

# Chapter 14

## Pests of the Oil Palm

---

The most important pests of oil palms are arthropods (insects, mites) and mammals, but other groups of animals may cause problems from time to time. In this section, we have grouped the arthropod pests according to the damage that they do to the palm. We believe this arrangement will be more useful to the non-specialist than a zoological classification. We have attempted to give the correct Latin names for pest species, but taxonomic changes are frequent. For some species, we have also given well-known but no longer valid names.

Wood (1968a) gave much still valid information of general application on ecology and control, while detailed information on African and American pests is to be found in special issues of the journal *Oléagineux* (Genty *et al.*, 1978; Mariau *et al.*, 1981) and also in Mexzón and Chinchilla (1993).

Growers should always use integrated pest management (IPM) systems (Wood, 2002). These involve the encouragement of biological control of pests, the adoption of agronomic methods that minimise the risk of pest outbreaks and, if pesticide application is unavoidable, the use of selective chemicals and application methods with minimal side effects. IPM has been widely applied in the oil palm industry for several decades, and much of the current understanding of the principles of IPM developed from work on tropical crops. As early as 1962, it was recognised that broad spectrum (killing a wide range of species), long residual, contact insecticides (BSLRCs) were causing pest attacks in oil palms, by upsetting the ecological balance between the pest and its natural enemies (Wood, 1971, 2002). Wood (1968a) enunciated the principles of what was then known as integrated pest control, with more than one-third of the book being devoted to explaining the reasons for pest outbreaks, methods of monitoring pest populations and ways of controlling pests without

disruption of the natural balance in the agroecosystem (see also Wood, 1976c, 1987).

As a result of the understanding of pest ecology that has been built up in all the main areas where the crop is grown, oil palms generally remain free of damaging pest outbreaks, without much need for intervention with insecticides. However, occasional pests may cause sporadic economic damage if the usually good environmental control, including biological control, is disrupted. For example, Wood *et al.* (1973) showed that a single bagworm outbreak, causing more or less complete defoliation of 10-year-old palms, reduced yield by 40–50% over the next 2 years. Many factors may disrupt natural balance, and when an outbreak does occur, it is important to try to understand what caused it. This can be difficult, because outbreaks may persist for some time after the original disturbance has disappeared. Wood (1979) suggested that this was because it can take time for natural enemy numbers to build up to match the numbers of pests. Under normal conditions in the tropics, all stages of the pest life cycle tend to be present, and there has thus been no pressure for natural enemies to evolve co-ordinated life cycles. If for any reason pest generations become synchronised, natural enemies may be heavily outnumbered, so that control of the pest breaks down.

There are numerous potential pests, which cause no significant damage under current conditions, but have the potential to do so if environmental control were disrupted by changes in agricultural practice (usually the application of an insecticide). In South East Asia, Wood (1968a) mentioned over 80 arthropod species; in Latin America, Mexzón and Chinchilla (1993) listed 41 species and Genty *et al.* (1978) over 70; in Africa, Mariau *et al.* (1981) listed 22 species and Wood (1983a) 26 species. Some potential pests are listed in Table 14.1.

**Table 14.1** Potential oil palm pests

Pest	Stage attacked	Damage	Occurrence	Reference	Comments
<i>Pests causing leaf damage</i>					
Red spider ( <i>Oligonychus</i> sp.)	Nursery	Leaf turns brown, necrotic	Widespread	1	Often induced by pesticide application. Not a problem with overhead sprinkler irrigation
Aphids	Nursery	Growth rate reduced	Malaysia Congo	1, 2	Severity has not justified treatment
Mealy bugs, scale insects	Nursery, field	Leaf, fruit		2, 3	Often tended by ants; control of ants may eliminate pest; serious damage rare
Grasshoppers	Nursery	Defoliation	Widespread	2	Several species; hand removal effective
Grasshopper, <i>Valanga nigricornis</i>	Young palms	Defoliation	Malaysia	2, 4	Particularly in new plantings, after drought; spraying may be necessary
Stink locust ( <i>Zonocerus variegatus</i> )	Young palms	Defoliation	West Africa	2, 5	Damage followed slashing of overgrown covers
Leaf-cutting ants <i>Alurnus humeralis</i>	Mature palms Mature palms	Defoliation Defoliation	Latin America Ecuador	2 6	Coleoptera: Chrysomelidae: Hispinae
<i>Homophylotis catori</i>	Mature palms	Defoliation	Africa	5, 7	Caterpillar: Zygaenidae (syn. <i>Chalconycles</i> )
<i>Leptonatada sjöstedti</i> <i>Hispoleptis</i> spp. (Hispinae)	Mature palms Mature palms	Defoliation Leaf miner	Africa Ecuador	5 2, 8, 9	Lepidoptera: Notodontidae Damage similar to <i>Coelaenomenodera lameensis</i> ; control by trunk injection (Ref. 9)
<i>Promecotheca cumingi</i>	Mature palms	Leaf miner	Malaysia	1, 8	Coconut pest, occasionally attacks oil palm Coleoptera: Chrysomelidae: Hispinae
<i>Norape argyrrhorea</i>	Mature palms	Defoliation	Peru	16	Lepidoptera: Megalopygidae; controlled by virus
Beetles	Mature palms	Bore into petioles	Malaysia, Africa	2	<i>Xylotrupes gideon</i> , <i>Platygenia barbata</i>
<i>Retracus elaeis</i> , orange spotting mite	Field	Orange spots	Colombia	10, 17	Eriophidae; may cause 50% crop loss; wettable sulphur gave effective control; K <sub>2</sub> SO <sub>4</sub> fertiliser reduced incidence
Slugs ( <i>Laevicaulis alte</i> )	Young seedlings	Damage to plumule	India	18	Hand-picking and salt application
<i>Zophiuma butawengi</i> (Hemiptera)	Mature palms	Yellow-bronze chlorosis	PNG	20, 27	Finschhafen disorder is caused by feeding; possible biological control by fungi
<i>Dasychira</i> sp. (hairy caterpillar)	Mature palms	Leaf miner	Malaysia	21	Lepidoptera: Lymantriidae
<i>Silvanus</i> sp. Silvanidae: Coleoptera)	Mature palms	Destroys spear leaf laminae	India	22	Associated with fungal infection – not clear which comes first
<i>Spodoptera</i> spp.	Nursery	Defoliation	PNG	23	Lepidoptera: Noctuidae
<i>Eurycantha calcarata</i> (stick insect)	Mature palms		PNG	23	Often in association with sexavae (Section 14.5.5)

(Continued)

Table 14.1 (Continued)

Pest	Stage attacked	Damage	Occurrence	Reference	Comments
<i>Pests damaging trunk or roots</i>					
<i>Eldana saccharina</i>	Nursery	Larvae bore into spear/bud	Africa	5	Lepidoptera: Pyralidae
<i>Dynastes (Augosoma) centaurus</i>	Nursery, field	Similar to <i>Oryctes</i>	Africa	2, 5	Coleoptera: Dynastinae
<i>Scapanes australis</i>	Young field palms	Similar to <i>Oryctes</i>	SE Asia	11, 23	Coleoptera: Dynastinae
<i>Sufetula</i> spp. (Lepidoptera: Pyralidae)	Mature palms	Root damage	Widespread	5, 12, 19	Damage seen in palms on peat; may cause significant damage to coconut
<i>Monolepta apicicornis</i>	Mature palms	Mines within root	West Africa	5, 13	Coleoptera: Chrysomelidae: Galerucinae
<i>Temnoschoita</i> spp. (Curculionidae)	Young palms	Boring from cut petioles	Africa	11, 24, 25	Avoid pruning before transplanting; mature palms rarely damaged
Cockchafer larvae	Nursery, field	Root damage	Malaysia	1, 14	<i>Leucopholis, Apogonia, Adoretus</i>
Cockchafers	Nursery, field	Leaf damage	Malaysia	1	
<i>Pests damaging fruit</i>					
<i>Tiquadra</i> spp.	Mature palms	Spear, bunch	Colombia	2	Damage similar to <i>Tirathaba</i> (Section 14.8.1)
<i>Demotispia neivai</i>	Mature palms	Fruit damage, followed by fungal infection	South America	26	Formerly <i>Imatidium</i> , <i>Himatidium</i> or <i>Pseudoimatidium</i>
<i>Prosoestus</i> spp.	Mature palms	Stigma damage, poor fruit set	West Africa	2, 15	Effect small, undamaged fruits enlarge to fill space of damaged; treatment expensive
<i>Elaeidophilos adustalis</i>	Mature palms	Stigma damage, poor fruit set	West Africa	15	Effect small; treatment expensive
Scale insects	Mature palms	Not serious		1	

References: 1: Wood (1968a); 2: Hartley (1988); 3: Ponnamma (1999); 4: Han and Chew (1978); 5: Mariau *et al.* (1981); 6: Mariau (1976b); 7: Airede *et al.* (1999); 8: Mariau (1999a); 9: Le Verdier and Genty (1988); 10: Genty and Reyes (1977); 11: Mariau *et al.* (1991); 12: Genty and Mariau (1975); 13: Mariau and Djob Bikoi (1990); 14: Wood and Ng (1969); 15: Philippe (1993); 16: Zeddani *et al.* (2003a); 17: R.C. Aldana (2003); 18: Kalidas *et al.* (2006); 19: Bonneau *et al.* (2007); 20: Gitau *et al.* (2011); 21: Lim and Kuang, 2007); 22: Potineni *et al.* (2011); 23: Dewhurst (2012); 23: Asante and Kumar (1986); 25: Buyckx (1952); 26: Genty and Mariau (1973); 27: Woruba *et al.* (2014).

We have not given detailed recommendations on pesticides, as these are constantly changing, with new compounds being developed and older ones withdrawn.

## 14.1 INTEGRATED PEST MANAGEMENT

The important aspects of an IPM system can be summarised as follows:

- Knowledge of the life cycle and ecology of the pest, and of its natural enemies, is required, if biological control is to be understood and manipulated.
- A monitoring or census system to ensure early detection of outbreaks should be in place, so that control measures can be planned and applied at the most appropriate time.
- Economic damage and action thresholds should be established, so that control measures are not taken unless and until they are necessary, giving the natural balance a chance to be re-established.
- Control measures must be selective, so that swift re-establishment of the natural balance is promoted.

Each of these aspects is discussed briefly in the following sections. For more detailed discussion in relation to

oil palms, see Wood (1971, 1976c, 1979, 1987, 2002). Other reviews are given by Ho and Teh (1997) and Chung and Sharma (1999). Oil palm workers have not always adhered to IPM principles, though; numerous papers have been published describing potential oil palm pests and testing insecticides for control, without any evaluation of the severity of damage or the extent of natural control. Many of the older recommendations took no account of the possibilities of IPM. In some instances, these have not been updated, probably because it has become apparent that control by natural enemies is sufficient, and no action is necessary.

### 14.1.1 Pest ecology

As Wood (1976c) pointed out, the environment in an oil palm plantation, with a uniform expanse of the crop and little seasonal change, would appear to favour the build-up of pests. Many occasional pests are commonly present in a stand of oil palms, and the reason that outbreaks do not usually occur is that numbers are restricted by the action of natural enemies; these include both predators on the pests and species that parasitise the pests. Outbreaks may occur if the natural balance between a pest and its enemies is upset for any reason.

