

Biological Control of Pests in Plantation Crops

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1. INTRODUCTION

Biological suppression of the key pests of agricultural plantation crops, such as coconut, arecanut, oil palm, cashew and cacao, and spices like cardamom and black pepper has been attempted in several laboratories in India. However, applied biological pest suppression is now widely practised in coconut only. In the remaining crops, only preliminary studies on the entomophagous insects and microbial pathogens associated with different pests and their role as potential biocontrol agents of pests have been carried out.

2. BIOLOGICAL CONTROL OF COCONUT PESTS

Biological control has been attempted against two major pests of the coconut palm, viz., the rhinoceros beetle, *Oryctes rhinoceros* L. and the leaf eating caterpillar *Opisina arenosella* Wlk. Investigations on the entomophagous insects and microbial pathogens associated with red palm weevil, *Rhynchophorus ferrugineus*, the phytophagous mite *Oligonychus iseilemae* and the lace bug, *Stephanitis typica* have also been taken up with a view to developing applied biological suppression of these pests. The slug caterpillars *Contheyla rotunda* H., *Latoia lepida* C. and *Macroplectra nararia* M. are affected in nature by a few bacterial and fungal pathogens and insect parasitoids. However, utilisation of these agents for field scale biosuppression of these pests has not been done.

2.1 *Oryctes rhinoceros* (L.)

Investigations on the natural enemy fauna associated with the breeding sites of rhinoceros beetle, such as cattle dung, compost, decaying coconut logs and stumps in different coconut growing tracts of the country including Lakshadweep and Andamans revealed the presence of a few potential indigenous predators, such as *Santalus parallelus*, *Scarites* sp., *Harpalus* sp., *Pheropsophus occipitalis*, *P. sobrinus* and *Agrypnus* sp. nr. *bifoveatus*. The adults and/or immature stages of these predators feed on the eggs and/or early instar grubs of *O. rhinoceros*. Evaluation of the predatory potential of these indigenous natural enemies revealed that the extent of pest suppression exerted by them is quite meagre in relation to the rate of multiplication of the pest.

Efforts were, therefore, made for the introduction and colonisation of the exotic reduvid predator, *Platyperis laevicollis* Distant, a native of Zanzibar. This bug feeds on the adult beetles and, as such, is capable of reducing the pest population numerically. It is quite amenable to laboratory rearing. It can be mass multiplied using preys such as ground roaches, coconut caterpillar, red palm weevil and released in *Oryctes*-infested fields. Field evaluation of the performance of the predator revealed that there was substantial reduction in pest incidence on the palms which received predator releases regularly (Antony *et al.*, 1979). Presence of a higher proportion of dead beetles on the crowns of infested palms indicated the efficiency of the released predator. However, population build-up of the predator was not observed in the release sites.

Release of *P. laevicollis* was also incorporated as one of the components in the integrated management of rhinoceros beetle and the same was tested in an adaptive research programme in farmers' fields at Sooranadu, Quilon district, Kerala by the Department of Agriculture, Kerala State.

The green muscardine fungus, *Metarhizium anisopliae* produces epizootics in *Oryctes* population, particularly when the climatic conditions such as low temperature and high relative humidity prevail. A method has been developed to mass culture the fungus on cassava chips and rice bran, supplemented with waste fish meal extract or urea as a source of nitrogen, in specially designed large aluminium vessels (Mohan and Pillai, 1982). Mass cultured fungus can be applied to the breeding sites of the pest at the rate of approximately 42.3×10^{10} spores per m³.

Feasibility of utilising coconut water, which is being wasted from copra making industry for mass culturing the entomopathogen *M. anisopliae* was tested and compared with that in potato dextrose broth. Higher mycelial weights and spore counts were recorded in coconut water media than those obtained in PDB. Further, the fungus produced more spores in filter sterile coconut water as well as in aseptically drawn coconut water from mature nuts than that in autoclaved coconut water.

A baculovirus disease was found to occur in the natural population of *O. rhinoceros* samples from different locations in Kerala to an extent of 54.2 per cent (Mohan *et al.*, 1983). The symptoms confirmed to those of the baculovirus disease of the pest recorded by Huger (1966) in Malaysia and subsequently introduced into several of the South Pacific Islands to control the pest population (Marschall, 1970; Zalazny, 1973; Bedford, 1976, 1977). The success story of this viral pathogen in many of the introduced areas led the researchers to document it as one of the most successful microbial control agents ever employed against an insect pest (Caltagirone, 1981).

Diagnosis of the virus disease in beetles and grubs based on the presence of cells with hypertrophied nuclei in the midgut lumen was standardised and this method was highly reliable for detection of infection in the initial stages. Immuno-osmophoresis was developed as a rapid serological method of diagnosis of baculovirus disease in beetles and grubs (Mohan and Pillai, 1983).

The sequence of pathological symptoms, which developed in virus-infected *Oryctes* grubs, has been elucidated. The median lethal doses of virus inoculum and lethal infection time for different instars of *Oryctes* grubs have been worked out (Mohan *et al.*, 1985). A method to diagnose baculovirus disease in field-collected beetles by examination of excreta has been standardised (Mohan *et al.*, 1986). This eliminates the need for dissecting the beetles for examination of gut aspirate, a routinely followed method of diagnosis. Effect of baculovirus infection on the longevity and fecundity of *O. rhinoceros* has been studied. Longevity of laboratory infected beetles (dosage : 10 LD₅₀ doses with reference to *Oryctes* grubs) was reduced by 40 per cent. The infected female beetles were rendered sterile (100% reduction in fecundity).

Survey for baculovirus disease of *O. rhinoceros* in Minocoy, Lakshadweep revealed total absence of virus disease in the natural population of beetles and their immature stages. This observation opened up the feasibility of introducing baculovirus to the Island for the biological suppression of the pest, which posed a serious problem to coconut cultivation. Field-collected beetles (130) were allowed to wade through the virus inoculum contained in a basin for 30 minutes. The inoculum contained 2 g of infected larval tissue in 1 l of phosphate buffer (0.05 M, pH8) which amounted to 31.6 LD₅₀ doses and 3 per cent sucrose. After the swim treatment, the beetles were confined together in a box containing rotted coconut wood powder mixed with the virus inoculum for 24 hours. The treated beetles were removed the following day and confined in a box with fresh coconut petiole pieces provided as feed for a week, since the infected beetles begin excreting baculovirus only after a week post-infection (Mohan *et al.*, 1986). The beetles were liberated after dusk in the field in April 1983.

Detailed pre-release observations of 10 per cent sample palms revealed 56.6 per cent leaf damage, 31.1 per cent spathe damage and 39.2 per cent fresh infestation on spindles. Post-release observations recorded eight months after the introduction of baculovirus revealed the establishment of the pathogen in the natural population of beetles and their breeding sites and drastic decline in the crop damage (Mohan *et al.*, 1989). The latest round of observation recorded during December 1988 revealed 7.0 per cent leaf damage, negligible spathe damage and spindle damage (only 4-5 cases per 2000 palms) and drastic decline in site occupancy of the pest in breeding places (Fig. 1). Nearly 62 per cent of the natural population of the pest showed baculovirus disease incidence.

