sterile, but the number was inadequate as compared to the population of insects (weevils) present.

Kurian : I said only that 75%of eggs collected from the area hatched. The possibility suggested by you about the inadequacy of the number of sterile males released in the area may be the main reason for this. It was our collaborators from BARC, Trombay, who decided on the numbers and supplied them to us for liberation.

Ananthakrishnan : I would add to the list of predators mentioned by the speaker, the predatory thrips, *Aleurodothrips fasciapennis.* In view of the fact that this species has contributed to the control of the scale *Aspidiotus destructor,* its role as a useful predator in this country may also be looked into.

Kurian : This will be done.

M.R.G.K. Nair : I suggest that attempts may be made to develop biological control methods for the nut bug *Paradesymes rostriatus* to minimise the use of insecticides for controlling the pest.

Kurian : This will be done.