1

Some Representative Palm Pests: Ecological and Practical Data

Laurence Beaudoin-Ollivier[1], Nunzio Isidoro[2], Josep A. Jaques[3,], Paola Riolo[2], Mohamed Kamal[4] and Didier Rochat[5]*

[1] *Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), Biological System Department, Research Unit Bioagresseurs, France*
[2] *Department of Agricultural, Food and Environmental Sciences, Marche Polytechnic University, Italy*
[3] *Universitat Jaume I, Department of Agricultural and Environmental Sciences, Campus del Riu Sec, Spain*
[4] *Agricultural Research Center, Plant Protection Research Institute, Department of Wood Borers and Termites, Egypt*
[5] *Sensory Ecology Department (UMR 1392), Institute of Ecology and Environmental Sciences of Paris, France*

1.1 Introduction

Almost all palms species (Arecaceae), around 2600 worldwide, are arboreal plants adapted to tropical or arid conditions; only a few, such as *Trachycarpus fortunei* (Chusan or windmill palm), are adapted to cooler temperate climates (Howard *et al*. 2001; APG 2009; Eiserhardt *et al*. 2011; Palmweb 2011; eMonocots 2013).

Some palm species produce large bunches of fruit that are rich in sugars or lipids. These species have long been cash crops, of which the famous coconut palm (*Cocos nucifera* L.), date palm (*Phoenix dactylifer*a L.), and African oil palm (*Elaeis guineensis* Jacq.) can be highlighted. Many other palm species hold local economic importance as food or for other technical uses.

Being among some of the most familiar plants, palms bear an exotic appeal with their unique shape, which has made, for instance, the Canary Island date palm (*Phoenix canariensis* Hort ex. Chabaud) one of the most planted ornamental palms worldwide, and particularly in Mediterranean countries. Owing to easy planting, rapid growth, and simple maintenance, many other palm species have been important ornamental plants for over a century and have great economic value. Their trade has increased considerably in recent years due to their prevalence in new urbanized areas and tourist resorts (André and Tixier Malicorne 2013). For example, 51,000 individual plants belonging to 421 palm species were introduced into La Réunion between 2000 and 2006 for a palm botanical garden project (Meyer, Lavergne, and Hodel 2008). Overall, palms are memorial markers of landscapes, either natural or artificial, such as orchards, botanical gardens, parks, and avenues, some of which have become UNESCO heritage sites.

Palms are characterized by rapid growth from a unique meristem where the stem, the fronds, and the inflorescences develop, forming large amounts of soft tissue that is rich in water and nutrients (see Chapter 2, this volume). They often produce large fronds

*J.A. Jaques was formerly J.A. Jacas

Handbook of Major Palm Pests: Biology and Management, First Edition.
Edited by Victoria Soroker and Stefano Colazza.

and large fruit bunches. Because of their diversity and these morphophysiological properties, palms shelter a great diversity of arthropods and are exploited by many herbivores, including insect and mite species. Less than 10% of the thousand arthropod species living on palms have been recognized as serious palm pests for cultivated species. These pest species have been repeatedly reviewed (Lepesme 1947; Bedford 1980, 2013; Mariau 2001; Howard *et al.* 2001) and interested readers should refer to these reviews for comprehensive information about these insects.

Lepesme (1947) reported that insects cause very little damage on wild palms. However, as soon as these species are cultivated in large areas, they become more susceptible to pest attack. The rapid and exponential increase of planted areas for coconut, date, and oil palms over the last 50 years (Rival and Levang 2013; Statistical series from FAO stat website 2015, http://faostat3.fao.org/home/E), especially under vast monocultures, and the increased trade of tall specimens of ornamental palms have favored the outbreaks of several species, reaching pest status (e.g. *Oryctes rhinoceros* (L.); see Section 1.3.2). Furthermore, some arthropods have colonized new areas where they have adapted to palm species that are absent from their native areas. Today, all cultivated palms are affected by native and invasive pests, such as *Rhynchophorus ferrugineus* (Olivier) (Section 1.3.4) and *Paysandisia archon* (Burmeister) (Section 1.3.6) in the Mediterranean, with both environmental and economic impacts (Chapin and Germain 2005).

This chapter is an overview of the main types of palm pests—23 species that were selected as an example of the relationships between palms and herbivorous arthropods from among the most damaging taxonomic groups: Lepidoptera, Coleoptera, and Hemiptera. These species are mostly pests of coconut, date, and oil palms, but also of ornamental species and sometimes wild endemic palms. They show some extremes in size and lifestyles under various latitudes.

For convenience, the pests included in this chapter are classified according to their main feeding habit/lifestyle: crown borers (5 species), defoliators (5 species), sap feeders (4 species), frond, inflorescence, or fruit dwellers (8 species), and root feeders (1 species). Some of these species have broader feeding habits and could have been classified otherwise. Each category is introduced by providing some general features that apply to a common lifestyle and practical consequences for their management. Subsequently, for each species, we briefly present and illustrate, using a datasheet format, typical ecological features: cycle, damaging stage(s), main host species, and distribution. Finally, we provide information about the pest's invasive status and possible interaction with other insect species.

1.2 General Features About Palms and their Pests

1.2.1 Palm Features are Suited to Arthropod Herbivores

Palms make up a homogeneous group of monocots, which have evolved for about 100 million years together with herbivorous arthropods (APG 2009; Eiserhardt *et al*. 2011; Thomas 2013). Insects have remarkably diversified to exploit all niches offered by higher plants: leaves, sap, stipe, roots, fruit, and seeds (Rochat *et al*. 2013). Thus, many insects have adapted to palms, sometimes as their exclusive food resource, and co-evolved with them, as in the case of palm weevils (*Rhynchophorus* spp.) (O'Meara 2001).

Palms share anatomical and physiological traits that make them unique (see Chapter 2, this volume), such as their typical growth and leaf organization in an apical bouquet at

the top of a single woody stem. Growth rate (stem elongation and frond production) is very rapid in most palms. For instance, oil palm can produce up to two new fronds per month (Corley and Tinker 2003; Jacquemard 2011). The apical part of the stem, including the forming fronds and inflorescences, is an area of intense metabolism and cell multiplication with a large amount of soft tissue that is highly hydrated and rich in nutrients. Sap flows and exudation upon cutting these tissues are generally quite plentiful. This amount of nutritious tissue is especially suitable for, and accessible to, borers. These tissues are sustained by the unfolded functional fronds, which display large photosynthetic areas that are available to sap feeders and defoliators.

Aerial roots grow, sometimes abundantly, at the base of the stem. This area has higher metabolism and cell multiplication than the rest of the stem and also offers food and shelter to other herbivores. In species that produce offshoots, such as the date palm or caespitose palms, the base of the stem is also a place worth feeding on as it gathers the root and crown properties, with actively growing tissues rich in water and nutrients (Lepesme 1947; Peyron 2000).

A peculiar vascular system from the roots to the fronds makes palms highly tolerant to stem damage, ensuring water and nutrient supply to the foliage. The stem/stipe, essentially made up of living parenchyma, also serves as an important stock of water and nutrients, which help the plant survive or recover from severe foliage or root losses. This organ is exploited by specialized borers (Lepidoptera, Coleoptera: Cerambycidae) (Lepesme 1947).

Finally, most palms produce large inflorescences that are protected in a spathe before blooming. Pollination is achieved in most palms by highly non-hymenopteran insects (Henderson 1986). The female inflorescence generally develops in large fruit bunches as in the date palm, coconut palm and African oil palm, which provide large nutrient resources that can be exploited by different species, which are often quite generalist, including post-harvest pests.

1.2.2 Main Arthropod Pests on Palms

All types of arthropod herbivores can be found on palms: polyphagous species that also feed on other plant taxa, and specialized species that develop only on Arecaceae. Owing to the large and diverse food resources offered by palms, all groups of herbivorous arthropods can be found on them. The species either live on the plant—the defoliators and sap feeders, or inside it—the leaf miners and borers, the latter able to reach large sizes sheltered in large and wide galleries. As an example, Carpenter and Elmer (1978) reported 54 species of mite and insect pests of date palm worldwide. In Israel, 16 major and 15 minor species have been recorded on this palm species (Blumberg 2008). Among them, Lepidoptera is the largest group (about 240 species) of pests on coconut, date, and oil palms. Caterpillars, of several species of Limacodidae, are among the most damaging. They are leaf eaters, attacking unfolded spathes and folded fronds. Other members of the Lepidoptera are miners of fronds, flowers, fruit, stems, nursery seedlings, or roots (Mariau 2001).

Lepesme (1947) described 167 species of Hemiptera living on the coconut palm and 74 on the oil palm *E. guineensis* Jacq. A large number of them were common to both palms species. Other hemipterans feed on date palm in dry climates. Some species are known or suspected to transmit diseases, such as various heart rots by *Lincus* sp. (Perthuis, Desmier de Chenon, and Merland 1985) or lethal yellowing diseases by *Myndus* sp. (Howard *et al*. 2001).

Coleopterans are also serious palm pests: many species of the family Scarabaeidae attack oil, date, and coconut palms in their adult form, whereas for other species (e.g. Curculionoidae and Chrysomelidae) the larvae damage the palm.

Many other insects living on palms, such as *Segestes decoratus* (Orthoptera, Tettigoniidae), *Graeffea crouanii* (Phasmida, Phasmatidae), *Macrotermes* spp. (Isoptera), and several species of Thysanoptera, are common on flowers (Mariau 2001).

1.2.3 Damage and Pest Management

Owing to (1) the importance of palm products, particularly oil, fruit, and their ornamental value; (2) the increase in planting in recent decades; and (3) palm pest diversity, damage can have huge economic consequences.

