# *Chapter 11*

# Pests

☆ *Chandrika Mohan and A. Josephrajkumar*

## 1. Introduction

The coconut palm faces serious challenges ranging from diseases to damage by insect pests, all of which may reduce productivity by as high as 30 per cent (Gitau *et al.*, 2009). The perennial nature of palms provide a continuous supply of food and shelter for the pest population build up which cause considerable damage to the crops during all stages of their growth. This chapter will be confined with respect to insect pests, mites and rodents interrupting coconut production. The major pests of coconut palm in India are rhinoceros beetle (*Oryctes rhinoceros* L.), red palm weevil (*Rhynchophorus ferrugineus* Oliv.), leaf eating caterpillar (*Opisina arenosella* Walk.), eriophyid mite (*Aceria guerreronis* Keifer) and the white grub (*Leucopholis coneophora* Burm.) (Rajan *et al.*, 2009). Emerging pests like coreid bug, scale insects, mealy bugs, slug caterpillars and rodents cause considerable damage to coconut in certain locations.

## 2. Rhinoceros Beetle (*Oryctes rhinoceros* Linn).

*Oryctes rhinoceros* commonly known as rhinoceros beetle or black beetle is a major pest of coconut in all the coconut growing regions of the world. Comprehensive reviews on *O. rhinoceros* have been published by Gressitt (1953) and Bedford (1980, 2013). The beetle is a major pest of oil palm (*Elaeis guineensis*) and also infests other palm species like date palm (*Phoenix dactylifera*), palmyrah palm (*Borassus flabellifer*). Gressitt (1953) presented an elaborate list of food plants of which includes 45 species of monocot plants that the beetle has been reported to infest, over 30 species of palms.

## 2.1. Biology

Adults of *O. rhinoceros* are large beetles 30-35 mm long and 14-21 mm breadth, black or reddish black in colour, stout and possesses a characteristic cephalic horn which is relatively larger in males (Figure 11.1d). The pygidium is densely clothed with reddish brown hairs on the ventral surface in the female. The female *O. rhinoceros* beetles deposit yellowish-white eggs (Figure 11.1a) in almost any form of dead and decaying vegetable matter *viz.*, farmyard manure, heaps of rotting paddy straw, wet sugar-cane trash, coir pith, composting plant tissues, decaying coconut logs, left over coconut stump *etc.* Average fecundity per female is 108 eggs. The larval and pupal stages are completed in the breeding grounds. The grubs are creamy white in colour with the body strongly arched dorsally (Figure 11.1b). Grub period is about 130 days with three instars. The pupa is uniformly brown in colour (Figure 11.1c) and is slightly convex dorsally and the pupal period varies from 20-29 days. Adult longevity is 3 - 4 months. Adults are active during night and remain hidden during daytime in the feeding or breeding sites. The life cycle from egg to adult stage takes about 5-6 months (Nirula, *et al.*, 1952; Nirula, 1955a, b).

## 2.2. Damage

The robust adult beetles cause damage to palms at all age groups by burrowing into the unopened spear leaf and feeds on juice from the host tissues. As the pest

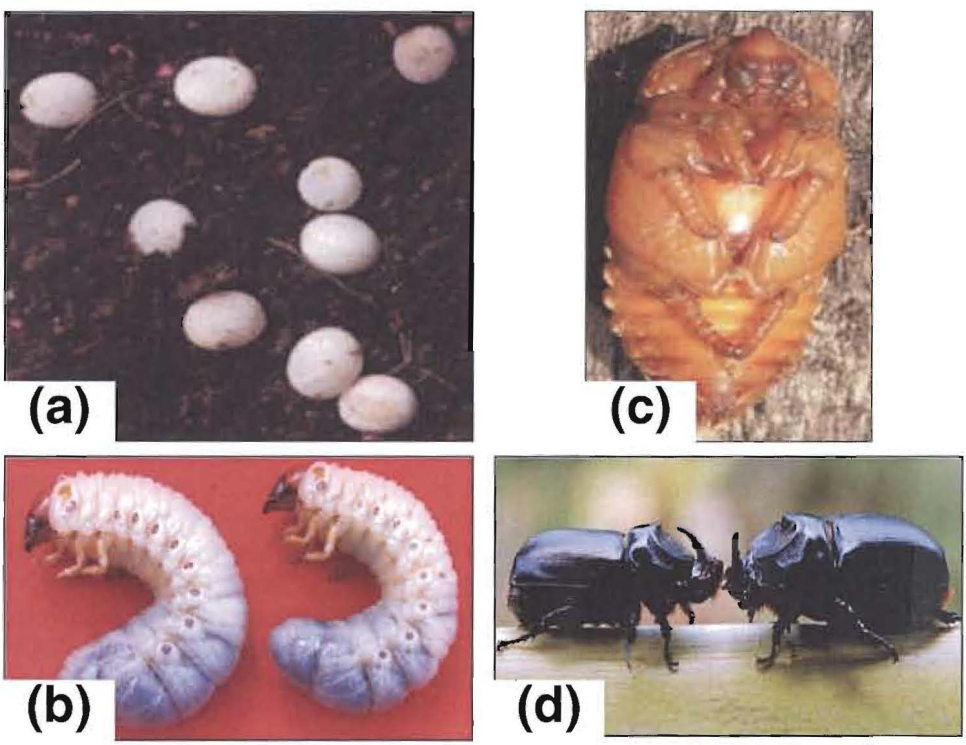


**Figure 11.1: Life Cycle of Rhinoceros Beetle**
**a) Eggs, b) Grubs, c) Pupa, d) Adult beetles.**

burrows deeper into the host (10-50 cm) it pushes out the chewed up tissues as fibres, which are seen extruding from the entry points (Figures 11.2b,c) once these injured leaves unfurl, they present a 'V' shaped cut pattern (Figure 11.2a). The damage to inflorescence is seen as round to oblong holes on the spathes, which soon dry up resulting in complete loss of nuts in the affected bunch. Attack in juvenile palms results in stunted growth and delayed flowering. Of late, it was found invading coconut seedlings in the nursery through collar entry and completely damaging the seedlings. Black beetle infestation has to be considered serious as the damage done by this pest provides egg laying sites for another lethal pest *viz.*, red palm weevil or for entry of fungal pathogens.

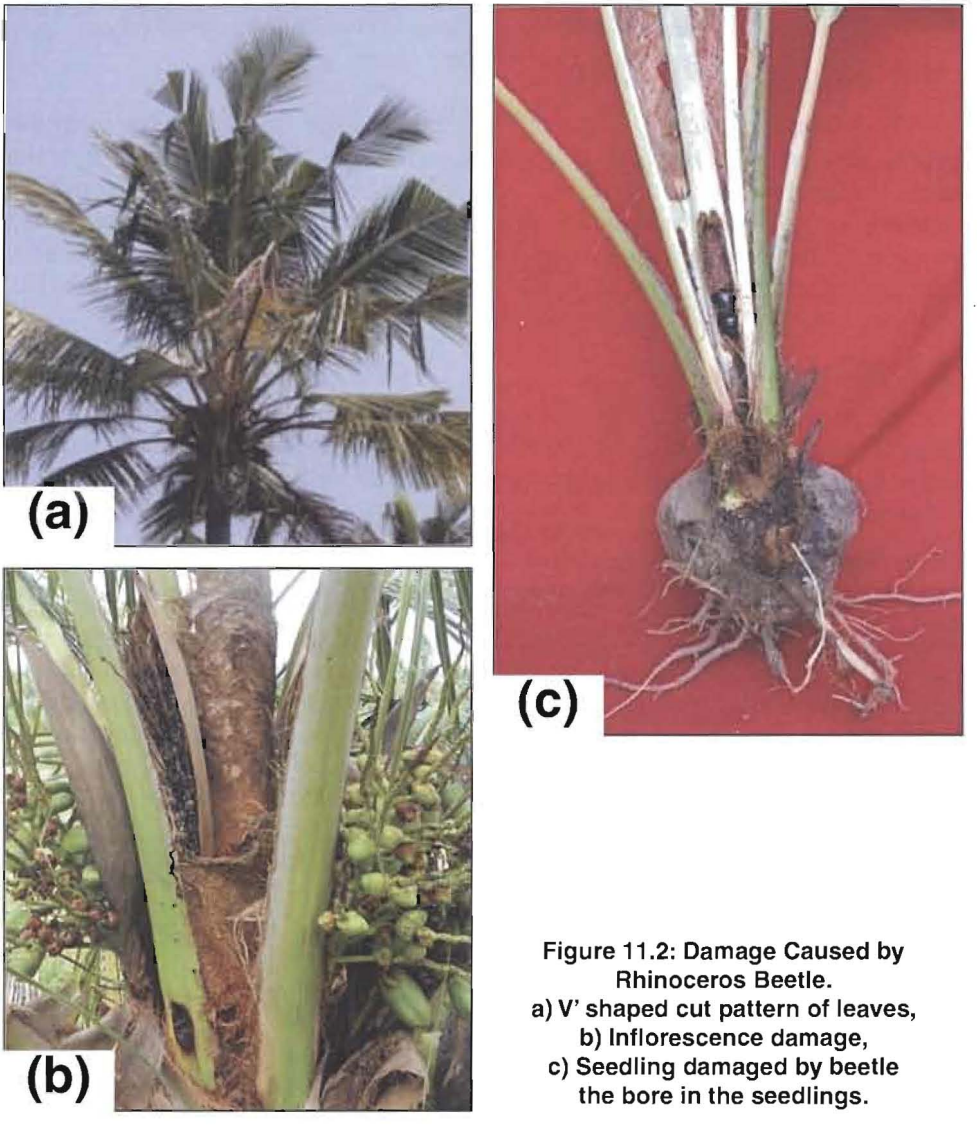


**Figure 11.2: Damage Caused by Rhinoceros Beetle.**
**a) V' shaped cut pattern of leaves,**
**b) Inflorescence damage,**
**c) Seedling damaged by beetle the bore in the seedlings.**

