Chapter 10

Organic Plant Protection Technologies

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1. Introduction

To meet the nutritive demand for ever growing population, agriculture technologies were boosted to intensive approach characterized by innovations designed to increase yield. Techniques included planting multiple crops per year, high yielding varieties, increased use of fertilizers, plant growth regulators, chemical pesticides and farm mechanization. Even though modem agriculture has definitely helped us to satisfy the demand to certain extent, heavy dependence on these inputs causes several disruptions to the ecological balance and it has been damaging the wealth of this planet largely. When farming is viewed in this direction, the concept of organic farming gains practical significance as it is a production system respecting the sustainability of nature. Organic agriculture aims to maintain the farming to be a live production system with sustainable nature. It supports us to live in harmony with nature. In our attempt to save the crops, pest control strategy in modem agriculture has a heavy dependency on pesticides. Pests and diseases along with weeds are known to cause an estimated crop loss of about 35 per cent of the potential food production worldwide (Sharma, 2002). In spite of our heavy dependence on insecticides for providing protection to the varieties of crops grown, their deleterious effect on the beneficial natural enemies and pollinators and the residues they leave in the palm and the environment limit the use of these poisons. An Integrated Pest Management (IPM) schedule comprising combination of different technologies – mechanical, sanitation, cultural, prophylactic, chemical and biological methods are the existing strategy globally recognized to manage pests of coconut and has proved to be quite feasible.

2. Pest Management Concept in Organic Farming

The basis of pest and disease management in organic farming systems is the reliance on the inherent equilibrium in nature. Use of bio control agents plays a crucial role in this aspect. The natural enemies are insect predators (insects that consume part or all of pest insects), parasites (insects that use other insects to produce their offspring, thereby killing the pest insect in the process), and pathogens (diseases that kill or decrease the growth rate of insect pests). Predatory insects on organic farms include lady beetles, lacewings, and spiders. Parasitic insects include wasps and flies that lay their eggs in/on pest insects, such as larvae or caterpillars. The emphasis on organic plantations should ideally be on the use of varieties resistant to pest and diseases.

Other methods that can be generally employed for the management of pests and diseases are: clean cultivation, improving soil health to resist soil pathogens and promote plant growth; crop rotation; encouraging natural biological agents for control of diseases, insects and weeds; using physical barriers for protection from insects, birds and animals; modifying habitat to encourage pollinators and natural enemies of pests; and using semio-chemicals such as pheromone attractants and trap pests. Biopesticides including micro organisms, parasites, predators and natural plant based pesticides from neem, tobacco and garlic are effective in managing pests of coconut and other intercrops. There are several examples of use of effective bio control agents for suppression of pest and diseases of coconut and other component crops.Pest management requires an overall rescheduling of various components of IPM in organic farming to maintain ecosystem sustainability. In organic agriculture, pest control strategies that compromise with the nature are suitably blended and employed to realize desirable results. Pest control strategies of a preventive rather than reactive nature are advisable in organic farming. The non-chemical and bio-rational methods of pest management that constitute the major components of IPM approach are ideal, eco-friendly and feasible in a sustainable crop production system like organic farming.

2.1. Biological Pest Suppression

Among the various components of IPM, biological pest suppression that utilizes the natural enemies of pests *viz.*, Entomophaga and Entomopathogens is the most effective tool for organic plant protection. One of the major steps involved in the biological control of pests is conservation of natural enemies which helps in regulating a particular species of pest in the ecosystem conserving the biodiversity of the ecosystem. A comparatively low level of pest incidence that occurs due to natural disturbances in the ecosystem can be corrected more easily and feasibly by intervention of an appropriate biocontrol agent. When a situation arises where natural enemies present in the ecosystem exert a low level of pest suppression, the need for augmentation through release of recommended natural enemies becomes more imperative. Biocontrol method is an advanced approach in the management of some of the major pests of coconut, oil palm, coffee and black pepper besides many annual crops. When an exotic pest is to be tackled, the need for deliberate introduction and colonization of its natural enemy to suppress the introduced pest becomes essential.

In our attempts to enrich the biodiversity by organic farming practices, several methods of conservation of natural enemies like providing nesting places, perching sites, water pan, nectar and pollen rich plants can be practiced (Sharma, 2002). Attempts to restore natural control mechanisms especially the natural enemies by selectivity of biodiversity within the ecosystem become more relevant in organic farming. Manipulation of the ecosystem inducing added activity of the natural enemies will be beneficial to reduce the pest population resulting in increased yield. Biocontrol agents have a range of attractive properties that include host specificity, lack of toxic residue, no phytotoxic effects, eco-friendly, human safety and the potential for pest management to be self sustaining. Biocontrol agents can also be produced locally which is in terms of choosing and matching natural enemies to small scale needs. Successful use requires fundamental knowledge of the ecology of both the pest and natural enemy. Biological control agents broadly involve entomophaga and entomopathogens.

2.1.1. Entomophaga

Entomophaga comprising mainly parasitoids and predators constitutes one of the major components in the natural control of crop pests.

2.1.1.1. Parasitoids

In the IPM of coconut pests, parasitoids are extensively utilized for the management of the black headed caterpillar *O. arenosella*, which is one of the dominant caterpillar pests of coconut palm. The larvae of *O. arenosella* feed on the parenchymatous tissues on the under surface of leaflets and construct galleries of silken webs reinforced with excreta and scrapes of leaf bits. Diagnostic symptoms of infestation are the presence of galleries on the lower surface of the leaflets with different stages of the pest and the upper epidermis intact. Pest infestation usually starts from the outer and middle whorl of leaves. On an average 40 per cent yield

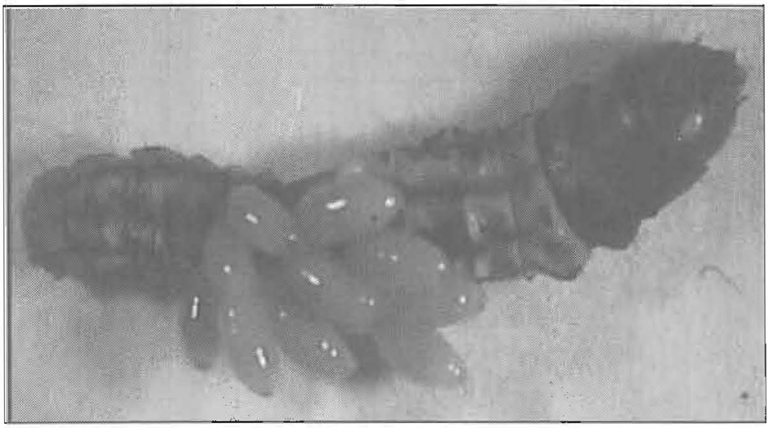

Figure 10.1: *Goniozus nephantidis*, Larval Parasitoid of Coconut Black Headed Caterpillar.

decline is noticed in severely affected palms (Chandrika *et al.*, 2010) and palms of all ages are susceptible to its infestation. Concealed habitat of the pest well covered by the larval galleries makes pesticide spraying practically very difficult. Hence, biological suppression with the release of parasitoids provides the best solution for the management of *O. arenosella* (Chandrika and Sujatha, 2006).