Borers are by far the most difficult group to manage. In the past, important use of insecticides was more or less successful but carried with it increasingly broad environmental concern. Many insecticides used in the past have been or are being progressively banned. In Indonesia, for example, the cost of controlling *O. rhinoceros* was estimated at $10 million in 1995. Control was based on manual collection of the larvae in breeding sites before replanting and of adults feeding in the galleries burrowed in the young palms, and on the application of insecticide granules on every palm every two weeks till the age of 2 to 3 years.

Integrated pest management includes alpha-cypermethrin and lambda-cyhalothrin applications given alternately every 10 days on the spear if more than 4% of fresh attack per interline is observed (Jacquemard 2011). Destruction of dead stems of palm trees and shredding of the infested stems are also recommended (Jacquemard 2011).

In the 1980s, Baculovirus strains were used against *O. rhinoceros* with some success, but the scarab population increased with the creation of new plantations and could no longer be controlled by this entomopathogen. The discovery of an aggregation pheromone (Hallett *et al.* 1995; Morin *et al.* 1996) led to evaluating the possible use of the mass trapping of adults. However, this technique did not prove useful as the young adults, which feed on the palm, responded poorly to the pheromone. Furthermore, beetle populations were so high and the insect so mobile that, despite important captures, damage could not be lowered (Beaudoin-Ollivier, unpublished). In the case of *Rhynchophorus* sp., chemical control offers interesting alternatives together with mass trapping based on aggregation pheromones (Hallett *et al.*, 1993) and kairomones (see Chapters 5 and 12, this volume).

Species feeding on the aboveground parts of the palm can be managed using methods based on their lifestyle. Monitoring and sanitation are particularly important to preventing catastrophic outbreaks. Most species co-occur with a guild of natural enemies, which can be managed by either conservation or augmentation. For example, the parasite *Rhysipolis* sp. is effective on *Stenoma cecropia* (Lepidoptera Gelechioidea Stenomatinae) in Ecuador and Columbia (Jacquemard 2011). *Stichotrema dallatorreanum* and gregarines are active on *Sexava coriacea* and *Segestes decoratus* (Orthoptera Tettigonioidea Tettigoniidae) (Jacquemard 2011). Specific commercial virus strains or those originating from infested caterpillars are also used on *Setora nitens*, *Setothosea asigna*, *Thosea* spp., and *Darna* spp. (Lepidoptera Zygaenidae Limacodidae) in Indonesia. *Cordyceps* on *Setothosea* spp. and *Paecilomyces farinosus* on *Euclea diversa* are also found (Jacquemard 2011).

1.3 Crown and Stem Borers

1.3.1 Pest Ecology, Damage, and Management

The insect species in this section exhibit tunneling activity in the crown for feeding during either the larval or adult stages, or both. In most species, the galleries are made in the growing tissues, which have the highest nutritional content. They affect the tissues of the stem and the growing fronds and inflorescences more or less randomly. Some preference for specific organs can be observed in certain palm borers, but this is the exception. Borers can attack the growing tip of either the mother stem or the offshoots in palm species that produce them, as in the date palm.

Injury is both mechanical and physiological. The galleries weaken the crown and/or stem, which can break as a consequence of the increasing weight of the fruit bunches, with a direct impact on production, or simply as a consequence of wind, rain, or nesting birds. The galleries also alter sap conduction. Injury to the apical meristematic tissues is lethal to palm trees as they grow from this unique point (see Chapter 2, this volume). In a few cases, specific palm pathogens can be vectored by these borers, such as that responsible for red ring disease by *Rhynchophorus palmarum* L. (Goodey 1960; Griffith 1974). In turn, tunneling of many borers favors the development of saprophytic microorganisms in the injured tissue and can cause the palm's decline and eventual death. In addition, severe tunneling induces malformations, particularly of fruit bunches and fronds, which also reduce the yield and decrease the ornamental value of the palms.

The management of these borers is difficult because they are essentially located in the crown, far from the ground and often deep inside the plant tissues. Contact insecticides can be efficient against the adults, which visit the palms for feeding and egg-laying. In turn, only systemic or fumigant insecticides are active against the insects present in the galleries. Some bio-insecticides (fungi, nematodes, and viruses) can penetrate the galleries or be carried by boring adults and offer alternatives to conventional insecticides. Since the 1990s, mass trapping using aggregation pheromones has been implemented against certain palm weevils (*Rhynchophorus* spp.) and rhinoceros beetles (*Oryctes* spp.) (El-Sayed *et al*. 2006).

1.3.2 *Oryctes rhinoceros* Linnaeus 1758 (Coleoptera: Scarabaeidae)

Oryctes spp. constitutes the most important pests of the coconut palm worldwide. They are typical horned beetles (Dynastinae, Oryctini) (Fig. 1.1a). Adults are stocky insects with morphological adaptation of the prothorax and forelegs bearing powerful spines or points dedicated to burrowing in plant tissues. *O. rhinoceros* (rhinoceros beetle, name often applied to most Oryctini species) in Southeast Asia and the Pacific and *Oryctes monoceros* Olivier in Africa are the most harmful.

The insect reproduces mainly in decaying palm wood where males emit an aggregation pheromone (Gries *et al*. 1994; Hallett *et al*. 1995; Morin *et al*. 1996; Allou *et al*. 2006). The adults are nocturnal and feed individually on the palms prior to mating (Morin, personal communication). Larvae contribute to wood recycling with their symbionts.

Distribution: Introduced into New Britain (Papua New Guinea), New Ireland (Bismarck Archipelago), Manus Island, Western and American Samoa, Tonga, Fiji, Wallis Island, Micronesia, Mauritius, and the Cocos Islands (Bedford 1974, 1980). It occurs from Southeast Asia to the Philippines and China, and several Pacific islands.

Host palms: *C. nucifera*, *E. guineensis*.

(a) (b) (c)

Figure 1.1 (a) *O. rhinoceros* adult. (b) Coconut palm damaged by *O. rhinoceros*. (c) Coconut crown damaged by *O. rhinoceros*.

Primarily found attacking coconut and oil palm, *O. rhinoceros* has occasionally been recorded on banana (Sharma and Gupta 1988), sugarcane, papaya, sisal, and pineapple (Khoo, Ooi, and Ho 1991). In Mauritius, ornamentals such as the royal palm (*Roystonea regia*), the cabbage palm (*Livistona chinensis*), the talipot palm (*Corypha umbraculifera*), and the raphia palm (*Raphia ruffia*) are also attacked (Bedford 1980).

Secondary hosts: *Musa paradisiaca* (plantain), *Saccharum officinarum* (sugarcane), *Carica papaya* (papaw), *Ananas comosus* (pineapple), Lantana, *Metroxylon sagu* (sago palm), and *Agave sisalana* (sisal hemp).

Harmful stage and damage: Adults. They feed by mining galleries at the base of the young leaves, which affects palm development and photosynthesis. They bore into the cluster of forming fronds, causing wedge-shaped or V-shaped cuts in the unfolded fronds or spears (Fig. 1.1b). In young palms, where the spears are narrower and penetration may occur lower down, the effects of the damage can be much more severe than in older palms (Wood 1968) (Fig. 1.1c).

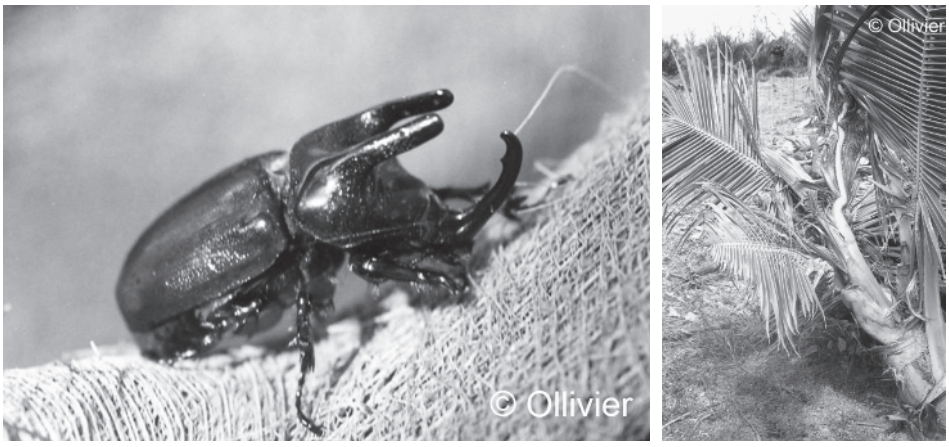
Risks: The larvae are capable of surviving in floating logs transported by ocean currents (Lever 1969).

1.3.3 *Scapanes australis* Boisduval 1832 (Coleoptera: Scarabaeidae)

This large beetle (up to 5 cm long and 2.5 cm in diameter), the New Guinea rhinoceros beetle, is sex dimorphic: males bear three long prothoracic horns (Fig. 1.2a), whereas the females do not. Males bore directly into the stem of the palm from the side for food and shelter (Bedford 1976). They call mates by emitting an aggregation pheromone during characteristic behavior at the entrance of their gallery at night (Prior *et al.* 2000). A male can be attracted to the caller. The latter and the newcomer then fight for possession of the gallery. Females are rare in the galleries but more frequent in dedicated organic matter heaps, where the larvae develop for at least 1 year outside the plantations (Beaudoin-Ollivier *et al*. 2001).

Distribution: Oceania and Eastern Asia: Papua New Guinea and the Solomon Islands (Bedford 1976; Waterhouse and Norris 1987), Indonesia (Kalshoven and van der Laan 1981), Philippines (Lepesme 1947; FAO 1966), and Singapore (APPPC 1987).

Host palms: *C. nucifera*, *E. guineensis*, *Areca catechu* (betel nut palm), *Musa* sp. (banana).



(a) (b)

Figure 1.2 (a) *S. australis* adult (male). (b) Damage due to *S. australis* attack.