The biggest singular advantage *Oryctes* baculovirus offers over other microbial control agents is in being an auto-transmissible pathogen capable of passing from generation to generation. The method of propagation involves the release of diseased beetles and no spraying of the virus is required on the crop to be protected, a standard practice adopted for propagation of other viruses. Spraying is labour intensive and adds to the cost considerably, particularly in plantation crops, and hence the input in the use of baculovirus for suppression of the pest is quite meagre.

Based on the success achieved in the biosuppression of the rhinoceros beetle in Minicoy, Lakshadweep, introduction of the virus was done at Androth, Lakshadweep

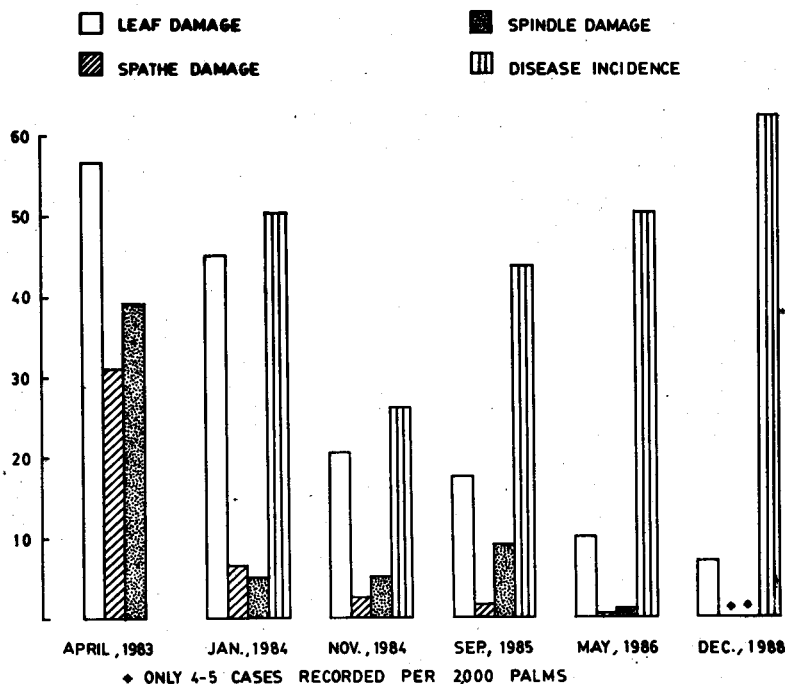


Fig. 1 : Impact of baculovirus release at Minicoy, Lakshadweep.

also in 1988. Introduction of the virus to other islands of Lakshadweep also is being taken up by the Directorate of Agriculture, Lakshadweep.

Impact of re-release of baculovirus in an already infected contiguous area has also yielded encouraging results. By augmenting the natural population of virus-infected beetles, substantial decline in the incidence of beetle and the resultant reduction in crop damage were observed.

2.2 *Opisina arenosella* Wlk.

The coconut caterpillar, *O. arenosella* Wlk. is subject to attack by a variety of indigenous natural enemies—parasitoids and predators. The major parasitoids include the larval parasitoids *Apanteles taragamae* Wilkinson, *Bracon hebetor* Say, *Goniozus (Parasierola) nephantidis* (Mues.), the prepupal parasitoid *Elasmus nephantidis* Rohw. and the pupal parasitoids *Brachymeria nosatoi* Habu, *B. nephantidis* Gahan, *B. hime atteviae* Joseph *et al.*, *B. lasus* Walker, *Antrocephalus hakonensis* (Ashmead), *Trichospilus pupivorus* Ferr., *Xanthopimpla punctata* F., *X. nana nana* Schulz., *Xanthopimpla* sp., etc. Evaluation of the role of these parasitoids in pest suppression revealed that the performance of *G. nephantidis*, *E. nephantidis* and *B. nosatoi* was better. These parasitoids are effective during summer season as well, which is the peak period of pest abundance.

A. taragamae is a solitary endo-parasitoid parasitising the early instar caterpillars of the pest. This parasitoid is prevalent in most of the *Opisina*-infested tracts. Augmentation of its population in the early stage of the pest build-up itself is quite advantageous. However, a technique for mass culturing the parasitoid in the laboratory was lacking. Ghosh and Abdurahiman (1988) observed that the female of *A. taragamae* lays maximum number of eggs on the second day of its emergence. For oviposition, the parasitoid prefers the host larvae confined within their own galleries. The second instar caterpillars are preferred best and the frass left by them acts as a strong attractant to the female parasitoids. This parasitoid completes its development from egg to adult in 15 days during summer months, whereas in cold weather it takes about 24 days to complete the life cycle.

Parasitism by *B. bebetor* Say in different intensities was recorded from several tracts (Sathiamma *et al.*, 1986). *B. hebetor* parasitised second to fifth instar caterpillars of *O. arenosella*. However, the second and third instar host caterpillars produced only male progeny and the fourth and fifth instar caterpillars are the ideal stages for mass multiplication of the parasitoid as they produced progeny of both the sexes.

Goniozus (Parasierola) nephantidis (Mues.) is one of the dominant species of ectoparasitoids of *O. arenosella* which is being widely used in the biological control programme against the coconut leaf eating caterpillar. The fifth and early sixth instar caterpillars of *O. arenosella* are the ideal host stages for successful parasitism, development of progeny and production of higher proportion of female parasitoids (Pillai and Nair, 1985; Pillai and Bhat, 1986).

The prepupal parasitoid *Elasmus nephantidis* Roh. has good searching ability, and capacity to locate and parasitise the prepupal caterpillars of *O. arenosella* remaining inside the silken cocoons within the larval galleries. The parasitoid is capable of withstanding high temperature of the summer season and is highly host-specific and stage-specific. For maintenance of its culture in the laboratory, regular supply of adequate number of prepupal caterpillars of *O. arenosella* has to be ensured (Pillai and Nair, 1982c).

Evaluation of intensity of natural parasitism of *O. arenosella* has revealed that the pupal parasitoids contribute to more than 50 per cent of the natural pest suppression. According to Joy and Joseph (1977; 1978), the most important pupal parasitoids of *O. arenosella* are the chalcidids, *Brachymeria nosatoi* and *B. nephantidis*. Although the eulophid parasitoid *Trichospilus pupivorus* was being mass multiplied and released in sizeable numbers for several years now, its extent of natural parasitism was very meagre in southern Kerala (less than 1%), while it was 14 per cent in northern Kerala. Pillai and Nair (1981) also found that more than half of the pest population was suppressed by the solitary pupal parasitoids. Field parasitism by the gregarious pupal parasitoid *T. pupivorus* was only 1.6 per cent. Laboratory and field studies carried out by Pillai and Nair (1982b) showed that a part of the population of *T. pupivorus* aestivated in the pupal stage during summer months between March and May. The poor searching and dispersal ability of the parasitoid, its low tolerance to non-optimal temperatures, inability

to discriminate between parasitised and unparasitised hosts leading to superparasitism and inability to compete with other species of pupal parasitoids were the major factors responsible for its inefficiency and low intensity of parasitism in the field.