## 2.3. Pest Management

Since the pest is an active flyer, integrated pest management (IPM) strategies adopted on a community basis are essential to bring an effective control of *O. rhinoceros* population. The major components of IPM package consist of sanitation, mechanical, chemical and biological methods. Restricting and managing the breeding sites could check the proliferation of the pest. Incorporation of the weed plant, *Clerodendron infortunatum* Linn. @ 10 per cent w/w in the farm yard manure/ compost pit is suggested as a probable management strategy for rhinoceros beetle (Chandrika and Nair, 2000) as this plant exerts insect growth regulatory properties on *O. rhinoceros*. Larval-pupal or pupal-adult intermediates, adults with malformed wings *etc.* are some of the common abnormalities elicited by the plant in *O. rhinoceros*. These malformed adults were unable to fly and survived for only 6-8 days.

### 2.3.1. Sanitation Method

The best management option is the elimination of breeding sites from the coconut plantation itself that provide developing niche for immature stages of the beetle. The dead and decaying coconut logs, heaps of fallen coconut leaves, shredded palm tissues and other organic debris in the vicinity of coconut plantations may be properly disposed off, since this act as prolific breeding grounds of the beetle. Farm yard manure should be properly dried and stored and composting tanks has to be iron netted to prevent beetle access.

### 2.3.2. Mechanical Control

This method involves periodic examination of the palm crown and removing the adult beetle by means of a metal hook during peak periods of pest abundance (June- September) and the bore hole has to be filled with a mixture of neem cake and sand.

### 2.3.3. Prophylactic Method

Filling the young leaf axils of the palm with repellent material is the prophylactic method. Application of powdered oil cakes of neem (*Azadirachta indica* A. Juss.), or marotti (*Hydnocarpus wightiana* Bl.) @ 250g mixed with equal volume of sand, into the top most three leaf axils around the spear leaf thrice a year during May, September and December is recommended as a prophylactic measure against rhinoceros beetle and red palm weevil (Chandrika *et al.*, 2001). Placement of naphthalene balls at the base of three top most leaf axils @ 12g/palm (3-4 numbers) and covering them with sand to prevent quick evaporation provide good protection against the pest for 45-60 days (Sadakathulla and Ramachandran, 1990). Placement of two perforated sachets each containing 3 g chlorantraniliprole (0.4 per cent ai) or fipronil (80 per cent *ai*) or botanical cake (20g) developed by ICAR-CPCRI was found effective during monsoon phase. During dry period, 100 ml of water may be poured over the sachet after placement to release the molecule (Josephrajkumar *et al.*, 2015a).

### 2.3.4. Biological Control

This method is the most important component in the IPM of *O. rhinoceros*. Two potential microbial agents *viz.*, *Metarhizium anisopliae* and *Oryctes rhinoceros*

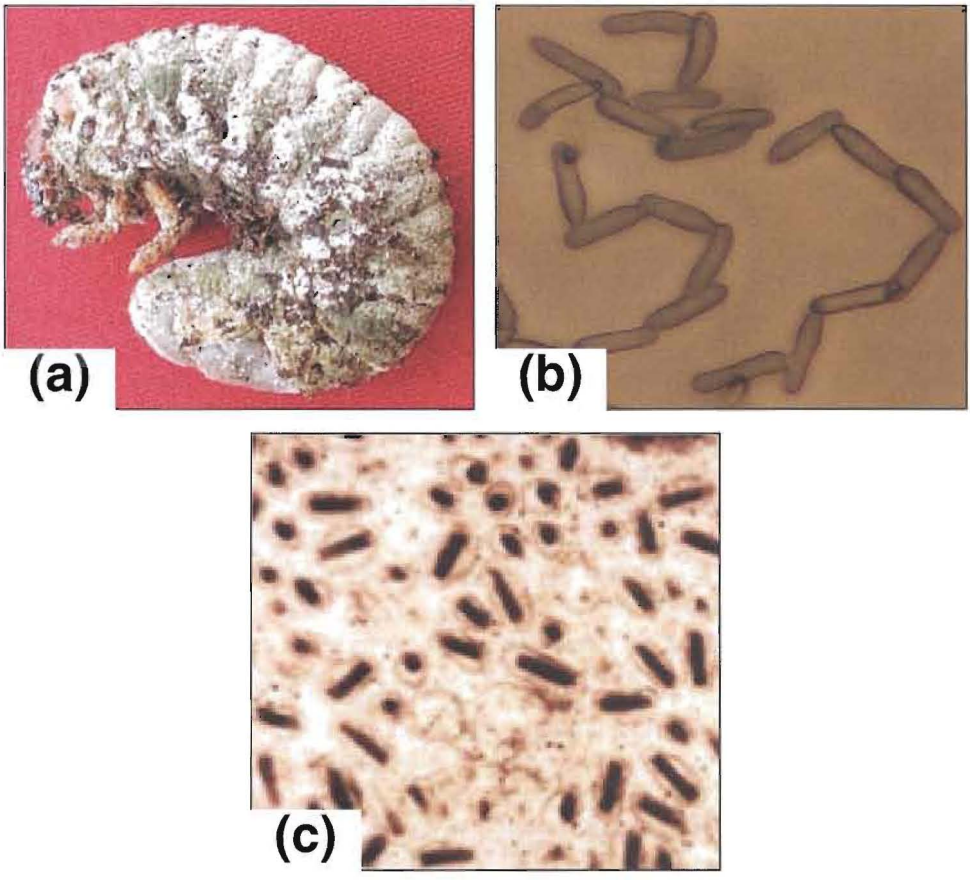


**Figure 11.3: Biological Control of Rhinoceros Beetle.**
**a) *Metarhizium anisopliae* infected grub; b) *Metarhizium anisopliae* spores;**
**c) *Oryctes rhinoceros* nudivirus.**

nudivirus (OrNV) cause disease to the immature and adult stages of the beetle (Figure 11.3). Use of these microbial control agents is advantageous because they are relatively host specific, does not cause environmental pollution, safe to humans and are compatible with other control methods.

The green muscardine fungus, *Metarhizium anisopliae,* causes epizootics in *O. rhinoceros* population during period of low temperature and high relative humidity (Nirula *et al.*, 1955). *M. anisopliae* var. *major* (spore size 10-14 µm) is highly infective and is being used widely for the control of this pest. It gains entry through membraneous joints of the cuticle of the host by mechanical and enzymatic action. All the stages of the host excepting the eggs are mycosed. Mass culturing of this fungal pathogen using cheaper substrates has been achieved and the fungal spores can be applied to the breeding grounds at $5.0 \times 10^{11}$ spores per $m^3$ (Dangar *et al.*, 1991). Area-wide farmer participatory mass production strategies were standardized and validated for the biomanagement of rhinoceros beetle (Chandrika *et al.*, 2010c;

Anithakumari *et al.*, 2016). *Oryctes rhinoceros* nudi virus attacks the larvae and adult beetles (Zelazny, 1979) and has been highly successful in reducing beetle populations in the South Pacific region. Field release of virus inoculated adult rhinoceros beetle reduces the damage caused by this beetle. Presence of OrNV in Kerala, India was reported by Mohan *et al.* (1983) Or NV gains entry in to the host orally through contaminated food material. Infected grubs become lethargic, stop feeding and crawl to the surface of the feed. As the virus multiples, the haemolymph content increases, fat bodies disintegrate and the midgut filled with black solid food is replaced with white viscous mucoid fluid. Dissemination of virus for pest management is effected by release of virus infected rhinoceros beetles @ 10-15 beetles/ha. The viral pathogen produces 100 per cent reduction in the egg laying capacity of female beetles and 40 per cent reduction in life span of affected population (Pillai, 1993). Extensive studies on the use of OrNV to suppress rhinoceros beetle population in Islands of Lakshadweep and Andaman-Nicobar had shown encouraging results during the last four decades (Mohan *et al.*, 1989; Pillai *et al.*, 1993; Jacob, 1996). The effectiveness of IPM package for management of rhinoceros beetle was well documented in mainland also (Nair *et al.*, 2010). Thus the success encountered by the use of this microbial pathogen has endorsed its claim as one of the landmark examples in the biological control of any insect pest.

### 2.3.5. Semiochemicals

Aggregation pheromones have been identified for the *O. rhinoceros* and *O. monoceros* as ethyl 4-methyloctanoate (Hallett *et al.*, 1995; Gries *et al.*, 1994) and these are commercially available. Specially designed PVC tube trap employing synthetic pheromone ethyl 4-methyloctanoate has been found to be quite feasible for trapping black beetles in good numbers (APCC, 2007, Rajan *et al.*, 2010; Nair, *et al.*, 2010). The traps are set up in the gardens @ 1 trap/ha and beetles trapped inside are collected periodically.