Harmful stage of the pest and damage: The adults, which feed on the juices from the bored tissues. Attack by *S. australis* is usually restricted to young palms, from just past the seedling stage to about 5 years of age. Owing to the large size of the borer and replicated attacks, fatal damage is extremely frequent. If the growing point is not destroyed, the fronds show typical V-shaped cuts or varying degrees of deformation (Fig. 1.2b): fronds are truncated, notched, or twisted, with the leaflets compressed and crumpled together (Bedford 1976).

Risks: *S. australis grossepunctatus*, from the northeastern islands of Papua New Guinea and the Solomon Islands, could pose a phytosanitary risk if it was accidentally transferred to the main island of Papua New Guinea (Beaudoin-Ollivier, personal communication). In this area only, *S. australis grossepunctatus* lives and is not a pest, for undetermined reasons. Local use and production of hybrid mature nuts and seedlings lower the phytosanitary risk of seedling transport between the islands.

S. australis attacks create sites that are highly propitious for the attraction and development of *Rhynchophorus bilineatus* (Beaudoin-Ollivier *et al.* 1999).

1.3.4 *Rhynchophorus ferrugineus* Olivier 1790 (Coleoptera: Dryophthoridae)

R. ferrugineus (red palm weevil or RPW) infests and kills palm species of high economic value, particularly coconut in Monsoon Asia, and more recently date palm and Canary Island date palm in the Middle East and Mediterranean Basin (Fig. 1.3a) (see Chapter 4, this volume). Both the larva and the adult feed on palms. Males emit an aggregation pheromone that attracts RPW in synergy with the odor of wounded palms or decaying fruit. The adult is a good flyer and prolific: 100 to 250 eggs/female (see Chapters 4 and 5, this volume).

Origin: Indo-Malaysia (Monsoon Asia), from eastward to the Philippines (Rugman-Jones *et al.* 2013).

Distribution: Today RPW is present in most countries from southwestern Europe (Portugal) to the Mediterranean and Black seas (see Chapter 4, this volume) and to the Middle East up until Pakistan plus the Canary Islands, Madeira, the Caribbean (Curacao and Aruba), Taiwan, and China (EPPO website for updated reports 2008; Abe, Hata,

(a) (b) (c)

Figure 1.3 (a) Damaged *P. dactylifera*. (b) *R. ferrugineus* adult. (c) *R. ferrugineus* larva.

and Sone 2009; El-Mergawy and Al-Ajlan 2011). RPW originating from tropical and subtropical areas has settled in temperate areas with a Mediterranean or arid climate, and has adapted to palms species that are not present in its native range.

Host palms: Chapter 4 and in particular Table 4.3 provides a critical and comprehensive list, an overview of which is given here:

- *with obvious susceptibility:*
  Sixteen species growing in the native tropical area: *Areca catechu*, *Arenga pinnata*, Borassus flabellifer, two *Caryota* spp., *C. nucifera*, two *Corypha* spp., *E. guineensis*, two *Livistona* spp., *Metroxylon sagu*, *Nypa fruticans*, two *Oncosperma* spp. and *Roystonea regia* are original RPW hosts; two species adapted to drier climates and common in northwestern India: *Phoenix sylvestris* and *P. dactylifera*.
- *less susceptible with obvious resistance:*
  These include *Chamaerops humilis*, *T. fortunei*, *Washingtonia robusta*, and *W. filifera*, which are common in the EU, and the Aegean *Phoenix theophrasti*.
- *susceptible with insufficient information:*
  Two *Brahea* spp., *Butia capitata*, *Howea forsteriana*, *Jubaea chilensis*, *P. theophrasti*, *Sabal* spp., and *Syagrus romanzzofiana* have all been naturally infested with RPW, resulting in death of some palms.
- *other potential hosts:*
  - *Non-palm:* Larvae can be bred on banana fruit (Salama and Abdel-Razek 2002), agave (Malumphy and Moran 2007), and sugarcane (Rahalkar, Harwalkar, and Rananavare 1972).
  - *Palm:* Larvae can develop in *Livistona decora* if artificially infested (Barranco *et al*. 2000), and Liao and Chen (1997) reported larval infestation of *Bismarckia nobilis* seedlings in Taiwanese nurseries.
  - *Potential non-host palm species:* There are no reports of natural infestations of *Archontophoenix alexandrae*, *Nannorrhops ritchiana*, or *Phoenix rupicola*. Furthermore, larvae did not develop to pupation under laboratory conditions on stem tissues of *N. ritchiana* (Farazmand 2002).

RPW has long been reported as a severe pest on coconut and date palm and, to a much lesser extent, as a regular pest on African oil palm as well as other palm species with traditional uses, such as the sago palm (Wattanapongsiri 1966; Faleiro 2006; El-Mergawy and Al-Ajlan 2011; Jacquemard 2011). *P. canariensis* and *P. dactylifera* are highly susceptible hosts in the invasion area (Faleiro 2006). *P. dactylifera* appears less susceptible than

P. canariensis. However, date palm and Canary Island date palms have shown differences in susceptibility within varieties, sexes, and hybrids (Rochat 2006; Salama, Zaki, and Abdel-Razek 2009). For example, more male than female *P. canariensis* and *P. dactylifera* are infested by RPW in Italy and Spain (Uribarrena 2013). Various other palm species with high patrimonial value, such as the endemic *P. theophrasti*, *J. chilensis*, or *Washingtonia* spp., can also be killed by the pest.

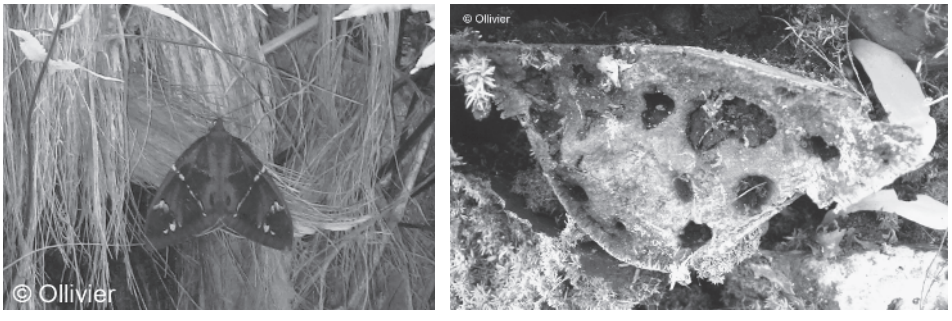
Harmful stages and damage: Both adults and larvae (Fig. 1.3b, c) are the most damaging stages by far. Once they reach the growing point, they kill the palm. Visible damage symptoms due to low to moderate attacks are similar to those observed for palm rhinoceros beetle attacks in tall specimens: characteristic cuts in the unfolded fronds and missing parts of adjacent leaflets eaten during frond formation. Under high attack, the entire crown dries up and collapses (see Chapter 9, this volume). Palm mortality is reported to be high on coconut palms in native areas and on *P. canariensis* and *P. dactylifera* in invaded areas (see Chapter 4, this volume).

Risks: Palms damaged by *O. rhinoceros* (Section 1.3.2) are often attacked by RPW where the two species co-habit. Similarly, *P. archon* (Lepidoptera: Castniidae) (palm borer moth; PBM, Section 1.3.6) could provide favorable cues for RPW host detection, thereby facilitating palm colonization in a new spot. Major attention should be paid to these risks to the southern and southeastern shores of the Mediterranean, where PBM is currently absent but may well adapt to using the date palm as a host.

1.3.5 *Castnia daedalus* Cramer 1775 (Lepidoptera: Castniidae)

Castniid adults have been named butterfly moths due to their diurnal activity and morphological resemblance to some butterflies, although they belong to the Cossoidea, a group that is well separated from the Papilionoidea (butterflies). *Castnia* (syn. *Eupalamides*) *daedalus* is one of the largest insect borers of palm stems and fruit bunches (Fig. 1.4a). The female can lay around 500 eggs (Ohler 1984). The larval stage lasts 315 days, as the caterpillars continuously feed and grow to the considerable size of about 13 cm in length and the diameter of a fat thumb (Huguenot and Vera 1981; Yaseen 1981).

Distribution: Amazon valley through the Guianas to Panama (Rai 1973), Venezuela, Surinam, Guyana, Brazil (northeast), Colombia, Ecuador, and Peru (Genty *et al*. 1978).



(a) (b)

Figure 1.4 (a) *C. daedalus* adult. (b) Holes as a result of *C. daedalus* caterpillar boring into the stem at the leaf bases of oil palm.

Host palms: *C. nucifera*, *E. guineensis*, genera *Euterpe*, *Pritchardia*, *Livistona*, *Mauritia*, *Maximiliana*, *Oenocarpus*, and *Roystonea* (Lepesme 1947; Lever 1969; Ferreira, Warwick, and Siqueira 1994), banana, sugarcane, and pineapple (Howard *et al*. 2001).

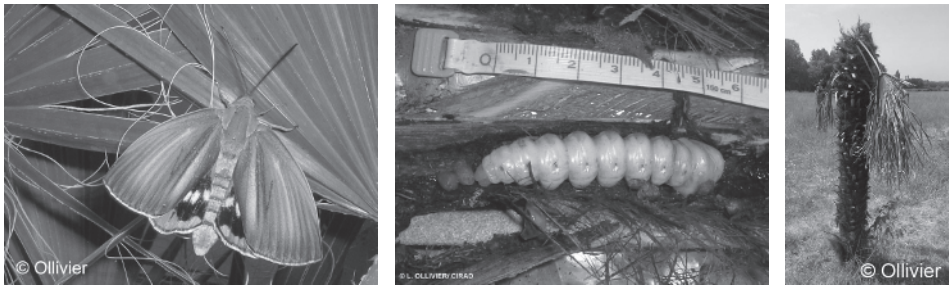
Harmful stage and damage: Caterpillars, especially due to their large size and long life. On hatching, the caterpillars bore into the stem at the leaf bases and form deep tunnels under the leaf bases and fruit bunches, causing them to wilt and fall due to lack of support (Fig. 1.4b). Feeding for almost 1 year can lead to considerable losses in fruit production (Rai 1973). Older caterpillars tunneling the trunk may cause large cavities under the stem apex and kill the palm (Schuiling and Dinther 2009). As the caterpillars continue feeding throughout this period, they may cause considerable damage to the stem of the palm. Significant reductions in fruit production have been reported in plantations infested by *C. daedalus* (Huguenot and Vera 1981).