One of the major factors in pest outbreaks in oil palms in the past was the use of BSLRC insecticides. These were often applied as a 'precautionary' measure against minor pest infestations, but their use could exacerbate the problem, by killing the natural enemies of pests, so that any biological control ceased to operate. The pest which became a problem after spraying was not always the same as that which had provoked the initial precautionary application. The possible effect of spraying with a broad-spectrum chemical is clearly illustrated in Fig. 14.1. When a 0.8 ha plot of palms was sprayed regularly with a low dosage of dieldrin (at that time still available), the population of the bagworm, *Metisa plana*, built up considerably over the next four generations, spreading out from the sprayed area. Wood (1968a) noted that it is difficult to prove that insecticides have caused outbreaks, but the coincidence has been sufficiently frequent (e.g. Sumantri *et al.*, 2011) as to leave little doubt.

One reason why spraying with broad-spectrum chemicals can cause a pest outbreak is that it is likely that a proportion of the pests will survive the spraying, but almost none of their enemies, simply because the pest is usually present in larger numbers than its enemies. In that case, the pest can then build up uncontrolled. With contact insecticides, patchy or uneven

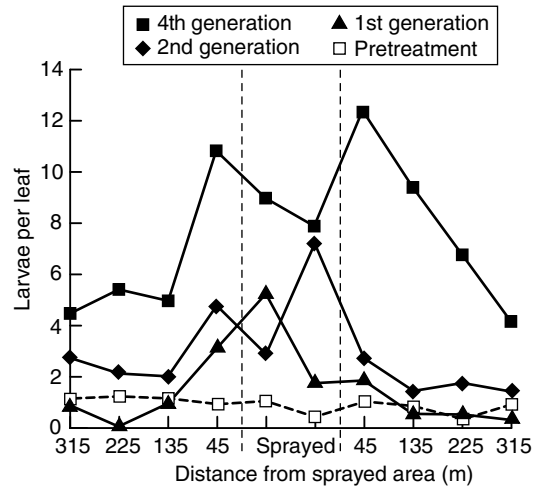


Fig. 14.1 Effects of dieldrin spray on population of *Metisa plana*. The population increased after spraying, centred on the sprayed area. (From Wood, 1971.)

application is likely to make matters worse, because the natural enemies are usually mobile and exploratory in their behaviour, so will move into sprayed patches, while the more static pest remains untouched elsewhere. Wood (2002) noted that a moderate kill of the pest with complete survival of enemies was probably better than a complete kill of both. An additional factor is that only one particular stage in the life cycle of the pest may survive; if so, then subsequent generations will be highly synchronised (e.g. Mariau, 1976a). As noted in the introduction to this chapter, control of the pest may then break down.

Pesticides are not the only cause of outbreaks, which sometimes occur in areas where pesticides have not been applied. Syed and Shah (1977) quoted circumstantial evidence to suggest that complete eradication of weeds by herbicide spraying had contributed to pest outbreaks in Sabah. They suggested that weed species were important food plants for the adults of parasitic wasps; weed eradication thus reduced the level of parasitism and allowed pest numbers to build up. Prior (1988) demonstrated the importance of two weed species in supporting a wasp parasitic on grasshoppers in PNG (see Section 14.5.5). Delvare and Genty (1992) recommended protecting and spreading certain weed species in Latin America, to support beneficial insects, and J.A. Aldana (2003a) listed numerous parasitoids found on such plants. In Malaysia, Ho (1998) showed that numbers of the bagworm, *M. plana*, were suppressed for about 200 m on each side of a planted

strip of *Euphorbia heterophylla*, a species shown to be attractive to a wide variety of different insects.

Wood (1968a) suggested that dust from dry dirt roads in plantations might be a disturbing factor. Dust can kill insects by abrasion of the cuticle and may affect the active natural enemy species more than relatively inactive pests such as caterpillars. The build-up may then be exacerbated by BSLRC application. Siburat and Mojiun (1998) observed outbreaks of leaf-eating caterpillars after floods, which might have eliminated natural enemies that lived on ground vegetation. Van Bael *et al.* (2004) reported an outbreak of caterpillars of several species on forest trees following an El Niño-related drought in Panama.

Knowledge of pest life cycles can be useful, particularly when synchronised generations occur. Life cycles for many Malaysian pests were given by Wood (1968a). Siburat and Mojiun (1998) gave a life cycle table for *Setora nitens*, showing the control measures appropriate for each stage. Studies of natural enemies can also be useful, although the enemies important under normal conditions may not be the most effective in containing outbreaks (Wood, 1979). Mariau *et al.* (1991) illustrated a number of the more important predators and parasites in South East Asia. Some 90% of the birds in oil palm plantations are insectivores and may consume large numbers of insects (Desmier de Chenon and Susanto, 2005a). Koh (2008a) showed that seedlings from which birds were excluded suffered increased insect damage, but the significance of birds compared to arthropod natural enemies in control of pests is not clear.

### 14.1.2 Action thresholds

Response should be related to pest numbers, rather than following a predetermined programme. Regular prophylactic pesticide applications can appear to give control, but by removing natural enemies, may ensure that the problem persists or provoke other problems. Defining a critical level of a pest provides the necessary link between ecology and economics (Wood, 1979). The economic damage threshold can be defined as the level at which the damage causes losses exceeding the cost of control measures. A warning level may be useful as an alert to potential danger. It is important also to understand whether the pest population is increasing, stable or decreasing.

As an example, studies of the damage caused by *Oryctes* in young oil palms have shown that, during the first year in the field, quite extensive defoliation has little or no effect on subsequent yield (Wood *et al.*, 1973; Liau and Ahmad Alwi, 1995). This appears to be because growth at that stage is not limited by photosynthetic

activity, so after partial defoliation, the remaining leaves can photosynthesise more rapidly to meet requirements for vegetative growth (see Section 5.2.2.1 for further discussion of this). Some degree of control of *Oryctes* is needed, because the beetle may kill young palms, not just defoliate them. In addition, if damage persists into the second year, it starts to affect yield (Liau and Ahmad Alwi, 1995; Chung *et al.*, 1999). The important point, though, is that apparently severe damage in the first year may have little economic effect, and the control strategy should take account of this.

The action level for a pest may depend on the weather; Mariau (1999b) noted that the leaf miner *Coelaenomenodera lameensis* multiplies more slowly during drought, so the action level can be higher.

### 14.1.3 Census systems

If responses are to be based on pest numbers, then a regular monitoring system must be in place. Pest numbers may be counted directly, or an assessment of damage may be made. Monitoring systems for leaf-eating caterpillars were discussed by Wood (1976c). Most systems involve at least two stages: a regular, superficial inspection for signs of pest incidence, the 'detection' stage, and more detailed assessment where such signs are found, the 'enumeration' stage. Chung *et al.* (1995a) described a system for bagworms, based on unpublished work by Wood, with three stages:

1. The *alert* stage involves looking for the small holes in leaves, which are signs of feeding damage. This inspection can be undertaken by harvesters and is frequent (fortnightly) but superficial.
2. When feeding damage is noticed, the *census* stage is activated. An upper frond from 1% of palms is cut down, and the number of individual bagworms and nettle caterpillars, both alive and dead, is counted by a specially trained team. The census is repeated in affected areas every 1 or 2 weeks, different palms being used each time to avoid excessive defoliation.
3. The results of the census determine whether the *action* stage is needed. Control measures are implemented if the census in affected and adjacent blocks shows that all of the following conditions are met:
  - Infestation is spreading.
  - Natural control appears to have failed.
  - The pests are at the small larval stage, with cocoons absent or very few.
  - Numbers exceed 5–10/frond for the smaller species, or 1–5 for the larger, indicating that there is a high risk of crop loss.

Mariau (1994) gave a more general review of census systems in various parts of the world, together with a list of advice notes on pests published in *Oléagineux* between 1967 and 1994. The recommended frequency of the alert stage depends on the expected pest species. The choice of leaf for detailed recording will depend in part on the particular pest, as some damage young leaves and some older leaves (Wood, 1976c). Calvache (2003a) emphasised the importance of locating the focus of an outbreak to ensure that treatment is efficient.

#### 14.1.4 Control measures

Various management practices are important components of IPM in ensuring that outbreaks do not occur. The probable importance of the weed flora as food plants for natural enemies has already been mentioned. Ground cover also plays a role in limiting *Oryctes* damage (see Section 14.4.1). Study of the life cycle of a pest may reveal an alternate host plant, the elimination of which from the plantation will help to control the pest.

If pesticide application is needed, it should be selective. The damaging effects of some of the older BSLRC chemicals have already been mentioned, but some modern chemicals are also broad spectrum and can cause problems if wrongly used. For example, although synthetic pyrethroids break down rapidly and have little residual effect in the tropics, they are broad spectrum and can damage natural enemy populations; Sumantri *et al.* (2011) gave several examples of recurrent pest outbreaks following the use of deltamethrin. Bio-insecticides (preparations of parasitic fungi or insect viruses or *Bacillus thuringiensis*) can be effective (e.g. Desmier de Chenon *et al.*, 1988; Sipayung *et al.*, 1990; Ramle Moslim *et al.*, 1995; Valencia, 2003a). Culture and release of viruses, bacteria and fungi parasitic on pest species is increasingly being advocated (Valencia, 2003b; Sumantri *et al.*, 2011).

Selectivity can be achieved not only by choice of chemical, but also by the timing and method of application. Knowledge of the pest life cycle may allow application to be timed to a stage when the maximum kill can be achieved, while sparing natural enemies. Thus, Mariau (1999b) claimed that spraying *C. lameensis* was most effective against adults; larvae within the leaf lamina are protected from contact pesticides.

One of the best methods of insecticide application to oil palms is by trunk injection (Wood *et al.*, 1974) or root absorption (Ginting and Desmier de Chenon, 1987; Reyes *et al.*, 2003). In this instance, the application method provides selectivity. A systemic pesticide

moves into the leaves, and only species that eat the leaves will be affected. The risk of affecting non-target species is usually minimal, although Prior (1988) noted effects on crows and domestic chickens after they had eaten grasshoppers that had been treated by trunk injection of monocrotophos. The injection is done by pouring the chemical into holes made with modified chainsaw drills. Tractor-mounted generators with electric drills and special equipment for immediate injection following drilling may be used (Sarjit, 1986); one team with a tractor and two drills can treat 15–20 ha in a day. Root absorption involves placing the cut end of a primary root in a plastic bag containing the insecticide; no special equipment is required, and Hasber *et al.* (2009) estimated that costs in Malaysia were slightly lower than for trunk injection.

Trunk injection and root absorption raise the concern that palm oil or kernels might be contaminated with pesticide, but no residues have been detected from monocrotophos or methamidophos treatment (Ooi *et al.*, 1975; Ng and Chong, 1982; Chee *et al.*, 2006). These two organophosphates are on the World Health Organization Type 1B list and no longer registered in most countries, though in Malaysia, monocrotophos is licensed specifically for trunk injection. Sumantri *et al.* (2011) listed several newer chemicals suitable for trunk injection, and Lai and Tey (2009) showed that acephate, which is less hazardous than other organophosphates, was effective against bagworms.

Insect pheromones, volatile chemicals produced as signals to other insects, are increasingly being used in pest-control strategies. For example, female bagworms are wingless and immobile and attract males by releasing a pheromone. Baiting traps with the pheromone to collect males could possibly disrupt mating and contribute to control of bagworms (Rhainds, 2000). Pheromone-baited traps may also be used for monitoring populations.

## 14.2 NURSERY PESTS

Several potential pests are listed in Table 14.1, but pests are not usually serious in nurseries. Red spider mite may have severe effects but is rarely a problem in nurseries irrigated by overhead sprinklers. Boron applications have been found to reduce spider mite injury (Rajaratnam and Law, 1975). Cutworms (Noctuidae), usually *Agrotis* sp., can cause damage in prenurseries, and *Spodoptera litura* may strip the leaf epidermis in nurseries.

