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Chapter 4

Cocoa

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1. Introduction

Cacao (*Theobroma cacao* L). is one of the most important cash crops grown worldwide. It is grown throughout the humid tropics with worldwide cultivated area of 50530790 ha in more than 75 countries. In India, it is cultivated in around 71000 with production of 15000 tonnes (FAO, 2014). Although cocoa has been cultivated for centuries in Central America, it is relatively new to Africa and even more recent in Asia. During 2013-14, the global production of cocoa is around 4370 thousand tonnes with the major producing countries are Cote d'Ivoire followed by Indonesia, Ghana, Nigeria and Cameroon (ICCO, 2015). It is mainly grown as a mixed crop in coconut and arecanut plantations and as under-storey crop in partially cleared forests. Over 1500 different insects are known to feed on cocoa, only about 2 per cent are of economic importance. These have been estimated to be responsible for up to 30 per cent losses in global production (Ploetz, 2007) and can play a major role in cacao boom and bust cycles (Clough *et al.*, 2009). In India, cocoa is known to be attacked by about 50 pests comprising mainly of mealybugs, tea mosquito bug, stem borer, aphids, stem girdler, leaf eating caterpillars and leaf eating beetles *etc.* (Rajagopal and Ananda, 2006).

2. Tea Mosquito Bug (TMB)/Mirids: *Helopeltis antonii* Signoret, *H. bradyi* Waterhouse and *H. theivora* Waterhouse

2.1. Occurrence and Distribution

Mirids are the major insects that affect cocoa worldwide. In Ghana, cocoa mirids have been recognized as a serious pest since 1908 due to their devastating effect. The most common species in Ghana and West African countries are *Distantiella theobroma* and *Sahlbergella singularis*. In South-East Asia, the *Helopeltis* spp. is responsible for

the damage related to mirids while *Monalonion* sp. are present in South and Central America. Little is known about the genetic background of mirids (Latip *et al.*, 2010). Of the 41 species of *Helopeltis* recorded in the old world tropics, only 3 species are confined to India *viz. H. antonii, H. theivora* and *H. bradyi* (Stonedahl, 1991). Among these, *H. theivora* is a major pest of cocoa and tea in India and Asia followed by *H. bradyi* and *H. antonii* (Srikumar and Bhat, 2013). It also has been reported damaging other economically important plants such as black pepper, camphor, cashew and cinchona (Stonedahl, 1991). Additional host plants of this species were given by Miller (1941) and Das (1984). In peninsular India, the population build-up of tea mosquito bug on cocoa occurs in the month of October to November and it synchronizes with cessation of the monsoon rain. Peak abundance noticed during January to February and the insects remain active until the onset of the monsoon.

2.2. Nature and Symptoms of Damage

A summary of feeding damage and visible symptoms on cocoa, tea and cashews is given by Stonedahl (1991). Nymphs and adults suck the sap from the young leaves and shoots of the host plants (Karmawati, 2007) to cause discolored necrotic area or lesion around the point of entry of the labial stylets into the plant tissue (Stonedahl, 1991). *Helopeltis* is typically a low density pest with high damage. Plants are strongly affected by the toxin injected during feeding by nymphs and adults (Asokan *et al.*, 2012), results in plasmolysis of the cells. Mirids feeding on shoots often result in the death of terminal branches and leaves, causing dieback (Figure 4.2). Cherelles develop characteristic eruptive spots and finally shriveled and fall off prematurely (Figures 4.1 and 4.2). Das (1984) reported that a single late-instar nymph of *H. theivora* could make as many as 80 feeding lesions in 24 hours. Feeding activity is highest in the early morning and late afternoon. Heavy infestations can lead to substantial levels of pod malformation and drop (Tan, 1974). Economic Threshold Level for cocoa mirid is about the one mirid per tree (Asogwa *et al.*, 2006; CRIN 2011).The chemical nature, potency of the toxin and the extent of damage by different species of *Helopeltis* vary depending on the species. Similarly there is a need to monitor natural enemies of *Helopeltis*, which requires their proper identification to the species level (Asokan *et al.*, 2012).

2.3. Biology

Adult bug is reddish-brown, about 6-8 mm long with a black head, red thorax, black and white abdomen (Figure 4.2). Female bug lays eggs on the tender tissues of new shoots, and soft tissues cherelles and pods. Eggs are reniform in shape and creamy white and microscopic. Presence of chorionic threads projecting outside the tissues is indicative of the presence of eggs inside. Mated female mirids lay up to 60 eggs that are embedded in the bark of stems or inside the pod husk. On hatching, young nymphs feed on tender leaves, which later become necrotic. Nymphs are wingless, orange coloured and ant-like with long legs. Nymphal development takes about 10-15 days with 5 instars. Longevity of female bug is for about 7 days, whereas male longevity is 9-10 days. Total life cycle completes in 25-32 days.

Guidelines for the determination of mirid damage threshold as reported by CRIN (2011) are:

1. Take a random sample of 100 cocoa trees for damage symptoms, such as lesion on pods, twig die back and canker
2. If less than 5 per cent damage is observed, do not spray
3. If between 5-25 per cent is damaged, apply spot spray,
4. If higher than 25 per cent damage is observed, then carry out blanket spray,
5. However, do not spray if more than 70 per cent of pod are ripen, and do not spray if harvesting of pod is due in less than 13 days
6. After pod harvesting, carry out a re-assessment to know whether to spray or not.

Table 4.1: Morphological differences of TMB Complex in Cocoa Garden

Sl.No.	*Morphological Characteristics*	*H. antonii*	*H. bradyi*	*H. theivora*
1.	Thorax/Body colour	Bright red or brownish black	Bright red or brownish black	Whitish stripe on the anterior portion with black thorax
2.	Abdomen colour	Black and white banded	Black and white banded	Light green in colour
3.	Hind femur	White band on the distal end	White band on the basal end (proximal)	No such white band
4.	Length of the antennae	Longer than body length	Longer antennae than other species	Longer than body length
5.	Body size	–	–	Smaller than other species

Scoring of TMB in Cocoa Garden

TMB damage can be quantified by recording die-back symptoms on shoots (per cent) from all four sides of the cocoa tree and the no of pods and cherelles damaged.