Brachymeria spp. accounted for about 90 per cent of the total pupal parasitism of *O. arenosella*. *B. nosatoi* is the most useful parasitoid in the biosuppression of the pest and *B. nephantidis* the second best. *B. nosatoi* has many outstanding qualities of an ideal biocontrol agent. Unlike the other species of *Brachymeria*, it does not act as a facultative hyperparasitoid. Higher summer temperatures and prolonged drought have no adverse effect on the rate of multiplication of the parasitoid. These qualities are seldom found in other species of parasitoids. *B. nosatoi* (Fig. 2) exerts strong regulatory pressure and its effect on the pest population is not highly variable. Although it was thought to be not amenable to laboratory multiplication, it can be reared in sufficient numbers in laboratory using the method described by Pillai and Nair (1982a). Unfortunately, its prevalence is limited to southern Kerala. It will be interesting to study the factors responsible for low percentage of its parasitism in north Kerala. *O. arenosella* is such a pest which can cause frequent outbreaks and extensive damage to coconut plantations, and in southern Kerala this situation is averted to a great extent, by the activity of *B. nosatoi* which is capable of suppressing nearly one third of the pupal population.

B. nephantidis is widely distributed in India, but it suppresses only nearly one sixth of the pupal population of *O. arenosella* in South Kerala. Outbreaks of *O. arenosella* occur in areas where *B. nephantidis* is present without *B. nosatoi* (Joy and Joseph, 1977). *B. lasus*, *B. hime atteviae* and *Antrocephalus hakonensis* are not significant species of parasitoids of *O. arenosella* in Kerala. However, parasitism by *B. hime atteviae* was observed to be significant in Salem area of Tamil Nadu. Yadav and Dhamalia (1986) observed four species of chalcidids, viz., *B. nephantidis*, *B. lasus*, *B. excarinata* and *B. hime atteviae* effecting parasitism ranging from 6.3 to 42.8 per cent in Gujarat.

Six species of ichneumonid parasitoids were recorded on *O. arenosella*. They are big-sized solitary wasps which have many characteristics in common. Most of them develop internally and have long life span. Three species of *Xanthopimpla* were identified as pupal parasitoids of *O. arenosella* in the field. Field observations revealed that parasitism by *X. nana nana* was very high in certain localized tracts in West Coast (Pillai and Nair, 1983). This parasitoid completed the egg to adult stages in 17-19 days and its longevity ranged from 30 to 50 days under laboratory conditions. *X. punctata* (Fig. 3) completed its life stages in 10 to 12 days in the laboratory. It breeds in *O. arenosella* during the period from July to December and its peak period of activity is during September and October. Without uniformly dispersing in all the *Opisina*-infested coconut gardens, the adult parasitoids congregated in some localised tracts close to the sea, back waters or other waterways or in irrigated coconut plantations and effected a high degree of parasitism, suppressing even the dominant species of pupal parasitoids like *B. nosatoi* (Pillai and Nair, 1989). Yadav and Dhamalia (1986) recorded 5.2 to 20 per cent parasitism by *X. punctata* in Mahuva, Gujarat.

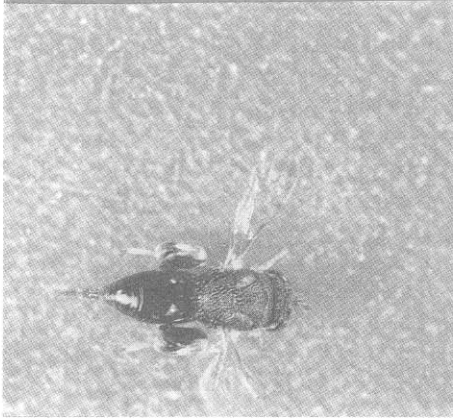


Fig. 2 : *Brachymeria nosatoi* Habu, a chalcidid pupal parasitoid of *Opisina arenosella*.

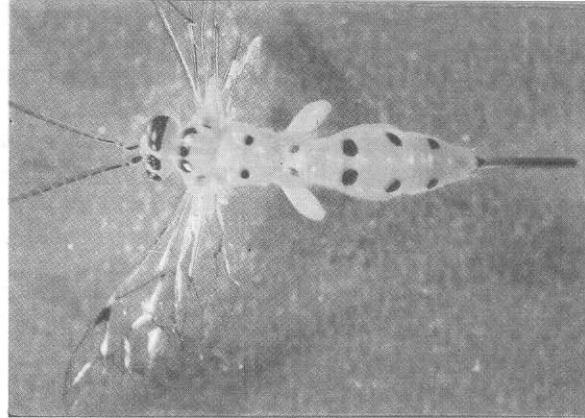


Fig. 3 : *Xanthopimpla punctata* F., an ichneumonid pupal parasitoid of *Opisina arenosella*.

Xanthopimpla sp. (undet.) was observed as a dominant species of pupal parasitoid of *O. arenosella* in some tracts in West Coast. This is smaller than *X. punctata* and *X. nana nana*. In host pupae such as *O. arenosella*, *Sylepta derogata* and *Margaronia indica*, the life cycle of parasitoid was completed in 12-16 days, whereas in *Anadevidia peponis*, it took 13 to 20 days. Sex ratio was female-biased and longevity of adults was 1 to 4 months (Pillai and Nair, 1987). Kapadia (1983) recorded *Echthromorpha agrestoria* Swederus as a pupal parasitoid of *O. arenosella* in Mahuva, Gujarat. However, the intensity of its parasitism was only less than 1 per cent.

Brachycoryphus nursei (Cameron) is another ichneumonid parasitoid which effects only negligible percentage parasitism in *O. arenosella* in the field. It is mostly ectophagous, but occasionally develops internally also in host pupae. It is unique in attacking and parasiting host larvae, prepupae and pupae. This parasitoid produces more female progeny than males in the field. However, the reverse occurs in the laboratory. Egg to adult stages of *B. nursei* are completed in 13-21 days. Majority of the adults emerged in 14 to 17 days. In view of its low searching ability, *B. nursei* does not make any marked impact on the population of *O. arenosella* in the field. Inundative releases of laboratory reared females also are not quite practicable in view of the fact that majority of the adults emerging in the laboratory culture would be males (Pillai and Nair, 1987).

Eriborus trochanteratus (Morley) found in India and Sri Lanka are two biotypes and only the latter parasitises *O. arenosella* caterpillars. In Sri Lanka, this parasitoid has been used for suppressing the pest population successfully. The Sri Lankan biotype of *E. trochanteratus* has been mass multiplied and colonised in *Opisina*-infested coconut gardens in Kerala. Even though the released parasitoid established in nature, hyperparasitism by *B. nephantidis* a primary pupal parasitoid of the pest itself, suppressed the population of the parasitoid to some extent (Pillai and Nair, 1986).