## 3. Red Palm Weevil (*Rhynchophorus ferrugineus* Olivier)

Red palm weevil (RPW), a concealed tissue borer is a lethal pest of palms and is reported to attack 17 palm species worldwide. Although the weevil was first reported on coconut, *Cocos nucifera* from South Asia, during the last three decades it has gained foothold on date palm, *Phoenix dactylifera* in several Middle eastern countries from where it has migrated to Africa and Europe through movement of infested planting materials.

### 3.1. Biology

The adult weevils measure 35 mm long and 12 mm wide and ferruginous brown in colour. The snout is elongated in both sexes and the dorsal apical half of the rostrum in males is covered with a patch of short tuft of brown hairs (Figure 11.4). The mean fecundity is about 175 eggs per female and the creamy white oval eggs are laid in small holes scooped out on soft tissues of the palm. After hatching, the grubs tunnel their way into the trunk and feed on the internal contents. The full-grown grub is stout, fleshy and apodous measuring 50mm long and 20mm in width. The fully-grown grubs by winding around themselves the fibrous threads

make the elongate oval fibrous cocoon. The life span of the adult is 76-133 days and the weevil completes its egg to adult stages in 4 months (Nirula, 1956c; Abraham, 1994).

**Figure 11.4: *Rhynchophorus ferrugineus.***

## 3.2. Damage and Symptoms

This pest affects the palms particularly during the early periods of growth below 20 years. Adult beetles lay eggs in the soft tissues in the cut or injured portions and the emerging grub tunnels into the stem and feeds on the tender tissues inside the palm. It remains hidden inside the palm for completing its life cycle and finally kills the palm if the infestation is unnoticed. The weevils are attracted to the fermenting smell and the pest incidence is quite severe in areas where palms are infected with bud rot/ leaf rot or infested by rhinoceros beetle. Usually the red palm weevil infestation symptoms are ambiently visible at advanced stage of pest infestation. However, on close monitoring of the palms some symptoms can be detected at the early stages also. Yellowing and later wilting of the inner and middle whorl of leaves, small circular holes on the palm trunk with exudation of amber coloured viscous fluid, longitudinal splitting of leaf base, gnawing sound of grubs and presence of cocoon/ chewed up fibers at palm base are the major symptoms of red weevil infestation. In general dwarf and hybrid palms are more susceptible to red palm weevil attack than tall genotypes. Shallow methods of planting and mechanical injuries on the palms also pave way for the pest attack. (Nirula, 1956c; Abraham and Kurian, 1975; Abraham, 1994; Nair *et al.*, 1997; Rajan *et al.*, 2009; Faleiro, 2006).

### 3.2.1. Pest Entry

a) Gravid females could selectively choose the crown region injured by the feeding rhinoceros beetle or leaf rot disease.

b) Entry through the leaf axil attachment at the trunk if the bearing bunches are dislocated from the point of contact due to overweight of developing nuts or succulence due to over nutrition.

c) Access through the collar or bole region where injury is met out through tractor or tiller ploughing as well as swollen bole region through erratic nutrient uptake and improper translocation.

The entry through crown region is more fatal and reported in good numbers in the endemic zones.

## 3.3. Varietal Preference

Among the two distinct types of coconut, dwarf cultivars are relatively susceptible to attack by RPW may be due to the presence of specific volatile cues

**Figure 11.5: Damage caused by Red Palm Weevil.**

and preferential substance for sustained feeding. Among the dwarf genotypes, Chowghat Green Dwarf, Gangabondom *etc.* are highly susceptible due to weak leaf axils to withstand the heavy nut load leading to fissures and injury. Adequate care and prophylactic leaf axil filling of insecticides can save the palm. Palms in the age group of 5-15 years irrespective of types are highly susceptible because the growing tip is so bulged out at this period on account of initiation of flowering and fruit set. Moreover, such juvenile palms are nutritionally empowered to feed one colony of eggs laid by adult weevil successfully. Though farmers prefer dwarf genotypes and many are found resistant to root (wilt) disease, strict monitoring and care would be the key of success for good establishment in dwarf palms (Josephrajkumar *et al.*, 2014 a).

## 3.4. Pest Management

Early detection of infestation in the field is important for any RPW-IPM programme. Being the internal tissue borer, it is very difficult to identify pest infestation symptoms at an early stage. Hence, close palm surveillance has to be stressed for early pest detection and management. An IPM for managing red palm weevil has been worked out and currently practiced with the following important components *viz.*, phytosanitation, prophylactic treatments, curative chemical treatments and pheromone trapping (Abraham and Kurian, 1972; Rajan and Nair, 1997).

### 3.4.1. Palm Density

Maintaining optimum palm density during planting is very important not only for harnessing highest benefits of light energy but also reduce the release of volatiles orienting the pest away from the host. Spacing for tall varieties 8 x 8 m and dwarf varieties 7 x 7 m is found ideal. Interspaces can be effectively used for raising intercrops so as to admix and diminish the volatile cues disorienting RPW away from host (Josephrajkumar *et al.*, 2014b).

### 3.4.2. Farm Hygiene

Crown toppled palms in a garden should be immediately destroyed so as to avoid lateral spread of the pest in the immediate vicinity. Such a farm hygiene sanitation drive is the key factor to reduce the incidence of the pest as the entire biology of the pest resides within infested coconut palm.

### 3.4.3. Close Scrutiny and Scouting

Knowledge delivery on systematic diagnosis through close monitoring and vigilant scouting is the need of the hour. Trained palm technicians *viz.*, Friends of Coconut tree (FOCT) need to be adequately enriched on pest scouting and their skill upgraded through organizations such as ICAR-CPCRI, State Agricultural Universities, developmental agencies *etc.* for effective and timely monitoring, sensitization and diagnosis of this killer pest. Any physical and physiological change on the crown-top to bole-under region should be closely scrutinized by the farmer himself to detect the attack in early curable stage once it is diagnosed early cure is definitely a remedy.

### 3.4.4. Injury Prevention

Avoiding physical injury to palms is very critical to reduce pest incidence as the fermenting smell emanating from the injured tissues orient weevils for egg laying. While cutting fronds, leaving at least 1 m from trunk, evading knife injury on crown region during crown clearing/tapping and careful tractor ploughing shunning away from bole and frond region to avoid injuries need to be overemphasized.

### 3.4.5. Detector

The cryptic nature of RPW challenges visual detection at the early stage of pest infestation. Several workers have attempted for development of detection device for early detection of red palm weevil infestation in palms through sensor-based

techniques. Acoustic detection of RPW activity was suggested and attempted (Mankin, 2011; Soroker *et al.*, 2004; Hetzroni *et al.*, 2016; Srinivas *et al.*, 2013). The detectors further required fine tuning for field level application.

### 3.4.6. Prophylactic Leaf Axil Filling

Prophylactic leaf axil filling with oil cakes such as neem, marroti, pongamia (250 g) admixed with equal volume of river sand/naphthalene balls (12 g)/6 g chlory dust/6 g chlorantraniliprole admixed with 250g sand/palm could repel rhinoceros beetle and even if the beetle is alighted, the feeding is restricted to test bites only. Leaf axil placement of two perforated polythene-sachet containing 3 g Chlorantraniliprole safeguarded juvenile palms for about 4-6 months. In bud rot endemic zone, placement of *Trichoderma*-coir pith cake was found effective. Lesser the physical damage on palms, lesser is the invasion by RPW. Therefore, prophylactic techniques not only prevent attack by rhinoceros beetle and bud rot infection, but also protect the palm from RPW incursion.

### 3.4.7. Chemical Control

After diagnosis, application of imidacloprid 18.5 SL 0.02 per cent (1 ml per litre of water) or spinosad 2.5 SC 0.013 per cent (5 ml per litre of water) or indoxacarb 14.5 EC 0.04 per cent (2.5 ml per litre of water) was found effective in the suppression of the pest (Josephrajkumar *et al.*, 2014b). Insecticide treatments are usually done after harvest of nuts and therefore a safe waiting period of 45 days is accomplished in this process before the next harvesting. In most cases young non-bearing palms are invaded by the pest. It was also found that there was no detectable residue of imidacloprid on leaves, nut and meat even after one-day after treatment up to 30 days period.

### 3.4.8. Entomopathogenic Nematodes

Entomopathogenic nematode (EPN) *Heterorhabditis indica* showed high virulence (LC 50 355.5 IJ) in the suppression of *Rhynchophorus ferrugineus* grubs as well as greater susceptibility (82.5 per cent) of pre-pupal stage than that of grubs. Synergistic interaction of *H. indica* (1500 IJ) with imidacloprid (0.002 per cent) against red palm weevil grubs was also reported. Imidacloprid dose used in the interaction study was one-tenth of recommended dose employed for curative management of the pest. Combined application of *H. indica* and imidacloprid (0.002 per cent) would be an effective curative treatment in the field level management of red palm weevil in coconut (Josephrajkumar *et al.*, 2013).