Grading of TMB attack on cocoa pods is as follows:

Score	*Damage Symptoms on Pods*
0	No lesions found on pods
I	25 per cent of the pods and cherelles with lesions
II	50 per cent of the pods and cherelles with lesions
III	75 per cent of the pods and cherelles with lesions
IV	Almost all the pods with lesion symptoms

2.4. Pest Management

- ☆ Shade and canopy management should be designed to achieve a balance between mirid control, flowering and black pod management and proper pruning to get maximum sunlight inside the canopy.
- ☆ Carry out regular observation for infestation during the month of September to April.

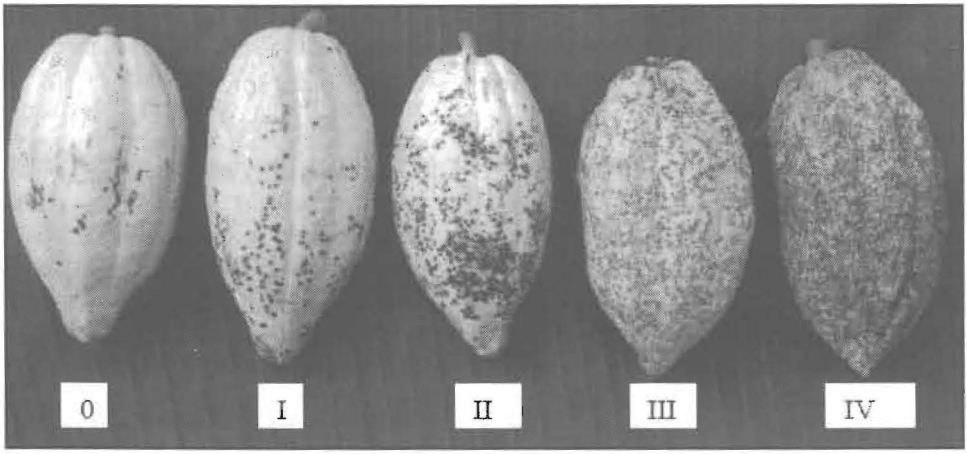

Figure 4.1: Tea Mosquito Bug Damage.

- ☆ Alternative hosts should not be used as shade trees on cocoa farms. Check the buildup of the pest population on cocoa as well as on the alternate hosts like cashew, guava, neem, drumstick, mahogany and black pepper in the vicinity of cocoa.
- ☆ Observe for any oozing out, necrosis symptoms. If the damage is more than 1 per cent, go for control measures.
- ☆ Spray imidacloprid (0.004 per cent) 17.8 SL @ 0.25 ml/lit. or lambda cyhalothrin (0.003 per cent) 5 EC @ 0.3 ml/lit. or Bifenthrin (0.008 per cent) @ 10 EC 0.8 ml/lit. If infestation persists, one more spray can be given at 20 to 30 days interval after first spray.
- ☆ Nymphs and adults of TMB feed generally in the morning and late afternoon hours. Hence, spraying operation should be carried out either in the early morning or late in the afternoon. Avoid spraying during mid-day as the bugs may hide under dense canopy.
- ☆ Spray *Beauveria bassiana* at 400g/acre at an interval of fifteen days (three times).
- ☆ Release of *Chrysoperla zastrowi sillemi* at 25,000 eggs per acre once.

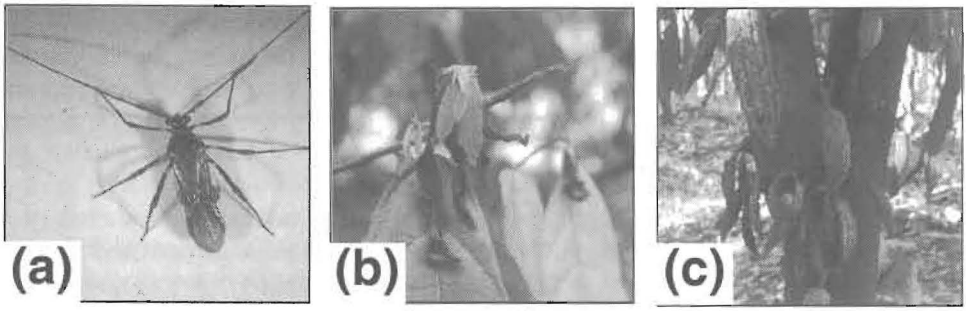

Figure 4.2

(a) Adult of *H. bradyi*, (b) Shoot with die back, (c) TMB infested cherelles.

3. Mealybugs: *Planococcus lilacinus* (Ckll.) and *P. citri* (Risso)

3.1. Occurrence and Distribution

P. lilacinus occurs mainly in tropical Asia and Oceania. Williams (1982) reported that the species was probably introduced into the South Pacific from Southern Asia. This pest is extremely polyphagous, feeding on tropical and sub-tropical fruit and shade trees within 35 families. Williams (1982), Cox (1989) and Ben-Dov (1994) provide comprehensive lists of hosts. Its chief hosts are cocoa, *Annona muricata, Psidium guajava* (guavas), *Ceiba pentandra* and species of *Bauhinia, Spondias* and *Erythrina* (Le Pelley, 1943). Other hosts include *Amaranthus gracilis*, bamboos, Citrus, Coffea, coconuts, *Ludwigia hyssopifolia, Mangifera indica, Mirabilis jalapa, Solanum nigrum, Solanum tuberosum, Sonchus arvensis, Spilanthes acmella* and *Vitis*. In India, it is reported as a serious pest causing damage to cocoa and is present in all the cocoa growing tracts of the country.

3.2. Nature and Symptoms of Damage

Both nymphs and adults of mealybug occur in colonies and infest growing shoots, terminal buds, flower stalks, foliage and pods and start sucking the sap (Figure 4.3). Symptoms on coconuts and cocoa are described as button nut shedding and drying up of inflorescence (Nair, 1981; Fernando and Kanagaratnam, 1987) and the death of tips of branches (Williams and Watson, 1988). Due to its damage, sunken patches in the developing pods result in the formation of scabs. Brown patches, irregular cracks and pits can be seen on mature pods. Dense colonies form conspicuous patches on fruits; copious honeydew excretion may result in sooty mould development near colonies and the attraction of attendant ants.