Meteroidea hutsoni (Nixon) (Braconidae) is a larval-pupal parasitoid, distribution of which is limited to certain tracts of Calicut District, Kerala. The percentage parasitism from individual collections varied from 0.26 to 35.64. Owing to the occurrence of high percentage parasitism in areas of its distribution, it is clear that once this parasitoid is spread to other areas, it can potentially supercede all other parasitoids. Field studies also highlight the need for more research on its biology and mass rearing techniques, so that it could be released into areas where its absence is felt (Mohamed *et al.*, 1982).

In order to assess the intensity of natural pupal parasitism of the pest and the relative contribution of individual species of parasitoids, a method of examination of the nature, size and position of emergence holes made in the pupal cases by different species of pupal parasitoids of the pest was developed (Pillai and Nair, 1982d).

Attempts on field colonisation of the laboratory reared exotic tachinid parasitoid *Spoggosia bezziana* Bar. from Sri Lanka, made in West Coast of Kerala did not meet with success. Though there were indications of establishment of the released parasitoid initially its percentage parasitism was quite low and the build up of population was hampered by hyperparasitism by *T. pupivorus* (eulophidae) and *B. nephantidis* (Chalcididae), which are primary parasitoids of the pest itself.

The exotic tachinid *Bessa remota* (Ald.) introduced from Malaysia was also mass multiplied and released in *Opisina*-infested coconut gardens in the West Coast of Kerala and at Salem in the interior tract of Tamil Nadu. The parasitoid failed to establish in any of the release sites.

Hyperparasitoids were recorded from several species of parasitoids. *Eurytoma albotibialis* Ashmead, recorded as a hyperparasitoid as well as a primary parasitoid of *O. arenosella* is predominantly a hyperparasitoid parasitising the larval/pupal stage of several species of parasitoids of the pest. Its importance as a secondary parasitoid in minimising the role of *Brachymeria* spp. in the natural suppression of the pest has been overlooked. The peak activity of *E. albotibialis* synchronises with that of *Brachymeria* spp. and *O. arenosella* during April-May. Consequently, the build-up of population of *Brachymeria* spp. was checked considerably at a time when the pest was likely to multiply rapidly taking advantage of the high temperature of summer season and low levels of population or total absence of certain other species of parasitoids. It was observed that during April and May, *E. albotibialis* suppressed 13.11 and 43.48 per cent, respectively of *Brachymeria* spp. population in the field (Pillai and Nair, 1985).

Species of *Pediobius*, *B. nephantidis* and an unidentified chalcidid were the other hyperparasitoids recorded on primary parasitoids of *O. arenosella*. Kapadia (1983) recorded *Pediobius bruchicida* (Ronadami) and *P. impraeus* (Walker) as hyperparasitoids on *G. nephantidis* and *B. brevicornis*. Both the species of secondary parasitoids were active during November-February. *P. bruchicida* parasitised 42-62 per cent *B. brevicornis* and 18-28 per cent *G. nephantidis* in the field.

George *et al.* (1984) developed a sampling technique for estimation of the field population of *O. arenosella* and its natural enemies. Formulae were evolved for estimating the total pest population on the palm by counting the number of pest present in the middle 41-60 per cent leaflets of the first 20 per cent leaves from the bottom. Field testing of this technique proved that the regression estimates based on the sampling procedure were appropriate for assessing the total population of *O. arenosella*.

Doses were worked out for the release of three species of important parasitoids of the pest. The optimum dose for release of *G. nephantidis* was 20 per cent, *E. nephantidis* 49.4 per cent and *B. nosatoi* 31.9 per cent of the target stages of the pest, when the parasitoids were released individually. However, when the three species of parasitoids were released in combination, the dose worked out to 40 per cent of the target stages of the pest. The parasitoids, when released at the above doses, could bring about 82.9, 81.0, 29.0 and 35.5 per cent, respectively, reduction in pest population (Sathiamma *et al.*, 1987).

Besides parasitoids, a number of predators also take a heavy toll of different stages of the pest in the field. The carabid predators *Parena nigrolineata* (Chaudoir) and *Calleida splendidula* (F.) are the important predators of the pest. Bioecology of these predators has been studied and their feeding potential evaluated (Pillai and Bhat, 1987; Pillai and Nair, 1990). The chrysopid *Ankylopteryx octopunctata candida* larvae feed on the eggs and early instar caterpillars of the *O. arenosella* (Sathiamma *et al.*, 1985). Yadava and Dhamalia (1986) observed the larvae of *Chrysopa* sp. preying on the eggs of *O. arenosella* in Gujarat. These predators were seen in abundance even during hot months when other parasitoids were least effective.

Four species of coccinellid beetles were recorded as predators. The grubs and adult beetles are voracious feeders. *Idgia dimelaena* grubs were recorded as pupal predators and *Creagriss labrosa* as larval predators of the pest (Pillai and Nair, 1986). *Cardiastethus* sp. (Anthocoridae) is a predator on the eggs and early instar caterpillars of *O. arenosella* recorded from different parts of Kerala (Mohammad *et al.*, 1982).

Spiders were recorded as one of the dominant groups of predators of *O. arenosella*. Twenty six species of spiders belonging to 12 genera and six families have been collected from *Opisina*-infested palms (Sathiamma *et al.*, 1985). *Cheiracanthium* sp., *Rhene* spp. and *Sparassus* sp. are the important predators on the immature and adult stages of the pest. The rate of predation varied from 0.70 to 1.54 caterpillars per day. This high rate of feeding combined with their long life span and their occurrence in the field throughout the year indicates their potential as efficient biocontrol agents of the pest. As such, it is essential to conserve their population in the field (Sathiamma *et al.*, 1987). *R. indicus* attained maturity in six moults in 77.5 to 83 days and lived for 51.25 to 139.83 days. *Cheiracanthium* sp. reached maturity in 12 moults within a period of 207 to 214.51 days and lived for an average period of 74.5 to 85.7 days (Sathiamma *et al.*, 1986).

Philip *et al.* (1982) reported a nuclear polyhedrosis in the black headed caterpillar. In the initial stages of infection, the caterpillars become sluggish, exhibited loss of appetite and the cuticle took an oily appearance. The colour of the larvae turned pink especially on the lateral and ventral aspects of the body. The larvae died in 3 to 8 days after infection usually within the larval galleries. The cadavers turned black within a short time.

2.3 *Rhynchophorus ferrugineus* F.

Abraham and Kurian (1973) observed an earwig *Chelisoches moris* F. feeding on the eggs and early instar grubs of red weevil in Kerala. This is a polyphagous predator.

Field-collected grubs of *R. ferrugineus*, which showed abnormality, developed certain symptoms, such as accumulation of fluid in the haemocoel, yellowing of fat, sluggishness, refusal to feed, dilation of the gut and diarrhoea. Light microscopic studies on gut, haemolymph, fat and nerve tissues showed hypertrophied nuclei, perinuclear halo formation, vacuolation of cytoplasm and disorganisation of chromatin. The gut tissues showed clear symptoms. Light microscopic studies of nerve tissues of grubs and gut, fat and nerve tissues of prepupae collected from the field also showed nuclear enlargement and abnormality of chromatin. Field-collected grubs maintained in the laboratory developed abnormality in behaviour and showed symptoms, such as blackening, softness of the body, fluid accumulation and diarrhoea. Bacterial septicaemia was suspected and examination of haemolymph under the microscope gave positive indications. Pathogenicity studies with the bacterial isolates are being carried out.