### 14.3 LEAF PESTS OF IMMATURE PALMS: AFRICAN SPEAR BORER

Most of the leaf pests of mature palms may also attack young palms. The African spear borer appears to attack mature palms only rarely, however. This moth, *Pimelephila ghesquierei* (Pyrilidae, Pyraustinae), first described from Congo, is found in all African territories. It is not a common pest, but on occasions, the damage done has been severe.

*Life cycle and damage:* Damage is most common between the second and fifth years in the field, but both nursery seedlings and older palms are sometimes affected (Buyckx, 1952). The eggs are laid at the base of the spear leaves. Usually, two or three larvae are found on young palms or up to a dozen on older ones and, typically, they penetrate the rachis and leaflets of the growing, unopened spears, forming galleries through them. The caterpillar does not kill the palm, but may be followed by weevil larvae, for example, those of *Temnoschoita*, or a bacterial rot that may prove lethal (Buyckx, 1952).

The caterpillars reach a length of 3–4 cm before pupating in a cocoon of fibrous debris. The whole life cycle takes 35–45 days; attacks can therefore be made at frequent intervals.

*Control:* Light attacks can be dealt with by removal of infected leaves and collection of the caterpillars and pupae. In the Ivory Coast, spraying has been carried out at intervals of 2–3 weeks in nurseries and for the first 2 years in the field, but older palms are less vulnerable to attack and are not usually treated (Mariau and Morin, 1971).

## 14.4 STEM DAMAGE TO YOUNG PALMS

### 14.4.1 *Oryctes* species (Dynastinae): Rhinoceros beetles

#### 14.4.1.1 *Distribution*

Species of *Oryctes* are found throughout the palm-growing areas of Africa, Asia and the Pacific. Damage is worst in young palms, and comparatively rare in palms older than 3 or 4 years, although Dhileepan (1988) recorded damage up to 15 years after planting in India, and isolated tall palms are often attacked.

The following species are the most important oil palm pests:

<i>O. rhinoceros</i>	The common rhinoceros beetle of the Far East, which has spread to the Pacific islands (Plate 14.1)
<i>O. gnu</i> ( <i>O. trituberculatus</i> )	Asia, less common
<i>O. boas</i>	Probably the most common species in Africa
<i>O. monoceros</i>	Africa
<i>O. owariensis</i>	Africa

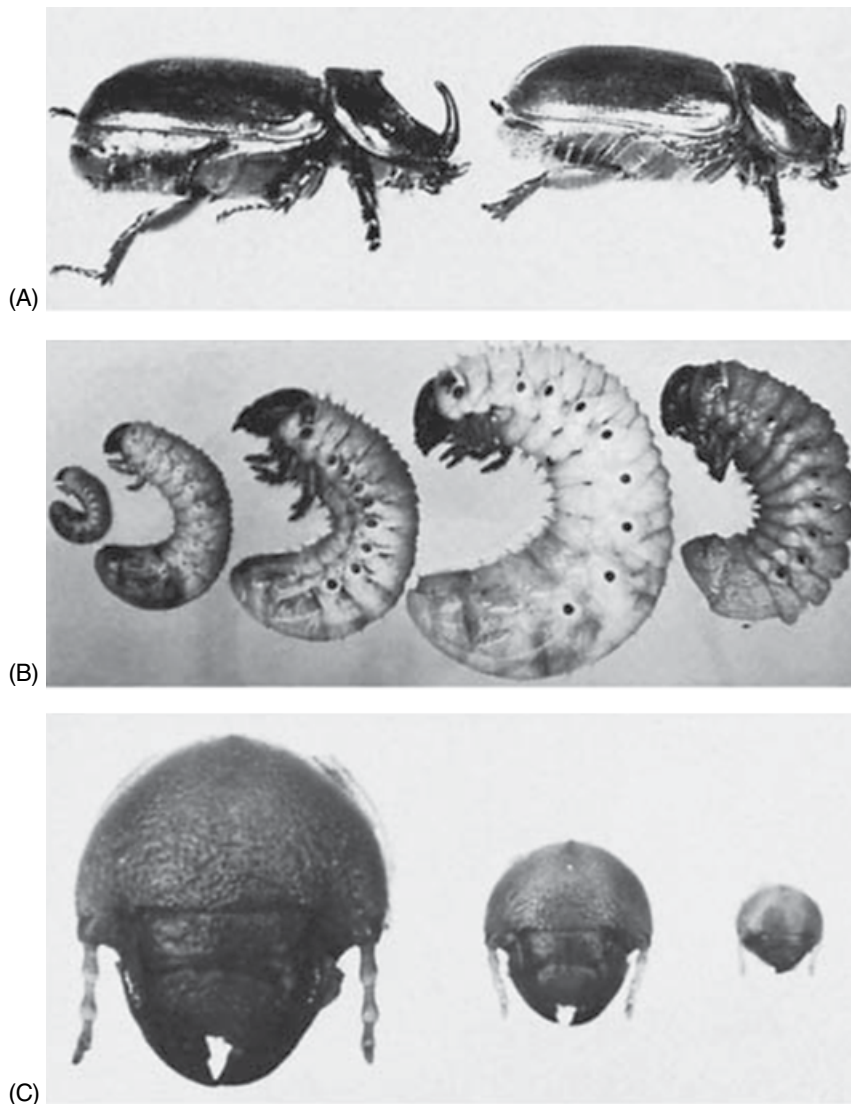
The Asian species are primarily pests of the coconut palm, but they attack other palms, both cultivated and wild. The African species attack the coconut and *Borassus* palms, but the largest population is to be found on the oil palm, owing to its ubiquity.

#### 14.4.1.2 *Description, life cycle and damage*

The male adult has the characteristic ‘rhinoceros horn’; in the female, the horn is smaller or, in the African species, is reduced to a triangular protuberance. The beetle is black and measures 4–6 cm long and 2–3 cm broad according to species, *O. trituberculatus* being larger than *O. rhinoceros*, and the African species *O. owariensis* being larger and *O. boas* being smaller than *O. monoceros*. The horn of *O. boas* is particularly long and curved.

The eggs are white, 3–4 mm in diameter and easily observed on breeding sites; they hatch after 11–13 days. The larva reaches a length of 4–10 cm. The duration of the larval stage varies considerably, ranging from around 100 to 200 days. Similarly, the adult stage may last for a few months or extend to over half a year. Before pupation, there is a short prepupal stage of a week; the adults emerge after a further 3 weeks. The eggs are laid on rotting vegetable matter. On an oil palm estate, decaying palm trunks and bunch refuse are common breeding grounds, and Norman and Basri Wahid (2004) showed that adults move into replants from surrounding mature palms. Empty bunches or other organic waste used as mulch may also provide breeding sites (Wan Zaki *et al.*, 2009).

The oil palm is damaged by the adult beetle, which bores its way through the petioles into the softer tissues of the younger, unopened spear leaves. The effect can be seen when these leaves develop and open, but the regularity of wedge-shaped cuts so characteristic with the coconut palm is not always so clearly seen in the oil palm. Previous attacks may be detected by the presence of holes in the petioles of older leaves. Attack is most damaging in young palms, since the growing point is occasionally reached, or bud rot may develop and kill



**Plate 14.1** *Oryctes rhinoceros* in Malaysia. (A) Adults, male (left), female (right). Note clump of hairs on abdomen of female. (B) Larval instars, 1st, 2nd, 3rd (early, late, prepupal). (C) Head capsules of larval instars; (left to right) 3rd, 2nd, 1st.

the palm. The holes may also give *Rhynchophorus* access to the palm (see Section 14.6.1), with *Rhynchophorus* damage, in turn, providing conditions suitable for *Oryctes* larvae (Zulnerlin and Fatah Ibrahim, 1999).

#### 14.4.1.3 Effect on yield

The effect of *Oryctes* damage on yield depends on palm age. Wood *et al.* (1973) compared two 2.4 ha plots, one with over 80% severe or medium damage by *Oryctes*

and one with only 6%, and found that the former yielded 2% less over the first 18 months of production. In this trial, damage probably ceased at least a year before harvesting started. Later damage can have more effect. Liao and Ahmad Alwi (1995) found that artificial defoliation of 2-year-old palms did affect yield: 50% defoliation on a single occasion reduced subsequent yield by 12%, and repeated ('chronic') defoliation reduced it by 24%. Chung *et al.* (1999) found that palms damaged by *Oryctes* 21 months after planting

yielded 80% less than undamaged palms in the first 12 months of production (although this comparison was based on groups of only 20 palms). With more than 70% of palms damaged, they estimated a loss of 2.1 t FFB/ha in the first year. Liau and Ahmad Alwi (1993) observed less damage in the second year in the field and harvested 5 t more fruit over the first 18 months of production from palms in a clean clearing than from plots with windrowed trunks.

Cahyasiwi *et al.* (2010) reported a trial in which good control was achieved with insecticides (see Section 14.4.1.4). In the control plots, damage was severe (though there were no fatalities recorded), and yield was reduced by 6.2 t FFB/ha over the first 18 months of production. Thereafter, damaged palms had recovered and differences were negligible.

#### 14.4.1.4 Control

Older methods of control involved destruction of breeding sites and hand collection of adult beetles. Where old palm trunks were not burnt, regular inspection to break up the rotting material and collect larvae was recommended (Barlow and Chew, 1971). This method was labour intensive, but Zulnerlin and Fatah Ibrahim (1999) found that in Indonesia, hand-picking was cheaper than insecticide application. In some countries, the larvae are hand-picked and eaten as a delicacy. Complete pulverising of trunks to sawdust-sized particles, thus largely eliminating breeding sites, has been claimed to reduce the population to less than 3% of that with the usual chipping, which cuts the trunk into fragments weighing 1.5–8 kg (Ooi *et al.*, 2001; Ooi and Heriansyah, 2005).

It was noticed in Malaysia that palms along or near roadsides might be heavily attacked while those within the field escaped injury. Wood (1968b) showed that interrow vegetation may form a barrier to beetle movement and, in young areas, may blur the palm silhouette which is believed to attract the beetle. When areas of young palms either kept bare or sown with a legume cover crop were compared, *Oryctes* breeding and damage were considerably higher on the bare areas (Wood, 1968b). Norman *et al.* (2005) showed a highly significant effect of cover crop depth on *Oryctes* numbers in heaps of trunk chips, with none found where the cover crop was more than 50 cm deep. In addition to its many other advantages, the planting of leguminous cover is undoubtedly an effective way of suppressing *Oryctes* attack. It has been confirmed that this approach is also effective against *O. monoceros* in Africa (Boyé and Aubry, 1973). Wood (1976a) noted that ground cover

does not totally eliminate attack, but reduces it to a very low frequency, such that effects on yield are unlikely to be important. He pointed out that *Oryctes* attack is rare on older palms, because the closed canopy itself forms a 'vegetative barrier'; isolated older palms are often attacked. Lee *et al.* (2005b) found that *Mucuna bracteata* covered windrowed trunks faster than other cover species (see Section 11.1.2.3), while Ong (2007) found that sweet potato (*Ipomoea batatas*) gave faster cover than *M. bracteata*.

Several authors have advocated prophylactic application of insecticide, usually a synthetic pyrethroid such as cypermethrin. Cahyasiwi *et al.* (2010) showed that this could give good control, with a profitable yield increase, but carbosulfan granules were just as effective and preferable in view of the potential damage from broad-spectrum pyrethroids (see Section 14.1.4). With a good cover crop (see above), insecticide application should not be necessary, but application of granules gives added protection.