Among the various parasitoids of *O. arenosella* (Table 10.1) hymenopterans predominate. Based on the stage of the pest on which the parasitoids develop they are treated as egg, larval, pre-pupal, larval-pupal and pupal parasitoids. Among the 40 species of parasitoids reported from black headed caterpillar of coconut in India, the gregarious larval ectoparasitoids *Goniozus nephantidis* Muesebeck and *Bracon brevicornis* Wesmael, the pre-pupal parasitoid *Elasmus nephantidis* Rohwer and the pupal parasitoid *Brachymeria nosatoi* Habu are the most promising ones (Pillai and Nair, 1993). The major desirable attributes of these parasitoids are their greater searching ability, capacity to withstand high temperature, production of higher proportion of female progeny, occurrence throughout the year, and abundance during peak period of the pest and their distribution in all pest infested areas.

Table 10.1: Important Parasitoids of *Opisina arenosella*

Name of Parasite	Family	Target Pest Stage	Nature of Parasitoid
Apanteles taragamae Vier.	Braconidae	Early larva	Solitary
Bracon brevicornis Wesmael	Braconidae	Late larva	Gregarious
Goniozus nephantidis Mues.	Bethylidae	Do	Do
Elasmus nephantidis Rohw.	Elasmidae	Pre pupa	Do
Goryphus nursei Lam.	Ichneumonidae	Larva-pupa	Solitary
Meteoridea hutsonii Nixon	Braconidae	Do	Do
Antrocephalus hakonensis Ashm.	Chalcididae	Pupa	Do
Brachymeria nosatoi Habu	Chalcididae	Do	Do
B. nephantidis Gahan	Chalcididae	Do	Do
Xanthopimpla punctuate F.	Ichneumonidae	Do	Do
X. nana nana Schlz.	Ichneumonidae	Do	Do
Trichospilus pupivorus Ferr.	Eulophidae	Do	Gregarious

Techniques have been developed for mass production of the promising parasitoids. The pest infested area should be monitored regularly and parasitoids releases should be initiated at the post monsoon period during November – December if there is any pest incidence. Parasitoids are to be released at the fixed dosages depending on the target stage of the pest at fortnightly intervals till the pest population is suppressed. As the release should synchronize with the stage of pest in the field, a sample of leaflets should be collected from infested palms at random and examined for live pest stages.

The parasitoid *Goniozus nephantidis* is released if the pest is at 3rd instar larval stage or above @ 20 parasitoid/palm and *Bracon brevicornis* @30 parasitoid/palm. The pre-pupal parasitoid *Elasmus nephantidis* and pupal parasitoid *Brachymeria nosatoi* are also very effective in managing the pest. They are released @ 49 and 32 per cent, respectively for every 100 prepupa and pupae estimated to be present on the palm (Sathaimma *et al.*, 1987). Before releasing in field, the parasitoids should be fed with honey and newly emerged parasitoid can be released in the field after three days of emergence. *G. nephantidis* and *B. brevicornis* could easily be mass multiplied on larvae of the rice moth *Corcyra cephalonica*. The pre-pupal parasitoid, *Elasmus nephantidis* is a highly host and stage specific parasitoid and always requires a steady supply of pre-pupa of *O. arenosella* for mass multiplication. This is the major constraint for mass production of *E. nephantidis* in the parasite breeding laboratories. Pupal parasitisms by many species of *Brachymeria* are observed in nature. Among them *B. nosatoi* is most potential for effective biocontrol since it possesses all the desirable attributes with high percentage parasitism, long life span, good searching ability and tolerance to high temperature. *B. nephantidis*, another major *Brachymeria* species in nature sometimes act as hyper parasitoid on primary parasitoids of *O. arenosella*.

Field Performance of Parasitoids

Using IPM technologies or exclusive release of promising biocontrol agents many demonstrations were laid out in the last two decades by ICAR-CPCRI in coastal Kerala and Karnataka. Studies conducted in an endemic area during 1990-1993 at Thodiyoor (Kollam District, Kerala) with the field release of the three stage specific parasitoids at fixed norms and intervals in *O. arenosella* infested coconut garden (2.8 ha) resulted in highly significant reduction (94 per cent) in pest population (Sathiamma *et al.*, 1996). Regular monitoring and release of stage specific parasitoids induced 52.6 and 94.7 per cent reduction in pest population after one and two years, respectively of parasite release in a heavily infested tract at Neendakara, Kollam Dist., Kerala. Large scale (1,400 ha) field validation of the biosuppression technology of coconut black headed caterpillar done during 1999-2002 in different geographic locations in coastal Karnataka (Ullal and Jeppinamogru) and coastal Kerala (Purakkad and Ayiramthengu) could achieve 93-100 per cent reduction in *O. arenosella* population in a period of two years with regular monitoring and release of stage specific parasitoids (Chandrika *et al.*, 2010) (Figure 10.2). Reports of biological suppression of *O. arenosella* in coastal districts of Odisha by the release

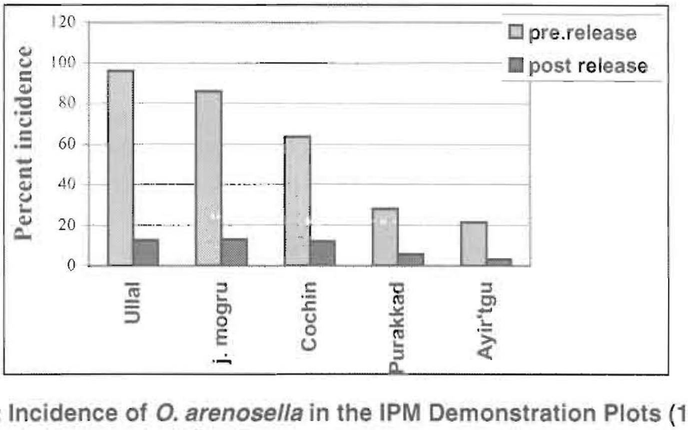

Figure 10.2: Incidence of *O. arenosella* in the IPM Demonstration Plots (1999-2002).

of parasitoids are also available. Successful biocontrol of *O. arenosella* was reported in Andhra Pradesh and timely augmentation of *G. nephantidis* @ 10 adults/palm at fifteen days interval suppressed the pest population in Karnataka. The higher frequency of occurrence of *G. nephantidis* in all the locations during post release period indicated the suitability of this larval parasitoid to adapt in various locations in the coastal belts of Kerala and Karnataka.