2.4 Foliage Mites

Dominant predators of the phytophagous mites *Oligonychus iseilemae* and *Tetranychus ludeni* include phytoseiid, cunaxid and stigmaeid mites. *Amblyseius* spp. occurred almost throughout the year except in January and July. Predatory potential and seasonal abundance of the predators and predator-prey ratio were studied. Techniques for culturing the predacious mites also have been standardised.

2.5 *Stephanitis typica* (Distant)

The major predators of the lace bug *S. typica* include *Stethoconus praefectus* (Dist.) (Miridae) (Mathen and Kurian, 1972), *Ankylopteryx octopunctata* (Chrysopidae) and spiders. Laboratory rearing of mirid predator was done on *S. typica* colonies established on potted coconut seedlings as well as on detached leaflets in bell jar cages. Studies on mass culturing the predator using *S. typica* colonies raised on alternate host plants are also in progress. A fungus isolated from field-collected dead lace bugs was also being tested for its pathogenicity.

3. BIOLOGICAL CONTROL OF ARECANUT PESTS

Three species of foliage mites and one species of perianth mite infest the areca palms and cause severe damage. Major species of foliage mites are the Cholam mite

Oligonychus indicus Hirst, the palm mite *Raoiella indica* Hirst and *Tetranychus fijiensis* Hirst (Daniel, 1977). Puttarudriah and Channabasavanna (1956) reported many coleopteran predators, chiefly coccinellids, of the palm mites. They include *Aspectes indicus* Arrew (Dermestidae), *Cylocephalus semipictus* Champ Var (Nitidulidae), *Stethorus parcepunctatus* Kapur, *S. tetranychii* Kapur, *Jauravia soror* (Wse.) and *Spilocarea bissetata* Muls. (Coccinellidae). These predators, particularly the species of *Stethorus*, keep mite population under check during summer months. Kapur (1961) recorded *Stethorus keralicus* as a predator of *R. indica* from Kerala. This lady bird beetle is one of the major predators of mite and it takes 12-14 days to complete its life cycle (Daniel, 1976).

Daniel (1979) recorded a number of indigenous predators and among them two species of *Stethorus* and a staphylinid beetle are the major predators of *O. indicus*. The coccinellid *S. keralicus* and phytoseiid *Amblyseius channabasavanni* Gupta & Daniel are the key predators of palm mite *R. indica*. *A. channabasavanni* female completes its developmental period in 98 h, whereas the male takes only 93.3 hours. A total of 15-38 prey eggs are consumed by the females and 14-19 eggs by males (Daniel, 1981). The natural enemy complex of areca palm mites include members of Thripidae, Chrysopidae, Anthocoridae and Cecidomyiidae as well.

Attempts on colonisation of the exotic phytoseiid mite *Phytoseiulus persimilis* A-H. for the biosuppression of arecanut mites were unsuccessful as this predator could not acclimatise to the local conditions at Vittal, Dakshina Kannada District, Karnataka (Daniel and Seshadri, 1976).

4. BIOLOGICAL CONTROL OF OIL PALM PESTS

In oil palm plantations, the rhinoceros beetle and red palm weevil are major pests. Impact of re-release of baculovirus in an already infected contiguous area was evaluated in the oil palm plantations at Palode, Kerala. Three years after re-release of baculovirus, *Oryctes* infestation on palms came down from 8.2 (June 1986) to 1.8 per cent (June 1989). Studies on the site occupancy of the pest also revealed higher incidence of baculovirus disease in the breeding places of pest in release sites. The diaspids, *Chrysomphalus aonidium* and *Pinnaspis aspidistrae* infest oil palm bunches. The potential pests include psychid, *Manatha albipes*, the lamacodid *Darna* sp., etc. Studies on the natural enemies of these pests have been taken up with a view to exploring the possibility of utilising them for biosuppression of the pests.

5. BIOLOGICAL CONTROL OF CASHEW PESTS

The information available on the natural enemies of cashew pests is quite meagre. Basu Choudhuri (1973) reported the green muscardine fungus *M. anisopliae* Metch. (Sorokin) from the grubs of cashew stem and root borer, *Plocaederus ferrugineus* (Coleoptera : Cerambycidae) and gave details of the symptomatology, epidemiology and pathogenicity. However, tests carried out with *M. anisopliae* isolated from *Oryctes* grubs revealed that this pathogen was not very effective, particularly when the inoculum was

applied by mixing with the feeding material of the grubs (cashew bark). Similar trials with the entomogenous bacteria, *Bacillus thuringiensis* Berl. and *Bacillus popilliae* Dutky also did not give encouraging results. The nematode-cum-bacterium culture, DD 136, at an inoculum dose of 100 nemas per gram body weight of host grubs, effected 50-60 per cent mortality of grubs within 24 days, when the inoculum was mixed with the feed (Pillai *et al.*, 1976).

Based on the report of utilisation of baculovirus of *Oryctes* for biosuppression of the stem and root borer of cashew in Sri Lanka, detailed studies on the pathogenicity of the viral pathogen have been carried out. However, no positive results could be achieved.

The natural enemies of the tea mosquito bug *Helopeltis antonii* include spiders, *Hyllus* sp. *Oxyopes schireta*, *Phidippus patch* and *Matidia* sp. which feed on the early instar nymphs (Devasahayam and Nair, 1986). Ambike and Abraham (1979) recorded the ant *Crematogaster wroughtoni* Forel feeding on the first and second instar nymphs of the pest in the field. A single ant was capable of devouring about 10 nymphs per day.

The reduvid bug *Endochus inornatus* (Stal.) was observed to feed on the adults and nymphs of tea mosquito. An adult bug was reported to feed on 10-15 adults and 10-20 nymphs of the pest per day. *Sycanus collaris* (Fab.), *Sphedanolestes signatus* Dist., *S. minisculus* Bergar, *Irantha armipes* Stal., *E. inornatus* Stal., *E. cingaensis* Stal., *Occamus typicus*, Dist. and *Alcmena* sp. have been recorded as predators of *H. antonii* from Goa. The reduvids are capable of feeding 1-5 adults/nymphs of tea mosquito per day. However, they are not specific predators of *H. antonii*. Preliminary attempts to colonies *S. collaris* under field conditions were unsuccessful (Sundararaju, 1984). A hymenopteran parasite *Erythmelus helopeltidis* Gahan (Mymaridae) has been recorded to parasitise the eggs of *H. antonii* in the field (Devasahayam and Nair, 1986). However, its intensity of parasitism was quite meagre.

In the absence of any efficient indigenous natural enemy exerting a high degree of pest suppression, the feasibility of introducing some exotic biocontrol agent for trials against tea mosquito has to be explored. Action had already been initiated to introduce the braconid parasitoid *Euphorus helopeltidis* Ferr. from Java.