Ethyl chrysanthemumate was found to be a strong attractant to *Oryctes*, and Turner (1973) suggested baiting traps with this compound, but Hallett *et al.* (1995) found that the aggregation pheromone, ethyl-4-methyloctanoate, was ten times more attractive to *Oryctes* than ethyl chrysanthemumate. This allows a much lower trap density, and Chung (1997) showed that one trap per 2 ha gave good control of damage, provided that the *Oryctes* population was not too large. Costs were lower than for insecticide application, but in a situation with severe infestation, Cahyasiwi *et al.* (2010) found that trapping was little better than untreated controls. They recorded a yield loss of 5.6 t/ha with trapping compared to systemic insecticide (carbosulfan) application. Desmier de Chenon *et al.* (1998) advocated trapping in the old stand for 6 months before replanting to reduce the population. Norman *et al.* (1999) suggested using pheromone trapping to monitor beetle populations and identify 'hot spots' where chemical control would be worthwhile. Plastic buckets are often used as traps, but Prasetyo *et al.* (2009) described an improved design with 1 m lengths of PVC pipe.

Much attention has been paid to the introduction and spread of insect parasites, fungi or viruses. A virus, *Rhabdionvirus oryctes*, first identified in Malaysia (Huger, 2005), has been introduced over most of the South Pacific where *O. rhinoceros* is a coconut pest. Infected beetles stop feeding, and fly and mate less frequently (Zelazny, 1977), and beetle populations have been reduced following introduction of the virus (Young, 1986). In Malaysia, although the virus is

widespread (Jackson *et al.*, 2003; Ramle Moslim *et al.*, 2009), only slight larval mortality has been recorded (Barlow and Chew, 1971; Ramle Moslim *et al.*, 2009).

Barlow and Chew (1971) identified a fungus, *Metarhizium anisopliae*, which infects the larvae; Tey and Ho (1995) applied cultures of this to *Oryctes* breeding sites and achieved high infection rates, coincident with reduced numbers of larvae. Noor Hisham *et al.* (2013) showed that spray application to trunk chips of 0.84 kg/ha of a powder formulation of *M. anisopliae* spores gave complete control. Ramle Moslim *et al.* (2007) described a pheromone trap which automatically inoculated the beetles with spores of *M. anisopliae* and then allowed them to escape.

There is a view that the adoption of zero-burn replanting methods has increased problems with *Oryctes*, but until the 1970s, all replants were zero-burn. The belief that the old stand must be completely uprooted to prevent *Ganoderma* attack (which is far from clear; see Section 13.4.3.7) led to burning or windrowing of the old trunks. With windrowing, if the old trunks were not adequately covered by vegetation, *Oryctes* could invade. Wood (1999) noted that *Oryctes* outbreaks in recent years have led some to question the ‘vegetative barrier’ effect mentioned previously, but he considered that in such cases, there was always some evidence that development of vegetation cover had been restricted, for example by felling too late after poisoning, by stacking the palm trunks well above the vegetation or by flooding.

Norman and Basri Wahid (1997) surveyed 640 estates in Malaysia, with a total of 280,000 ha of immature palms. *Oryctes* infestations were reported from 16% of the area, with 13% of outbreaks described, subjectively, as ‘serious’ or ‘very serious’. However, only 3% of outbreaks were in palms older than 18 months, and we have seen that before that age damage has little effect on subsequent yield.

Samsudin *et al.* (1993) found much higher *Oryctes* numbers in an underplanting than in an area where the old stand had been felled and trunks chipped before planting. Incidence was particularly high if the underplanted old stand was poisoned and left standing, as expected from the absence of vegetation cover. Similar observations have been used as an argument against underplanting (see Section 9.4.4.3), but provided that the old stand is felled and quickly covered by ground vegetation, there should not be a problem (Hakim *et al.*, 1998; Corley and Palat, 2013). If *Oryctes* does build up in an underplanting, though, there could be significant effects on yield. If the last of the old stand is cleared 2 years after underplanting, there might be damage to

palms aged 2 years or more, and damage at that age has been shown to affect yields (see Section 14.4.1.3).

Jacquemard *et al.* (2002a) found large differences between oil palm families in amount of damage (though with no indication of statistical significance), and considered that some genotypes were more attractive to *Oryctes* than others. While this might not be important for seed production, they suggested that it should be considered in clone selection.

#### 14.4.1.5 Conclusion

If a good legume cover is established early in an oil palm replant, this effectively suppresses *Oryctes*, and the amount of damage to young palms should be small. As it has been clearly established that quite severe defoliation during the first year in the field has little effect on subsequent yield, in most situations, it is unlikely that *Oryctes* control measures will be needed. Only if severe damage continues beyond the first 18 months in the field would the possible loss in yield justify treatment, in which case a systemic insecticide such as carbosulfan should be used as granules. Spraying with synthetic pyrethroids should be avoided because of possible disruptive effects on other pest species.

#### 14.4.2 *Strategus aloeus* (Dynastinae)

This beetle, which somewhat resembles *Oryctes*, is distributed throughout tropical America, where it has been troublesome in several oil palm plantations (Mariau, 1976b).

*Incidence and damage:* The adults attack young palms in the field or nursery by digging a hole in the ground near the palm, from which they bore their way into the plant just above the roots. Often, in a young palm, the growing point is reached and the plant killed. Eggs may be laid in the palm, which is then consumed by the developing larvae, or in rotting stumps, trunks and vegetation.

*Control:* In view of the lethal attack on young palms by the adult, control measures are required in areas where the beetle is common. As eggs may be laid in rotting stumps and trunks, the measures to be taken against the larval stage are the same as for *Oryctes* species: destruction of breeding sites and collection of larvae. During wet weather, fortnightly inspections have been recommended; in dry weather, *Strategus* attack is rare.

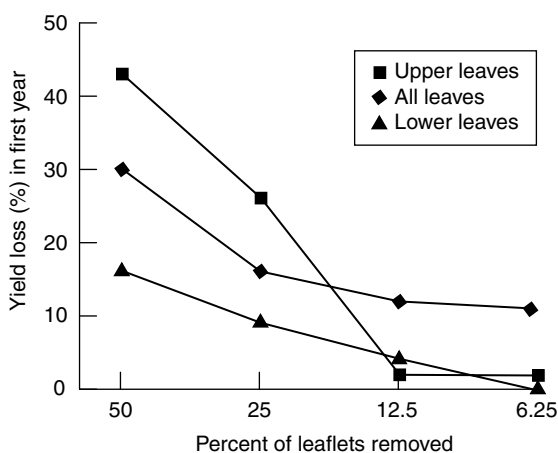
It does not appear to be recorded whether the ‘vegetative barrier’ effect which controls *Oryctes* is effective against *Strategus*.

## 14.5 LEAF PESTS OF MATURE PALMS

### 14.5.1 Effects on yield

Numerous species eat leaf tissue of mature palms and have the potential to cause significant defoliation. The effects of this on yield were investigated by Wood *et al.* (1973), who used manual defoliation to simulate the effect of attack by a leaf-eating pest on 8-year-old palms. Figure 14.2 shows that, in the first year after defoliation, 50% damage caused a crop loss of over 40%, if restricted to the upper half of the canopy (i.e. all leaflets in the upper half destroyed). This corresponded well with observations in a severely attacked area. Damage to the lower leaves had comparatively little effect, because those leaves are shaded by younger leaves at the top of the canopy, and contribute relatively little to total canopy photosynthesis. Less severe damage caused smaller losses.

The most severe treatment caused a further 17% crop loss in the second year. Study of monthly yields showed that there was a large shortfall about 10 months after defoliation, attributable to inflorescence abortion, and a further shortfall between 22 and 26 months, due to an effect on sex ratio (see Section 5.4 for discussion of these yield components). A mature oil palm canopy consists of about 40 leaves, and as leaf production rate is around 24 per year, the palm will take over a year to recover from damage to the younger, upper leaves.



**Fig. 14.2** Effects of artificial defoliation on subsequent yield. Different degrees of defoliation were applied by stripping off leaflets, to upper leaves, lower leaves or all leaves. (From Wood *et al.*, 1973.)

This study allows action levels to be estimated for any pest that causes defoliation. Wood (1977) noted that the cost of treatment by aerial spraying or trunk injection would be covered by a yield gain of no more than 3%. Figure 14.2 suggests that even quite mild defoliation could cause a loss of that order. The question, then, is not whether the cost of treatment will be recovered, but whether the outbreak will come under natural control anyway. If surveys indicate that numbers are increasing, and if a proven integrated control measure, such as trunk injection or an insect pathogen, is available, it will be advisable to take action at a fairly early stage.

### 14.5.2 Nettle and slug caterpillars

A wide variety of different caterpillars feeds on oil palm leaves. Nettle and slug caterpillars and bagworms (Section 14.5.3) are the most frequent pests. Mariau *et al.* (1991) presented good colour photographs of most of the important species, and of their natural enemies, but little information on control. Syed and Saleh (1993) described IPM systems for these pests in Indonesia.

#### 14.5.2.1 Distribution

Nettle and slug caterpillars (Limacodidae) have been recorded as pests in all oil palm-growing areas. Wood (1987) listed the species that have been recorded as causing significant damage to oil palms (Table 14.2) and other crops. Some species, such as *Darna trima*, are common, yet severe damage may be unusual. Outbreaks of several species have been attributed to prior use of contact insecticides.

#### 14.5.2.2 Life cycles and damage

Severe infestations may develop rapidly, as the life cycles are only a few weeks long and reproduction rates are high. The eggs are deposited on the leaflets; the caterpillars usually feed on the underside, often stripping the surface when young, but when larger, they may eat away the whole lamina, leaving only the midrib (Plate XVII). Pupation may be on the ground, in cracks in the soil or attached to the leaf.

Mariau *et al.* (1991) gave critical levels, in terms of number of larvae per frond, for most species in South East Asia, together with recommendations on insecticides. Different species attack different parts of the crown: *D. trima* is first found on leaves 9–17,

**Table 14.2** Nettle and slug caterpillars reported to have reached outbreak levels on oil palms

Species	Synonym	Location	Frequency <sup>a</sup>	Reference
<i>Susica malayana</i>	<i>S. pallida</i>	W Malaysia	Occasional	1
<i>Setothosea asigna</i>	<i>Thosea asigna</i>	W Malaysia, Sabah, Sumatra	Often	2, 6
<i>Setora nitens</i>		W Malaysia, Sabah, Sumatra	Frequent	2, 3
<i>Birthosea bisura</i>	<i>Thosea bisura</i>	W Malaysia	Occasional	2
<i>Ploneta diducta</i>	<i>Darna diducta</i>	W Malaysia	Occasional	2, 3
<i>Ploneta bradleyi</i>		Sabah, Sumatra	Occasional	6
<i>Darna trima</i>		W Malaysia	Often	2, 3
		Sabah	Often	4
<i>Darna mindanensis</i>	<i>Darna</i> sp. nr. <i>trima</i>	Philippines	Often	2
<i>Darna furva</i>		South Thailand	Often	5
<i>Darna catenatus</i>		Sulawesi	Often	6
<i>Thosea vetusta</i>		Borneo	Occasional	3
<i>Parasa pallida</i>	<i>Latoia pallida</i>	West Africa	Often	7
<i>Parasa viridissima</i>	<i>Latoia viridissima</i>	West Africa	Often	7
<i>Episibine intensa</i>		Guyana, Colombia	Frequent	8
<i>Episibine sibirides</i>		Peru	Often	8
<i>Euclea diversa</i>		Central and South America	Often	8
<i>Euclea cuprostriga</i>		South America	Often	8
<i>Euprostema elaeasa</i>	<i>Darna metaleuca</i>	Central and South America	Frequent	8, 9
<i>Natada pucara</i>		Central and South America	Occasional	8
<i>Natada subpectinata</i>		South America	Occasional	8
<i>Sibine fusca</i>		South America	Occasional	8
<i>Sibine nesea</i>		South America	Occasional	8

Source: Based on Wood (1987).