Parasitoids Reported from other Pests

Although parasitoids are reported from other pests of coconut, they were not successfully introduced as effective biocontrol agents. The scoliid wasp *Campsomeriella collaris* Fabr. parasitizes larvae of white grubs in the field. *Scolia cyanipennis* Fabr. and ectoparasitic mites are also observed in association with the different stages of the rhinoceros beetle. The egg parasitoid *Chrysochalcisea indica* was recorded from the coreid bug *Paradasynus rostratus* and the mymarid parasite *Parallelaptera* sp. on the eggs of *Stephanitis typica*. The parasites reported on the scale insect of coconut, *Aoniediella orientalis*, include *Aphytis chrysomaphali* Marcat and *Cauca parvipennis* Gaham, and *Cocobius reticulatus* (Aphelinidae). Further study in this line is required to collect and catalogue more parasitic species and to standardize the techniques for field application and evaluation.

2.1.1.2. Predators

Many species of spiders, coccinellids, reduviids, predatory ants, mites and thrips are well documented as effective predators. Spiders are important predators of insect pests. They suppress pest species to low densities at all growth stages. They are generalist predators and polyphagous in habit. Spider fauna contributes a major group of natural enemies in cropping systems (Hazarika and Chakraborti, 2007). Habitat manipulations like conserving ground litter, using safer pesticides *etc.* contribute to their conservation. Insect and spider predators are abundant in the coconut ecosystem. Insect predators are frequently observed in the breeding grounds of the rhinoceros beetle. They feed on the eggs and early instar larvae of the beetle. The important predators are *Santalus parallelus* Payk. (Coleoptera: Histeridae) (Antony and Kurien, 1966), *Pheropsophus occipitalis* Macleay, *P. lissoderus* Chaudior, *Chelisoches morio* (Fabricius) (Coleoptera: Chelisochidae) (Sathiamma *et al.*, 1982) and species of *Scarites sp.* (Coleoptera: Carabidae), *Harpalus* and *Agrypnus* sp. near *bifoveatus* Candeze (Coleoptera: Elateridae) (Kurien *et al.*, 1983).

An exotic predator *Platymeris laevicollis* Distant (Coleoptera: Reduviidae), was imported from Zanzibar to India for the control of rhinoceros beetle. As compared to the indigenous predators, *P. laevicollis* feeds on adult beetles. The predator is long lived (170-240 days) and fecundity high (110-170 eggs/female) and could easily be mass multiplied on ground roaches. Field release of predator was done in coconut plantations in Kerala and Karnataka @ 6 bugs/palm and could achieve significant reduction in beetle population and the damage to the palm. Leaf damage was reduced to 13.1 per cent, nil spathe damage and 1 per cent spindle damage as compared to 59.2 per cent, 2.5 per cent and 37.0 per cent, respectively, recorded during pre release observations. But the predators failed to establish under field conditions (Antony *et.al.*1979; Kurien *et al.*, 1983).

A variety of predatory fauna is also available in nature in association with *O. arenosella* (Table 10.2). The most important insect predators are the carabid beetle, *Parena nigrolineata* Chaud, anthocorid bug *Cardiastethus* spp, chrysopids, *Ankylopteryx octopunctata candida* Fab., coccinellids, ants and spiders. Spiders, though generalist predators and polyphagous, contribute a major group of natural enemies in coconut ecosystem. Spiders are the most dominant group of predators on *O. arenosella*. Species of *Cheiracanthium, Rhene* and *Sparassus* are the important spider predators and contributed nearly 21 per cent of the total spider fauna available on coconut foliage. They consume the immature and adult stages of *O. arenosella*. *Cheiracanthium* sp. consumed the prey @1.19 caterpillars per day. Male *Cheiracanthium* took 204-224 days and females 194-206 days to reach adulthood. Longevity varied from 35-122 days (male) and 51-127 days (female). Maximum population was recorded in the field during July. *Rhene indicus* is one of the common spiders feeding on *O. arenosella* caterpillars. Per day consumption was 0.7 caterpillars per predator. It reached maturity in 71-98 days (male) and 70-98 days (female). Longevity was 25-77 days (male) and 71-296 days (female). August was the peak period of the predator activity in the field (Pillai and Nair, 1990a, 1993; Sathiamma *et al.*, 1985 a, b; 1987, Nasser and Abudurahiman,1990, 1998).

Table 10.2: Important Predators of *Opisina arenosella*

Name of Predator	*Predator Stage*	*Prey Stage*
Ankylopteryx octopunctata candida Fab. (Chrysopidae)	Nymph	Egg/Early larva
Calleida splendidula F. (Carabidae)	Larva/adult	All stages
Parena nigrolineata Chaud. (Carabidae)	Do	Do
Cheiracanthium melanostoma Thor. (Clubionidae)	Do	Do
Rhene indicus (Salticidae)	Do	Do
Sparassus sp (Sparassidae)	Do	Do
Cardiastethus sp. (Anthocoridae)	Nymph/adult	Egg/Early larva

Predators of Scale Insects, Mealy Bugs, Lace Bug, White Flies

Scale insects, mealy bugs, coreid bug, lace bug and whiteflies are observed in most of the coconut plantations as minor pests. Their population is kept under check by the natural predators which are very active in the coconut ecosystem. Predators play a predominant role in limiting coconut scale population. Reports of a range of predators *viz., Scymnus saverini* Wsc., *Scymnus* sp., *S. apiciflavus* Mots. *Pharellus minutissimus* Sic. *Azyatrinitatis* Hshl, *Pentilia insidiosa* Muls. and *Scymnus aeinipennis* on scale *Aspidiotus destructor* are available (Mohandas and Remamony,1993). The coccinellids *Chilocorus nigritus* Fab. and *Pseudoscymnus dwipakalpa* Ghorpade, *Cybocephalus* sp are predacious on *A. destructor* and *Aonidiella orientalis*. Sadakathulla (1993) developed techniques for the mass production of *C.nigrita* on *A. destructor* reared on pumpkin fruit (*Cucurbita maxima* Wall.). *C. nigrita* consumed 11 adults and 120 crawlers of *A. orientalis* in 24 h. The mite *Saniosulus nudus* Summers preyed on an average 15 crawlers of *A. orientalis* in 24h (CPCRI, 1990, 93). Fourteen insects and twenty-three spiders are observed as predators on *Stephanitis typica*. The identified insect predators are the mirid *Stethoconus praefectus* D., chrysopid *Ankylopteryx octopunctata octopunctata* Fabr., reduviids *Endochus inornatus* Stal., *Rhinocoris fuscipes* Fab., *Euagoras plagiatus* Burm. and earwig *Chelisoches morio*. Fab. The mealy bugs associated with coconut in India are *Palmicultor palmarum, Pseudococcus longispinus, Pseudococcus cocotis, Dysmicoccus* sp. and *Rhizoecus* sp. *Spalgis epius* (Lycaenidae) and species of *Pullus* and *Scymnus* (Coccinellidae) are the natural enemies recorded from mealy bug colonies. They exert limited check of the pest population. The predators of coreid bug include the ant *Oecophylla smaragdina* and the reduviid *Endochus* sp. Two types of whiteflies *viz.*, areca whitefly, *Aleurocanthus arecae* and spiralling whitefly *Aleurodicus dispersus* have been recorded from coconut in India. Their population is kept under check by the activity of predators *viz., Seragium parcesetosum, Jauravia pallidula, Cybocephalus* sp. *etc.* Two species of lady bird beetles namely *Chilocorus subindicus* and *Scymnomorphus* sp. were found predatory on spiralling whitefly.