Studies on the natural enemy complex of pests such as leaf and blossom webber, *Lamida monocusalis*, leaf miner *Conopomorpha syngamma* and apple and nut borer *Thylocoptila panrosema* are in progress in different centres of cashew research.

6. BIOLOGICAL CONTROL OF COCOA PESTS

Though a variety of insects numbering more than 50 species have been recorded as pests of cacao only a few are persistent and serious ones. The mealy bug *Planococcus lilacinus*, the black aphid *Toxoptera aurantii* and hairy caterpillar *Lymantria ampla* are the major pests affecting cacao.

Mealy bug colonies have been found to be affected by the coccinellid predator *Pullus* spp. and the caterpillars of the lycaenid *Spalgis epius*. Populations of these predators are more during summer season, which is incidentally the peak period of pest abundance. In the field, nearly 28-32 per cent of mealy bug colonies are invaded by these natural enemies. Detailed investigations on the parasitoids affecting mealy bugs are yet to be undertaken.

Colonization of the exotic predator *Cryptolaemus montrouzieri* and evaluation of its efficacy in biosuppression of the pest revealed that the predator could not establish and build up its population in the release sites even after two years. The presence of attendant ants, particularly the red ant *Oecophylla smaragdina* might have contributed to the failure of establishment of the predator.

Investigations on the natural enemies of pests, such as aphids, defoliating caterpillars and case worms are still in progress for developing applied biocontrol programmes against them.

7. BIOLOGICAL CONTROL OF BLACK PEPPER PESTS

Nearly 20 species of insect pests are known to be associated with black pepper in India. The most important among them are the flea beetle *Longitarsus nigripennis* Mots., the top shoot borer *Cydia hemidoxa*, the marginal gall forming thrips *Liothrips karnyi*, and scales and mealy bugs, such as *Lepidosaphes piperis*, *Lecanium marsupiale*, *Pinnaspis aspidistrae* and *Ferrissia virgata*.

No natural enemy, which could be used for the biological suppression of the flea beetle or its immature stages, has been hitherto recorded. Three species of hymenopteran parasitoids, namely, *Apanteles* sp. (Braconidae), *Euderus* sp. (Eulophidae) and *Goniozus* sp. (Bethyidae) have been recorded as natural enemies of the top shoot borer. The former two species parasitise the late instar caterpillars and the latter early stage caterpillars of the pest.

The major predators of the gall thrips include *Montandoniella moragueri*, *Androthrips flavipes*, *Rhodesiella* sp. and *Lestodiplosis* sp. Biology, feeding potential and seasonal abundance of these predators have been studied for utilising them for biosuppression of the pest.

8. BIOLOGICAL CONTROL OF CARDAMOM PESTS

The aphid, *Pentalonia nigronervosa* f. *caladii* Van der Goot is the vector of 'Katte' disease of cardamom. During rainy season, heavy mortality of aphid population due to infection of the entomogenous fungus *Verticillium intertextum* was recorded. Deshpande *et al.* (1972) reported heavy colonisation of this fungus on *P. nigronervosa* at Mudigere, Karnataka.

In the field, colonies of aphid are fed up on by *Pullus* sp. and *Coccinella transversalis* F. (Coccinellidae), *Ischiodon scutellaris* Fab., *Paragus tibialis* and *Episyrphus viridaureus* (Wied.) (Syrphidae) and an unidentified hemerobid (Rajan, 1981).

Earlier reports on the parasite complex of *Conogethes (Dichocrocis) punctiferalis* Guen., the shoot and capsule borer of cardamom, include *Eriborus (Dioctes) trochanteratus* (Morley), *Xanthopimpla australis*, *Brachymeria* spp., *Theronis inareolata*, *Bracon brevicornis*, *Apanteles* sp. *Palexorista parachrysops* (Bezzi), etc. Varadarasan (1987) recorded *Friona* sp. (Gelinae : Ichneumonidae) as a larval parasitoid of the pest. The extent of natural parasitism by the dominant species of parasitoids in different cardamom growing tracts of the country is to be assessed and suitable steps taken for the mass multiplication and release of the potential parasitoids.

Varadarasan (1986) recorded *Apanteles* sp. (*Vitripennis* species group = *Glyptapanteles*) (Braconidae : Hymenoptera) from the hairy caterpillar *Eupterote cardamomi* Renga. The geometrid cardamom looper *Eumelia rosalia* Cram. was also found to be parasitised by the same species. *Sturmia sericariae* (Tachinidae) and *Aphanistes eupterotes* (Ichneumonidae) were recorded parasitising *E. cardamomi* (Nair, 1975). Detailed investigations on the extent of pest suppression exerted by natural enemies in different cardamom growing tracts have to be undertaken.

REFERENCES

- Abraham, V.A. and Kurian, Chandy. 1973. *Chelisoche moris* F. (Forficulidae : Dermaptera), a predator on eggs and early instar grubs of the red palm weevil, *Rhynchophorus ferrugineus* F. (Curculionidae : Coleoptera). Proc. National Symp. Plantation Crops, 1972. *J. Plantn. Crops* (Suppl.), 1 : 147-52.
- Ambika, B. and Abraham, C.C. 1979. Bio-ecology of *Helopeltis antonii* Sign. (Miidae : Hemiptera) infesting cashew trees. *Entomon.*, 4 (4) : 335-42.
- Antony, J., Daniel, Mariamma, Kurian, Chandy and Pillai, G.B. 1979. Attempts on introduction and colonisation of the exotic reduviid predator, *Platymeris laevicollis* Distant for biological suppression of the Coconut rhinoceros beetle *Oryctes rhinoceros* L. Proc. PLACROSYM II, 1979. pp. 445-54.
- Basu Choudhuri, J.C. 1973. Mycosis of stem and root borers of cashewnut, *Plocaederus ferrugineus* L. (Coleoptera : Cerambycidae). *J. Plantn. Crops* (Suppl.), 1 : 164-67.
- Bedford, G.O. 1976. Use of a virus against the coconut palm rhinoceros beetle in Fiji. *PANS*, 22 : 27-34.
- Bedford, G.O. 1977. Virus against coconut rhinoceros beetle in Fiji. *South Pac. Bull.*, 27 : 27-34.
- Caltagirone, L.S. 1981. Land mark examples in classical biological control. *Ann. Rev. Entomol.*, 26 : 213-32.
- Daniel, M. 1976. Biology and predatory habits of the lady bird beetle, *Stethorus keralicus* Kapur (Coleoptera : Coccinellidae) predator on the palm mite. *J. Plantn. Crops*, 4 : 7-9.
- Daniel, M. 1977. The spider mite *Tetranychus fijiensis* Hirst on the betel nut palm. *Acarologia*, 19 (2) : 220-29.
- Daniel, M. 1979. Survey of the indigenous predator of arecanut phytophagous mites. Proc. PLACROSYM-II 1979. pp. 227-36.
- Daniel, M. 1981. Bionomics of the predacious mite *Amblyseius channabasavanni* (Acarii : Phytoseiidae) predacious on the palm mite. In *Contribution to Acarology in India* (Channbasavanna, G.P., Ed.). pp. 161-73.