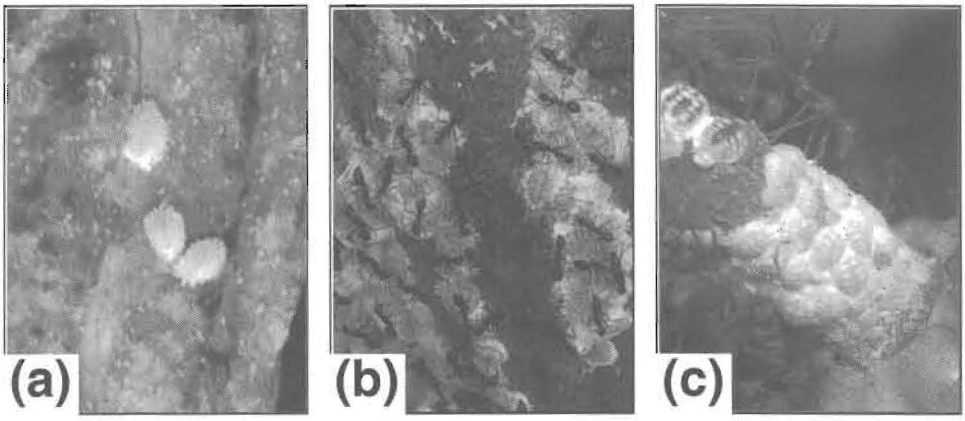

Figure 4.3: Mealybugs.
(a,b) *Crisicoccus hirsutus*, (c) *Planococcus lilacinus*.

3.3. Biology

Mealybugs are small, oval and light yellow. A female can lay around 200 eggs which hatch into nymphs within six hours. Nymphal period lasts for 20-25

days. Ants are attracted to the sugary substance excreted by the mealybugs and thus ants serve as protective and carrying agents for them. Though the pest occurs throughout the year, but peak population are noticed during April to May when the high temperature and low rainfall prevail in the Western Ghats region. With the advent of southwest monsoon, the population gradually declines (Nair, 1981).

3.4. Pest Management

- ☆ Timely pruning of the cocoa trees will reduce the colony build up.
- ☆ Neem oil suspension of 3 per cent may be sprayed on pods and foliage at the early stage of infestation.
- ☆ Spray Fenthion (0.04 per cent) 80 EC 0.5 ml/L or Dimethoate (0.06 per cent) 30 EC 2 ml/L. Give a second round of spray after 30 days if the incidence persists.
- ☆ Conserve natural enemies like coccinellid beetles (*Coccinella septempunctata, Scymnus coccivora, Chilocorus nigrita etc.*), syrphids (*Eristalis* spp., *Volucella* spp) and chrysophids (*Chrysoperla zastrowi sillemi*) which feed on the aphids and reduce the population.
- ☆ Release predatory lady bird beetles at 5-10 adults/tree.
- ☆ Destroy ant nests to minimise the spread of the pest.

4. Aphid: *Toxoptera aurantii* Boyer

4.1. Occurrence and Distribution

This is a polyphagous pest and its recorded hosts are chiefly shrubs and trees which comprises of 122 species belonging to 37 families in India. Alternate hosts includes camellia, coffee, *Ficus, Hibiscus, Ixora,* kamani, lime, macadamia, mango, mock orange, *Pittosporum,* pomelo and *Vanda* orchid. Occasional out breaks of *T. autantii* in citrus orchards and tea plantations made this insect pest as an economically important species in India. This insect is present throughout the year with a peak from August to January. Aphids, in general, are not considered as serious pests, but their severity results in leaf curling and flower wilt.

4.2. Nature and Symptoms of Damage

Both nymphs and adults colonize the tender leaves and shoots, cushions, cherelles, flower buds and feed on the tender plant parts. Severe feeding results in flower shedding and crinkling and twisting of leaves (Figure 4.4). Honey dew excretion attracts the sooty mould development, which hinder the photosynthetic rate.

4.3. Biology

Reproduction is mainly by parthenogenetic and viviparous and it occurs exclusively on the undersurface of flush leaves. The development of the aphid is temperature-dependent but at the optimum temperature, it takes 6 days to become adult passing through four instars. The incidence of alates in populations is influenced both by high aphid density and leaf age. Adult apterus, 1.60 ± 0.11


Figure 4.4: Colonies of *T. aurantii* on Cocoa Leaves and Flower Bud.

mm long, shiny black colour, oval in shape, antennae about two-thirds the length of the body, whereas alate are winged form, 1.65 ± 0.20 mm long, smaller in width than apterate and also relatively thinner (Firempong, 1997).

4.4. Pest Management

- ☆ Cultural practices like timely pruning of the cocoa trees will reduce the colony build up.
- ☆ Spraying Fenthion (0.04 per cent) 80 EC 0.5 ml/lit or Dimethoate (0.06 per cent) 30 EC 2 ml/lit. will reduce the incidence and spread. If re-occurrence of the pest is noticed, second spray may be given after an interval of 20 to 30 days.
- ☆ Natural enemies feed on the aphids and reduce the population. These include coccineld beetles (*Coccinella septempunctata, Scymnus coccivora, Chilocorus nigrita etc.*), syrphids (*Eristalis* spp., *Volucella* spp) and chrysophids (*Chrysoperla zastrowi sillemi*).

5. Thrips: *Selenothrips rubrocinctus* (Giard)

5.1. Occurrence and Distribution

The redbanded thrips, *Selenothrips rubrocinctus* (Giard), was first described from Guadeloupe, West Indies, where it was causing considerable damage to cocoa. As a result, it was referred to as the cacao or cocoa thrips. The earliest report relating to this thrips was a report by W.E. Broadway in 1898, when he called attention to the "blight" of cocoa. The redbanded thrips is a tropical-subtropical species thought to have originated in northern South America (Chin and Brown, 2008).