### 3.4.9. Semiochemicals

The most viable technology of RPW management through semiochemicals has been attempted for quite some time. With the synthesis and availability of ferrugineol based pheromone lure for RPW, the IPM programme was modified to incorporate pheromone traps and it was successfully utilized to combat the pest in coconut and date palm (Faleiro, 2006). Installation of pheromone traps with ferrugineol embedded on nanoporous matrix @ 1 trap/ha was found effective in mass trapping of weevils (Subaharan *et al.*, 2014). Impregnation of kairamonal

blends containing host-induced volatiles enhanced the weevil catches substantially. Slow and sustained release of pheromone blends for a period of six months was achieved in nanoporous matrix along with the reusable strategy of the matrix. Timely servicing of food baits once in 6 days and avoiding traps in gardens with juvenile palms or palms intercropped with tall intercrops (banana)has to be ensured. A farmer-participatory community approach would be the key factor in successful field realization. Palms around the traps would be monitored strictly to avoid slippages, if any.

## 4. Eriophyid Mite (*Aceria guerreronis* Keifer)

Coconut eriophyid mite, *Aceria guerreronis* Keifer (Eriophyidae: Acarina) is the most destructive pest among the various species of eriophyid mites affecting coconut palm in 30 countries of Tropical America, Africa and Asia. In India, coconut eriophyid mite was first reported from Ernakulam district of Kerala during 1998 (Sathiamma *et al.*, 1998). Within a short span of time the mite had spread rapidly to all major coconut growing regions of the country and currently its incidence is seen in entire coconut growing states of West and East Coast of India and North-East part of India (Nair, 2000; Ramaraju *et al.*, 2000; Mallik *et al.*, 2003; Khan *et al.*, 2003). The occurrence of the pest was also reported from Lakshadweep Islands (Mullakoya, 2003). Coconut palm is the primary host of *A. guerreronis*. It has also been recorded from cocosoid palm *Lytocaryum weddelliana* in Brazil (Flechtmann, 1989) and palmyrah palm (*Borassus flabellifer*) in India (Ramaraju and Rabindra, 2001).

### 4.1. Biology

Coconut mite is a microscopic creamy white, vermiform organism measuring 200-250 microns in length and 36-52 microns in breadth. The body is elongated, cylindrical, finely ringed and bears two pairs of legs at the anterior end (Figure 11.6). Mites attain sexual maturity within a week's time and start laying eggs. An adult mite lays about 100-150 eggs. The eggs hatch into protonymphs, deutronymphs and finally to adults. The total life cycle is completed in 7-10 days.

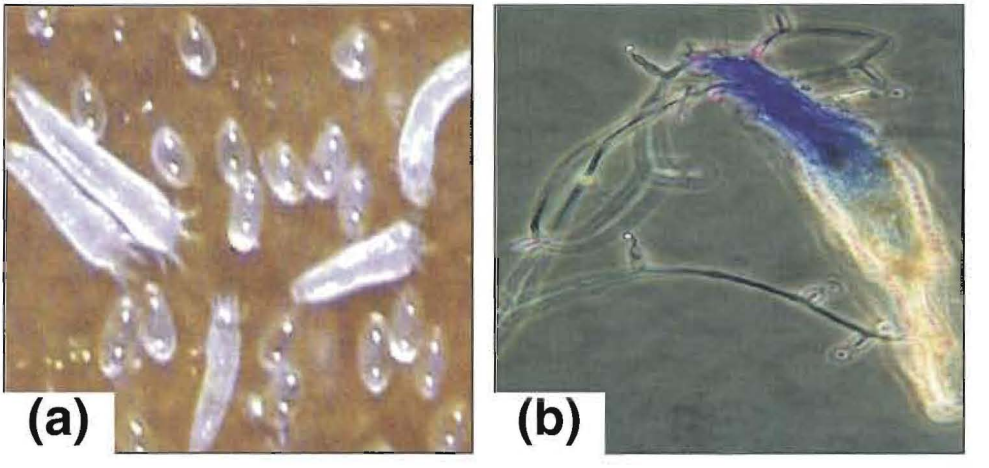


**Figure 11.6: a. Eriophyid Mite Colony; b. *H. thompsonii* Infected Mite.**

## 4.2. Nature of Damage and Symptoms

In coconut, mites infest the developing young buttons after pollination and are seen in the floral bracts (tepals) and the soft meristematic portions beneath the perianth. Entry of the mite into the nuts takes place during the early phase of the development immediately after fertilization. The mite thus gaining entry into the nuts multiply and form active colonies containing various stages of development *viz.*, eggs, nymphs and adults. Usually in a developing nut, the coconut mite colonies are seen as 2 or 3 congregations on the meristematic regions of the buttons below the perianth. Under favourable conditions, the high reproductive potential and shorter life cycle of the mite result in the enormous multiplication of the colonies. When colony size becomes substantially increased, mite comes out of the interspaces between the tepals of the developing nut for dispersal. The dispersal of the pest takes place mainly through wind. Honeybees and other insects visiting inflorescence of coconut also act as agents for dispersal (Rajan *et al.*, 2010).

The mite infestation symptoms are observed approximately one month after the initial colonization of the mite inside the fertilized buttons. Appearance of elongated white streaks below the perianth is the first external visual symptom on young buttons (Figure 11.7). In many cases, an yellow halo develops around the perianth. Within a few days this halo develops into yellow triangular patch pointing towards the distal end of the button. This can be clearly seen in 2-3 month old buttons. In a short time the yellow patch turns into brown and show necrotic patches on the periphery of the perianth. As the nut grows the injuries form warting

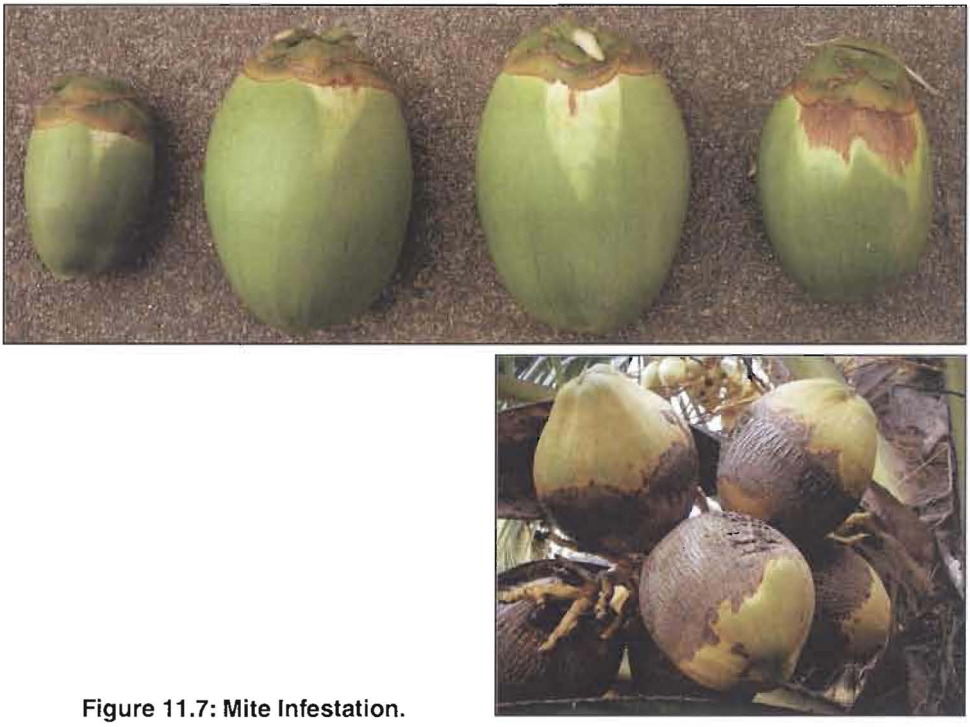

**Figure 11.7: Mite Infestation.**

and longitudinal fissures on the nut surface (Figure 11.7). In severe infestation the husk develops cracks, cuts and gummosis. Shedding of buttons and young nuts and malformation of nuts as a result of retarded growth are the other indications associated with severe attack of the pest (Nair, 2000).

In India, during 1998 when the pest outbreak was reported almost 70 per cent of nuts were affected showing malformation and reduction of nut size (Nair, 2000). But observations recorded during subsequent years revealed overall reduction in incidence and intensity of pest in areas of its initial occurrence (Nair *et al.*, 2003). In Kerala though pest damage has been reported initially ranging from 50-70 per cent, later surveys carried out in Alappuzha district during 2000 has shown significant reduction in crop loss indicating an average loss of 30.94 per cent in terms of copra and 41.74 per cent in husk production (Muralidharan *et al.*, 2001). Surveys carried out by ICAR-CPCRI in Kerala during 2004 registered lower levels of pest incidence with comparatively less intensity of infestation. The loss in terms of copra in Southern districts of Kerala ranged from 8-12 per cent compared to an average loss of 25 per cent in initial years (Rajan *et al.*, 2007).

## 4.3. Pest Management

Over five dozen systemic and contact insecticides have been evaluated world over and recommended from time to time for management of coconut mite (Nair *et al.*, 2005). In India also, a wide spectrum of pesticides have been tried by various research agencies including both Central Institutes and State Agricultural Universities (Nair *et al.*, 2005; Ramaraju *et al.*, 2000; Saradamma *et al.*, 2000; Mallik *et al.*, 2003). Owing to the concern over environment contamination by repeated chemical pesticides application, currently botanical pesticides *viz.*, neem based biopesticides are recommended for management of the pest in the field.

### 4.3.1. Cultural

Removal of dried spathes, inflorescence parts, fallen nuts *etc.* and burying them in the soil or burning them reduces the pest inoculums and consequent infestation.