- Daniel, M. and Seshadri, S.N. 1976. Observations on *Phytoseiulus persimilis* A-H. (Acarina : Phytoseiidae) for control of the phytophagous mites of areca palm. *Acarology Newsletter*, 3 : 5-6.
- Deshpande, R.S., Viswanath, S. and Rahiman, M.U. 1972. A new entomogenous fungus on banana aphid *Pentalonia nigronervosa* Coq. vector of 'Katte' disease of cardamom (*Elettaria cardamomum* Maton.). *Mysore J. Agric. Sci.*, 6 : 54.
- Devasahayam, S. and Radhakrishnan, Nair, C.P. 1986. The tea mosquito bug *Helopeltis antonii* Signoret on cashew in India. *J. Plantn. Crops*, 14 : 1-10.
- George, M.V., Sathiamma, B. and Vijaykumar, K. 1984. A technique to estimate field populations of coconut leaf eating caterpillar. *Proc. PLACROSYM-V* 1982. pp. 638-43.
- Ghosh, S.M. and Abdurahiman, U.C. 1988. Biology of reproduction of *apanteles taragamae* Wilkinson (Hym : Braconidae) a larval parasitoid of *Opisina arenosella* (Walker) the caterpillar pest of coconut. *Entomon.*, 13 (2) : 147-55.
- Huger, A.M. 1986. A virus disease of the Indian rhinoceros beetle *Oryctes rhinoceros* (Linnaeus), caused by a new type of insect virus *Rhabdionvirus oryctes* gen.n. *J. Invertebr. Pathol.*, 8 : 38-51.
- Joy, P.J. and Joseph, K.J. 1977. Role of pupal parasites in the biological control of the black headed caterpillar. *Indian Cocon. J.*, 8 (1) : 1-2 & 3.
- Joy, P.J. and Joseph, K.J. 1978. Relative incidence of the pupal parasites infesting *Nephantis serinopa* Meyrick, the black headed caterpillar pest of coconut in Kerala. *Bull. Ent.*, 19 : 185-87.
- Kapadia, M.N. 1983. Record of a new pupal parasite of *Nephantis serinopa* Meyr. in Gujarat. *Indian Cocon. J.*, 13 (11) : 5.
- Kapadia, M.N. 1983. Record of *Pediobius* spp. as hyperparasites of *Perisierola nephantidis* M. and *Bracon brevicornis* W. in Gujarat. *Indian Cocon. J.*, 14 (5) : 7.
- Kapur, A.P. 1961. A new species of *Stethorus* Weise. (Coleoptera : Coccinellidae) feeding on arecanut palm mites in Kerala, Southern India. *Entomophaga.*, 6 (1) : 35-38.
- Kurian, C., Pillai, G.B., Antony, J., Abraham, V.A. and Natarajan P. 1983. Biological control of insect pests of coconut—A review. In *Coconut Research and Development* (Nayar, N.M., Ed.). *Proc. Internatl. Symp. Cocon. Res. & Dev.*, Kasaragod, 1976. pp. 361-75.
- Marschall, K.J. 1970. Introduction of a new virus disease in the coconut rhinoceros beetle in Western Samoa. *Nature*, 225 : 288-89.
- Mathen, K. and Kurian, Chandy. 1972. Description, life history and habits of *Stethoconus praefectus* (Distant) (Heteroptera : Miridae) predacious on *Stephanitis typicus* Distant (Heteroptera : Tingidae), a pest of coconut palm. *Indian J. Agric. Sci.*, 42 (3) : 255-62.
- Mohammad, U.V.K., Abdurahiman, U.C. and Remadevi, O.K. 1982. *Coconut Caterpillar and its Natural Enemies*. Zoological Monograph No. 2. Calicut University. pp. 162.
- Mohan, K.S. and Pillai, G.B. 1982. A method for laboratory scale mass multiplication of *Metarhizium anisopliae*. *Folia Microbiologica*, 27 (4) : 281-83.
- Mohan, K.S. and Pillai, G.B. 1983. Immuno-osmophoresis techniques for quick diagnosis of *Oryctes* virus (Baculoviridae) of rhinoceros beetle, *Oryctes rhinoceros* L. *Indian J. Exptl. Biol.*, 21 : 470-71.
- Mohan, K.S., Jayapal, S.P. and Pillai, G.B. 1983. baculovirus disease of *Oryctes rhinoceros* population in Kerala. *J. Plantn. Crops*, 11 (2) : 154-61.
- Mohan, K.S. Jayapal, S.P. and Pillai, G.B. 1985. Response of *Oryctes rhinoceros* larvae to infection by *Oryctes* baculovirus. *J. Plantn. Crops*, 13 (2) : 116-24.
- Mohan, K.S., Jayapal, S.P. and Pillai, G.B. 1986. Diagnosis of baculovirus infection in coconut rhinoceros beetles by examination of excreta. *J. Plant. Dis. and Protn.*, 93 (4) : 370-83.
- Mohan, K.S., Jayapal, S.P. and Pillai, G.B. 1989. Biological suppression of coconut rhinoceros beetle (*Oryctes rhinoceros* L.) in Minicoy, Lakshadweep by *Oryctes* baculovirus—Impact on pest population and damage. *Proc. PLACROSYM-VII* 1986. *J. Plantn. Crops*, 16 (Suppl.) : 163-70.