References: 1: Wood (1968a); 2: Wood *et al.* (1977); 3: Ho and Sidhu (1986); 4: Wood and Nesbit (1969); 5: Wood (1987); 6: Mariau *et al.* (1991); 7: Mariau *et al.* (1981); 8: Genty *et al.* (1978); 9: Genty (1976)

<sup>a</sup>Occasional: one or two recorded outbreaks only; frequent: extensive, heavy and recurrent outbreaks in more than one location, for some period of time; often: intermediate between occasional and frequent.

*Setothosea asigna* and *Setora nitens* (Plate XVIB) on leaves 9–25 and *Ploneta diducta* and *P. bradleyi* on older leaves (Mariau *et al.*, 1991). In severe outbreaks, the entire crown may eventually be defoliated. The effect on yield depends on the extent of defoliation and on which part of the crown is damaged. As noted previously, loss of young leaves is more damaging than loss of older leaves.

#### 14.5.2.3 Control

Numerous parasites and predators of the Limacodidae have been recorded. Species attacking *S. nitens* (Plate XVID) included five species of wasp, four parasitic flies and two predatory bugs (Wood, 1966, 1968a). *Setothosea* and related species are attacked by a virus, a fungus (*Cordyceps* sp.) and several predatory or parasitic insect species (Tiong, 1979).

Wood *et al.* (1977) described a series of experiments on the control of nettle caterpillars in Malaysia. They

considered *B. thuringiensis* insecticides to be very promising. The trials confirmed the need for chemical intervention on occasion. The utilisation of diseased pests by spraying suspensions of crushed bodies has also been successful. Tiong (1982) described control of *S. asigna* by an integrated programme similar to that advocated by Wood *et al.* (1977), in which chemical intervention was confined to quelling high-density infestation and combined with the encouragement of the natural fungal and insect enemies. In Sarawak, *D. trima* was controlled using a virus inoculum prepared from diseased larvae. There was high mortality within 8 days after spraying this with mist blowers, and resurgence, such as was common after 5 weeks with chemical insecticide spraying, did not take place (Tiong and Munroe, 1977).

The biology of *Euprostema elaeasa*, which is among the more serious of the numerous South American caterpillar pests, was studied by Genty (1976), who found several important parasites, including a wasp, *Casinarina* sp. Genty recommended that the parasite population

be carefully examined before control measures are decided upon. Zeddam *et al.* (2003b) identified a virus which might be used for control of *E. elaeasa*, while Valencia (2003a) showed that it could be controlled by application of *B. thuringiensis*. Reyes *et al.* (2003) used root absorption of monocrotophos or dicrotophos for control.

*Sibine fusca*, another American species, is attacked by several bugs, and Genty (1981) recorded a wasp, *Apanteles* sp., and two flies, *Palpexorista coccyx* and *Systropus nitidus*, which not only parasitise the larvae but also transmit a viral disease which can be artificially spread (Meynadier *et al.*, 1977). Mexzón *et al.* (1996) controlled *Sibine megasomoides* in Costa Rica by spraying with *B. thuringiensis* and deltamethrin.

*Parasa viridissima* has defoliated oil palms in Cameroon, Nigeria, Liberia and Uganda, while *P. pal-lida* has been a pest of oil palms in the Ivory Coast (Mariau and Julia, 1973; Mariau *et al.*, 1981). In the Ivory Coast, spraying 3 weeks after the appearance of the first caterpillars was recommended (Mariau and Julia, 1973). Fediere *et al.* (1990) described the use of a virus for control of *P. viridissima*.

#### 14.5.2.4 Monitoring

A pheromone produced by the female of *D. trima* has been identified by Sasaerila *et al.* (2000), who suggested that it could be used to trap males and hence to monitor the population. Desmier de Chenon *et al.* (1996) recommended using pheromone traps for monitoring populations of *S. asigna*. They indicated that this was cheaper than conventional census systems and might give an earlier warning of pest build-up.

### 14.5.3 Bagworms

Several members of the Psychidae have been pests of the oil palm in Asia since the start of the plantation industry, but the prevalent species appear to change from time to time and place to place. As with nettle caterpillars, effects on yield will depend on the extent of defoliation.

#### 14.5.3.1 Life cycles and damage

The larvae of bagworms are encased in bags constructed of pieces of leaf bound with silk. *Metisa plana* and *Pteroma pendula* feed on the upper surface of the leaf, the scraped portion first becoming dried out and then forming a hole. Further damage is done by the removal of pieces of leaf to make the case. Badly damaged leaves soon dry up and this gives the lower and middle part of the crown a characteristic grey



**Plate 14.2** Bagworms in Malaysia: (left) *Metisa plana*; (right) *Pteroma pendula*. (B.J. Wood.)

appearance, the only green leaves being the youngest. *Mahasena corbetti* feeds on the underside of the leaf. Surviving caterpillars pupate in their cases on the underside of the leaves. Balasubramaniam and Chung (2013) recorded a 35% yield loss in the year after a severe outbreak of *Dappula tertia*.

The size and form of the bags and the manner in which they are attached to the leaf help to distinguish the species. *M. plana* has a short, hooked attachment and the bag is about 13 mm long (Plate 14.2). The case of *P. pendula* is about 6 mm long, is rather rough and hangs on the end of a long vertical thread. *M. corbetti* is much larger and the case is more ragged (Plate XVII); Syed *et al.* (1973) studied the life cycle of this species. The male moths of all species fly from their cases, but the females are wingless and remain in the case. They attract the males with a pheromone and mate while still in the case, each then laying hundreds or thousands of eggs, depending on the species. On hatching, the caterpillars acquire their own cases and feed in groups. The life cycles take between 2.5 and 4.5 months (Syed, 1978).

Norman *et al.* (1996) described 18 species of parasitoid associated with *M. plana* and *M. corbetti* in Malaysia.

#### 14.5.3.2 Control

Application of a systemic insecticide such as monocrotophos by trunk injection (see Section 14.1.4) is much the most effective method of control (Wood *et al.*, 1974).

Aerial spraying of trichlorfon is also effective for large outbreaks (Wood, 1968a, Noor Hisham *et al.*, 2013).

Syed and Saleh (1993) described a census system for *M. corbetti*. Syed and Saleh (1998) achieved effective control of this pest by spraying part of an infested area with a granulosis virus. Basri Wahid *et al.* (1996) tested preparations of *B. thuringiensis* against *M. plana* and *M. corbetti*. The best preparation was as effective as trichlorfon, but some were much less effective. Rhains (2000) suggested that control should be possible using pheromones to trap males and disrupt mating; this has been done successfully with another bagworm species, *Thyridopteryx ephemeraeformis* (Klun *et al.*, 1986). Shamsilawani *et al.* (2007) suggested that the fungus *Paecilomyces* spp. might be used.

Chung and Sim (1993) discussed a situation where bagworms had become a constant problem in a particular area and were apparently not easily controlled. They showed that standard procedures (census twice per month, trunk injection where the threshold of 10 larvae per leaf was exceeded), provided they were correctly followed, could reduce an apparently chronic infestation within a few months to a level where natural enemies took over control.

Ho (1998; Ho and Teh, 1999) demonstrated the value of *E. heterophylla*, a ground cover species which supports several of the natural enemies of bagworms, in minimising build-up of *M. plana*. Ho *et al.* (2003) showed increased numbers of natural enemies and increased parasitisation and reduced numbers of *M. plana* up to 100m from strips of *E. heterophylla* or *Cassia cobanensis*. The latter is perennial, so should be more useful.

#### 14.5.3.3 Other bagworms

Wood (1968a) mentioned species of *Pteroma*, *Clania* (now *Dappula*) and *Amatissa* as showing limited increases in Malaysia from time to time. Sumantri *et al.* (2011) recorded an outbreak of *D. tertia* in Sumatra. *Oiketeticus kirbyi* occurs in Costa Rica (Genty *et al.*, 1978).

In Colombia and Ecuador, *Stenomoma cecropia* (Stenomidae) has occasionally caused extensive damage. This species has a fixed bag and eats by journeys from it while remaining attached by fibres (Genty, 1978). In serious outbreaks, aerial spraying with trichlorfon has been used. Reyes *et al.* (2003) used root absorption of monocrotophos or dicrotophos for control.

#### 14.5.4 Other caterpillars

Damage by caterpillars of other families is also reported from time to time. *Homophylotis catori* (formerly *Chalcomyces*) (Zygaenidae), which has a life cycle of

about 30 days, was reported as causing serious local damage in the Ivory Coast (Genty, 1968). Outbreaks followed the use of BHC against leaf miner. *Pyrrhochaletia iphis* (Hesperiidae) and *Epimorius adustalis* (Psychidae) have been reported from Congo (Frazelle and Buyckx, 1962).

In Malaysia, Wood (1968a) and Mariau *et al.* (1991) recorded a large number of leaf-eating caterpillars, few of which, however, have done any significant damage.

In America, colonies of mixed species of Lepidoptera have characteristically developed on some plantations, and the method and timing of control has influenced the balance between species. *Opsiphanes cassina* (Brassicidae) did much damage as a leaf eater and was reported to be encouraged by carbaryl spraying, but reduced by using lead arsenate or *B. thuringiensis* (Rojas-Cruz, 1977). Calvache (2003c) reported that it could be controlled by trapping.

#### 14.5.5 Grasshoppers

Bush crickets, long-horned grasshoppers or treehoppers (Tettigoniidae) are described as the principal pest of oil palms in PNG (Prior, 1988; Caudwell, 2000). Several species, collectively known as sexavae (Dewhurst, 2012), are oil palm pests: *Segestes decoratus*, *Segestidea defoliaria* and *S. novaeguineae* were listed by Prior (1988); Dewhurst (2012) included *Segestidea gracilis*, and mentioned several other species, but noted that the genus *Sexava* has not been recorded on oil palms. Prior mentioned 80–90% defoliation by *S. defoliaria*, but Dewhurst (2012) considered *S. decoratus* to be the greatest threat. Prior listed a number of species parasitic on sexavae, but according to Caudwell (2000), experience suggests that populations are not well controlled by natural enemies. Sexavae eggs are laid in the soil and hatch after rains, giving a synchronised single generation (Page and Lord, 2006), and once light damage is observed, this will steadily increase until severe defoliation has occurred.

*Control:* Bush crickets can be controlled by trunk injection of monocrotophos (Prior, 1988) or methamidophos, but treatment must be in the early stages of an outbreak to be effective. Caudwell (2000) described a census system based on the amount of visible leaf damage, rather than on pest numbers. Mass rearing and release of egg parasites was described by Prior (1988), but it seems that these methods do not give complete control, and further work on biological control methods is in progress (Kathirithamby *et al.*, 1998; Caudwell, 2000).

### 14.5.6 Leaf miner (*Coelanomenodera lameensis*)

This beetle is found on oil palms and, to a lesser extent, on coconut and *Borassus* palms throughout West and Central Africa. Serious attacks, causing widespread defoliation, have been reported from Ghana, Benin, the western part of Nigeria, Ivory Coast and West Cameroon. There are numerous species of *Coelanomenodera*. Until 1980, the main oil palm pest was thought to be *C. elaeidis*, but then two species were recognised, with *C. minuta* thought to be the more important. It now appears that the pest is a third species, *C. lameensis* (Berti and Mariau, 1999). Although *C. elaeidis* occurs on oil palms, it is not thought to be involved in outbreaks (R. Philippe, pers. comm., 2001).