Predators of Coconut Eriophyid Mite

The nut infesting eriophyid mite *A. guerreronis* Keifer has emerged as one of the serious pests of coconut in India in 1998 and has become the major pest of coconut palm in a very short spell. Mites live in colonies on the tender portion of the buttons covered by the perianth and suck sap from the meristematic tissues. The symptom of attack is the appearance of elongated white patches below the perianth, later turning to pale yellow and brown. As the nut grows, the injury forms wartings and longitudinal fissures on the nut surface. Severe infestation results in button shedding, reduced kernel weight and reduction in fiber content. Currently botanical pesticides are recommended for mite management. A variety of predatory mites and smaller insects are associated with *A. guerreronis* in different parts of the

Figure 10.3: Eriophyid Mite Infested Coconuts.

world. Predatory mites belonging to Phytoseiidae, Bdellidae and Tarsonemidae are encountered in various collections. In India, the phytoseiid mite *Neoseiulus baraki* is the most dominant predator in the field. Other predatory mites include *Neoseiulus paspalivorus* and *Bdella* species. The insect predators encountered with coconut mite population in the field are thrips, coccinellids and syrphid maggots. But these are found only occasionally and in very few numbers. An increasing trend of incidence and better establishment of predatory mites in the field over the years are observed. The activity of the predators is high during June to December in the field. Compared to the young developing nuts below three months, more predators are encountered in 4-6 months old nuts. The predatory mites are larger in size compared to the coconut mite and they gain entry only later into the nuts. This is one of the limiting factors for the wider use of the predators. However, conservation of the predatory fauna in the ecosystem is beneficial to regulate the coconut mite in nature. Marimuthu *et al.* (2003) had reported three species of predatory mites *viz. Amblyseius paspalivorus, Bdella* sp and a tarsonemid attacking mite colonies in the field in Tamil Nadu. Predatory mites belonging to phytoseiidae, Tarsonemidae and Bdellidae attacking eriophyid mite colonies in the field was reported by Naseema Beevi *et al.* (2003). Mallik *et al.* (2003) reported that among the Phytoseiid mites, *A. paspalivorus* and the tarsonemid *Lupotarsonemus* sp are the predatory mites more encountered with mite colonies in Karnataka. The tarsonemid is found attacking on egg and the phytoseid attacking on all stages of mite. Predatory insects are very seldom reported on eriophyid mite. Nair *et al.* (2003) reported one species each of syrphid, thrips and coccinellid associated with mite colonies in the field.

The efficiency of the predators is neither fully assessed nor widely used in the biological control programmes of *O. arenosella*. Habitat manipulations like conserving ground litter, using safer pesticides *etc.* contribute to their conservation. The earwig *Chelisoches morio* (Fab.) feeds on the eggs and early instar grubs of red palm weevil in the field. Venkatesan *et al.* (2003) reported that *C. exiguus* could be reared using artificial diet. Lyla *et al.* (2006) evaluated *C. exiguus* against *O. arenosella* and found that the predator proved to be very efficient in suppressing the pest population. *Bergirus maindroni* Grou. (Mycetophazidae), *Dicrodiplois* sp. (Cecidomyiidae) *Spalgis epius* (Westwood) (Lycaenidae) and species of *Pullus* and *Scymnus* (Coccinellidae) were the natural enemies recorded from mealy bug colonies. They exerted limited check of the population (CPCRI, 1995).

Mites form important pests of arecanut palm. *Tetranichus fijiensis* Hirst, *Oligonychus indicus* Hirst, *O. biharensis* Hirst (Tetranichidae) and *Raoiella indica* (Tenuipalpidae) are the major species recorded (Nair, 1986; Nair and Daniel, 1982). Puttarudraiah and ChannaBasavanna (1956) had recorded some coleopteran predators on both *O. indicus* and *R. indica*. They included *Aspectes indicus* Arrow (Dermestidae), *Cybocephalus semipictis* Champ (Nitidulidae), *Stethorus parcepunctatus* Kapur, *S. tetranychi* Kapur, *Jauravia sorar* Wsc. and *Spilocarea bisselecta* Muls. (Coccinellidae). These predators particularly *Stethorus* kept the mite population in check during summer months. Kapur (1961) had described a new species, *Stethorus keralicus* from Kerala on *R. indica* and Daniel (1976) had studied the biology and predatory habits. Daniel (1979) recorded a number of indigenous predators and among them, two species of *Stethorus* and a staphylinid beetle were the major predators of *O. indicus*. The coccinellid, *S. keralicus* Kapur and the phytoseiid, *Amblyseius channabasavanni* Gupta and Daniel were the key predators of the palm mite *R. indica*.

Tea mosquito bug, *Helopeltis* sp. is the most serious pest of cashew and cocoa in India. Sundararaju and Sundarababu, (1999) reviewed tea mosquito bug's pest status, hosts and pest management practices. *Crematogaster wroughtonii* Forel (Formicidae) has been reported as a predator of nymphs of the pest (Ambika and Abraham, 1979). Spiders, *Hyllus* sp., *Oxyopes schireta*, *Phidippus patch* and *Matidia* sp. have been reported as predators of *H. antonii* (Sundararaju, 1984; Devasahayam and Radhakrishnan Nair, 1986). Reduviid bugs *viz.*, *Sycanus collaris* (Fab.), *Sphedanolestes signatus* Dist., *S. minisculus* Bergar, *Irantha armipes* Stal., *Endochus inornatus* Stal., *E. cingaensis* Stal., *Occamus typicus*, Dist. and *Alcmena* sp. have been recorded as predators of *H. antonii* (Sundararaju, 1984).

2.2. Entomopathogens

Biological control using entomopathogens is an important component of IPM. It is possible to use specific micro-organisms that kill arthropods. These include entomopathogenic fungi, nematodes, bacteria and viruses. The microbial agents which play a vital role in the bio suppression of various pests of coconut have been examined and in the case of black beetle (*Oryctes rhinoceros* L.) this group of natural enemies has been thoroughly studied.

2.2.1 Fungi

Entomopathogenic fungi are of considerable importance in crop pest control because of their ability to infect a wide range of insect pests through *non per os* infection. In coconut pest management, entomopathogenic fungi such as *Beauveria bassiana*, *Metarhizium anisopliae*, *Hirsutella thompsonii* are the best utilized globally. Fungi require relatively high humid microclimate (>70 per cent RH).

a) Green Muscardine Fungus as a Potential Enemy of Rhinoceros Beetle

The rhinoceros beetles cause damage to palms of all age groups by boring into the unopened spindles and inflorescence. As the pest bores deeper into the host, it pushes out the chewed up tissues, which are seen extruding from the entry points. Once these injured spindles open up, the green leaves present a geometric 'V' shaped cut pattern. The damage to inflorescence is seen as round oblong holes on the spathes, which soon dry up. The pest occurs throughout the year and breeds in cattle dung, compost, dead and decaying organic debris like coconut and other palm trunks, cocoa pod shells, oil palm bunch waste, coir dust, rotting paddy straw and sugar cane waste *etc.* The life cycle is completed in 6 months on an average.