5.2. Nature and Symptoms of Damage

Symptoms of *S. rubrocinctus* attack on cocoa result from feeding by adults and/or larvae on the leaves and pods. On leaves, the feeding punctures cause the development of chlorotic spots and premature leaf drop, while on the pods, they cause brown patches that coalesce during severe infestations to form a dark brown, corky layer of dead cells that makes the estimation of pod ripeness virtually

impossible. Necrotic lesions are produced in the leaves and pods by adults and nymphs, and in the flowers by adults.

5.3. Biology

The female is about 1.20 mm in length and has a dark brown to black body underlain by red pigment chiefly in the first 3 abdominal segments; the anal segments retain a reddish black color, and the wings are dark (Figure 4.5). The male is similar, but smaller and is seldom collected. The nymph and pupa are light yellow to orange with the first three and last segments of the abdomen bright red. After hatching, there are two nymphal stages lasting 9-10 days. Fully-grown second stage nymphs are about 1 mm long. The two nymphal stages are followed by two resting stages (pre-pupal and pupal stages). The resting stages last 3-5 days before adults emerge (Chin and Brown, 2008).

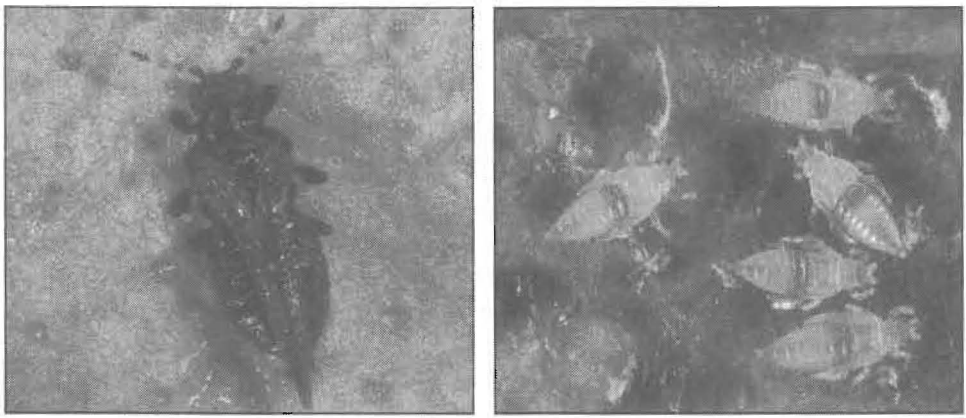

Figure 4.5: Adults and Nymphs of Redbanded Thrips.

5.4. Pest Management

- ☆ Redbanded thrips are preyed upon by a large assortment of natural predators such as spiders and mites, lacewings, predatory thrips, and predatory bugs, especially minute pirate bugs (Chin and Brown 2008; Funderburk *et al.*, 2007).
- ☆ Spray Fenthion (0.04 per cent) 80 EC 0.5 ml/lit or Dimethoate (0.06 per cent) 30 EC 2 ml/lit. Give a second round of spray after 30 days if the incidence persists.

6. The Red Branch Borer: *Zeuzera coffeae*

6.1. Occurrence and Distribution

This pest is found distributed in all the cocoa growing areas. The population is greater during post-monsoon months when up to 65 per cent of the plants may be damaged by the pest, in an endemic area. Entwistle (1985) reported this pest on cocoa from Sri Lanka, Malaysia, Java, West Irian and the territory of Papua New

Guinea, and a similar species on cocoa from Sabah and Peninsular Malaysia. *Zeuzera coffeae* is a pest of cocoa and is important as a branch and trunk borer of many trees.

6.2. Nature and Symptoms of Damage

This pest often flares up and causes conspicuous leaf necrosis and dieback of branches in mature cocoa, particularly in early maturity. The caterpillar bores into branches and the distal part subsequently dies. As the caterpillars grow older they will move down the stem, progressively attacking the older stem. The galleries formed are especially damaging to young cocoa, often causing the snapping-off of smaller branches (Figure 4.6). A characteristic yellowish or reddish mixture of fluid and frass particles is present on the attacked portion. The excreta are seen in lumps sticking on to the bark or in a heap on the ground below. The attacked part dies eventually, and in saplings, the whole plant may be killed from a single attack. This pest inside the branches is protected to a larger extent, direct application of insecticides into the bore holes leads to death of the caterpillar (Keane and Putter, 1992).

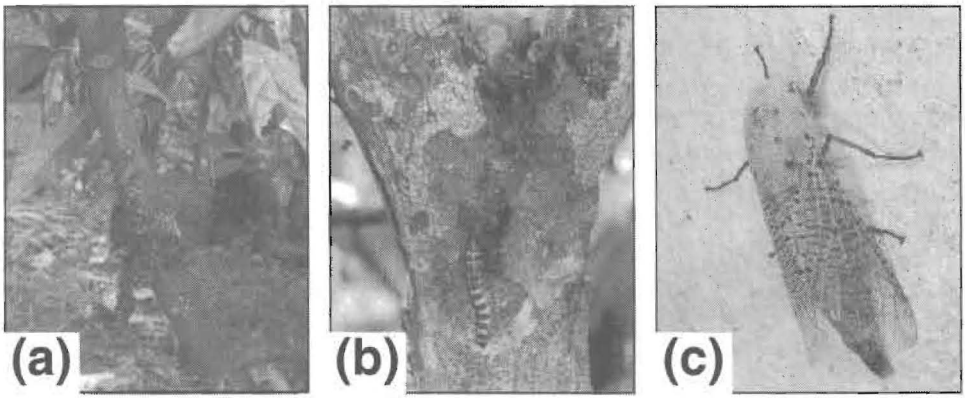

Figure 4.6

(a) Galleries on Stem made by *Z. coffeae*, (b) Larva boring into cocoa stem, (c) Adult of *Z. coffea*.

6.3. Biology

The eggs are yellowish and are laid in groups on the small stems and branches. They turn dark yellow prior to hatching. The young larvae remain together for some time, and then disperse by a silken thread which is caught by wind and carried to different branches. The full-grown larva has a brownish head and is predominantly reddish brown in colour, with an average length of 6.5 cm. The larval period lasts for 60-100 days. Before pupation the larva makes an exit hole covered by a loosely severed piece of bark. Pupation occurs inside the larval tunnels, and the life cycle takes about four to five months for completion. The adult is a leopard moth with wings which have dark spots on a white translucent background (Figure 4.6).