1.3.6 *Paysandisia archon* Burmeister 1880 (Lepidoptera: Castniidae)

P. archon (PBM; Fig. 1.5a) is another butterfly moth, which has not been reported as a pest in its native region (South America), with the exception of reports from Buenos Aires (Bourquin 1930; Montagud Alario 2004; Sarto i Monteys *et al*. 2005). In contrast, in France, Italy, and Spain, it is an invasive pest, which causes serious damage and palm mortality (Fig. 1.5b), especially in nurseries of ornamental palms (Montagud Alario 2004; Riolo *et al*. 2004; EPPO/OEPP 2008). The life cycle of this palm borer has been described by Sarto i Monteys *et al*. (2005) and Sarto i Monteys (2013). The adult is in flight from May to September in Europe. It flies between the hours of 1100 and 1600. Mating peaks between 1400 and 1500 and 87% of the females are fertilized and start laying eggs 1.25 (±1.14) days after mating (Delle-Vedove *et al.* 2012). Vision is sophisticated and plays an important role in adult behavior (see Chapter 7, this volume). Chemical communication in the PBM remains controversial, but it certainly does not use the long-range female-attractive sex pheromone typical of moths (see Chapter 7, this volume).

Origin: Argentina, Brazil, Paraguay, and Uruguay (Miller 1986; Lamas 1995; Sarto i Monteys 2002; González, Domagala, and Larysz 2013).

Distribution: Introduced in Cyprus, Denmark, France, Greece (including Crete), Italy (including Sicily), Slovenia, Spain (including Balearic Islands), the United Kingdom (isolated occurrence), Belgium, Bulgaria, and Croatia in Europe, as well as in Switzerland. It is still unknown in the other Mediterranean countries (Reid 2008; Buhl *et al*. 2009;



(a) (b) (c)

Figure 1.5 (a) *P. archon* adult. (b) *P. archon* last-instar larva. (c) *T. fortunei* killed by *P. archon* caterpillars.

EPPO 2014 version 5.3.1. accessed June 26, 2014; Psirofonia and Niamouris 2013) (see Chapter 6, this volume).

Host palms:

- In the native area: *P. canariensis*, *Butia capitata*, *C. humilis*, *Livistona chinensis*, *Syagrus romanzoffiana*, *Trithrinax campestris*, and *Butia yatay* (Sarto i Monteys 2013) (see Chapter 6, this volume).
- In the Mediterranean: the above-mentioned palm species, as well as *Brahea armata*, *B. edulis*, *Livistona australis*, *L. decora*, *L. saribus*, *P. dactylifera*, *P. reclinata*, *P. roebelenii*, *P. sylvestris*, *P. theophrasti*, *Sabal mexicana*, *S. minor*, *S. palmetto*, *T. fortunei*, *T. wagnerianus*, *Washingtonia filifera*, and *W. robusta* (see Chapter 6, this volume).

T. fortunei, *C. humilis* and *P. canariensis* are by far the most attacked palm species by PBM in France, Italy, and Spain (Drescher and Jaubert 2003; Riolo *et al.* 2004; Chapin 2006; André and Tixier Malicorne 2013; Sarto i Monteys 2013).

Harmful stage and damage: Damage is entirely inflicted by the larvae, whose feeding activity can cause deformation of the crown (Fig. 1.5b). If the larvae reach the apical bud, the palm dies (Fig. 1.5c). The eggs are laid in the fibers in the crown or in the upper part of the stem. The neonate larvae penetrate rapidly into the stem. Larvae excavate galleries until pupation. They can be found tunneling in different parts of the palms: early instars in the stem and fruit of *C. humilis*, or within the leaf rachis (especially in *P. canariensis* and *W. filifera*). In *T. fortunei*, the first-instar larvae can bore into the young packed fronds. Large larvae are found in the stem of 2- to 10-year-old *T. fortunei* and *C. humilis* and tend to bore into and remain within the very core of these structures, where humidity is higher and temperature more stable (Riolo, Isidoro, and Nardi, 2005; Sarto i Monteys *et al.* 2005).

Risks: The PBM is listed as a quarantine pest in EPPO member countries. Galleries produced by the larvae can facilitate secondary infestation by pathogens as *Talaromyces erythromellis* (Frigimelica *et al*. 2012). Damage by PBM may attract RPW and provide suitable sites for females to lay eggs and colonize palms as secondary pests.

1.4 Defoliators of Fronds (= Leaves)

1.4.1 Pest Ecology, Damage, and Management

These insects consume the leaflets of the fronds, essentially reducing photosynthesis. As many defoliators are subject to intense outbreaks, these species can seriously stress the palm trees and reduce fruit yield. They generally do not cause direct death of the palms. However, important feeding activity of defoliators favors attacks by palm-pathogenic fungi such as the tropical *Pestalotiopsis* spp.

Most pest defoliators on palms are caterpillars from various Lepidoptera families (mainly Coleophoridae, Hesperiidae, Limacodidae, Lymantriidae, Noctuidae, and Psychidae) and beetles, both larvae and adults (Chrysomelidae). They are either quite generalist herbivores on arboreal or shrub plants, or much more specialized species that are dependent on Arecaceae, such as many hispine beetles or some Nymphalidae species. Some small species are leaf miners, such as the larvae of *Coelaenomenodera lameensis* (Section 1.4.4), and some larger larvae can show some borer activity, such as the *Sesamia* caterpillars (Section 1.4.6). In addition, there are a great variety of

occasional palm defoliators, but sometimes with a severe impact, belonging to various orders and families, such as long-horned grasshoppers (Orthoptera), and stick insects (Phasmida).

As they live in the crown in the open air, they can be controlled using various types of insecticides, either synthetic or biological. The management of outbreaks in large plantations is nevertheless costly due to the need to treat wide areas and the crown at the top of the plants, which requires dedicated (e.g. aerial) means. Despite some research, no biocontrol on a large scale has ever been implemented against such pests.

1.4.2 *Pistosia dactyliferae* Maulik 1919 (Coleoptera: Chrysomelidae)

P. dactyliferae, a small (5–6 mm) Indian species, was observed for the first time in the southeast of France in 2004, and was thought to have been eradicated after action had been taken against it. Then, in 2006, it was recorded in a nursery in Italy (Tuscany), and again in France in 2012 in the Botanical Garden of Saint-Jean-Cap-Ferrat (Besse, Panchaud, and Gahlin 2013; Panchaud and Dusoulier 2013, 2014). Larvae live in groups. The life cycle is short, about 1 month, and under laboratory conditions, there are 5–6 generations per year (Besse, Panchaud, and Gahlin 2013).

Origin: India.

Distribution: Introduced in Europe: France (Alpes-Maritimes) and Italy (Tuscany).

Host palms: *P. canariensis*, *Washingtonia* sp., *C. humilis* (Drescher and Martinez 2005), *Syagrus romanzoffiana* (Chapin and Germain 2005), *Sabal minor*, *S. palmetto*, *S. causiarum*, *T. fortunei*, *Rhapidophyllum hystrix*, and *Butia* sp. In the Saint-Jean-Cap-Ferrat botanical garden, *Trachycarpus* and *Phoenix* were the more susceptible genera to *P. dactyliferae* attack.

Harmful stages and damage: Both larvae and adults feed on the external tissues of the rachis and prefer the dark parts of the crown (Drescher and Martinez 2005) (Fig. 1.6a, b). They may concentrate on the central fronds of young palms, which dry up. Severe attacks can kill the palms. Adults seem to be nocturnal. Damaged rachises are covered by sawdust and show brown spots due to feeding activity by the larvae (Fig. 1.6a).

Risks: *P. dactyliferae* is a threat to Mediterranean nurseries and horticultural areas and is potentially invasive due to its nocturnal activity, small size, and rapid multiplication. It may provide favorable conditions for RPW oviposition and hence colonization by the weevil, as well as for pathogenic fungi.

1.4.3 *Brontispa longissima* Gestro 1885 (Coleoptera: Chrysomelidae)

There are several species of *Brontispa* (coconut leaf beetles) specialized on palms, of which *B. longissima* is the most harmful. The adult is a small (8–9 mm), elongate, flattened beetle (Fig. 1.7a). The larva is elongated as well, and bears lateral expansions and setae typical of the hispine group. Larvae inhabit the closely packed central cluster spear of fronds (Fig. 1.7b, c).

Origin: *B. longissima* was originally described in the Aru Islands. It is native to Melanesia, from Java to Vanuatu (Indonesia, possibly Irian Jaya, and also Papua New Guinea, including the Bismarck Archipelago).

Distribution: Widespread in Southeast Asia and the Pacific. Most islands of the Pacific, and also present in Malaysia, Indonesia, Vietnam, Philippines (EPPO 2014), and northern Australia (Fenner 1984; EPPO 2014).