Among the entomopathogens, the green muscardine fungus *Metarhizium anisopliae* (Metsch.) Sorokin (Deuteromycotina: Hypomycetes) is one of the most effective and successful biocontrol agents in coconut ecosystem as a potential pathogen of *O. rhinoceros*. *M. anisopliae* var. *major* (spore size 10-14 µm) is highly infective variety used widely for the control of this pest. All the stages of the host excepting the eggs are mycosed. The fungus is very active during monsoon when the relative humidity is 70-90 per cent and the temperature is 26-28°C. The infected grub becomes sluggish and mortality occurs within 10-15 days. The body of the infected grub becomes hardened and white powdery fungal colonies appear in the joints of the integument. Within a week green coloured spores are produced and finally the cadavers become black and mummified. The mass production of the fungus has been developed at ICAR-CPCRI using solid (cassava chips and rice bran mixture supplemented with nitrogen source) and liquid (coconut water) media. Different substrates like broken rice/wheat grains, millets *etc.* also are found to be cheaper substrates for multiplication of the fungus. For the field application of the fungus, the fungal spores are mixed with sterile water and used to drench the breeding materials of the rhinoceros beetle @ of 5×10^{11} spores/m^3. The fungus survives in the breeding material for long periods. Use of this fungus for biocontrol of rhinoceros beetle has been popularized as a women friendly technology and ICAR-CPCRI is presently facilitating farm level production of this fungus to cater local needs.

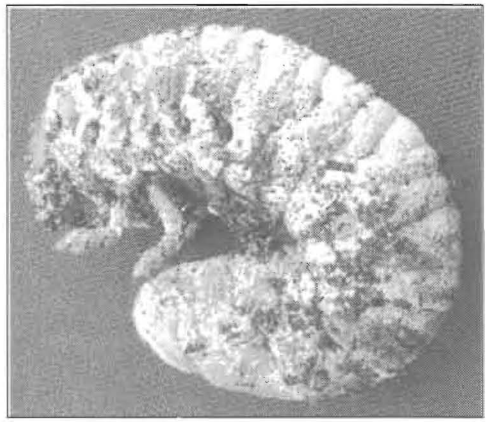

Figure 10.4: *Metarhizium anisopliae* Infected Grub of Rhinoceros Beetle.

b) *Hirsutella thompsonii*: A Promising Fungal Pathogen against Coconut Mite

The fungus *Hirsutella thompsonii* has been reported as a predominant pathogen among microbial pathogens of eriophyid mite. In India the incidence of *H. thompsonii* was recorded from Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Pondicherry and Lakshadweep Islands. In Kerala, local strain of *H. thompsonii var. synnemetosa* could be isolated from field samples. ICAR-CPCRI could collect virulent native isolates of this fungus from different locations of India. Talc based formulations of the virulent strains of this fungus are being evaluated for the suppression of coconut eriophyid mite in the field and preliminary results indicated 70-80 per cent suppression in pest population. Other fungal species associated with eriophyid mite include species of *Paecilomyces, Beauveria, Metarhizium, Sporothrix, Verticillium,*

Figure 10.5: Coconut Eriophyid Mite Infected with *Hirsutella thompsonii*.

Acremonium, Aspergillus, Penicillium and *Fusarium*. However, the bio-efficacy of these fungi as biocontrol agents of mite in field conditions is not fully studied.

2.2.2. Virus

a) Oryctes rhinoceros Nudi Virus

The Oryctes rhinoceros nudi virus (OrNV) was discovered in 1960 in Malaysia and has been effectively used to control the rhinoceros beetle in coconut and oil palm in Southeast Asia and the Pacific. It is a classical example of successful inoculation and long term control of an insect pest. The virus consists of rod shaped virions and replicates in the nuclei of infected cells. On the basis of its (ultra) structure, OrNV was previously considered to be a so called non–occluded baculovirus (NOB). Due to the lack of occlusion bodies, it was later removed from the family Baculoviridae. OrNV contains a double stranded DNA genome of about 130 kilobase pairs. The virus gains entry into the host through contaminated food and it multiplies in the mid gut epithelial cells and fat bodies of grubs and adults. Infected grubs become lethargic, stop feeding and move to the surface of the feeding media. With the multiplication of the virus in the mid gut epithelium of the grub the fat body disintegrates and the haemolymph content increases giving a translucent appearance for the grub. The diseased grub dies within 15-20 days. The infection by OrNV results in reduction of the longevity of the beetle by 45 per cent and fecundity by 95 per cent relative to the healthy beetles. Diseased adults also become inactive.

Figure 10.6: Inoculating Rhinoceros Beetle with Oryctes Rhinoceros Nudi Virus.

Mass Production of the Virus

The Oryctes virus is mass multiplied and maintained in the laboratory on live grubs. The OrNV infected grubs are dissected, the swollen midgut is taken out and the viral suspension of the midgut is prepared by grinding with phosphate buffer. This viral inoculum is fed to the healthy grubs to induce infection. The inoculated grubs are reared on sterilized food (cow dung, coir pith or saw dust) moistened sufficiently. The development of OrNV infection is to be monitored in the inoculated grubs and the whole procedure of inoculation of healthy grubs is repeated to maintain the viral culture in the host. The grubs showing external symptoms such as translucent gut or extroversion of rectum has to be dissected immediately; otherwise secondary infection with other pathogens like *Pseudomonas etc.* takes over and destroys the OrNV infection.

Field Release

For field release, either the adult beetles are inoculated orally using a syringe with the OrNV inoculum or they are allowed to wade through the virus inoculum (2g of infected larval gut tissues in 1 litre of phosphate buffer) contained in a basin for 30 minutes. After the inoculation, the beetles are confined together in a box containing rotten coconut wood powder mixed with the virus inoculum for 24 hours. The treated beetles are removed the following day and confined for a week in a box containing fresh coconut petioles provided as food, since the infected beetles begin to excrete the virus only a week after infection. The infected beetles are liberated after dusk in the field. 12-15 infected beetles per hectare are recommended to disseminate the virus in nature.