#### 14.5.6.1 Life cycle and damage

The method of feeding and life history were recorded in Ghana by Cotterell (1925). Detailed studies have been made of the biology of this insect and of its control (reviewed by Mariau, 1976a). The life cycle takes about 94 days, accounting for the pest damage sometimes reappearing every 3 or 4 months. The adults continue to live on the undersurface of the leaf for 3–4 months during and after laying eggs.

A single female of *C. lameensis* may lay several hundred eggs; *C. elaeidis* is less prolific, perhaps explaining why outbreaks of that species do not occur (R. Philippe, pers. comm., 2001). The larvae mine under the upper epidermis of the leaflets of palms of all ages except, normally, those below 3 years old in the field. In a severe attack, the greater part of the leaf tissue will be destroyed (Plate XVII). A single gallery mined by a larva to attain its full development measures about 15 cm in length and is 1 cm broad. Severely attacked palms have a typical appearance; the young leaves are green, being little attacked, while the remainder are grey–brown and withered, with desiccated, rolled-in leaflets. Later, the withered laminae shatter, leaving the leaflet midribs only.

The effect of damage on yield is similar to that of other pests which cause defoliation (Section 14.5.1). Philippe *et al.* (1979) estimated that there was a 40% yield loss in the 2 years following an outbreak.

#### 14.5.6.2 Control

The census method developed in the Ivory Coast (Mariau and Bescombes, 1972) involved counting of adults and larvae on a leaf between 25 and 30 (i.e. in the lower part of the canopy), with small and large larvae, nymphs and adults being recorded separately. When

the number of larvae exceeds 20 and of adults exceeds 3, treatment is considered necessary.

Spraying with Evisect (thiocyclam), using a tractor-drawn sprayer or a helicopter, or by fogging, was recommended by Philippe (1990a, b). A single treatment was usually effective, but sometimes a second application 3 weeks after the first was needed. There was only a small effect on the population of the pollinating weevil, *Elaeidobius kamerunicus*, and there were no detectable residues of thiocyclam in palm oil. Trunk injection (Section 14.1.4) has also been recommended (Philippe and Diarrassouba, 1979).

Cotterell (1925) reported hymenopteran parasites of both the eggs and the larvae, as well as fungal parasitism. Mariau and Lecoustre (2004) found that egg mortality was greatest during hot and dry weather. Egg and larval parasites of *Coelaenomenodera* were identified (Morin and Mariau, 1974; Mariau and Morin, 1974), but none was sufficiently numerous to have much limiting effect in outbreaks (Mariau *et al.*, 1978), so a search was made for possible parasites to introduce into the Ivory Coast for control of the pest. In Cameroon, Timti (1991) found that leaf miner attacks were fewer where *Crematogaster* ants were present and suggested that the pest could be controlled by collecting these ants and distributing them in affected areas.

## 14.6 STEM PESTS OF MATURE PALMS

### 14.6.1 *Rhynchophorus* species (Curculionidae): Palm weevils

*Rhynchophorus* is a potentially lethal pest. In Asia and Africa, its incidence on the oil palm is not very high; deaths have been noted in Africa where leaves have been cut abnormally short and wounding of adjacent leaf bases has resulted. In America, incidence may well be higher. Deaths from *Rhynchophorus palmarum* attack have been noted in young plantings within the grove areas in Bahia, Brazil, and the pest is quite frequently encountered on oil palms in other parts of the continent.

#### 14.6.1.1 Distribution and description

Species of these large weevils are to be found attacking palms in all parts of the tropics. The larvae tunnel into the crown and trunk, and the palm may be killed. As pests of the oil palm, the distribution of the more important species is as follows:

<i>R. phoenicis</i>	Africa	
<i>R. palmarum</i>	America	Gru-gru beetle
<i>R. ferrugineus</i>	Asia	Red palm weevil, red-stripe weevil
<i>R. papuanus</i>	Sulawesi, New Guinea	

The larvae attain a length of some 5 cm. The cocoons, constructed of concentrically placed fibres, extend to 8 cm in length and 3.5 cm in breadth. The adults show distinct specific differences but are usually about 4–5 cm long and 2 cm broad. *Rhynchophorus ferrugineus* is the common red palm weevil of the east; it is the species most commonly found in Sumatra and Malaysia (described under the synonym *R. schach*). The oil palm has, however, proved far less prone to attack than the coconut palm.

#### 14.6.1.2 Life cycle and damage

*Rhynchophorus* weevils lay their eggs on cut or damaged surfaces of many palm species, and the larvae tunnel into the crown and trunk (Plate 14.3). The tissues around the growing point then begin to decay and the palm may be killed. The external symptoms of attack have been described as similar to those of *Fusarium* wilt: the leaves show a gradually increasing chlorosis



**Plate 14.3** *Rhynchophorus palmarum* larva found in a 'spear rot' palm in Nicaragua. (B.J. Wood.)

and fracture in strong winds. *Rhynchophorus* is also a vector for the nematode that causes red ring disease (see Section 13.4.7). The combination of damage and red ring disease can be a significant problem in America, but there are few records of damage by *Rhynchophorus* in Malaysia or Indonesia.

The life cycle lasts for less than 3 months. The weevil commonly breeds in the stumps of a felled palm field, newly cut stumps being preferred. *Oryctes* and *Rhynchophorus* species are often present in a plantation at the same time. Wounds made by *Oryctes* adults give a means of *Rhynchophorus* infection, while *Rhynchophorus* damage will provide conditions suitable for *Oryctes* larvae (Hartley, 1988; Zulnerlin and Fatah Ibrahim, 1999).

#### 14.6.1.3 Control

Effective control of *Rhynchophorus* attack is not easy. In the first place, wounding of the palm must be avoided and the petioles must not be cut close to the trunk. Secondly, all dead or felled palms should be destroyed within the period of the beetle's life cycle. Measures for the control of *Oryctes* and other large beetles will help to reduce the incidence of *Rhynchophorus*. Mariau (1968) described various preventive and curative measures, including hooking the larvae from their tunnels with the aid of a wire.

The most promising approach is to trap the adult weevils. Initially, traps were baited with sugar cane, pineapple, banana or palm tissue, but pheromone-baited traps are more effective. Oehlschlager *et al.* (1992) described the aggregation pheromone of *R. palmarum*. This compound, 'rhynchophorol', is released by male weevils and attracts others of both sexes to the site of release. Pheromones have also been described for *R. phoenicis* (Gries *et al.*, 1993), *R. ferrugineus* (Hallett *et al.*, 1993) and various other species. Additional attractants include ethyl acetate and ethyl propionate, which are produced by damaged palm tissue, and the most effective traps were baited with the pheromone and palm tissue pieces (Gries *et al.*, 1994). The work on pheromones was summarised by Giblin-Davis *et al.* (1996). Chinchilla *et al.* (1996) described the use of pheromone-baited traps to capture *R. palmarum* and hence to control red ring disease.

Several parasites of *Rhynchophorus* species have been recorded. Moura *et al.* (1993) described a tachinid fly, *Paratheresia menezesi*, which parasitises *R. palmarum* in Brazil. Dembilio *et al.* (2010) isolated a strain of the fungus *Beauveria bassiana* which parasitises *R. ferrugineus*.

### 14.6.2 Termites

As plantings on peat have expanded, termites have become an increasing problem (Mariau *et al.*, 1991, 1992; Lim and Silek, 2001; Faszly Rahim *et al.*, 2003). Cheng *et al.* (2008) identified several species which made nests at the base or on the trunks of oil palms in Malaysia, but the only one which damaged palms was *Coptotermes curvignathus* (Rhinotermitidae). This species, which was rare on mineral soils but predominant on deep peat, burrows into the stem of both young and mature palms and may cause fatal damage. Problems with termites on peat soil had been attributed to the timber residues in such soils (see Section 4.4). Cheng *et al.* (2008) considered that *C. curvignathus* infestation in oil palms on peat was because that species predominates in the original swamp forest.

*Control:* Removal of timber residues has been advocated, but Cheng *et al.* (2008) considered that this was unlikely to have much effect, and the volume of timber in some peats makes it impracticable. Lim (2005a) recommended spraying infested trees with fipronil and also spraying round the base of the tree to prevent reinfestation. *Metarhizium anisopliae* and *Beauveria bassiana* both show promise for control (Rozziashah *et al.*, 2013; Ginting *et al.*, 2013). Hasnol *et al.* (2007) showed that compaction before planting reduced the incidence of termite infestation.

## 14.7 ROOT PESTS: OIL PALM ROOT MINER

The caterpillar of the moth *Sagalassa valida* (Brachodidae) has been found mining in the roots of oil palms in Colombia, Ecuador, Peru and Brazil. Up to 80% of the root system may be destroyed, and attacked palms may die. Calvache (2003b) listed it as occurring throughout Colombia, but its frequency is unclear.

*Life cycle and damage:* The adult moths live in the undergrowth and among the pruned palm leaves in the interline. The site of egg laying has not been observed, but it is presumed that it is in moist material at the base of the palm. The young larvae, which are no more than 1 mm long, penetrate the primary roots immediately after hatching but can also move through the soil to attack roots some distance from the point of hatching. They at first eat the external part of the root, leaving the central cylinder intact; this partial destruction stimulates the production of new branch roots. Older larvae grow to 2 cm long and cause complete destruction of the tissues of the roots in which they mine (Genty, 1973).

In areas of attack, it has been noted that the number of caterpillars increases with the age of the palm, and in some palms, 50–80% of the root system has been destroyed, including old and recent damage. Some attacked palms fall over (Genty, 1981). The amount of damage is highly variable but tends to be greater on the edge of a plantation near the forest or near to rivers and streams.

The possibility that sudden wither is associated with damage by this caterpillar is mentioned in Section 13.4.4.

*Control:* Genty (1977) considered that the extent of the damage done to the roots in itself justified treatment and stated that a generalised yellowing of the leaves may be due solely to *Sagalassa*. He recommended routine checks by examination of one hole, 40 × 40 × 50 cm deep, at the foot of one palm/20 ha every 6 months. If more than 20% of the primary roots are attacked, more intensive checks are done, and if 20% attack is still found, then an insecticide should be applied around the bases of the palms. Treatment was always followed by rapid regeneration of the root system.

Gomez *et al.* (2003) found that incidence was lower where the ant *Pachycondyla harpax* was present. They also noted that application of a layer of empty bunches could prevent the caterpillar from getting to the roots, but R.C. Aldana (2003) found that this reduced but did not completely prevent damage.

## 14.8 PESTS ATTACKING FRUIT AND BUNCHES

In addition to the insects listed in the following text, rats do considerable damage to fruit bunches (see Section 14.9.1).

### 14.8.1 Oil palm bunch moth

*Tirathaba rufivena* (Pyralidae: Galleriinae; formerly *T. mundella*) is widespread in Malaysia and Indonesia and can reach epidemic proportions, especially in young areas. It appears to have become a particular problem on peat soils, but it is not clear why this should be so.

*Life cycle and damage:* Eggs are laid in the bunches, especially those overripe or rotten, and in inflorescences or bunches lying on the ground. Caterpillars bore into developing fruit or feed on the surface of ripening fruit. They are sometimes found tunnelling into the base of a spear leaf. They grow to 4 cm before pupating inside the bunch. The life cycle is about 1 month.