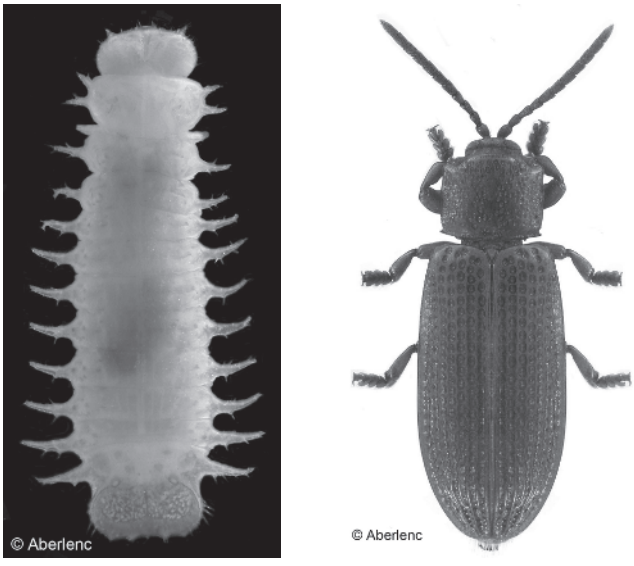


Figure 1.6 (a) *P. dactyliferae* larva. (b) *P. dactyliferae* adult.

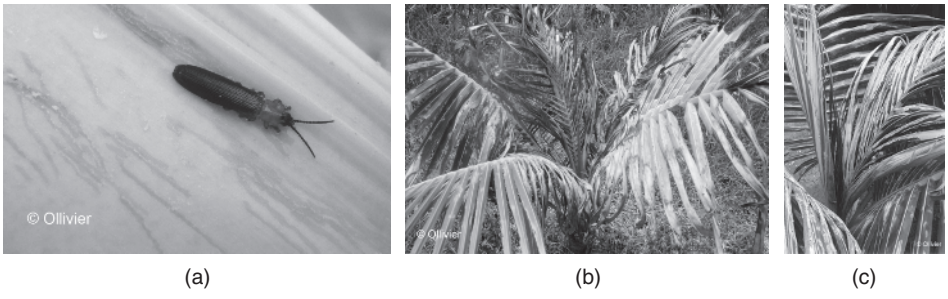


Figure 1.7 (a) *B. longissima* adult. (b) and (c) Damage on coconut palms in the nursery.

Host palms: *C. nucifera*, *Areca catechu* (betel nut palm), *Metroxylon sagu* (sago palm), and some other native and ornamental palms are also attacked.

Harmful stages and damage: Damage is caused by the larvae and adults, which feed on leaflet tissues of the coconut palm (Manciot 1965; Maddison 1983) (Fig. 1.7a). Larvae feed mostly on the epidermis of the young growing fronds. All stages are found between the leaflets or within folded leaflets. *B. longissima* mostly affects the seedlings and palms within the first year in nurseries, killing young spears and eventually the whole plant. When attack is severe, complete defoliation of the palms may result and older palms can also be seriously damaged.

Risks: Neglected palms are more heavily attacked than those kept free from undergrowth (Frogatt and O'Connor 1941; Kalshoven and van der Laan 1981; Maddison 1983). If palms are young or suffering from poor growing conditions, death will occur. Vietnam has experienced a widespread outbreak of *B. longissima* since 2001, whereas prior to that, it was not a serious pest of coconut. It has been estimated that

there are now 1 million infested coconut palms in that country (Batugal, personal communication).

1.4.4 *Coelaenomenodera lameensis* Berti 1999 (Coleoptera: Chrysomelidae)

C. lameensis (leaf-mining hispine) is considered the most economically important hispine pest of plants in West Africa (Wagner, Atuahene, and Cobbinah 1991). It feeds on the leaf tissue between the two epidermal layers, causing the formation of a "blister-like" mine. Four generations are possible in one year. The number of eggs laid by one female varies considerably, from about 100 to more than 400 (Morin and Mariau 1971). Outbreaks induce considerable defoliation of cultivated palms, such as oil palm (Fig. 1.8a).

Distribution: Central and Western Africa: Benin, Cameroon, Ivory Coast, Ghana, Nigeria, and Sierra Leone (Hargreaves 1928; Jover 1950; Cachan 1957) including Madagascar.

Host plants: *C. nucifera*, *E. guineensis* older than 3–4 years, *Borassus* sp., *Raphia* sp., ornamental palms (Cotterel 1925).

Harmful stages: Both the imaginal and larval stages mine the leaflet chlorophyllous parenchyma (Fig. 1.8b, c). The adult causes less serious damage (Fig. 1.8d). Leaflets of younger (central) fronds appear withered, gray-brown with rolled edges. Thousands of larvae per leaf lead to the direct destruction or complete desiccation of the frond. The ravages are visible on the lower leaves first, and then move to the crown. When attacks are severe, the palms can be completely defoliated (Mariau *et al*. 1981).

Risks: Radiating out from the initial focus, *C. lameensis* can rapidly contaminate a whole plantation if no method of control is applied.

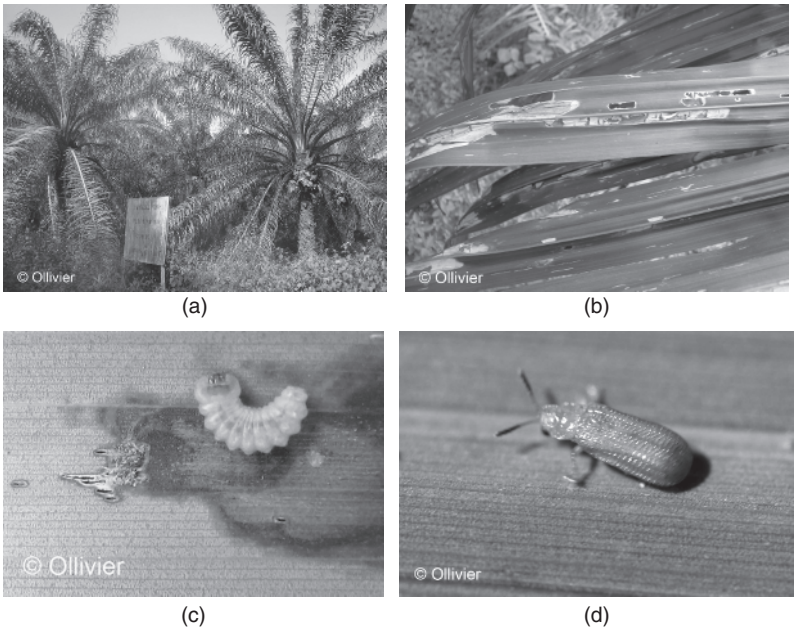
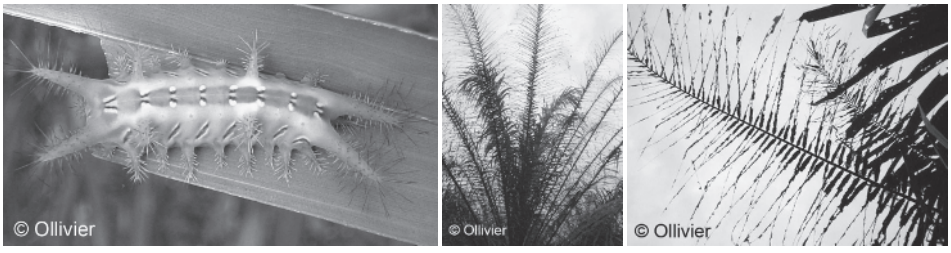


Figure 1.8 (a) Outbreak of *C. lameensis* on oil palm trees. (b) Tunnels within the foliar tissue. (c) *C. lameensis* larva. (d) *C. lameensis* adult.



(a) (b) (c)

Figure 1.9 (a) *S. nitens* caterpillar showing urticating spines. (b) Defoliation on oil palm due to *S. nitens*. (c) Damaged leaf.

1.4.5 *Setora nitens* Walker 1855 (Lepidoptera: Limacodidae)

Of the dozen or so most common and most dangerous species of leaf-eating Lepidoptera, *S. nitens* is the major oil palm and coconut leaf-eating pest in Southeast Asia. Periodically, it explodes into a major pest, causing severe damage to coconut and oil palm plantations. The caterpillars are quite polyphagous but particularly appreciate palm fronds. Together with the larvae of Zygaenidae, they are called slug caterpillars due their globose and fattened body shape and hidden head and legs, sometimes with large tentacle-like points at each extremity of the body, as in *S. nitens* (Fig. 1.9a). They are brightly colored. The moth is stocky and brown.

Severely damaged palms are almost entirely defoliated (Fig. 1.9b, c). The body of the caterpillars is armed with urticating spines that cause considerable discomfort and may endanger the health of laborers employed in the plantations (Lever 1969); this characteristic has led to its other common name of nettle caterpillar (Fig. 1.9a).

Distribution: Malaysia, Singapore, Burma, Vietnam, China, India, and Indonesia (Lepesme 1947; Ohler 1984; Cock, Godfray, and Holloway 1987).

Host palms: *C. nucifera*, *E. guineensis*, *Nipa* sp. Also, *Nephelium lappaceum*, cocoa, banana, tea, tobacco, coffee, and citrus (Lepesme 1947; Cock, Godfray, and Holloway 1987).

Harmful stages and damage: The larvae form windows on the leaf undersurface epidermis, which, particularly on coconut, allows access to the *Pestalotiopsis* fungus (Cock, Godfray, and Holloway 1987). Severe outbreaks can cause considerable defoliation (Fig. 1.9b, c). *S. nitens* attacks the older fronds then moves progressively to the younger ones. The larvae attack oil palms of all ages but the consequences are most important on those aged 2–8 years (Cock, Godfray, and Holloway 1987).

Risks: If regular quantitative monitoring is not undertaken and a critical number of young caterpillars per frond is not detected, the outbreak can be devastating.

1.4.6 *Sesamia nonagrioides* Lefèbvre 1827 and *Sesamia cretica* Lederer 1857 (Lepidoptera: Noctuidae)

The stem borers *S. nonagrioides* and *S. cretica* are considered the most important pests of maize and sorghum in many countries in the Mediterranean region (Anglade 1972; Commonwealth Institute of Entomology 1979). *S. cretica* is a pest of maize and sugarcane mainly in eastern Mediterranean countries.