6.4. Pest Management

- ☆ Pruning of affected and dried branches and killing of larvae should be practiced. If the branches are not dried, killing larvae through a bore hole by inserting sharp iron needle can be tried.
- ☆ Applying insecticide solution (2 ml of Chloripyrifos/lit of water) by swabbing with cotton lint and keeping it in the bore hole will be effective.

7. Capsule Borer, *Conogethes punctiferalis* Guenee

7.1. Occurrence and Distribution

Conogethes punctiferalis is an important polyphagous pest attacking many economically important crops. Occurrence of this pest has been reported in cocoa during 1972 in Sri Lanka, Malaysia and Indonesia (Entwistle, 1985). The caterpillars cause damage up to 80 per cent of the flower cushions in about 40 per cent of the trees. During 1975, a study of cocoa pests in Thrissur district of Kerala revealed that *C. punctiferalis* was found to damage cocoa flower cushions severely and occasionally on cocoa bark (Chandramohanan and Harishkumar, 1975).

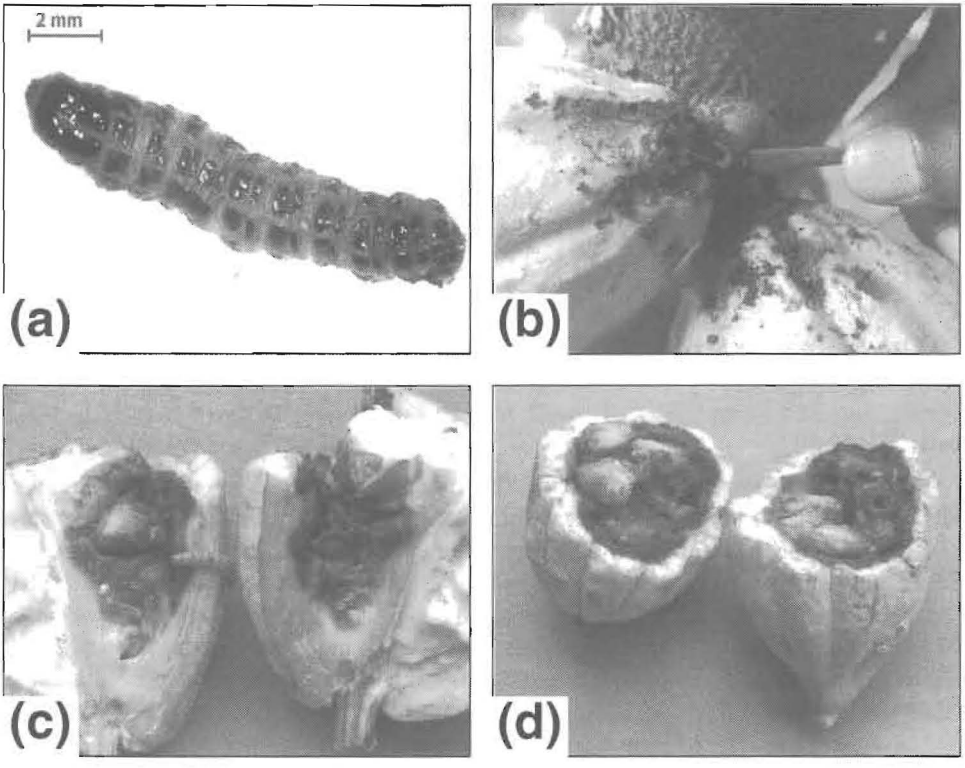

Figure 4.7. Capsule Borer.

(a) Larva of *C. punctiferalis*, (b) Damaged cocoa pods with larva, (c and d) Rotten cocoa beans due to *C. punctiferalis* damage.

7.2. Nature and Symptoms of Damage

Larvae feed on the rind of cocoa cherelles/pods, later bore into pods, feed the internal contents of the pods, the granular faecal pellets are seen outside the pods (Figure 4.7). When pods/cherelles touch each other, it is easy for the larvae to damage more than one pod/cherelle. Pods damaged by *Conogethes* are exposed to secondary infection by pathogens that lead to pod rot (Alagar *et al.*, 2013). The larvae sometimes feed on flower buds and flowers cushions. Damaged flower cushions may dry and shed prematurely. The damage of *C. punctiferalis* on cocoa is observed from December and peak incidence is noticed during March to May.

7.3. Biology

Adult moth is medium sized, wingspan of about 3 cm, with small black dots on pale yellowish wing (Figure 4.7). A single female moth laid pinkish oval flat eggs singly or in groups of 2 or 3 mostly in between wart or grooves of pods/cherelles/flower cushions of cocoa. Incubation period of eggs is about 3- 4 days. The full grown larvae very active, 3 to 3.5 cm long, reddish brown, has brown marks on each segment with pinkish tinge, fine hairs on the body with dark head and prothoracic shield. Total larval period is about 24 days. Longevity of male and female moth is about 6 and 7 days respectively. Larvae were seen under a cover of silk and frass or excreta throughout their development. Pupation takes place inside the damaged pods or cherelles or in a thin silken cocoon outside the damaged pods/cherelles. Adult emerged in 7 to 10 days. Total life cycle completes in 25 to 33 days (Alagar *et al.*, 2013).

7.4. Pest Management

- ☆ Clearing off the damaged orchards and debris, scraping off the fruit tree bark in which larvae overwinter, and burning the crop after harvest may reduce the overwintering pest population.
- ☆ Setting light traps (some fumigant on a piece of cotton placed under a 60 W black light) and sugar-vinegar traps (containing a mixture of sugar, vinegar water and insecticide) in orchards and fields may reduce the adult population.
- ☆ In China, covering fruits with paper bags to keep away from adults from egg laying proven successful.
- ☆ Monitoring and mass trapping of male adults with different blends of E10-hexadecenal and Z10-hexadecenal.

8. Pod Borer, *Conopomorpha cramerella* Snellen

Cocoa pod borer (*Conopomorpha cramerella*) is a pest of cocoa in South-East Asia. Although the earliest report of damage caused by this pest was noted by Jansen (1860), the cocoa pod borer was first taxonomically described at the beginning of the 20th century and named *Acrocercops cramerella* (Snellen, 1904). Recently the generic placement of this species has been revised and it is now known as *Conopomorpha*

cramerella (Bradley, 1986). In cocoa, damage by this pest makes the processing of cocoa pods difficult and reduces cocoa bean quality.