*Control:* Wood and Ng (1974) recommended spraying with endosulfan, but Basri Wahid *et al.* (1991) found that Thuringide (*B. thuringiensis* – Bt) was more effective than endosulfan and cheaper than other effective insecticides. Lim (2011) found that Bt was more effective than cypermethrin; the latter also had unwanted effects on the pollinating weevil *E. kamerunicus* and on earwigs (*Chelisoche morio*), which were said to be a predator of *T. rufivena*.

Two larval parasites have been identified: a chalcid wasp, *Antrocephalus* sp., and an ichneumon wasp, *Venturia palmaris*, of which the latter was more common and appeared to be the more promising for possible biological control (Ng, 1982).

### 14.8.2 *Eupalamides cyparissias* (Castiniidae): Oil palm bunch miner

This pest (formerly known as *Castnia daedalus*) has done serious damage to bunches in Guyana, Surinam and Peru.

*Life cycle and damage:* The butterfly, which has a wing span of 17–21 cm, lays its eggs on unripe bunches. The larvae grow to 13 cm and then pupate in the leaf bases. The larvae bore into the peduncles, bunches and the stem, causing rotting. There is a high mortality from wasp and fly parasitism (Korytkowski and Ruiz, 1980).

Palms are attacked as soon as they start bearing, and provided harvesting is complete, the larvae will be detected in the bunches and a measure of control obtained (Huguenot and Vera, 1981). Mariau and Huguenot (1983) described methods of estimating populations of larvae of different stages with the object of initiating control measures before the dangerous later larval stages are reached.

*Control:* Various control methods have been tried. Van Slobbe (1983) found injection of monocrotophos and carbofuran ineffective, but application of granular carbofuran in the spear region was successful. Huguenot and Vera (1981) recommended trichlorfon or carbaryl. R.C. Aldana (2003) showed that incidence could be reduced by harvesting bunches at 8-day intervals instead of 15 days. Aldana *et al.* (2003) described methods for multiplying the egg parasite *Ooencyrtus* sp., but gave no data on effectiveness of control.

## 14.9 MAMMALS AND BIRDS AS PESTS

### 14.9.1 Rats

#### 14.9.1.1 *Distribution*

In the past, the most important mammalian pest of oil palms in Malaysia was *Rattus tiomanicus*, the Malayan wood rat. Young plantings may be infested by the rice

field rat, *R. argentiventer*, but *R. tiomanicus* is found in virtually all established oil palm plantations in Malaysia and also in South Sumatra (Sumantri and Wood, 2012). The black, house or roof rat (*R. rattus diardii*) has also become an oil palm pest in parts of Malaysia (Wood *et al.*, 1988) and may now be almost as common as *R. tiomanicus*. Other rat species found in Asian oil palm fields are *R. exulans* and the bamboo rat, *Rhizomys sumatrensis*.

In West Africa, the genus *Rattus* only occurs as introduced species in populated areas, but several other species are found in plantations. *Dasymys incomtus*, *Lemniscomys striatus*, *Lophuromys sikapusi* and *Uranomys ruddi* were recorded in the Ivory Coast by Bellier (1965) and Brédas *et al.* (1968).

A long-term study showed that the population of *R. tiomanicus* in a Malaysian plantation without rat control fluctuated slowly between about 200 and 500 rats/ha (Wood, 1984). Wood and Liao (1984b) showed that *R. tiomanicus* was potentially capable of doubling in number every 46 days. However, in the absence of control measures, the actual population remained relatively stable over long periods, rarely exceeding about 500 rats/ha. The reasons for this were not clear, but external environmental variables were deemed unlikely to be controlling factors, and predation appeared to depend on rat numbers, rather than the reverse. It seemed that there was some intraspecific mechanism, with population pressure affecting recruitment of young rats. This should be remembered when considering possibilities for biological control by predators (see Section 14.9.1.3).

#### 14.9.1.2 *Damage*

Wood (1976b) estimated that a population of 300 rats/ha would consume about 480 kg of mesocarp/year, representing a loss of about 240 kg oil (Plate 14.4). This is about 5% of a good plantation yield, but the estimate ignored the loss of detached fruit. Taking account of detached fruit, Liao (1990) estimated total losses at up to 10% of production.

In an untreated area, palms showing fresh damage ranged from 0 to 39%, with an average over 10 years of 11% (Wood and Liao, 1984a). Wood (1976b) showed that there was a broad relationship between amount of fresh damage and rat population and considered that 5% fresh damage indicated an economically damaging infestation. However, the correlation between amount of damage and rat population is not very strong, either for fresh damage or for detached fruit removed (Liao, 1990).



**Plate 14.4** Fruit damaged by rats; the apical part of the mesocarp, and the kernel, have been eaten. (from Corley, 2001).

Young palms are sometimes attacked, probably mainly by *R. argentiventer*. Noor Hisham *et al.* (2013) found that 2% of palms had to be replaced as a result.

#### 14.9.1.3 Control

The development of control methods in relation to population ecology was reviewed by Wood and Chung (2003). Poison baiting has been the main method of control, using anticoagulants, but there has been much interest in the possibility of biological control by owls.

Detailed instructions for baiting were given by Wood and Nicol (1972). Baits consisted of warfarin in cubes of maize and other ingredients, solidified with wax. The baiting procedure was a simple one: one bait per palm was distributed, with replacement of missing baits at 4-day intervals, until acceptance fell below 20%. With this system, rat populations could be reduced to negligible levels by four or five rounds of baiting. The recommendation was to repeat baiting every 6 months, although reinfestation could take over a year. Reinfestation appeared to be partly from outside, and partly from survivors (Wood, 1970). The former source is reduced by systematic baiting over large areas. Costs of control by baiting are typically equivalent to between 10 and 25% of the value of the lost oil (Wood, 1977; Chung and Balasubramaniam, 2000).

Warfarin baiting worked well for many years, but warfarin resistance eventually developed (Wood *et al.*, 1990) and is now widespread in Malaysia. Where resistance has developed, newer anticoagulants such as brodifacoum and bromadiolone have proved effective. With

increasing labour costs, Chung and Balasubramaniam (2000) investigated alternatives to the replacement baiting method. They found that the replacement system remained the cheapest, even with high labour costs, but if sufficient labour was not available, then placing several baits per palm, or one large bait, in a single round was an effective alternative. Chua *et al.* (2007) showed that difethialone and flocoumafen were as effective as brodifacoum. It should be noted that all these anticoagulants are classified as Type 1A pesticides by the World Health Organization and so are supposed to be phased out under the sustainability criteria of the Roundtable for Sustainable Palm Oil. Chung (2011b) noted that control has sometimes failed because of 'bait avoidance'. He recommended the development of new, more attractive formulations and also increased efforts to build up owl populations (see *Biological control*).

Recommendations for control of rats in Africa (IRHO, 1976) involved warfarin baiting on the same basis as described by Wood and Nicol (1972), together with wire-netting collars to protect young palms.

*Biological control:* Numbers of barn owls, *Tyto alba*, have increased enormously in Malaysia, following the expansion of the oil palm industry. In 1951, Glenister (1951) classified the species as 'very rare in Malaya', having been recorded only three or four times. By the 1980s, Lenton (1985) described it as common, and a similar change has occurred in Sumatra (Duckett, 2008). Lenton (1980) showed that numbers were limited by lack of nest sites and designed a nest box; these have been used successfully to encourage

breeding in plantations. By 1989, Smal (1990) found one owl per 17 ha in one oil palm plantation and one breeding pair per 8.5 ha in another.

Duckett (1982) summarised the work by Lenton, showing that barn owls consumed large numbers of rats, which could comprise as much as 98% of their diet. It was calculated that a breeding pair of owls and their young would consume 1200–1500 rats/year (see Duckett and Karuppiyah, 1990). With one pair per 8.5 ha (see above), this is equivalent to about 160 rats/ha.year.

With an uncontrolled population of up to 600 rats/ha, there must be some doubt as to the degree of control that owls will exercise, and Wood (1985) noted that there is no well-documented example of a predator exercising continuing control over a vertebrate pest. Often, the predator population depends on the prey population, rather than vice versa; thus, snakes disappeared from oil palm plantations after rat control by intensive baiting started (Wood, 1985). We have already noted that rat populations stabilise at a certain level, despite having the potential to multiply exponentially. If a proportion of the population is removed by a predator, reproductive success may simply increase to restore the equilibrium population level. Alternatively, the population may stabilise at a lower level. Key questions then are: what is the equilibrium population level under owl predation, and is the amount of damage caused by that population economically acceptable?

Numerous authors have shown that owl numbers can be increased by providing nest boxes, but actual data on control of rats are sparse, and those studies that have been done have not taken account of the large fluctuations in rat population that can occur in the absence of any control measures (Wood, 1984). Heru *et al.* (2000) found that numbers trapped diminished by 80% in the 2 years after owls were introduced, and the final rat population may have been below the range of normal population fluctuations (Wood, 1984), suggesting that owls had an effect. In Malaysia, Smal (1990) found that rat numbers decreased after the owl population built up, but rat numbers also fell to a similar level in fields without nest boxes. This could have been because the owls hunt over a large range, well beyond the fields with nest boxes, but it could also have been a natural decline caused by some other factor. Chia *et al.* (1995) estimated populations of up to 400 rats/ha under owl predation in one estate, comparable to levels without control (see Section 14.9.1.1).

Several comparisons of fresh damage levels before and after the introduction of owls have been made. It might be argued that the amount of damage is what

matters, not the number of rats, but fresh damage is only a rough indicator of rat population and is not the only damage done. Other rodents have been shown to change their habits when predators are about (e.g. Abramsky *et al.*, 1996), and it is possible that, when owls are present, rats spend more time in frond piles, consume more detached fruit and do less damage to bunches still on the palm. If feeding is mostly on detached fruit, then when considering the economics of rat control, one must ask whether such fruit would have been recovered if it had not been taken by rats (see Section 11.5.5.2).

Wood (1976b) considered that 5% fresh damage indicated an economically damaging population level. This has been interpreted as meaning that less than 5% damage is acceptable, but Wood used the 5% figure as an indication of a need for control by baiting. After baiting, damage should be reduced to zero and will remain at that level for several months, so the average amount of damage over time would be well below 5%. Ho and Teh (1997) found that damage in a 500 ha block of palms decreased to below 5% by the third year after establishment of owls and remained low for the next 5 years, without baiting. Adidharma (2002) claimed that fresh damage level was reduced from 30 to 0.14% after introduction of owls to a 14,000 ha plantation in Indonesia, but other authors reported damage above 5% in the presence of owls (Duckett and Karuppiyah, 1990; Smal, 1990; Hoong H.K., 2000; Sumantri and Wood, 2013). While the amount of damage done when rats are controlled solely by owls may be less than without control, it is often above the threshold for baiting recommended by Wood (1976b). Labour costs are much higher now than in 1976, but Sumantri and Wood (2013) considered that 5% fresh damage remained a useful action threshold.

Very few comparisons of anticoagulant baiting and owls have been made. Chung *et al.* (1995b) compared two 500 ha blocks, one with warfarin baiting and the other with one owl nest box per 7.5 ha. Owls reduced the rat population to consistently below 50/ha after about 20 months, but baiting gave a lower population, which was achieved more rapidly. The comparison was somewhat confounded because there appeared to be more *R. r. diardii* and fewer *R. tiomanicus* in the baiting block. With both control methods, fresh damage was reduced to well below 5%.