Impact of the Release of OrNV

In India, the population of *O. rhinoceros* and its damage on coconut palm was checked substantially when the OrNV was released in the pest infested areas of Lakshadweep Islands. In Minicoy, there was a reduction of 76.9 per cent leaf damage, 93.8 per cent spathe damage in a period of 30 months. In Androth islands leaf, spathe and fresh spindle damage showed reduction of 75.4, 56.1 and 74.8 per cent, respectively in a period of two years and the OrNV population showed an increase from nil to 60.6 per cent showing the establishment of the pathogen in the pest infested area (Mohan *et al.*, 1989). Similar results were observed in the mainland in Chittilappilly, Trichur, Kerala, where pest incidence reduced from 100 to 23 per cent and there was 80.6 per cent reduction in leaf and 100 per cent reduction both in spathe and fresh spindle damage when OrNV was re-released in a period of 3 years during 1989 to 1992. Establishment of OrNV in native population of *O. rhinoceros* at Sipighat, Andamans by release of the virus is also reported (Jacob, 1996). From nil infection during the pre-treatment period in 1989 the infection has increased to 61 per cent in 1991. By augmenting the natural population of virus infected beetles, sustained reduction in beetle incidence and crop damage can be achieved even in already infected contiguous areas (Biju *et al.*, 1995). The biggest singular advantage OrNV offers over other microbial agents is in being an auto transmissible pathogen capable of passing from generation to generation. The method of its propagation involves the release of diseased beetle and no spraying of the virus to the crop is required. Significant reduction in rhinoceros beetle damage by the combined use of two potential biocontrol agents (*M. anisopliae* and OrNV) was reported from large scale field studies (2,400 ha) done in Alappuzha (75.1 and 79.4 per cent reduction in leaf and spindle damage) and Kasaragod (66.6 and 95.8 per cent reduction in leaf and spindle damage) districts during 1999-2002 (Nair *et al.*, 2010).

2.2.3. Bacteria

Bacterial pathogens *Acinetobacter calcoaceticus* and *Pseudomonas alcaligenes* have been identified as pathogens of *O. rhinoceros* grubs. *Bacillus thuringiensis* Berliner and *Serratia marcescens* B. are observed to be pathogenic to *O. arenosella* in the field. So far no effective microbial agent could be identified on red palm weevil which is a fatal enemy to coconut palm. *Pseudomonas aeruginosa* was identified as facultative pathogen of red palm weevil. A yeast isolate has also proved to be a transitional pathogen producing mortality in weevils/grubs. Reports on the infectivity of *Bacillus thuringiensis* subspecies kurstaki (Btk.) and a polyhedrosis virus to larvae of red palm weevil are available. These pathogens were isolated from the field in Egypt and stored for 4 years as air dried smears on glass slides, before being tested. Record of eugregarine protozoan pathogen *Pseudomonocystis* sp., which infect 22.7 per cent of the third instar white grubs in the field is available.

2.2.4. Entomopathogenic Nematodes

Entomopathogenic nematodes (EPN) in the families Heterorhabditidae (represented by the genus Heterorhabditis) and Steinernematidae (represented by the genera Steinernema and Neosteinernema) have been used to suppress populations of soil and cryptic insect pests in a variety of agro-ecosystems. EPN are obligate parasites of insects and kill their hosts with the aid of bacteria carried in the nematode's alimentary canal which provide nutrients to the nematodes, produce antibiotics and inhibit competing microbes, and kill the host through septicemia. They are associated with mutualistic bacteria in the genus Xenorhabdus for Steinernematidae and Photorhabdus for Heterorhabditidae. The positive attributes of these nematodes as biological control agents are that they have a broad host range, are safe to invertebrates, plants and other non-target organisms, have no known negative effect on the environment, are easy to mass produce *in vivo* and *in vitro*, are easily applied using standard spray equipment, can search for their host, kill rapidly (within 48 h), have the potential to recycle in the environment, are compatible with biological pesticides, are amenable for genetic selection for desirable traits and are exempt from registration in many countries.

Field Efficacy

Moisture conditions have been recognized as one of the most important factors in the soil environment affecting survival, virulence and persistence of nematodes. Entomopathogenic nematodes need high relative humidity to survive and a film of free water for movement. They may become dormant at very low soil moistures.

In vivo Multiplication of Entomopathogenic Nematodes (EPN)

In vivo mass production of EPN has been standardized using *Galleria mellonella* larvae in the laboratory by filter paper inoculation technique. *Steinernema* sp. infected cadavers turn creamish-white in colour characteristic of the bacterium (*Xenorhabdus poinarii*) housed in it whereas, *Heterorhabditis* sp. infected insects become reddish-brown due to *Photorhabdus luminescens*. After required incubation, the cadavers are placed in White's trap for the emergence of nematodes. From the White's trap, the nematodes wriggle out and migrate all over the Petri dishes under minimum moisture content. Nematodes, thus, emerged out are harvested by adding water and later filtered for concentrating the nematodes. On an average 2-3 lakh nematodes are produced from each insect.

Use of EPN against Coconut Insect Pests

EPN has been found promising in the management of red palm weevil and white grubs infesting coconut. An entomopathogenic heterorhabditid nematode was isolated from Egypt and United Arab Emirates planted with date palm trees and has shown potential for the control of red palm weevil. Among the species of EPN evaluated against the grubs of red palm weevil, *R. ferrugineus*, in filter paper based bioassay, *Heterorhabditis* sp. was found to be more virulent than *Steinernema* sp. and the local isolate *H. indicus* was found to be more virulent inducing 92.5 per cent mortality @ 1500 IJ/grub. Talc based EPN formulation of *H. indicus* elicited higher mortality than water suspension based formulation on coconut petiole based bioassay. Among the four species of EPN evaluated against the coconut white grub in soil-column bioassay, *Steinernema abassi* was found to be virulent inducing 37-45 per cent mortality of white grubs @ 5000 IJ/grub in a period of 96-120h. Species specificity against various pests, concentration of IJ and moisture content hold the key in the field success of EPN on a large scale. Field evaluation of the promising EPNs against red palm weevil and white grubs are to be undertaken on priority as these two major pests are not having any effective biocontrol agents.

2.3. Limitations of Biocontrol Methods

Under the present market system, many biological control products have not competed well with less expensive and more effective synthetic pesticides. The down sides of biocontrol agents are that most are niche products, pest control is not immediate, there can be lack of environmental persistence, and efficacy can be low and unpredictable particularly in outdoor environments. Timely availability of quality bioagents, quantity, farmers perception about biological control, short shelf life of bioagents, formulation, storage and registration *etc.* are some of the limiting factors for popularization of biocontrol technology. Biosystematics of insect groups especially parasitoids and predators is of prime importance in biocontrol. Illustrated easy to use identification guides should be made available for research and extension workers. Identification service is lacking for major groups of crop pests and their natural enemies. Regional approaches to catalogue biodiversity would be ideal.

2.4. Botanical Pesticides

Botanical pesticides are having a prominent position in pest management under organic agriculture. As botanical pesticides are safe for the non-target organisms, they are preferred in organic pest control strategies. Botanical pesticides are used either as repellents or as primary insecticides having adverse effect on the physiological functioning of insect pests. Derivatives from various species of plants have been in use for plant protection from ancient days onwards in agriculture. More than 600 plant species are reported to have pesticidal properties. Tulsi, Mahuva, Lantana, Tobacco, Marigold, *Clerodendron infortunatum etc.*, are some important plants used for pest management. Insecticidal properties of neem were proved beyond doubt in ancient times and in modern agriculture, neem based pesticides are getting importance because of their versatile ability to control many pests of agricultural importance. *Azadirachtin* is the active principle having insecticidal property present in neem tree. Decoction of neem leaf, neem oil cake, powdered neem seed and seed oil are used in various dilutions mixed with washing soap to effect satisfactory control of various groups of foliage pests in many field crops. In coconut mite management, use of neem pesticides is recommended either as spray

Figure 10.7: ***Clerodendron infortunatum*** **Plant.**

or as root feeding (Nair *et al.*, 2005). Neem cake/pongamia cake mixed with sand is effectively utilized for prophylactic leaf axil filling to repel rhinoceros beetle from coconut palm (Rajan *et al*,. 2009).