8.1. Occurrence and Distribution

The cocoa pod borer is known to occur in Saudi Arabia, China, Thailand, Brunei, Indonesia, Malaysia, Vietnam, Papua New Guinea, the Philippines, Samoa, Sri Lanka, Taiwan and Vanuatu. Currently, this pest is not present in India.

8.2. Nature and Symptoms of Damage

Cocoa pod borer (CPB) causes losses to cocoa by boring through the wall and into the pod, feeding on the pulp of bean and placenta of the pod (Figure 4.8). Damage to the funicles of pods results in malformed and undersized beans, in severe infestation it produce small flat beans that are often stuck together. It also causes the pod to yellow or ripen unevenly and prematurely. Young, green cocoa pods are particularly susceptible to attack by the pest. The beans from seriously infested pods are completely unusable. The fruit pulp becomes hard and the normal fermentation process used to produce the cocoa flavour precursors is made ineffective. Live pod borers are tough and can disperse over long distances. The CPB is also a pest of rambutan (Janny *et al.*, 2003).

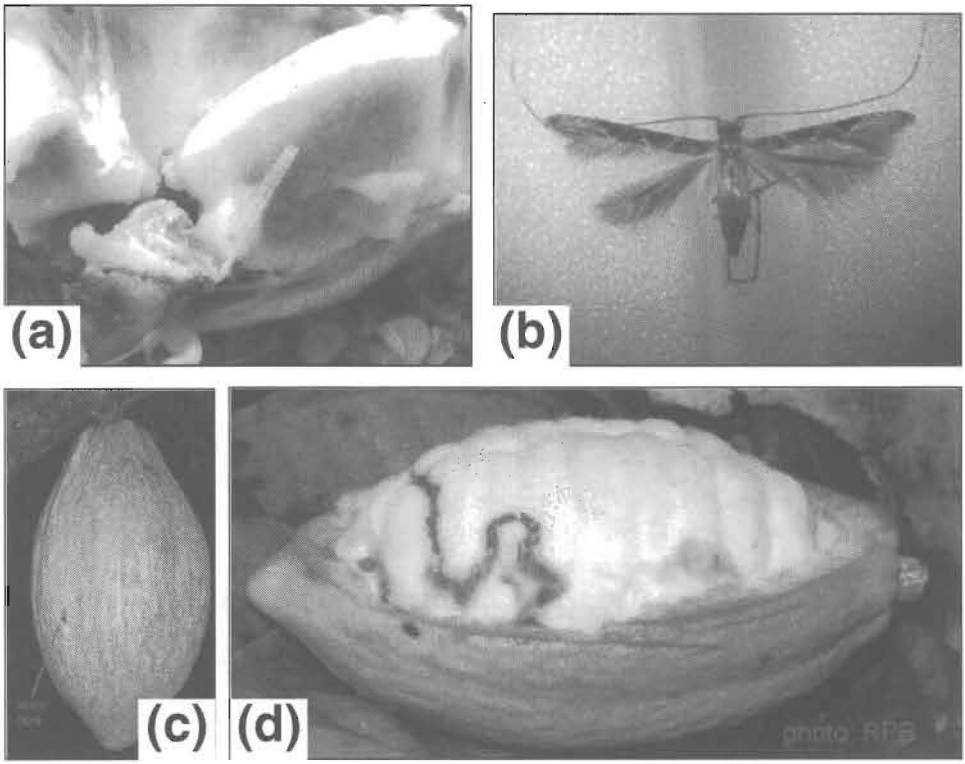

Figure 4.8: Cocoa Pod Borer.
a) Larvae, b) Adult moth, c) Entry point, d) Tunnel made by CPB.

8.3. Biology

CPB lays oval shaped, disk-like shape eggs and yellow-orange in colour. Eggs are laid singly anywhere on the pod surface, although there appears to be some preference for the pod furrows. Eggs are laid on pods more than 5 cm in length. Egg stage lasts for 6- 9 days. On hatching, the first larva stage (instar) is translucent white in colour and about 1 mm long. Larvae tunnel out through the pod wall, leaving an easily identifiable exit hole. Entire larval stage takes 14-18 days to complete, with 4-6 instars. Pupation site could be in the furrow of the pod, or green or dried leaves and other debris. Larvas spins an oval-shaped cocoon over itself and enter into pupation. Pupal stage normally takes 6-8 days to complete. Moths are most active at night; A female can normally produce 50-100 eggs in its lifetime. During the day, adult moths normally rest underneath horizontal or near-horizontal cocoa branches. The adult has a protective coloration that blends with the resting place making them difficult to spot (Figure 4.8). Adult longevity is generally about one week, but they can live up to 30 days. In total, the entire life cycle takes about 1 month to complete.

8.4. Pest Management

Control of pod borer is difficult. However, it can be managed effectively using an integrated approach that includes good crop hygiene, early pod harvesting, insect trapping and chemical sprays.

- ☆ Sanitation practices involving the complete harvesting of ripe or damaged pods, burying of pod husk, placenta, rotten pods are recommended.
- ☆ Regular pruning of the cocoa canopy to less than 4 m in height is also good practice.
- ☆ Timely pruning and regular harvesting of pods minimises the pod borer attack.
- ☆ Destroy infected pods/infested crop residues.
- ☆ Follow early practice of "rampasan" involved removal of all pods longer than 5 cm during intercrop period, which breaks the life cycle of the pest (Entwistle, 1985).
- ☆ Grow clones with smooth pods are less susceptible than clones with rough pods (Wessel, 1983).
- ☆ Pod-sleeving with plastic bags also reduces attacks of CPB. Pods should be sleeved when they are about 8-10 cm long and the sleeves should be left throughout the pod maturation period (Entwistle, 1985).
- ☆ Ant species such as black ant (*Dolichoderus thoracicus*) and the weaver ant (*Oecophylla smaragdina*) are known to prey on larvae at emergence from the pods and on pupae, and disturb adults. Ants can be augmented and manipulated to colonise areas within a cocoa garden.
- ☆ Release of an egg parasitoid, *Trichogrammatoidea bactrae fumata* is found to be effective.