Distribution: The geographic origins of *S. nonagrioides* and *S. cretica* are most likely Africa and Asia (Commonwealth Institute of Entomology 1979; CABI 2015). The distribution of both species includes southern Europe, Africa, the Middle East (east, west, and northwest), and some Atlantic islands (Eizaguirre and Fantinou 2012; CABI 2015).

Host plants: Although both species are mainly found on Poaceae, they are highly polyphagous pests with a fairly wide range of hosts other than those reported above, which comprise millet, rice, grasses, melon, asparagus, palms, banana, plus various ornamental and wild plants (Riolo *et al*. 2007; Eizaguirre and Fantinou 2012; CABI 2015). In central-eastern Italy (Marche region), young plants of *T. fortunei* and *W. filifera* in nurseries have been infested by one or the other species (Riolo *et al*. 2007).

Harmful stage and damage: On palms, the caterpillar causes damage to the fronds on either the foliage or the rachis. The larvae of these species can bore into the young packed fronds and feeding damage to leaves becomes obvious as the frond develops, opens, and expands, showing a series of consecutive perforations on a circular sector (Fig. 1.10a, b). In some cases, these larvae have also penetrated into the leaf rachis (Fig. 1.10c, d, e). These symptoms are similar to those caused by young larvae of *P. archon* (see Chapter 9, this volume).

Risks: The two species may spread in the Mediterranean and northern Europe with global warming and worsening of the sanitary situation in palm nurseries.

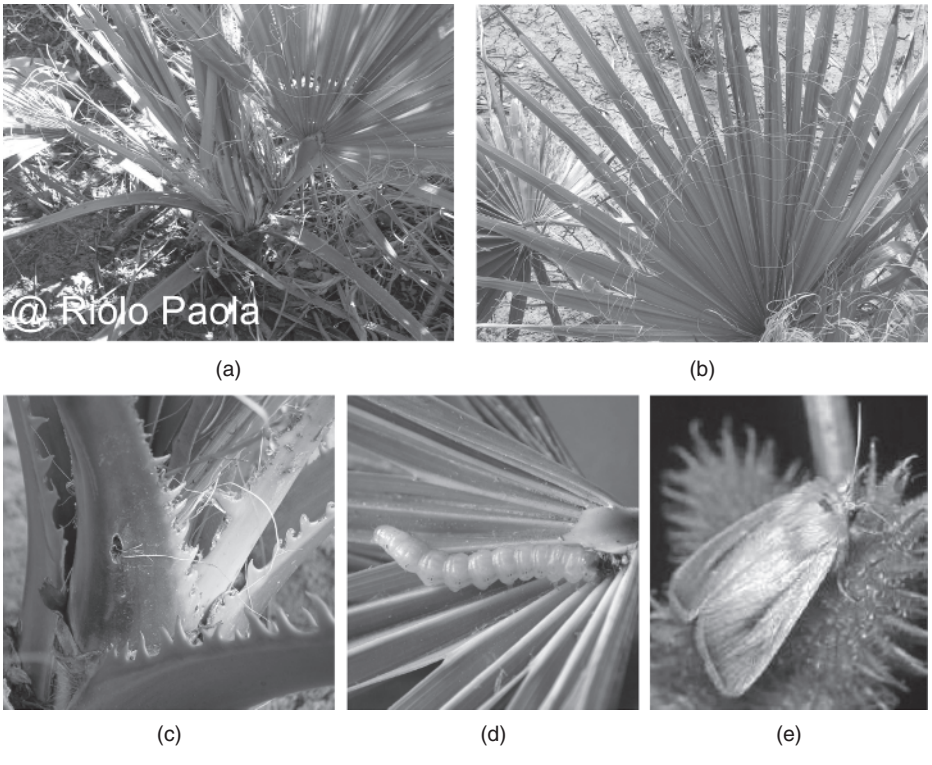


Figure 1.10 Damage of *S. nonagrioides* on *W. filifera*. (a) and (b) Presence of perforated leaves. (c) Presence of larval gallery hole within leaf rachis. (d) *S. nonagrioides* larva and (e) adult.

1.5 Sap and Frond (= Leaves) Feeders?

1.5.1 Pest Ecology, Damage, and Management

These insects have piercing-sucking mouthparts and feed mainly on fronds, including the rachis and base. Immature and adult forms share the same feeding habit and contribute to additional damage on cultivated plants. A few species are strictly dependent on palms. They belong to the order Hemiptera. The main pest species are from the Auchenorhyncha, with species from various families related to the plant hoppers, and from the Sternorrhyncha, comprising aphids, scales, and whiteflies, together making up the former Homoptera group (Howard *et al*. 2001). Many species of Sternorrhyncha are typically capable of parthenogenetic reproduction and very high multiplication rates. These features enable them to cause very severe outbreaks, favored by physiological stress to the palm species. The latter is frequent in date palms due to abnormal climatic conditions with unusually hot periods and drought, an imbalance in the mineral nutrition, or damage by other pest herbivores.

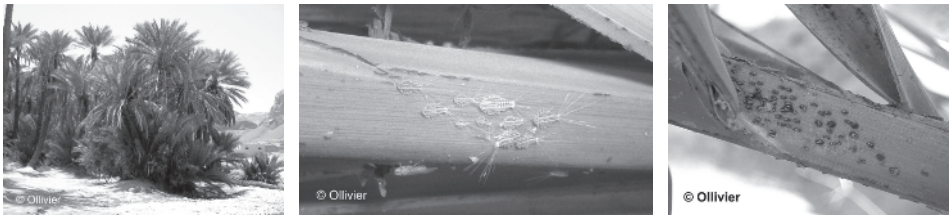
The very large colonies of sap feeders may totally cover the foliage, leading to exacerbated damage, both direct by insect feeding and indirect due to the excretion of honeydew, which covers the leaves and fruits and favors the development of sooty mold. The palm trees then suffer due to an important reduction in photosynthesis due to the screen effect of the organisms and feces and to the necrosis of the leaflets due to the injection of salivary toxins. The whole crown can dry, leading to yield reduction. The fruit value can be severely downgraded due to fouling by the sap feeders.

The management of sap feeders is particularly difficult, especially in village farming with low economic capabilities. Preventive sanitary measures are important, based essentially on healthy management of the plantations with regular palm and land cleaning and appropriate watering and fertilization practices, but so is a cropping system that favors natural biological control. Chemical control is challenging because of the need to treat the entire canopy, added to the worldwide increase in sap-feeder resistance to many insecticide families and the environmental and human health concerns.

1.5.2 *Ommatissus binotatus* Fieber 1876 (Hemiptera: Tropiduchidae)

O. binotatus (dubas bug, plant hopper, or date palm leafhopper) infests date palm. The palms are weakened and photosynthesis is reduced (Fig. 1.11a). Honeydew dripping from the palms soils the fruit bunches and causes fruit atrophy, resulting in downgrading of dates.

Origin: Iberian Peninsula.



(a) (b) (c)

Figure 1.11 (a) *P. dactylifera* affected by *O. binotatus*. (b) *O. binotatus* immature stages. (c) Damaged axils of leaflets on rachis.

Distribution: Sicily (Guglielmino 1997), south of France (Labonne and Bonfils 1998; Howard *et al.* 2001), Israel (Klein and Venezian 1985), Iraq, Iran, Libya, the United Arab Emirates, Saudi Arabia, Kuwait, Bahrain, the Sultanate of Oman, Egypt, Algeria, and Sudan (El-Haidari and Al-Hafidh 1986). Large populations have been found in Egypt and Libya (Talhouk 1977).

Host palms: *P. dactylifera* (common), *C. humilis*.

Harmful stages and damage: All stages (Fig. 1.11b) attack all of the green tissues that are easily accessible in the axils of leaflets on the rachis but also in frond midribs, the bunch stalks, and the pedicels and fruit themselves (Fig. 1.11c). Sap that exudes from the feeding points and the honeydew excreted by the insect ferment and encourage the development of microorganisms (bacteria, fungi) on the leaflets, which turn yellow and dry out (Fig. 1.11a, c).

Risks: Infestation is spread through the transfer of seedlings or offshoots at the foot of mother palms, which contain eggs in the petioles.

1.5.3 *Aspidiotus destructor* Signoret 1869 (Hemiptera: Diaspididae)

A. destructor (coconut scale, transparent scale) is a highly polyphagous diaspid scale insect. It is the most widespread and destructive sap-feeding species on coconut palm, wherever it occurs. It is also an important economic pest of mangoes in Asia and Africa, and of bananas in most tropical areas. However, *A. destructor* appears to be naturally controlled in most regions, and few major outbreaks have been recorded in recent years.

Distribution: Of unknown origin, it was described from La Réunion and reported from Madagascar by Lepesme (1947). It is now reported from most tropical and subtropical regions worldwide and present in nearly all countries where coconuts are grown (Anon 1966).

Host palms: *C. nucifera*, *E. guineensis*, *Phoenix* spp. (Lepesme 1947).

Its range of host plants is very wide, including many tropical trees and other tropical crops, as well as many wild plants. Its hosts are typically perennial species and include many species of fruit trees, such as avocado, breadfruit, mango, guava, and papaya, *Actinidia*, banana, and mango.

Harmful stages and damage: The scales form a crust over the lower surface of all leaflets, which become yellow due to heavy loss of sap. The scale-feeding activity also blocks the stomata, causing fronds to die (Fig. 1.12a, b, c). On coconut palms, frond stalks, flower clusters, and young fruit can also be affected. In extreme cases, the leaves dry up, entire fronds drop off, and the palm dies. The intensity of the attack depends on local ecological conditions: older trees (over 4 years) or trees on well-drained soil are

(a) (b) (c)

Figure 1.12 (a) *A. destructor* scales. (b) Dry coconut leaves. (c) Yellow coconut leaves.

seldom seriously infested. In turn, neglected plantations and densely planted palms are particularly susceptible. Dry weather favors this pest. Wind and various animals—such as insects, birds, and bats—assist in disseminating this pest (Menon and Pandalai 1958). Mariau and Julia (1977) reported that mineral nutrition of the palm may affect the dynamics of *A. destructor* population.