### 4.3.2. Botanicals

Spraying 2 per cent neem oil-garlic mixture or azadirachitn 10,000 ppm @ 0.004 per cent or root feeding with neem formulations containing azadirachtin 50,000 ppm at 7.5 ml or azadirachtin 10,000 ppm at 10 ml with equal volume of water three times during March-April, October-November and December-January is recommended for the management of the pest (Rajan *et al.*, 2009). Three sprayings of palm oil (200 ml) and sulphur (5g) emulsion on the terminal five pollinated coconut bunches during January-February, April-May and October-November evinced significant reduction (67.4 to 69.8 per cent) of mite incidence (Josephrajkumar *et al.*, 2016).

### 4.3.3. Biological

Presently, emphasis is given for development of biocontrol strategies as they are safe and ecofriendly and vital in sustainable management of the pest. The fungal pathogen, *Hirsutella thompsonii* (Figure 11.8) has received considerable attention throughout the world as the most effective natural enemy of eriophyid mite of

coconut (Kumar, 2002; Beevi *et al.*, 1999; Kumar *et al.*, 2001). Application of talc based preparation of *Hirsutella thompsonii* @ 20 g/l/palm containing 1.6 x $10^8$ cfu with a frequency of three sprayings per year reduced mite population significantly (Chandrika *et al.*, 2014). The predatory mite *Neoseiulus baraki* is effectively utilized for biomanagement of the pest in Sri Lanka. Release of 5000 *N. baraki*at at 3-4 month intervals on to quarter of the coconut plantation for 2 years has been recommended to control the coconut mite (Aratchige *et al.*, 2012b).

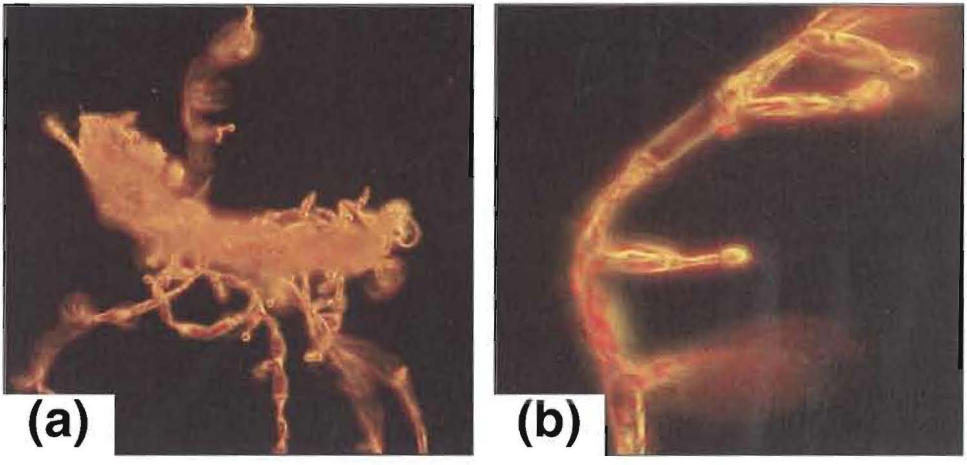


**Figure 11.8: a. *Hirsutella thompsonii* Infected Mite; b. *H. thompsonii* Spores.**

### 4.3.4. Varietal Preference

Kalpaharitha (a selection of Kulasekaram Tall) recorded lowest mite incidence in the field at ICAR-CPCRI and could be a preferred choice in endemic zones (Josephrajkumar *et al.*, 2016).

### 4.3.5. Plant Health Management

The nutritional status of the palm plays a significant role in the management of the pests. The nutrient management package consists of balanced application of NPK fertilizers at recommended doses in two splits (Urea 1.0 kg, rock phosphate 1.5 kg, muriate of potash 2.0 kg), recycling of organic biomass in coconut ecosystem using *in situ* vermi composting or growing of green manure crops like cow pea or sunnhemp and its incorporation in coconut basin and conservation of soil moisture by appropriate mulching methods.

IPM package was demonstrated in farmer's fields at Krishnapuram village, Kerala covering 25 ha area of coconut gardens in 208 farmer holdings. Here the integrated nutrient management technology was implemented along with recommended practice of azadirachtin spraying thrice a year and the mite incidence could be brought down to 15.3 per cent from 68 per cent over a period of three years (Rajagopal *et al.*, 2003).

## 5. Black Headed Caterpillar (*Opisina arenosella* (syn. *Nephantis serinopa*)

The black headed caterpillar, *Opisina arenosella* (syn. *Nephantis serinopa*), is a major pest of coconut in India and Sri Lanka (Rao *et al.*, 1948; Nirula, 1956a,b; Jayaratnam, 1941). In India, this pest is distributed in Andhra Pradesh, Gujarat, Karnataka, Kerala, Maharashtra, Goa, Orissa, Tamil Nadu, and West Bengal. It is mostly observed in the proximity of water bodies especially in the coastal and backwater tracts and occasionally in the interior areas adjacent to river beds and paddy fields.

### 5.1. Bioecology

The grey coloured adult moth is 10-15 mm long with wing expansion of 20-25 mm (Figure 11.9). The male is smaller than female, with a slender abdomen ending in a short brush of scales. Eggs are laid on the abaxial surface of pinnae near old larval galleries which hatch in 5 days. Fecundity is about 137 eggs/female. Larval body is cylindrical, slightly compressed with three longitudinal reddish brown stripes dorsally and a black head (Figure 11.9). Average larval period is 42 days and the final instars measure about 154 mm long. There is a distinct pre-pupal stage for 2 days when the larva spins a whitish cocoon around its body and enters the pupal stage. The moth emerges out in about 12 days. The total life cycle from egg to adult takes about 8-10 weeks. The adult moths live for about 5-7 days (Nirula, 1956a; Nirula *et al.*, 1951; Chandrika and Sujatha, 2006).

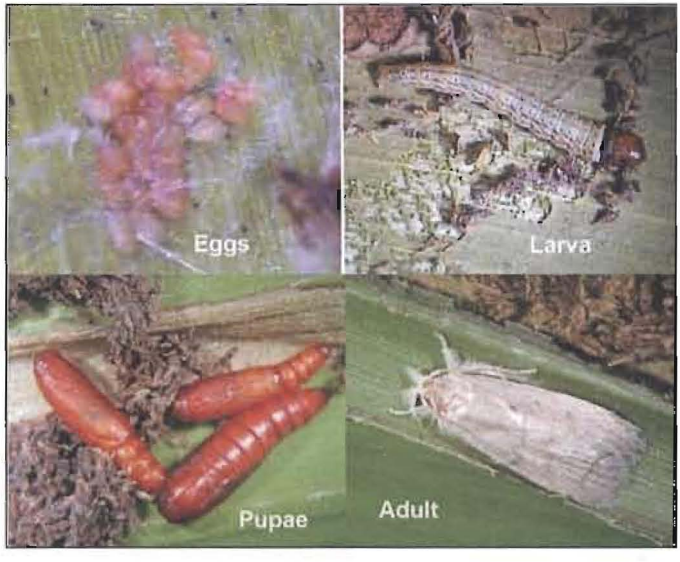


**Figure 11.9: Life Cycle of *O. arenosella.***

### 5.2. Damage and Symptoms

The voracious caterpillars feed on the chlorophyll containing leaf tissues leaving the thin upper epidermis. The affected portions get dried and form conspicuous grey

patches on the upper frond surface (Figure 11.10). Usually the feeding and drying starts from the outer whorl of fronds and proceeds inwards. Severe pest damage results in complete drying of middle to inner whorl of fronds also (Lever, 1969) from a distance the crown of such palms appears burnt (Fig.10). Close examination of pinnae shows presence of larval galleries with live or dead stages of the pest on the abaxial side. It is important to note that in coconut frond, drying occurs due to many reasons like lightning, drought, diseases *etc.* Hence in tall palms, dried fronds should be cut and examined for presence of larvae to identify the correct pest problem. As the palms succumb to heavy loss by the non functioning of affected fronds, a crop loss of up to 45 per cent in terms of nut yield was recorded from infested palms in the succeeding year of severe pest incidence apart from rendering the leaves unsuitable for thatching and other purposes (Chandrika *et al.*, 2010a).

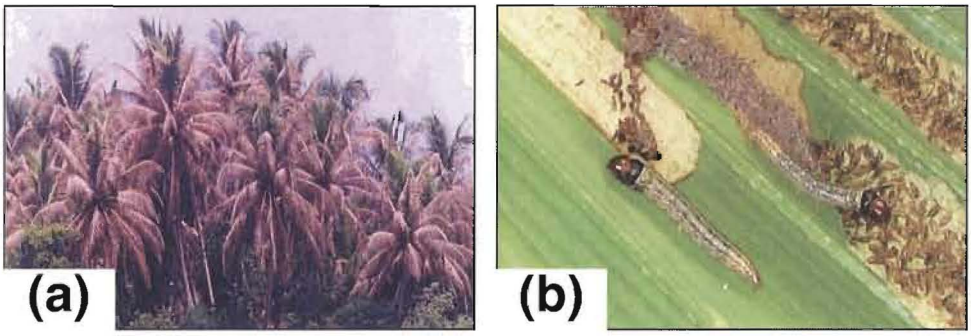


**Figure 11.10: Damage Caused by Black Headed Caterpillar, *Opisina arenosella***
**a) Burnt appearance of palms; b) Larval galleries.**

The pest infests coconut palms round the year from mild to medium intensities and affects palms of all age groups. Sporadic out breaks occur usually under favourable conditions. Generally in the West Coast of India, pest infestation reaches peak in hot summer months of February to May. Climatic factors particularly high temperature and relative humidity are correlated to pest outbreak on the East coast maximum population is reported from April to June. After the onset of monsoon, there will be decline in the population of the pest, but there is a chance of pest build up in the endemic areas from November – December. Hence, monitoring the endemic areas regularly at monthly intervals from November onwards helps in locating pest attack at a very early stage itself.