- ☆ The fungus, *Beauvaria bassiana* has also been found to infect larvae and pupae, causing a 100 per cent death rate.
- ☆ Sex pheromone for CPB identified as a blend of (E,Z,Z)- and (E,E,Z)-4,6,10-hexadecatrienyl acetates and corresponding alcohols. Trap densities of four and eight per ha were used to give economic control (Day, 1985; Beevor *et al.*, 1986; Beevor *et al.*, 1993).

9. Leaf Eating Insect Pests

Some of the leaf eating caterpillars occurs sporadically and seasonally in the cocoa garden. Generally, the damage caused by these caterpillars is simply loss of leaf, although in young cocoa, they can distort growth.

9.1. *Lymantria obfuscate* Walk. (Lepidoptera: Lymantriidae)

This is a serious pest of cocoa in all the cocoa growing tracts in India.

9.1.1. Nature and Symptoms of Damage

The brownish hairy caterpillars feed voraciously on tender leaves. During day time, the caterpillars congregate on the fallen leaves and twigs around the base of the plant or on the basal surface of the main stern.

9.1.2. Biology

A female moth, on an average, lays about 300 eggs. Eggs hatch in 8 days. Larval period lasts for 25 to 38 days and the pupal period is about 7 days. Longevity of female and male is for 3 - 4 days and 4 - 6 days, respectively. Males are winged, slender and brownish in colour with wavy markings on the fore-wings.

9.2. *Lymantria ampla* Walk. (Lepidoptera: Lymantriidae)

This is a closely related species of *L. obfuscata*, resembling it in biological features and damage caused.

9.2.1. Nature and Symptoms of Damage

The caterpillars are seen in the field after monsoon showers, and the damage is caused by feeding on the tender flushes.

9.2.2. Biology

A single female lays about 1000 eggs. The incubation period is about for 9 days. The larval period lasts for 27-38 days by having 4- 5 instars.

9.3. *Euproctis subnotata* Walk. (Lepidoptera: Lymantriidae)

9.3.1. Nature and Symptoms of Damage

The hairy caterpillars are found feeding on tender leaves as well as on the surface tissue of young pods. Pods are preferred over leaves for feeding, and the attacked young pods dry up. The yellowish moth lays eggs in masses of 8-10 on the lower surface of leaves and covered with hairs. The egg, larval and pupal stages last for 5, 4 to 7 and 8 to 10 days respectively.

9.4. *Euproctis guttata* Walk (Lymantriidae : Lepidoptera)

This is a related species of *Euproctis subnotata* which is observed to feed on cocoa leaves and pods causing similar damage. The moth is yellowish, lays eggs in groups on the lower surface of the leaf. The egg stage is from 6-8 days, the larva 18-27 days, and the pupa 9-14 days. During the survey it was found that the caterpillars of both these species together cause about 28 per cent damage to pods. The period of infestation is during June - July.

9.5. *Adoxophyes privatana* Walk (Tortricidae: Lepidoptera)

The caterpillar web young leaves together and feed from within, making irregular holes. The tiny moth lays eggs on tender twigs which hatch in about 6 days. Larval period is completed in 16-20 days and the pupal period is about 4 days. Pupation takes place within the webbed leaves. Total life cycle is completed in 26-30 days.

9.6. *Spodoptera litura* Biosd. (Noctuidae: Lepidoptera)

The caterpillars damage the nursery plants by voraciously defoliating the leaves. Affected seedlings show a tendency for premature branching. Eggs are laid on the leaves and covered with buff coloured hairs. On an average, 200- 300 eggs are laid by a female. Egg, larval and pupal period last for 5, 15-17 and 8-14 days respectively.

9.7. Other Caterpillar Pests

Other caterpillar pests of cocoa recorded are *Hyposidra talaca* Walk (Geometridae), *Spilosoma obligua* Walk (Arctiidae), *Dasychira mendosa* Hb. (Lymantriidae), *Pericallia ricini* F. (Arctiidae) Semilooper, *Achaea janata* L. (Noctuidae), *Pteroma plagiophelps* Hamps (Psychidae) and *Clania sp.* (Psychidae).

10. Vertebrate Pests

The vertebrate pests include rats, squirrels, palm civet and birds and they inflict loss of the crops by feeding and damaging the pods. A heavy damage (75 per cent) can be seen by rodents in any of the farmers' fields having cocoa plantations (Advani, 1982).

10.1. Rats and Squirrels

The Western Ghats squirrel, *Funambulus tristriatus* Waterhouse; the South Indian palm squirrel, *F. palmarum* Linnaeus and the black rat, *Rattus rattus* Linnaeus were observed to be causing much damage to cocoa in South India; the palm civet, *Paradoxurus hermaphroditus* Pallas and the bonnet monkey, *Macaca radiata* Geoffroy were causing minor damage (Bhat *et al.*, 1981). Regular trapping of rodents and bats in cocoa plots resulted in cost benefit ratio of about 1:500 in plantations near Kasaragod, increasing the productivity by more than ten times per ha (Advani, 1982).

10.1.1. Occurrence and Distribution

Rat damage is reported from most of the tropical countries including islands. In the Far East, palm rats and squirrels, in particular *Callosciurus notatus*, caused

damage. The latter caused severe bark stripping of young cocoa plants (Hafidzi, 1982). Pod losses vary widely, but may reach 90 per cent at times (Han and Bose, 1980: Wood, 1984). Heavy losses noticed in India, e. g from the Western Ghats squirrel, *Funambulus tristriatus*, the South Indian palm squirrel (*F. palmarum*) and *Rattus wroughtoni* (Bhat, 1992; Baco *et al.*, 2010). Other territories where rodent damage to cocoa is recorded include West Indies, Pacific islands and South America. Han and Bose (1980) estimated 100-300 rats/ha. Without control measures, losses from small mammals over 7 weeks fluctuated in the range 75-90 per cent of pods, equivalent to 70 kg of dry beans per week. Rodents adapted themselves to this plant within a span of 8-10 years after the initial cultivation. The extent of rodents damage varies from 8 -51 per cent per cent in different cocoa growing tracts of Southern India (Mariamma, 2008). The amount of damage is very variable and depends upon the conditions under which the cocoa is grown. Cocoa grown under coconuts is susceptible to attack by both rats and squirrels. In the pacific islands, up to 60 per cent of pods may be lost (Williams, 1973).