2.5. Semiochemicals

Semiochemicals which are considered to be a modern tool in IPM concept has a pivotal role in eco-friendly pest management programmes. Semiochemicals

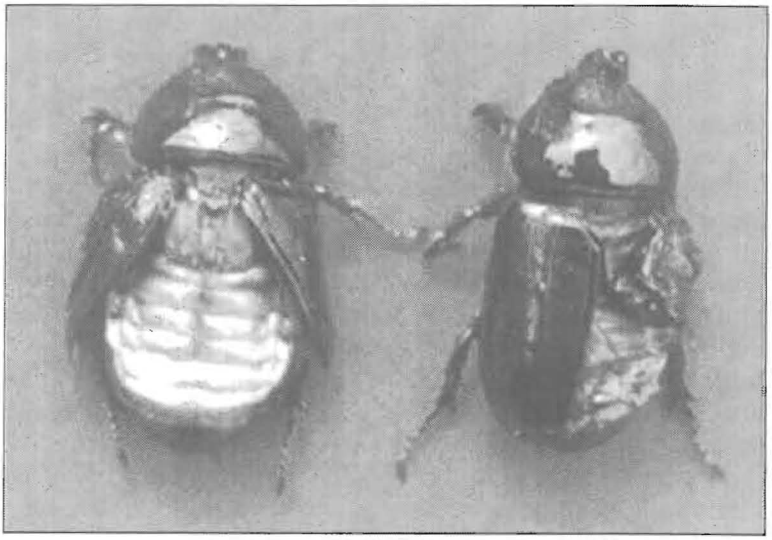

Figure 10.8: ***Clerodendron infortunatum*** **Induced Malformation in Rhinoceros Beetle.**

are compounds released or emitted by plants and animals for specific communication purposes. If the communication is between the same species (Instraspecific), they are called pheromones, and on the other hand if the communication is between two different species (Interspecific), they are called kairomones. Insect pheromones fall into several categories usually related to functions *viz.*, sex pheromones, aggregation pheromones, alarm pheromones, trail pheromones, *etc.* Pheromones that have been used most successfully in pest monitoring/control are sex pheromones of Lepidoptera and aggregation pheromones of Coleoptera. The application of pheromones in crop protection may be indirect as population monitoring agents or direct as tools in mass trapping, lure and kill and mating disruption techniques (Yadav *et al.*, 2004). In plantation crops, successful attempts have been recorded for the control of coconut red palm weevil, *Rhynchophorus ferrugineus* (Nair and Saritha, 2003).

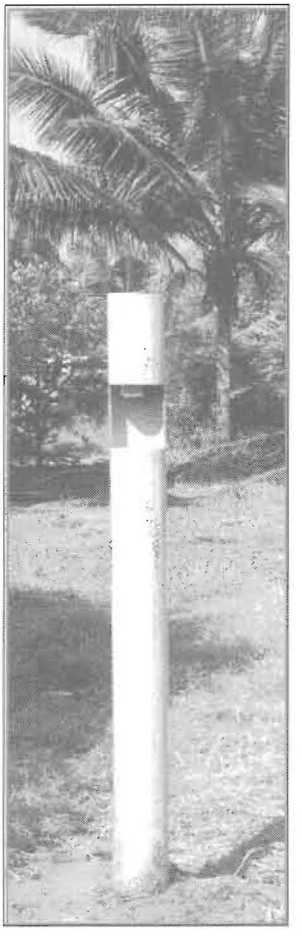

Figure 10.9: Pheromone Trap for Rhinoceros Beetle.

2.6. Light Traps or Attractant Traps

Red palm weevil of coconut are attracted to food lure traps employing the natural food substances. White grubs are major pests of coconut, arecanut, tuber crops, sugarcane and ground nut and they are successfully managed using light traps. Trapping of adult beetles during their emergence period coinciding with onset of monsoon is found to be one of the effective strategies in IPM of white grubs.

2.7. Agronomic Practices

Historically, agronomic practices or cultural manipulations of plants were the most important methods for controlling and preventing crop losses. Farmers continuously refined them with experience. Among the oldest techniques for managing pests are sanitation, destruction of alternate hosts, tillage, avoidance and planting of crop cultivars that resist pest attacks. The worldwide awareness of safe environment provided impetus to foster non-chemical pest management strategies. Of these strategies, cultural control constitutes the most farmer-oriented approach, where weak points in the biology and behaviour of insects are exploited and pressure is exerted on the population by manipulating the environment. An understanding of natural defense mechanisms present in the host against the pest is useful to prepare a pest control programme where agronomic methods are to be utilized. Also, a thorough knowledge of pest, host, host-plant interaction and optimum environment for both are necessary in this method. In an agricultural country like India, agronomic management practices are of immense importance because of low cost of inputs, easy in their adoption and acceptance by farmers. Nutritional management of the plant is important in managing pest problems and is very important in sucking pests like coconut eriophyid mite.

2.7.1. Sanitation

Removal and destruction of breeding materials, manipulating over-wintering sites, pruning of infested plant parts *etc.* are sanitation methods that can be employed in organic agriculture. Sanitation is important to prevent introduction of insects, pathogens, nematodes and weeds into pest free fields and to reduce losses in infested fields. Sanitation practices such as use of healthy seed material, burning and destruction of crop refuse, clean storage, *etc.*, reduce pest population, discourage breeding and hibernating sites and prevent carry over to the next crop season. These methods are economical, effective and easy to adopt. Depending upon the crops and types of pests that affect the crops, sanitation methods can be practiced by farmers.

Crown cleaning in coconut reduces the coreid bug damage and also removes the nesting sites of rodents. Phyto-sanitation is the key factor in the management of major pests of plantation crops like rhinoceros beetle and red palm weevil of coconut and stem borers affecting crops like cashew, coffee, cocoa, *etc.* Avoiding breeding sites of black beetle in the immediate vicinity controls its attack in coconut plantations. Timely pruning and pod harvest at ripening time is important in reducing pest menace in cocoa.

2.7.2. Tillage

Tillage is an integral factor in destroying food sources and habitat of the pests within the field. In addition tillage plays a major role in rhizosphere microflora

Figure 10.10: Summer Ploughing for Pest Management.

and microfauna. Tillage operation changes the texture, nutritional composition and pH of the soil which becomes less favourable to weeds and soil inhabiting insects. Deep ploughing during the pre-monsoon and post-monsoon seasons helps in control of soil insects like white grubs, termites and army worms. Many times, tillage operations are also essential in managing nematodes and rodents.