## 5.3. Pest Management

The pest can be effectively managed by the biological control methods. However, an Integrated Pest Management (IPM) strategy is recommended for management of the pest in severe out break conditions.

### 5.3.1. Mechanical

Early to mild stages of infestation can be reduced by cutting and burning the badly affected fronds/pinnae. In case of very severe infestation also, removal and burning of fully dried 2-3 outer whorl of leaves helps in removing the pupae and

other pest stages. Careless disposal of the pest affected leaves in the vicinity of healthy palms, can lead to newer infestations. This aspect has to be well taken care of while transporting pest infested leaves/leaflets to pest free areas as such or using pest infested leaves for wrapping other commodities for transporting to newer areas.

### 5.3.2 Chemical Control

Since a very rich natural enemy fauna is associated with the pest in the field, chemicals are generally not being encouraged for pest management of *O. arenosella.* In case of very severe out breaks one spray of chlorantraniliprole @ 0.1ml/L of water (0.002 per cent) is recommended. Spray solution has to reach the underside of fronds to drench the larval galleries of the pest. Due to the difficulty experienced spraying tall palms, chemical spraying recommendation is at a low profile in IPM.

### 5.3.3. Biological Control

Field performance on biological suppression of coconut leaf eating caterpillar through release of stage specific parasitoids was established as early as 1920s (Nirula, 1956a; Rao *et al.*, 1948) and successful field biocontrol of this pest by release of parasitoids are well documented (Sathiamma *et al.*, 1996; Ghode *et al.*, 1987; Cock and Perera, 1987; Sathiamma, 1993; Mohanty *et al.*, 2000; Chandrika and Sujatha, 2006; Venkatesan *et al.*, 2006; Sujatha and Chalam, 2009).

Among coconut pests, the black headed caterpillar in the natural environment is attacked by the highest number of parasitoids and predators. Among the 40 species of parasitoids recorded from India (Pillai and Nair, 1993; Sujatha and Singh, 1999), the larval parasitoids *Goniozus nephantidis* (Bethylidae), *Bracon brevicornis* (Braconidae), the prepupal parasitoid, *Elasmus nephantidis* (Elasmidae), and the pupal parasitoid *Brachymeria nosatoi* (Chalcididae) are the most promising ones. The major desirable attributes of these parasitoids are their greater host searching ability, production of higher proportion of females, occurrence throughout the year and their distribution in all pest infested areas. Techniques have been developed for mass production of the promising parasitoids. The pest infested area should be monitored regularly and parasitoid releases should be initiated at the post monsoon period during November – December at the very beginning of pest incidence. Parasitoids are released synchronized with the stage of pest in the field at fixed dosages at fortnightly intervals till the pest population is suppressed. Presence of larvae in the leaflets should be confirmed before release of parasitoids to avoid unnecessary wastage of parasitoids. The parasitoid *Goniozus nephantidis* (Figure 11.11) is released if the pest is at 3$^{rd}$ instar larval stage or above at the rate of 20 parasitoid/palm and *Bracon brevicornis* (Figure 11.11) at the rate of 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 at the rates of 49 and 32 per cent respectively for every 100 pre-pupa and pupae estimated to be present on the palm (Sathaimma *et al.*, 1987; Sathiamma *et al.*, 1996; Chandrika *et al.*, 2010b). Feeding the parasitoids with honey and exposing the newly emerged parasitoids to the host odours (smell of the volatiles of the injured *O. arenosella* larvae and host feeding gallery volatiles) was found to improve the host searching efficiency of *G.nephantidis* (Subaharan *et al.*, 2005). *G. nephantidis* and *B. Brevicornis* could easily

be mass multiplied on larvae of the rice moth *Corcyra cephalonica*. The prepupal 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.

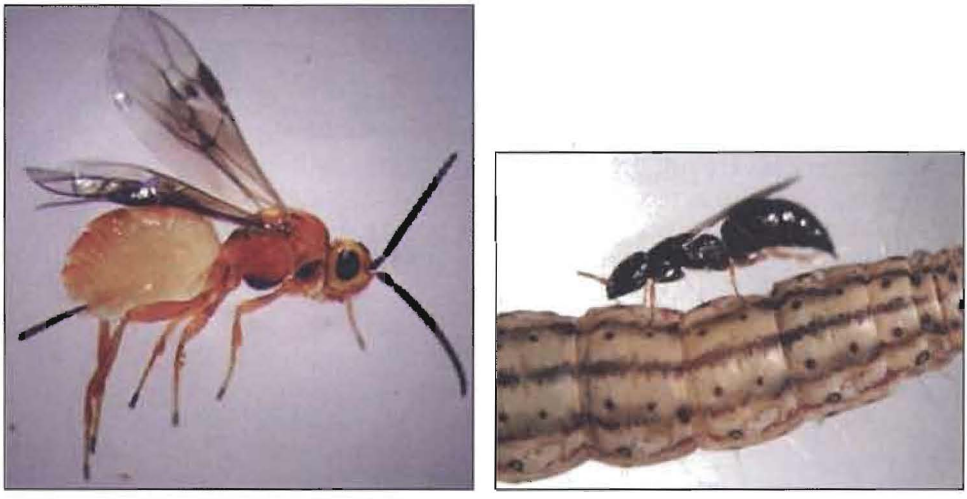

**Figure 11.11: Parasitoids *Bracon brevicornis* and *Goniozus nephantidis*.**

Insect and spider predators are abundant in the coconut ecosystem. The dominant insect predators are the carabid beetles *Parena nigrolineata, Calleida splendidula*; anthocoreid *Cardiastethus exiguus*, Chrysopids *Ankylopteryx* sp. *Chrysopa sp, etc.* A total of 26 species of spiders are recorded with the pest of which *Rhena, Sparassus* and *Cheiracanthium* are the major predators. Predatory ants also play major role in population reduction of *O. arenosella* in the field. Although some pathogens like species of *Serratia* and *Aspergillus* were reported on *O. arenosella* they are not so far exploited as effective biocontrol agents (Sathiamma *et al.*, 2001).

## 6. White Grub (*Leucopholis coneophora* Burm)

### 6.1. Damage and Symptoms

*Leucopholis coneophora* is a subterranean pest of coconut and occurs mainly in sandy loam soil and attains pest status in discontinuous patches along the Western coastal tracts especially of Kerala and Karnataka. They also feed on tubers, rhizomes and vegetables, which are grown as intercrops in coconut gardens. Continuous feeding by the grubs on mature palms results in yellowing of leaves (Figure 11.12), premature nut fall, tapering of stem, delayed flowering, retardation of growth and reduction in yield. Adult beetles emerge out of soil along with pre monsoon showers in May and peak grub population is seen in the coconut basin during August – October (Abraham and Mohandas, 1988; Chandrika and Vidyasagar, 1993).

### 6.2. Pest Management

Deep ploughing during pre and post-monsoon periods exposes the grubs to predators. Mechanical collection and destruction of beetles during peak emergence

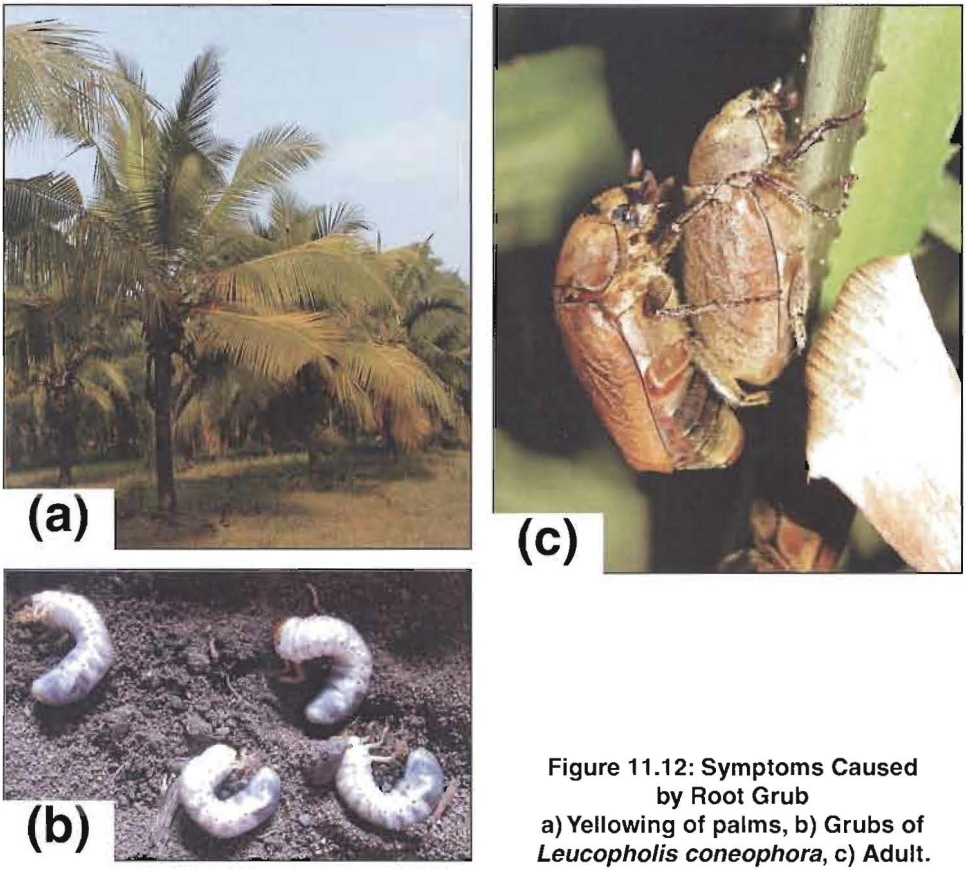


**Figure 11.12: Symptoms Caused by Root Grub**
**a) Yellowing of palms, b) Grubs of *Leucopholis coneophora*, c) Adult.**