Smal (1990) and others have suggested that good control might be achieved by a combination of barn owls and limited baiting. If this is to be done, it is essential that owls eating poisoned but still living rats should not be affected by the anticoagulant. There are various

reports that owls are not affected by warfarin, but Lee (1995) found that warfarin and the second-generation anticoagulants were all toxic to owls. The second-generation anticoagulants were more toxic, but doses of warfarin taken by rats, and hence by owls, were higher. Tey and Ahdly Arbain (2005) combined owls and warfarin baiting, and showed that when baiting rounds were reduced from 6-monthly to 9- or 12-monthly, costs were reduced but fresh damage increased from below 1 to 4–5%. Owl numbers were greatest where baiting was least frequent. Noor Hisham *et al.* (2013) quoted damage levels below 1% using chlorophacinone baiting and owls; baiting costs were reduced by 90% and total costs by 30% compared to baiting alone. More work is needed if an integrated system using both owls and baiting is to function effectively, particularly on the choice of anticoagulant where warfarin resistance occurs.

For young palms, Noor Hisham *et al.* (2013) preferred baiting to wire-netting collars, which were considered too expensive.

#### 14.9.1.4 Conclusion

Control of rats with anticoagulant baits is well established and cost-effective. However, as Chia *et al.* (1995) noted, the fact that planters will abandon a proven method in favour of barn owls, which are ‘at best unproven’, is a clear indication of the attraction of biological control. Owl populations are easily built up by provision of nest boxes, and they consume large numbers of rats. It appears that the equilibrium rat population in the presence of owls may be lower than in their absence, but the rats still do some damage. Duckett (2011) reported one estate which had done no baiting for 18 years; the level of damage was presumably considered acceptable, but was not mentioned. In most studies, the amount of fresh damage has remained close to the 5% level that Wood (1976b) considered to indicate the need for baiting. For a proper comparison with baiting, the cost of this residual damage must be included in the costs of rat control by owls. Reliable trials would need to cover large areas, because of the hunting range of the owls, and would have to include an uncontrolled area to show natural population fluctuations. Until such trials are done, the effectiveness and the economics of biological control of rats by owls remain uncertain.

#### 14.9.2 Other mammals

The ‘cutting grass’, *Thryonomys swinderianus*, is common in Africa, and young areas planted near to the forest are particularly at risk from its devastating attacks.

Protection against this pest using wire collars is described in Section 10.1.4.3. Porcupines (*Hystrix brachyura*) attack young palms on forest margins, gnawing through to the bud. Wire collars are not effective; zinc phosphide baits with palm oil in cassava root (Wood, 1968a) and chemical repellents (Chandrasekharan and Edmunds, 1976) have been employed.

Elephants have done great damage to young plantings in South East Asia. According to Blair and Nache (1981), most damage was done in 1- to 3-year-old palms, with up to 99% destruction over hundreds of hectares. Their estimate of replacement costs and crop loss was equivalent to about US\$12,000 per hectare in 2013 dollars. Chong and Dayang Norwana (2005) recommended trenches, 2.5 m deep and wide, or electric fences as effective exclusion methods, while preservation of forest corridors and non-forested buffer zones can help to minimise incursion.

Wild pigs damage or kill young palms, and monkeys occasionally pull up seedlings. Liaw (1983) described trapping methods used in Sabah for the control of these pests. In Indonesia, electric fences have proved effective for excluding pigs (Schmidt, 1986).

Squirrels (*Callosciurus* spp.) are occasionally troublesome in Asia, eating the mesocarp and sometimes attacking nursery plants. Hafidzi (1993) found that most squirrels consumed some mesocarp, often in substantial quantities. They may also feed on the larvae of *T. rufivena* (see Section 14.8.1).

#### 14.9.3 Birds

The long-tailed parakeet (*Psittacula longicauda*), the blue-rumped parrot (*Psittinus cyanurus*) and the Malay lorikeet (*Loriculus galgulus*) have all been troublesome in Malaysia. Most destructive is the long-tailed parakeet, which feeds in flocks of up to 30 birds, carries away ripe fruit from the bunch and tends to scatter it about half eaten. Such damage can be distinguished from rodent damage by the single beak groove in the fruit. The other species feed close to the bunch and do not scatter the fruit. Shooting is the only control known, and with the long-tailed parakeet, this does not seem to have been very effective (Wood, 1968a). However, with the expansion of the area under oil palms, most estates are now contiguous with other cultivated land, rather than adjacent to the parakeet’s forest habitat, so their importance as a pest has diminished (B.J. Wood, pers. comm., 2001).

The American black vulture (*Coragyps atratus*) has become a pest in Brazil, Colombia, Honduras and

elsewhere. In some countries, these birds are protected by law as useful scavengers, and special permission must be obtained to shoot them. This course has been adopted in Colombia. In India, Dhilepan (1990) estimated that birds consumed up to 2.8 t FFB/ha.year. He suggested that cages could be used to protect bunches.

In West Africa, the village weaver (*Ploceus cucullatus*) may be locally troublesome, stripping the leaflet laminae from a wide area to make nests in adjoining trees. It is usually necessary to fell the nesting trees to disperse the birds.

## 14.10 INSECT VECTORS OF DISEASES

As well as causing direct damage, some insects play an important role as vectors of disease (Gitau *et al.*, 2009). *Leptopharsa gibbicarina* (Hemiptera: Tingidae) appears to be the vector of *Pestalotiopsis* in leaf wither, and control of this insect has checked the spread of the disease (see Section 13.3.2). A bug, *Recilia mica* (Delphacidae), has been implicated in the transmission of blast disease (see Section 13.2.4). The weevils *Rhynchophorus palmarum* and *Metamasius hemipterus* are vectors of the nematode that causes red ring disease (see Section 13.4.7). Two species of *Sogatella* (Homoptera: Delphacidae) have been shown to transmit a coconut disease similar to dry bud rot (Julia and Mariau, 1982) (see Table 13.1).

Several insects have been associated with sudden wither (see Section 13.4.4). *Sagalassa valida* was first suggested, then the hemipteran *Myndus crudus* (*Haplaxius pallidus*), but *Lincus lethifer* and *L. tumidifrons* (Hemiptera: Pentatomidae) now appear the most likely candidates. *M. crudus* appears to be the vector for lethal wilt (Section 13.4.5).

## 14.11 PESTS OF OTHER COMPONENTS OF THE OIL PALM AGROECOSYSTEM

### 14.11.1 Pests attacking pollinating weevils

Since its introduction to oil palm-growing areas outside Africa, the pollinating weevil *E. kamerunicus* (see Section 2.2.2.5) appears generally to have thrived. There have been occasional suggestions that poor pollination was due to pest or disease attack, but there is no convincing evidence for such effects. Liao (1985)

reviewed what was known at that time, and little seems to have been added since. Najib Ahmad *et al.* (2007) showed that weevils were killed by cypermethrin, emphasising the dangers of such broad-spectrum insecticides.

The main predators on the weevil in the Far East are undoubtedly rats. These consume large numbers of larvae, destroying the old male inflorescences in the process, and Liao (1985) showed that rats grew more rapidly on a diet supplemented with weevil larvae. Basri Wahid and Halim Hassan (1985) considered that rat populations, and the amount of damage done, had increased since the introduction of the weevil. Chiu *et al.* (1985) estimated that up to 80% of weevil larvae might be eaten by rats, but noted that the weevil population remained high enough to ensure good fruit set. Ponnamma *et al.* (2006) noted spiders, earwigs and lizards as predators of *E. kamerunicus* in India, but despite these, fruit set was reasonable at 64% (see Section 5.4.7.1). Desmier de Chenon and Susanto (2005a) found that weevils constituted up to 80% of the diet of two birds, *Orthotomus ruficeps* and *Prinia atrogularis*.

Kang and Zam (1982) detected, and eradicated, two species of parasitic nematodes in weevils imported to Malaysia. There have been more recent reports of weevils parasitised by nematodes (R.A. Syed, unpub.; Rao and Law, 1998), and Poinar *et al.* (2002) described a new species, *Elaeolenchus parthenonema*, which reproduces asexually and is an internal parasite of *E. kamerunicus*. Rao and Law showed that parasitised weevils had shorter life expectancy and lower reproductive rates than unparasitised. They considered that these effects, combined with low numbers of male inflorescences (the weevil breeding sites) during periods of high oil palm sex ratio, could lead to the poor fruit set which has sometimes been observed in parts of East Malaysia. In contrast, Basri Wahid *et al.* (2003) found no effect of the nematode on weevil fecundity and considered that it was unlikely to affect fruit set, but they recommended long-term monitoring.

Caudwell *et al.* (2003) found up to 50% of weevils parasitised by nematodes in PNG, but of 450 weevils dissected in Ghana, only one had nematodes, which appeared to be of a different genus from *Elaeolenchus*. Caudwell *et al.* also found no nematodes in weevils in Costa Rica, and they considered it unlikely that the nematode originated from Africa.

Poinar *et al.* (2003) identified a new, non-parasitic species of nematode, *Cylindrocorpus inevectus*, which lives on bacteria from oil palm flowers and dead weevils, and relies on *E. kamerunicus* for dispersal of juveniles.

Krantz and Poinar (2004) found a mite, *Proctolaelaps* sp., which preyed on *C. inevectus* and also used *E. kamerunicus* for transport.

### 14.11.2 Pests attacking legume cover crops

Wood (1976a) and Liao (1979) reported that leaf-eating caterpillars, grasshoppers and cockchafers may do considerable damage to legume cover crops. Perhaps equally importantly, though, Wood also noted the existence of ‘chronic’ pests, particularly the bug *Chauliops bisontula*. The occurrence of this pest in Malaysia, and the debilitation that it can cause, may explain why cover crop growth is often very weak in that environment. Liao (1979) reported a trial in which cover crop pests were controlled by insecticide spraying. The planted legume species made up a consistently greater proportion of the total ground cover biomass in the sprayed than in the unsprayed plots, indicating that the pests were reducing the vigour of the legumes. In unsprayed plots, more than half of the biomass consisted of weeds by 11 months after sowing.

Liao did not recommend insecticide spraying of the cover crop as a practical measure; spot spraying of weeds with herbicide is clearly more environmentally benign. However, the trial did help to explain why so much time and effort has to be spent on managing and maintaining the cover crop in Malaysia, whereas in most countries *Pueraria phaseoloides*, and the other leguminous species used, grows strongly in young palm plantings, easily suppressing most weeds.

### 14.11.3 Other pests

The stable fly or biting house fly, *Stomoxys calcitrans*, is not a pest of the oil palm, but bites mammals to suck blood. It breeds in piles of empty fruit bunches, and in Colombia, it can become a severe irritant to oil palm workers and draught animals. It is attracted to the colour blue and can be trapped on sheets of sticky blue plastic (Calvache, 2003c). J.A. Aldana (2003b) identified a parasitoid which might also be used for control.

### 14.11.4 Biological control of weeds

Insects which live on weed species may be used for biological control of those weeds. Sipayung and Desmier de Chenon (1996) discussed the introduction of a gall fly, *Procecidochares connexa*, from South America to Indonesia for control of *Chromolaena odorata* (Siam weed – see Section 11.1.2.2). Chiu *et al.* (2005) reported that this had almost completely eliminated *C. odorata* from estates where it had been introduced.

Cock (1982) listed several species which might be used for biological control of *Mikania micrantha*, but attempts to introduce a thrips to Malaysia, PNG and the Solomon Islands failed (Day *et al.*, 2012). In PNG, good control has been obtained with a rust fungus, *Puccinia spegazzinii* (Day *et al.*, 2012). Parasitic plants (*Cuscuta* spp.) have been recommended for control of *M. micrantha* and *Asystasia intrusa* (Chiu *et al.*, 2002; Chiu and Hao, 2004), but Desmier de Chenon and Susanto (2005b) showed that these also depressed growth of legume cover crops, so should not be used.