10.1.2. Nature and Symptoms of Damage

The rats usually gnaw the pods near the stalk portion whereas squirrels gnaw the pods in the center (Figure 4.9). The rats are known to damage the mature as well as immature cocoa pods whereas the squirrels damage only the mature ones. They gnaw the pods and feed on the mucilage covering of the beans (Rajagopal and Ananda, 2006). The damage is compounded by ensuing fungal infection and affected pods are all lost. All rodent species while feeding on cocoa pods leave tooth marks on pods. Though the tooth marks made by different rodent species are not distinguishable, the same can be distinguished from the marks on the pods that had been attacked by monkeys, civet cats or birds. Squirrels are diurnal and rats are nocturnal in habits. The population of squirrels is found to be 4 to 5 numbers per hectare of cocoa garden. The home range of squirrels is 2 ha. Rat population is about 25-30 per hectare and home range is 0.5 hectare only. The population of *Rattus rattus* is about seven times that of Western Ghats squirrels, the intensity of squirrel damage to cocoa is nearly three times more than that caused by rats (Mariamma, 2008). Many species of rats

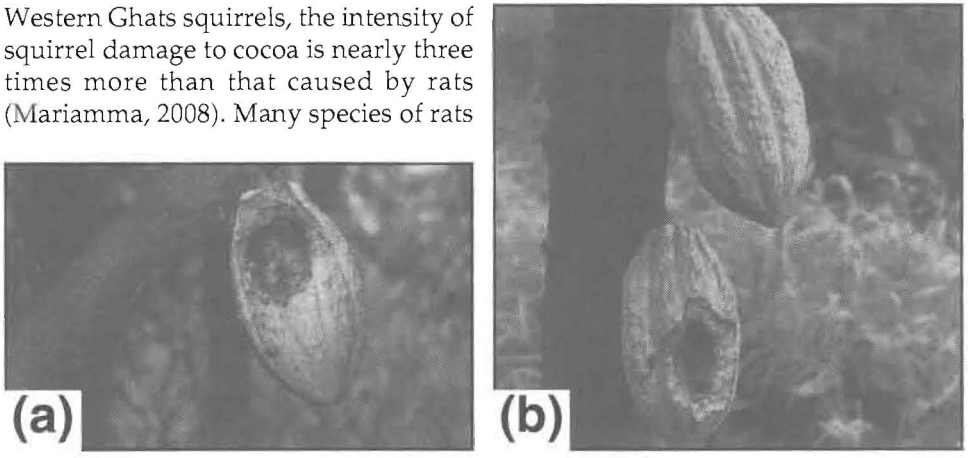

Figure 4.9: Vertebrate Pests.
(a) Rat damage, (b) Squirrel damage.

damage both young and mature pods. Often, squirrels are more important than rats. One squirrel can attack up to 4 cocoa pods per day. A rat on average takes one whole week to attack up to 4 pods. However, the rats alone have been reported to damage more than 9000 pods per hectare. Squirrels like heavily shaded farms. Both squirrels and rats prefer badly maintained farms.

10.1.3. Management

- ☆ An integrated approach on a locality basis is essential for the management of rodents.
- ☆ Clean cultivation should be followed to reduce the refuges of rodents.
- ☆ Habitat manipulation is yet another important step for rodent management. Crown cleaning of palms generally expose the nesting places of the rats to predators.
- ☆ Timely harvest of mature cocoa pods will reduce rodent damage to a certain extent.
- ☆ Squirrels are best controlled by trapping with wooden or wire mesh single catch 'live' trap with ripe coconut kernel as the bait. Trapping is more successful if carried out during the lean period (September-November) when the alternate foods such as paddy, cashew apples and jackfruit are not available.
- ☆ Single dose anticoagulant rodenticide 10g Bromadiolone (0.005 per cent) wax cakes twice at an interval of 10-12 days on the branches of one cocoa tree out of every five trees is recommended.
- ☆ Indiscriminate killing of predators such as owls, rat snakes, mongoose etc should be discouraged.

10.2. The Palm Civet, *Paradoxurus hermaphrodites*

10.2.1. Occurrence and Distribution

The palm civet, *Paradoxurus hermaphroditus* Pallas also known as toddy cat, is a nocturnal tree climber. It is present in many cocoa growing tracts of India and Malaysia. About 12.8 per cent damage is noticed in some areas by this pest.

10.2.2. Nature and Symptoms of Damage

The palm civet bites and breaks the husk of cocoa pods. The piece of broken chunk is 2.0 to 3.0 cm in diameter. There is no distinct pattern of damage. Two distantly placed markings caused by the canine teeth are very much prominent on the pod husk. Piles of defecated beans are seen scattered around the cocoa plantations.

10.2.3. Management

Trapping is best method for the management of palm civet.

11. Birds

The Golden backed woodpecker, *Dinopium sp.* is seen making small holes on

cocoa pods and eats the mucilage inside. Extent of damage by this animal in cocoa plantation is very negligible.

12. Conclusion

Effective management of pest problems is frequently complex and usually involves agronomic, pest control, logistic, economic and sometimes even political factors. All these factors need to be taken into account to fully appreciate and accurately diagnose pest problems and make appropriate recommendations to farmers. It is also essential to understand current practice and how decisions are made before it is possible to improve the decision making process in pest management in cocoa farming systems. The relevant information should be gathered such as proper knowledge of the pests under cropping conditions, Monitor development of insect pests and their natural enemies, Identify critical time of pest incidence, Make decisions based on the problems and economic thresholds, Use correct dose and application technique and finally management strategy. Also, the closer the IPM system fits a farmer's needs then the greater is the likelihood of adoption. Thus, successful implementation of an IPM system in the protection of farm products should logically be preceded by the development of effective IPM programmes and the packaging of expert systems.

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