period is adopted as an effective management practice and was found to be the highly significant than light trap collection. Drenching the root zone with chlorpyrifos 20EC @ 2.5ml/L or imidacloprid 17.8 SL @ 675 ml/ha or bifenthrin 10 EC @ 20 litre/ha during May-June and September- October are recommended for management of grubs (ICAR-CPCRI, 2015). A scoliid wasp, *Campsomeriella collaris* (Fabricius), eugregarine protozoan pathogen *Pseudomonocystis* sp., and *Codyceps* sp. were found to parasitize the grubs in the field under natural condition. Drenching aqua suspension of entomopathogenic nematode, *Steinernema carpocapsae* in the interspaces at 5-10 cm depth with 1.5 billion IJ/ha. Repeat application of EPN as and when needed based on the grub population.

## 7. Coreid Bug (*Paradasynus rostratus*)

Nymphs and adults puncture the meristematic regions of tender buttons (1-3 months old) injecting toxin around the feeding site causing necrosis and these spindle-shaped depressions could be visible (Figure 11.13) when the perianth of shed button is removed. Infested female flowers get dried and stay attached to the inflorescence. Most of the infested buttons and tender nuts shed down. Retained

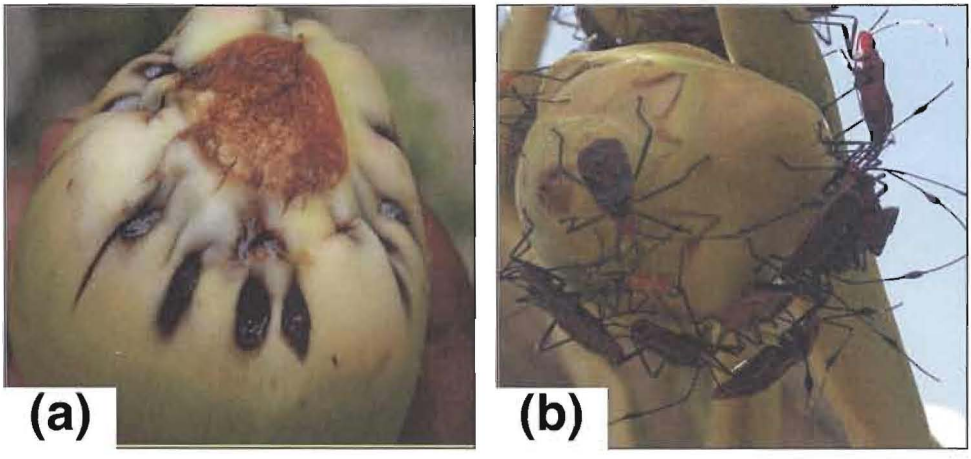


**Figure 11.13: a) Damage Caused by Coreid Bug; b) Adult Nymphs of *Paradasynus rostratus*.**

nuts on the bunch develop furrows and crinkles (Figure 11.13) on their husks and are malformed. In many cases gummosis can be seen on such damaged nuts.

Regular crown cleaning has to be undertaken to destroy eggs and immature stages of the pest. Spraying of azadirachtin 300 ppm @ 0.0004 per cent (13 ml/l) or lambda cyhalothrin @ 1ml/litre on young pollinated coconut bunches during May-June and September-October were found effective for satisfactory control of the pest in the field. Among the natural enemies, the weaver ant, *Oecophylla smaragdina* is found to be the most efficient predator of coreid bug in the field. *Chrysochalcisea indica. Chrysochalcissa oviceps* and *Gryon homeoceri* were identified as potential egg parasitoids.

## 8. Scale Insect (*Aspidiotus destructor*)

Scale insects are distributed throughout tropical and subtropical regions of the world, particularly on Islands and is present in all coconut growing tracts globally. Female scales are confined on the undersurface of leaves, but occasionally they attack frond stalks, flower clusters and young fruits. Crawlers of *A. destructor* settle and develop into scales with yellow spots. The bright yellow colour of affected palms is clearly visible from a great distance. In extreme cases, the leaves dry out and entire fronds drop off. Heavy infestation results in stunting of new leaves, reduction of crop yield or complete crop failure. Attack on fruits causes shriveling of nuts leading to premature nut fall (Lever, 1969; Howard *et al.*, 2001).

Strict surveillance on the transport of infested plant parts across borders should be envisaged. Heavily infested twigs and branches are to be pruned off to eliminate scales when infestations are on limited parts of the plant. Three sprays of 2.5 per cent fish oil resin soap or neem oil 0.5 per cent were found to be effective in reducing the population of *A. destructor*. Coccinellid beetles, *Chilocorus nigritus, Cryptognatha nodiceps, Pseudoscymnus anomalus, Pseudoscymnus dwipakalpa, Scymnus luteus, Rhyzobius* spp. and *Telsimia nitida* suppress the pest population by predation.

## 9. Slug Caterpillars (*Macroplectra nararia, Conthyla rotunda, Latoia lepida*)

Early-instar caterpillar feeds on undersurface of coconut leaflets by scrapping the surface tissues giving a glistening appearance on the feeding area. Leaf spot-like black halo marking develops on the feeding areas which later coalesce and form bigger lesions. Late instar caterpillars feed voraciously the leaf tissues leaving only the midribs and the feeding injury is often exacerbated by grey leaf blight fungus, *Pestalotiopsis palmarum*. In severely infested palms, premature drooping of leaves and shedding of nuts were also observed bringing drastic reduction in nut yield (Rajan *et al.*, 2011).

Establishment of light traps in endemic tracts could help in monitoring of the pest as well as reduce the population of moths (Sujatha *et al.*, 2011). Larvae of *M. nararia* are parasitized by *Eurytoma tatipakensis* Kur., *Euplectromorpha natadae* Kur. and *Secodes narariae* Kur under natural condition. Good nutrition as well as irrigation is required to recoup the infested palms which take about 20-24 months.

## 10. Rodents (*Rattus rattus wroughtoni*)

Rats scoop small hole about 5 cm diameter near the stalk region of 3-6 month old tender nuts which usually fall off in 2-6 days (Figure 11.14). Rats also damage leaf stalks, unopened spathe, female flowers and mature nuts in the field as well as in the stored nuts. This arboreal black rat usually construct nest on coconut crown using leaflets and other palm parts. Hence, removal of dried fronds, spathes etc. regularly from the crowns expose the nesting placing of rats to predators. A habitat alteration discourages rats from population build up on the crown. Planting coconut seedlings in correct spacing as well as destruction of fallen fronds and other palm residues at regular intervals is important to ward off the rat activity from coconut gardens. Wrapping the trunk of coconut trees using polythene sheets was found effective in reducing rat damage in Minicoy, Lakshadweep. Placement of 10 g Bromadiolone (0.005 per cent) blocks two times at an interval of 12 days on the

**Figure 11.14: Rat Damage in Coconut.**

crown of one tree, out of every five trees, is recommended for effective control of black rat (Bhat *et al.*, 1993). This method is highly cost-effective. If the damage is restricted to certain palms, only such palms require baiting. Rat snakes and Barn owls are the common predators that control the rat population. Absence of these two predators in Lakshadweep flared up the rat population in the Island system.

## 11. Alert on Invasive Pests

Bio-security covers the introduction of plant and animal pests and diseases, introduction of genetically modified organisms and their products and introduction and management of invasive alien species and genotypes. It is in this context the likely advent of insect pests like coconut leaf beetle (CLB), *Brontispa longissima* Gestro (Chrysomelidae: Coleoptera) and armoured scale insect, *Aspidiotus rigidus* Reyne (Diaspididae: Hemiptera) in India would be devastating and more likely an issue of bio-security in our country (Josephrajkumar *et al.*, 2015b).

A recent incidence of CLB in Maldives and Union of Myanmar, attacking the tender leaves of young coconut palms and its possible entry poses an imminent threat to coconut industry in India (Rethinam and Singh, 2004). The countries to the West of Myanmar, Bangladesh and India are at a very high level of risk. For a country like India, where coconut and coconut based industries support millions of people, the pest incursion would be catastrophic.