2.7.3. Resistant Cultivars

Genetic resistance is one of the oldest methods of pest control. Growing resistant cultivars is the most effective and economic means of controlling plant pests. Resistant cultivars are also the first line of defense against pests. Resistant varieties should be used in concert with other pest suppression or pest control measures. Plant resistance provides a built-in ability to allow fewer pests and cut off the extra load of insecticides in the crop. Keeping in mind the diversity and intensity of pests in a particular place, selection of resistant/less susceptible varieties holds well in pest management. Tall varieties of coconut are found to be tolerant to red palm weevil damage. Orange dwarfs are tolerant to mite damage in coconut.

2.7.4. Trap Crops

Trap crops or catch crops are species of plants which are planted to attract and retain a pest species or to provide a more favourable habitat to increase natural enemies. Trap crop provides protection either by preventing the pest from reaching the main crop or by concentrating them in certain parts of the field, where they can be economically destroyed. Trap crops have been utilized in control of nematodes. Marigold as a trap crop for nematodes in vegetable fields and black pepper garden is common at many places.

2.7.5. Regulation of Alternate Hosts of Pests

Many economically important pests are known to survive on collateral hosts which constitute mainly the weeds grown in the vicinity of the agricultural land or a subsidiary crop grown in the field. The coreid bug of coconut not only infests coconut but also infests collateral hosts like guava, cashew, cocoa and tamarind. Tea mosquito bug is a common pest of cocoa and cashew. Knowledge on the feeding behaviour and biology of the pests of cultivated crops would enable the farmer in utilizing the technology effectively.

2.8. Pest Surveillance

Pest surveillance and monitoring system plays a major role in pest management in an organic farming system. The farming community has to be aware about the pest problems of the crop, the behavior and population ecology of the pests and their natural enemies for employing appropriate technology at a time of urgency. This is possible only through an effective transfer of technology programme by an interactive involvement of research- extension agencies and farming community.

3. Ecological Engineering for Pest Management

Ecological engineering for pest management has recently emerged as a paradigm for considering pest management approaches that rely on the use of cultural techniques to effect habitat manipulation and to enhance biological control. This novel approach is based on informed ecological knowledge rather than high technology approaches such as synthetic pesticides and genetically engineered crops.

Below Ground

There is a growing realization that the soil borne, seed and seedling borne diseases can be managed with microbial interventions, besides choosing appropriate plant varieties. The activities that can increase the beneficial microbial population and enhance soil fertility are:

1. Crop rotations with leguminous plants which enhance nitrogen content
2. Keeping soils covered (mulched) year-round with living vegetation and/ or crop residue
3. Adding organic matter in the form of farm yard manure (FYM), vermicompost, crop residue, which enhances the soil organic carbon as well as below ground biodiversity of beneficial microbes and insects.
4. Application of balanced dose of nutrients using biofertilizers based on soil test report
5. Application of biofertilizers with special focus on mycorrhiza and plant growth promoting rhizobia (PGPR)
6. Application of *Trichoderma harzianum/viride* and *Pseudomonas fluorescens* for treatment of seed/seedling/planting materials in the nurseries and field application (if commercial products are used, check for label claim and certification under organic cultivation). However, no registration is required for biopesticides that are produced by farmers for own consumption in their fields.

Above Ground

Natural enemies play a very significant role in control of foliar insect pests. Diversity of natural enemies contributes significantly to management of insect pests both below and above ground. They may require food in the form of pollen and nectar; shelter, overwintering sites and moderate microclimate, *etc.* and alternate hosts when primary hosts are not present.

In order to attract natural enemies, the activities to be practiced include the following:

1. Raise the flowering plants/compatible cash crops along the borders of the plantation by arranging shorter plants towards main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population.
2. Grow flowering plants on the internal bunds inside the field.
3. Allow naturally growing weed plants such as *Tridax procumbens, Ageratum* sp, *Alternanthera* sp *etc.* which act as nectar source for natural enemies.
4. Reduce tillage intensity so that hibernating natural enemies can be saved.

5. Grow appropriate companion plants which could be trap crops and pest repellent crops. These crops will also allow natural enemies as their flowers provide nectar and the plants provide suitable microclimate.
6. Due to enhancement of biodiversity by the flowering plants, the number of parasitoids and predators (natural enemies) will also increase. The major predators are a wide variety of spiders, ladybird beetles, long horned grasshoppers, Chrysoperla, earwigs, *etc*.

4. Future Thrusts in Pest Management

The increasing awareness on the ecological aspects of pest management and the inclination to conserve ecosystem without disruption for maintenance of sustainability among various stake holders are appealing in recent years. Utilization of frontier areas like information technology can make tangible effects in safer pest/disease management systems. Proper planning on the adoption of apt control measures to save the crop is possible through reliable prediction of pest/disease out break based on weather forecast. Employment of modem tools like remote sensing and geographical information system (GIS) will be useful in assessing crops loss and pest/disease incidence and using the information from such sources, advance action plan can be taken up to schedule effective plant protection strategies over larger areas within short period. Exploring the potential of farmer's knowledge and finding out scientific basis for such indigenous technical knowledge of farmers are to be priority areas in our attempts to manage the plant health problems in organic agriculture. Bio informatics is a recent field by which speedy dissemination of information is achieved. This helps in proper understanding and timely action to tackle situations like accidental introduction or sudden out breaks of pest species.

5. Conclusion

All the proven cases with the promising bioagents have confirmed a meaningful way of pest management utilizing the indigenous fauna for the biological suppression of the pests of plantation crops especially coconut. The indigenous natural enemies proved to be quite useful in controlling the pests, particularly rhinoceros beetle and leaf eating caterpillar. The biosuppression of rhinoceros beetle by employing viral pathogen OrNV is documented as one of the classical examples of biocontrol of an insect pest. Proper monitoring and release of stage specific parasitoids could effectively bring down the population of coconut leaf eating caterpillar in the field. The current scenario warrants an augmentative release of these promising bioagents in areas wherever pest infestation is found. Spider fauna plays an important role in the natural suppression of pests in the field. Conservation of these biocontrol agents of the pests has become quite imperative. Limitation on use of pesticides or to identify safer and ecofriendly pesticides is required to integrate the biocontrol agents in IPM. As predators are mostly polyphagous, release of predators when parasitoids are active has to be avoided. Pollen and nectar bearing plants in the vicinity provides supplementary food for predators such as chrysopids, coccinellids and mites. More detailed studies on the bioecology of different species of parasitoids and predators affecting the key pests of plantation crops are to be undertaken with a view of utilizing them for biocontrol suppression of the pests. Farmer field schools have proved as the most effective tool in technology transfer and capacity building of farmers. Training farmers and setting up farm level production units of biocontrol agents would ensure timely distribution of quality bioagents to the stake holders. Community level approach is highly essential to curb pest/disease menace in plantation crops.

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