1.5.4 *Parlatoria blanchardi* Targioni, 1868 (Homoptera, Diaspididae)

P. blanchardi (date white scale or Parlatoria date scale insect) is a sap-feeder on palm hosts.

Origin: Arabian Gulf countries.

Distribution: Spain, Italy, France (Foldi 2001), and Sudan. It has spread into India and central Asia, the Middle East, North Africa, Turkey, Australia, and North and South America (Smirnoff 1957).

Host plants: *P. dactylifera*, *P. canariensis*, *P. reclinata*, and *W. filifera* (Lepesme 1947), *Hyphaene thebaica* (Howard *et al.* 2001).

Harmful stages and damage: The scales are hidden by the sheath of fibers that wrap the frond base, where they prefer to live. When the population develops and infestation increases, the colonies tend to occupy the whole frond, concentrating first on the hardest parts: rachis and petioles. Feeding on fronds causes necrosis of the tissues. Heavily infested fronds turn yellow and die prematurely. Damage is very serious on young palms between 2 and 8 years of age, but even under severe attack the palm and its offshoots do not die (Zaid *et al.* 1999). The scales first infest the older foliage and then move to the younger foliage and finally the fruit (Howard *et al.* 2001). Fruits attacked by the insect shrivel up, and remain small and unmarketable.

Risks: The date palm cultivars show differential susceptibility to *P. blanchardi* (Dabbour 1981). This pest is usually spread by trade of the offshoots.

1.5.5 *Aleurotrachelus atratus* Hempel 1922 (Hemiptera: Aleyrodidae)

Although not commonly known as a serious pest of coconut, since 2002 in the Comoros Islands, the white fly, *A. atratus*, has caused considerable damage to coconut palms through sap feeding (Streito, Ollivier, and Beaudoin-Ollivier 2004; Borowiec *et al.* 2009) (Fig. 1.13a, b). The sooty mold that develops on the honeydew excreted by whiteflies worsens the damage, significantly affecting palm growth and yield (Fig. 1.13a). The feeding habit and the resultant damage are somewhat similar to those of the coconut scale *A. destructor*. It is considered a typical invasive pest.

(a) (b) (c)

Figure 1.13 (a) Coconut affected by *A. atratus*. (b) *A. atratus* affecting coconut in the nursery. (c) *A. atratus* puparium.

Origin: Tropical America (Brazil) (Lepesme 1947; Mound and Halsey 1978).

Distribution: In the Neotropics: Most of the Caribbean Islands, Brazil, Colombia, Guyana, Mexico, Puerto Rico, Venezuela, and Florida in the USA (Evans 2007; Delvare *et al*. 2008). It has recently been reported from the Palaearctic region: Canary Islands (Hernandez-Suarez *et al*. 2003), the Pacific region: Hawaii (Wong *et al.* 2006) and Samoa, and the Afrotropical region: Sao Tomé (Martin 2005), and Saint Helena (Howard *et al.* 2001). It also occurs on various islands in the southwestern Indian Ocean: La Réunion, Seychelles, and Comoros, and in glasshouses in Paris (France) (Streito, Etienne, and Balmès 2007; Borowiec *et al*. 2009), Madagascar, Mozambique, and Mauritius (Beaudoin-Ollivier *et al*. 2004).

Host palms: *C. nucifera* is the major host (Mound and Halsey 1978); nine other species of Arecaceae—among them *Syagrus schizophylla*, *E. guineensis*, and *Adonidia merrillii*—are commonly attacked (Howard *et al*. 2001; Evans 2007). In the Indian Ocean and Paris greenhouses (France), *A. atratus* was recorded on 56 palm species (Borowiec *et al*. 2009).

Harmful stages and damage: All three immature instars, the third corresponding to the fourth or "pupal" stage (Howard *et al*. 2001) (Fig. 1.13c) feed on fronds. Observation of palms reveals a depigmentation of the leaflets related to the whitefly activity, which interferes with normal cell functioning. Plasmolysis symptoms on leaves characterize very serious weakening. In addition, feeding whiteflies secrete excess sugars—honeydew—which is the food source for a number fungal species called "dark sooty mold" or "fumagine." This sooty mold causes black spots that prevent gas exchange and, therefore, photosynthesis (Streito, Ollivier, and Beaudoin-Ollivier 2004) (Fig. 1.13a, b).

Risks: *A. atratus* is well adapted to surviving tropical storms. Dissemination risk is high due to exchanges of coconut material. It is a risk in greenhouses and for ornamental palms in urban areas. The wide host range may facilitate this whitefly's spread.

1.6 Inflorescence and Fruit Borers

1.6.1 Pest Ecology, Damage, and Management

There are many insect pollinators on palms, which are mostly pollinated by beetles with remarkable co-evolution (e.g. by Coleoptera: Curculionidae) (Henderson 1986). In contrast, there are quite a limited number of pests that focus on feeding on palm fruits or flowers, as compared to the diversity of palm defoliators and borers. Damage to the inflorescences and fruit bunches may be important by crown borers such as *C. daedalus*, which severely spoil the forming bunches.

Palm fruit and their nutritious mesocarp, such as of dates, are attacked by several generalist species, mostly moths (Pyralidae) and beetles (Nitidulidae), as well as some bugs and mites. Damage is severe when the insect feeding leads to fruit abortion (e.g. mites or *Aphomia sabella* for dates) or directly compromises the fruit's market value and storage. Many pest moths of dates damage the fruit, both during growth on the palm and post-harvest in warehouses. There are a few species that cause economic damage to the seeds.

Effective management of moth pests relies largely on adequate sanitation and cultural practices at the plantation level, and benefits from methods that favor natural biocontrol

based on the many parasitoids or predators present in the environment (Lepesme 1947; Moore 2001). Physical protection of date bunches using dedicated nets, which prevent egg-laying, have been recommended. Today, chemical protection in the field is difficult as the larvae spend most of their time in the fruit and efficient insecticides have been banned. Fumigation is efficient in warehouses, but methyl bromide is in the process of being banned and alternative solutions, such as using modified atmosphere or cold, require costly dedicated facilities.

1.6.2 *Batrachedra amydraula* Meyrick 1916 (Lepidoptera: Batrachedridae)

B. amydraula (lesser date moth) is by far the most serious pest of developing date fruit, which may cause more than 50% loss of the crop. Heavy infestations reduce the yield considerably, with losses of up to 75% recorded in some locations (Carpenter and Elmer 1978). It damages fruit in both the field and in storage (Dowson 1982).

Distribution: Egypt (Badawi, Kamel, and Saleh 1977), Israel, Bangladesh to western Saudi Arabia, Yemen, Iraq and Iran, Libya and United Arab Emirates, as well as most of North Africa (Sayed *et al*. 2014).

Host plants: *P. dactylifera* and *Derris trifoliata* (Fabaceae).

Harmful stage and damage: The imago oviposits on and near inflorescences (Fig. 1.14a). The larvae bore into the inflorescences and the bases of immature date fruit. They sometimes consume the seeds in tender seed varieties (Howard *et al.* 2001) (Fig. 1.14b). Larval attack on the young dates usually stops fruit growth (Fig. 1.14c). The larva can move from one fruit to another, causing more damage. Damaged fruit wither and are shed.

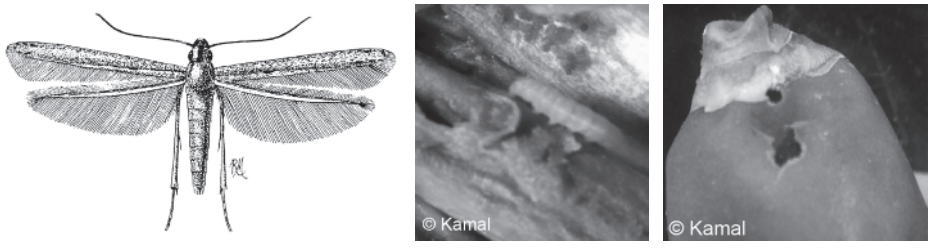
Risks: In Israel, most date varieties are susceptible to the pest.

1.6.3 *Tirathaba rufivena* Walker 1864 (Lepidoptera: Pyralidae)

This moth has a few names: the oil palm bunch moth, the coconut spike moth, and the greater spike moth (Eloja and Abad 1981). It causes serious damage in Southeast Asia and the Pacific region. Various other *Tirathaba* spp. cause similar damage. Young palms are more heavily damaged than older palms, due to their compact crown.

Distribution: Asia from Sri Lanka to New Guinea and possibly eastward to Vanuatu (Waterhouse and Norris 1987; Howard *et al.* 2001).

Host plants: Palms: *C. nucifera*, *E. guineensis*, *Areca catechu*, *Nypa fruticans*, *Plectocomia* spp., *Pritchardia pacifica*, *Roystonea regia* (Lepesme 1947; Howard *et al.* 2001); non-palm: Musa, Phaseolus, and Coix (Lepesme 1947).



(a) (b) (c)

Figure 1.14 (a) *B. amydraula* adult (Source: Lepesme 1947). (b) *B. amydraula* larva boring into date fruit. (c) Damage on immature date fruit.

(a) (b)

Figure 1.15 (a) *T. rufivena* caterpillar damaging coconut flowers. (b) Dry inflorescences of coconut due to *T. rufivena* caterpillars.

Harmful stage and damage: Caterpillars: When the egg hatches, the young larvae begin feeding on newly opened male flowers. The later instars also bore into the female buttons, causing them to shed prematurely (Fig. 1.15a). The attacked female buttons soon decay and drop to the ground, often with fully grown larvae inside (Waterhouse and Norris 1987). The species is harmful by causing extensive premature nut fall (Fig. 1.15b).