### 11.1. *Brontispa longissima*

Adult beetles measure 7.5-10.0 mm long and 1.5-2.0 mm wide, with a conspicuous orange to reddish pronotum. The anterior part of elytra is also orange to reddish in colour. Grubs and adult beetles inhabit the developing unopened still folded heart leaves of coconut palm and feed on leaf tissues.

### 11.2. *Aspidiotus rigidus*

Hard scale, *A. rigidus*, is a close relative of *Aspidiotus destructor*. Though *A. destructor* is under check by natural enemies, *A. rigidus* is ravaging Philippines incurring huge loss to coconut growers in that country. Bioinvasion of *A. rigidus* in Philippines has infested approximately 7,80,000 trees affecting 50-70 per cent of the coconut farms in Batangas and the nearby provinces (Watson *et al.* 2014). So far there is no report of *A. rigidus* infesting coconut palm from India. Strict quarentine regulations have to be imposed as these pests can be passively carried through any inert packaging materials, nuts *etc.*

### 11.3. *Wallacea* sp.

The chrysomelid beetle *Wallacea* sp. (Figure 11.15) feeding on the spear leaf region of coconut seedlings was recently recorded from South Andaman and little Andaman Islands (Prathapan and Shameem, 2015). Though 80-90 per cent of seedlings were infested by the pest damaging 40 per cent leaf area, seedling mortality was not observed. The feeding niche of *Wallecae* sp. confining on coconut spindle is a matter of concern, however, the pest was not observed from any adult palm during the snap survey conducted in October 2014 by ICAR-CPCRI (ICAR-

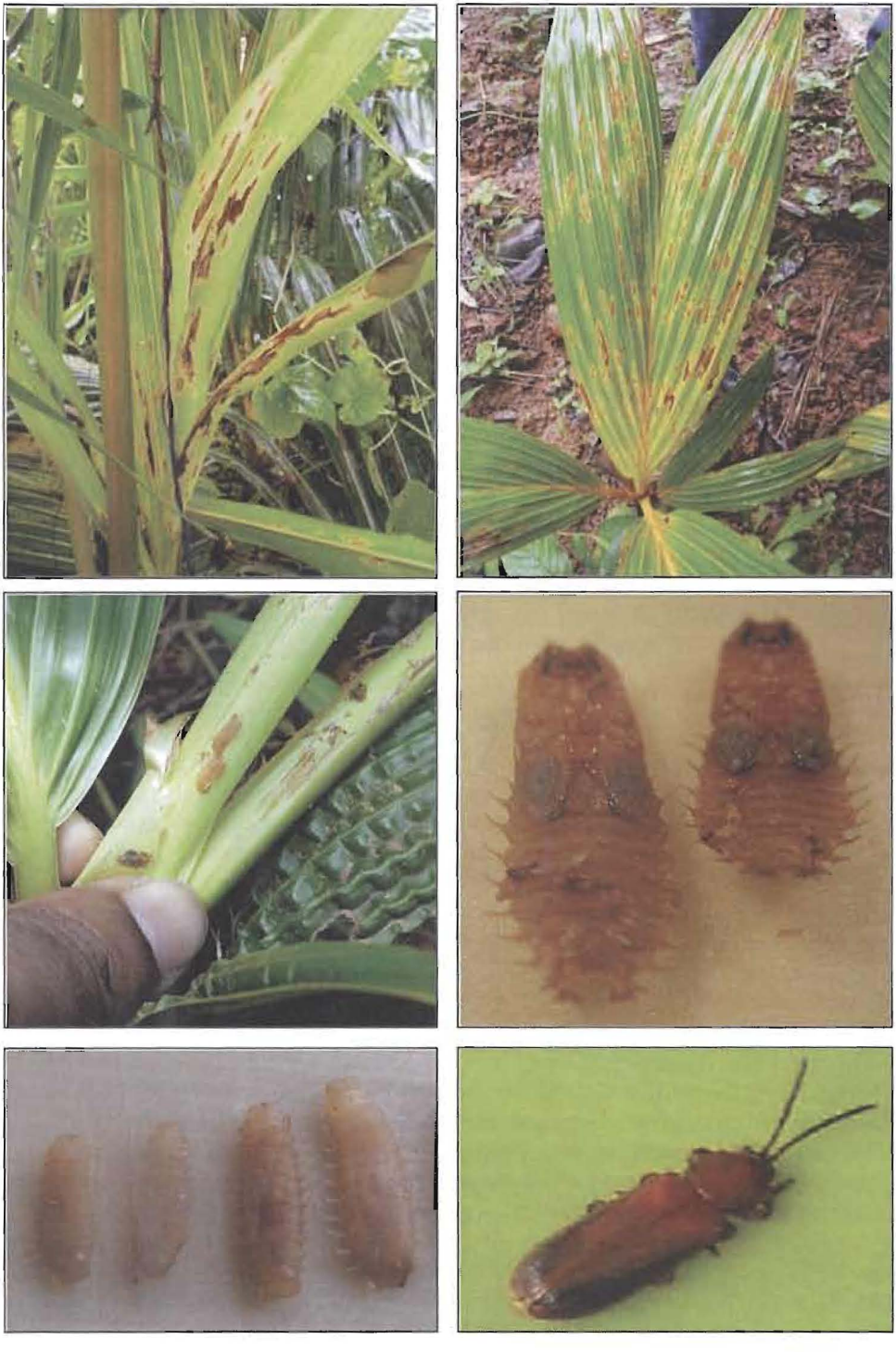

**Figure 11.15: Symptoms Caused by *Wallacea* sp.**

CPCRI, 2015). Invasive nature of *Wallacea* sp. is under scrutiny, as a close relative *Wallaceana* sp reported from Indonesia. Adult beetles are brownish with six rows of constrictions on each elytron and measured 4.72 mm long and 0.9 mm wide. They are active fliers may be for a short distance. Grubs possessed short-lateral spines on each body segments with prominent mandibles for active feeding and measured 5.75 mm long and 0.8 mm wide. Grubs and adults remain within the folds of the spindle leaves and feed from within. Typical feeding damage was seen within the leaf folds before unfurling along with faecal matters. In severe cases, the feeding streaks coalesce forming broader lesion with brown margin (Figure 11.15). Though a few feeding adult beetles were observed in between the leaf folds of emerged leaves, the grubs were mostly confined within the spindle region only. Pupae are located at the point of leaflet attachment to the main petiole. Pupae are exarate with exposed appendages and well-developed wing pads and are mostly located on the point of attachment of leaflet with the main petiole. Eggs could not be collected during the short survey programme. Incursion management of invasive pests involves strengthening quarantine, surveillance and monitoring as well as sensitization campaign. Finally, a planned and holistic programme through awareness creation, capacity building on incursion management and strict quarantine are essentially warranted to combat invasions due to such biosecurity threats. Creation of an incursion management team comprising of experts from all disciplines as well as an emergency preparedness module would be the need of the hour to tackle accidental introduction of invasive pests in to the country.

## 11.4. *Agonoxena argaula*

The coconut flat moth, *A. argaula* Meyrick (Agonoxenidae : Lepidoptera) is reported as a main pest on coconut in Pacific Island countries recorded maily from Fiji, Samoa, Guam, Hawaii, Palmyra and Tongo. However, its occurrence is not reported from our country so far and remains as a potential invasive species. Besides coconut, it also attacks other palms *viz.*, *Metroxylon* sp. and *Clinostigma* sp. Caterpillars feed from undersurface of coconut leaflets initially from middle aged leaves and extending to older ones giving a sick appearance to palms. In severe outbreak conditions, as high as 40 per cent leaf damage was observed causing 20 per cent nut reduction. In young palms, growth is tremendously affected. Long thin window-like feeding damage is explicit on leaflets and larvae are confined on thin web covering the leaflets. In many cases, the symptoms are akin to that of leaf eating caterpillar damage prevalent in South India. Eggs are laid on undersurface of leaves along the midrib. Caterpillars are greenish and turn yellowish measuring 2 cm when matured. When disturbed, caterpillars are extra active moving backward and forward and sometimes dropping down. Adults are small moth measuring 5-9 mm long with prominent white stripe on males. The pest build up is normally under check by the natural parasitism of stage-specific parasitoids *viz.*, *Apanteles* sp., *Bracon* sp. and *Brachymeri* sp (Lever, 1969; Jerard 2016, Personal communication). Any change in the biotic balance including weather factors lead to outbreak. Being a potential invasive threat, a careful surveillance and awareness campaign in synergy with stringent quarantine strategies are called for.

**Figure 11.16: Symptoms Caused by *Agonoxena argaula*.**

## 12. Conclusions

Pest management in coconut production system is very critical in the emerging climate change scenario where shift in pest status is quite imminent. The pest of minor importance is emerging as major pests, augmenting emphasis on ecological lineage and crucial interrelationship of pest-defender-pollinator in the ecosystem. A careful makeover from pest management to health management through agro-ecosystem based stimulo-deterrant diversionary approach is gaining momentum for sustainable pest suppression from a farmer-centric strategy, health management has opened vistas for community-centric farmer participatory module including Farmer Field School to subdue pest outbreak. A holistic approach is pivotal for accomplishing health management in palms with greater thrust on agronomic and soil health components. Potential threats of invasive pests need to be addressed by strengthening surveillance, effective quarantine mechanism and timely implementation of sensitization campaign. An emergency preparedness module in synergy with formation of incursion management team would be the need of the hour.

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