- Nair, M.R.G.K. 1975. *Insects and Mites of Crops in India*. ICAR, New Delhi. pp. 404.
- Philip, B.M., Mathai, S. and Jacob, A. 1982. A nuclear polyhedrosis of the black headed caterpillar, *Nephantis serinopa* Meyrick (Lepidoptera : Cryptophasidae). *Curr. Sci.*, **51** : 611.
- Pillai, G.B. 1978. Pests of pepper. In *Proc. Natl. Sem. on Pepper 1977*, Calicut. pp. 15-17.
- Pillai, G.B. 1985. Biological control of pests of plantation Crops. *Proc. Natl. Sem. Entomoph. Ins.*, Calicut. 1985. pp. 232-37.
- Pillai, G.B. and Bhat, S.K. 1986. Parasitism, development of progeny and sex-ratio of *Parasierola nephantidis* Mues. (Bethyridae) on different instars of *Opisina arenosella* Wlk. (*Nephantis serinopa* Meyr.). *Indian Cocon. J.*, **14** (11) : 3-5.
- Pillai, G.B. and Bhat, S.K. 1987. Role of pupal parasitoids in the natural suppression of the coconut caterpillar *Nephantis serinopa* Meyrick. *J. Plantn. Crops*, **9** : 84-87.
- Pillai, G.B. and Nair, K.R. 1982a. A technique for laboratory multiplication of *Brachymeria nosatoi* Habu and other species of chalcidid parasitoids of *Nephantis serinopa* Meyrick. *Entomon.*, **7** : 213-17.
- Pillai, G.B. and Nair, K.R. 1982b. A note on *Trichospilus pupivora* Ferr., a parasite of *Nephantis serinopa* Meyr. *Entomon.*, **7** : 225-26.
- Pillai, G.B. and Nair, K.R. 1982c. Mating behaviour and biology of *Elasmus nephantidis* Rohw. (Hymenoptera : Elasmidae), a parasitoid of *Nephantis serinopa* Meyrick. *J. Plantn. Crops*, **10** : 33-38.
- Pillai, G.B. and Nair, K.R. 1982. A method to estimate the intensity of natural pupal parasitism of *Opisina arenosella* Wlk. (*Nephantis serinopa* Meyrick). *J. Plantn. Crops*, **10** : 86-91.
- Pillai, G.B. and Nair, K.R. 1983. *Xanthopimpla nana nana* Schulz. (Hymenoptera-Ichneumonidae), a new pupal parasitoid of *Opisina arenosella* Wlk. on coconut. *J. Plantn. Crops*, **11** : 65-69.
- Pillai, G.B. and Nair, K.R. 1985. Observations on *Eurytoma albotibialis* Ashm. (Hymenoptera : Eurytomidae) a hyperparasitoid of the coconut leaf eating caterpillar, *Opisina arenosella* Wlk. *Proc. Natl. Sem. Entomoph. Ins.*, Calicut 1985. pp. 102-105.
- Pillai, G.B. and Nair, K.R. 1985. Mating and host paralysing behaviours of *Goniozus (Parasierola) nephantidis* (Mues.) (Hymenoptera : Bethyridae) on *Opisina arenosella* on coconut. *Proc. Natl. Sem. Entomoph. Ins.*, Calicut 1985. pp. 123-25.
- Pillai, G.B. and Nair, K.R. 1986. Observations of *Eriborus trochanteratus* (Morley) (Hymenoptera : Ichneumonidae), a larval parasitoid of *Opisina arenosella* Wlk. *J. Plantn. Crops*, **14** (1) : 11-14.
- Pillai, G.B. and Nair, K.R. 1986. Additions to the natural enemy complex of the coconut caterpillar, *Opisina arenosella* Wlk. *J. Plant. Crops*, **14** (2) : 134-40.
- Pillai, G.B. and Nair, K.R. 1987. Observations on *Xanthopimpla* sp. (Hymenoptera : Ichneumonidae) a pupal parasite of *Opisina arenosella* Wlk. on coconut in Kerala. *J. Biol. Control*, **1** (1) : 7-10.
- Pillai, G.B. and Nair, K.R. 1987. *Brachycoryphus nurseri* (Cameron) (Hymenoptera : Ichneumonidae), a parasitoid of *Opisina arenosella* Wlk. on coconut in Kerala, India. *J. Plantn. Crops*, **15** (1) : 9-14.
- Pillai, G.B. and Nair, K.R. 1989. Observations on *Xanthopimpla punctata* F. (Hymenoptera : Ichneumonidae), a pupal parasitoid of *Opisina arenosella* Wlk. *Proc. PLACROSYM-VII. J. Plant. Crops*, **16** (Suppl.) : 173-77.
- Pillai, G.B. and Nair, K.R. 1990. On the biology of *Calleida splendidula* (F.) (Coleoptera : Carabidae) a predator of the coconut leaf eating caterpillar *Opisina arenosella* Wlk. *Indian Cocon. J.*, **20** (12) : 14-17.
- Pillai, G.B., Dubey, O.P. and Singh, V. 1976. Pests of cashew and their control in India—A review of current status. *J. Plantn. Crops*, **4** : 37-50.
- Puttarudriah, M. and Channabasavanna, G.P. 1956. Some new insect and mite pests of areca palm in Mysore-II. *Arecanut J.*, **7** (1) : 9-10.
- Rajan, P. 1981. Biology of *Pentalonia nigronervosa* F. caladii Van der Goot, vector of 'Katte' disease of cardamom. *J. Plantn. Crops*, **9** (1) : 34-41.

- Sathiamma, B., Jayapal, S.P. and Pillai, G.B. 1985. Record of *Ankylopteryx octopunctata candida* (Fabricius) (Neuroptera : Chrysopidae) as egg and larval predator on *Opisina arenosella* Wlk. the leaf eating caterpillar of the coconut palm. *Curr. Sci.*, **54** : 1128.
- Sathiamma, B., Jayapal, S.P. and Pillai, G.B. 1985. Spider fauna of coconut palms and their role in biological suppression of the coconut leaf eating caterpillar, *Opisina arenosella* Wlk. *Proc. Natl. Sem. Entomoph. Ins.*, Calicut. 1985. pp. 53-55.
- Sathiamma, B., Pillai, G.B. and Jayapal, S.P. 1986. Bioecology of *bracon hebetor* Say (Hymenoptera : Braconidae), an indigenous larval parasitoid of the leaf eating caterpillar, *Opisina arenosella* Wlk. (Lepidoptera : Cryptophasidae). *J. Plantn. Crops*, **14** (2) : 140-45.
- Sathiamma, B., Jayapal, S.P. and Pillai, G.B. 1987. Observations on spiders (Order : Araneae) predacious on the coconut leaf eating caterpillar *Opisina arenosella* Wlk. (*Nephantis serinopa* Meyrick) in Kerala : Biology of *Rhene indicus* Tikader (Salticidae) and *Cheiracanthium* sp. (Clubionidae). *Entomon.*, **12** (2) : 121-26.
- Sathiamma, B., Jayapal, S.P. and Pillai, G.B. 1987. Observations on spider (Order : Araneae) predacious on the coconut leaf eating caterpillar *Opisina arenosella* Wlk. (*Nephantis serinopa* Meyrick) in Kerala : Occurrence and seasonal abundance. *Entomon.*, **12** (2) : 175-78.
- Sathiamma, B., Pillai, G.B., Jose Abraham, Keshava Bhat, S., Jayapal, S.P. and Nair, K.R. 1987. Norms for release of larval, prepupal and pupal parasitoids of *Opisina arenosella* Wlk., the leaf eating caterpillar of coconut palm. *J. Plantn. Crops*, **15** (2) : 118-22.
- Sundararaju, P. 1984. Studies on cashew pests and their natural enemies in Goa. *J. Plantn. Crops*, **12** (1) : 45-47.
- Varadarasan, S. 1986. New record of a braconid parasite on cardamom hairy caterpillar *Eupterote cardamomi* Reng. and cardamom looper *Eumelia rosalia* Cram. *Entomon.*, **11** : 260-61.
- Varadarasan, S. 1987. New record of larval parasite, *Frona* sp. (Gelinae : Ichneumonidae) on cardmom shoot borer *Dichocrocis punctiferalis* Guen. (Pyralidae : Lepidoptera). *Curr. Sci.*, **56** (7) : 312.
- Yadav, D.N. and Dhamalia, H.R. 1986. Natural enemies of *Opisina arenosella* Wlk. the black headed caterpillar of coconut in Gujarat. *Indian Cocon. J.*, **16** (12) : 9-10.
- Zelazny, B. 1973. Studies on *Rhabdionvirus oryctes* III. incidence in the *Oryctes rhinoceros* population of Western Samoa. *J. Invertebr. Pathol.*, **22** : 353-63.