Risks: Loss of nut production has to be sustained before consideration is given to this problem.

1.6.4 *Ectomyelois ceratoniae* Zeller 1839 (Lepidoptera: Pyralidae)

This moth, commonly known as the "carob moth," is a considerable agricultural pest, recognized as the most economically damaging pest of the date industry in California (Warner 1988; Nay and Perring 2005), and of high-value nut and fruit commodities.

The adult moth has a wingspan of 22–24 mm and is creamy white to gray, brownish, or even dark brown. The shade also varies according to palm date variety as related to date color (Idder *et al*. 2009). Eggs are laid on the dates and hatching begins within 3–7 days. The larval period is about 3 weeks in warm months and 8 weeks in colder months. The adult lives only 3–5 days, during which time the female may lay 60 to 120 eggs. Three or four generations are produced annually (Carpenter and Helmer 1978). Taking into account the moth's life cycle, it is recommended to protect the fruit bunches, to clean the plantation of wind-fallen fruit and to fumigate harvested and stored dates. The use of pheromone traps will not only help determine the emergence of moths but also estimate their population level. The rate of infestation could be lowered by spraying the infested fruit with *Bacillus thuringiensis* (Djerbi 1994).

Distribution: Widespread in the Mediterranean areas of Europe, North Africa, and Asia (Carpenter and Helmer 1978), Iran, and Israel (Rochat, personal communication). It has been reported in Spain, Italy, Greece, and France (Le Berre 1978).

Host plants: *P. dactylifera*, *Ceratonia siliqua*, *Punica granatum*, citrus fruit, *Pistacia vera*, *Juglans regia*, *Prunus dulci*, *Macadamia integrifolia*, *Acacia farnesiana*, *Caesalpinia sappan*, *Cassia bicapsularis*, *Ricinus communis*, *Erythrina monosperma*, *Haematoxylum campechianum*, *Prosopis juliflora*, and *Samanea saman.*

(a) (b) (c)

Figure 1.16 (a) *C. cautella* adult. (b) and (c) Damage on date fruit by *C. cautella* larva. Reproduced with permissions of HP Aberlenc.

Harmful stage and damage: The larva of the carob moth attacks dates in plantations, packinghouses, and storage. It attacks maturing fruit, especially the drier ones, and causes damage by feeding and by accumulating grass.

Risks: Through introduction in dried fruit. It is the main constraint for export (Doumandji 1981; Doumandji-Mitiche 1983; Idder 1984; Raache 1990; Haddad 2000). If fruit is not fumigated promptly and stored properly, serious losses can occur (Carpenter and Helmer 1978).

1.6.5 *Cadra cautella* Walker 1863 (Lepidoptera: Pyralidae)

The moth *Cadra* (= *Ephestia*) *cautella* is known as the almond moth or tropical warehouse moth. It is one of the most destructive insect pests attacking date palm fruit in the field, and infestation continues in storage post-harvest (Fig. 1.16a). Ali, Metwally, and Hussain (2003) stated that semi-dry dates are the most injured by *C. cautella* during storage, with approximatively 50% of stored dates being lost after 6–7 months of storage.

Distribution: In all tropical and warmer temperate areas of the world.

Host plants: It attacks dried dates, carob, and almonds (Gough 1917). A range of stored foods, especially cereal (maize, rice, wheat, sorghum, millet, oats) flours, and other cereal products, dried cassava, groundnuts, cocoa beans, dried mango, dates, nutmeg, mace, cowpeas, and other dried stored products (Bondar 1940). Polyphagous species (Lepesme 1947).

Harmful stage of the pest: Larvae feed on the pulp of the date fruit (Fig. 1.16b, c).

Organ damaged: Dried fruit post-harvest, male and female flowers of coconut palms (Bondar 1940).

Risks: Adults do not feed during their short lives but stored food is contaminated with dead bodies, frass, excreta, and larval webbing.

1.6.6 *Aphomia sabella* Hampson 1901 (Lepidoptera: Pyralidae)

Aphomia (= *Arenipses*) *sabella* (greater date moth) is found inside flowering/fruit bunches as well as fruit (Fig. 1.17a). There are two generations a year with overwintering of the larvae of the second generation. The caterpillars (23 mm at maximal growth) spend most their lives inside the inflorescences or fruit, living for a while externally in silken tubes (Hussain 1974). Pupation occurs in the crown.

Distribution: Throughout the date-growing regions of North Africa, the Middle East, and northern India (Lepesme 1947). It was first recorded in Spain in 1999 (Asselbergs 1999; Chapin and Germain 2005).

Host palms: *P. dactylifera*, *P. canariensis* (Kehat and Greenberg 1969).

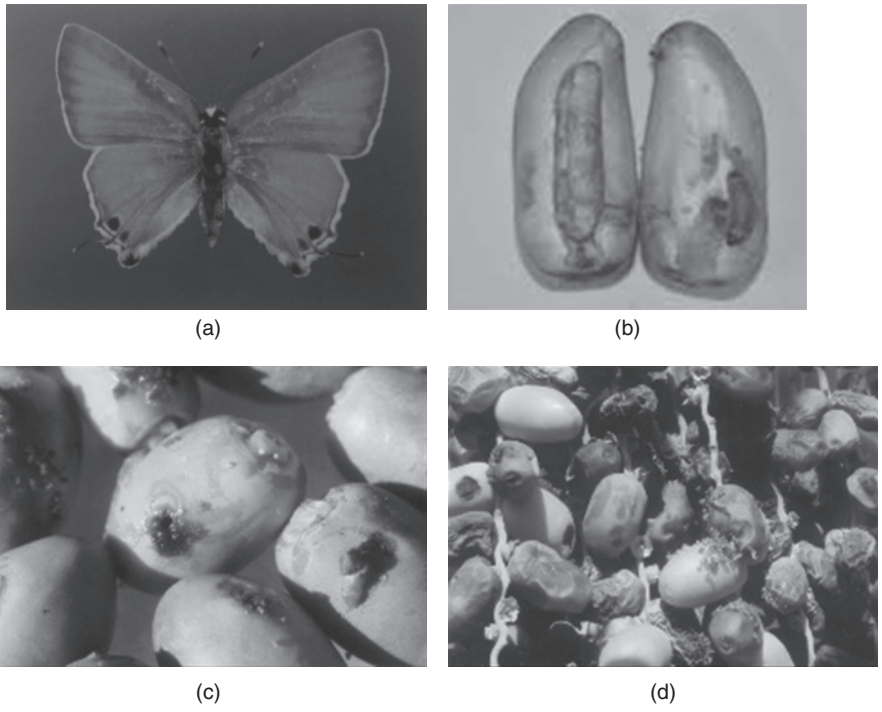
(a) (b)

Figure 1.17 (a) *A. sabella* adult. (b) *A. sabella* damages the peduncle of the inflorescence.

Harmful stage of the pest: The neonate caterpillars bore into the unopened spathes or just blooming female inflorescences. The larvae can also attack more developed inflorescences and the petioles of young fronds, but also inside developing fruit (Fig. 1.17b) (Balachowsky 1972; Howard *et al.* 2001).

1.6.7 *Virachola livia* Klug 1834 (Lepidoptera: Lycaenidae)

V. livia (pomegranate fruit butterfly) causes significant damage to date palm (Mashal and Albeidat 2006) in several Middle-Eastern countries (Fig. 1.18a). This species has



(a) (b)

(c) (d)

Figure 1.18 (a) *V. livia* adult. (b), (c), and (d) Damage on fruit due to *V. livia* caterpillar.

the same capacity as the carob moth, *E. ceratoniae* (Lepidoptera: Pyralidae), to damage pomegranate and date fruit.

Distribution: Egypt (Willcocks 1922), Arabian peninsula, Jordan, Sultanate of Oman, and Tunisia (Abbas *et al*. 2008).

Host palms: *P. dactylifera*; also pomegranate (*P. granatum*) orchards.

Harmful stage and damage: The neonate larvae perforate the fruit. Caterpillars further tunnel for feeding until pupation (Fig. 1.18b, c, d). This is generally accompanied by an invasion of saprotrophic fungi and bacteria, making the fruit unmarketable. In Egypt, the Sewi and Mathour date varieties are seriously damaged by this pest.

Risks: Sanitation of the traditional orchards where both pomegranate and date palms are cultivated should be recommended to remove as many of the fallen fruit, which shelter larvae, as possible.

1.6.8 *Coccotrypes dactyliperda* Fabricius 1801 (Coleoptera: Scolytidae)

Eleven species of *Coccotrypes* have been described by Lepesme (1947). *C. dactyliperda* is 1.5 mm (males) to 2 mm (females) (Fig. 1.19). Adults are shiny reddish-brown with a convex shape, covered with hairs on the dorsal surface. The species uses the haplodiploid sex-determination system. The sex ratio in the field is strongly female-biased (Blumberg and Kehat 1982). In Africa, four species (*C. dactylifera*, *C. congorus*, *C. nigripes*, and *C. perditor*) are found on the fallen fruit of *E. guineensis* (Alibert 1946; Mariau, 2001).

C. dactyliperda (= date seed beetle or date stone beetle) is considered a primary pest of date palm worldwide (Blumberg and Kehat 1982; El-Shafie 2012).

Distribution: Middle East region, North Africa, Indian subcontinent, North America (Lepesme 1947; Carpenter and Elmer 1978), and Israel (Kehat *et al.* 1966; Avidov and Harpaz 1969).

Host palms: *Phoenix* spp., including the date palms *P. dactylifera* and *P. canariensis*. *Areaca catechu*, *C. humilis*, *Livistona chinensis*, *W. filifera*, *E. guineensis*, *Sabal bermudana* (Lepesme 1947).

Harmful stages and damage: All stages. The female beetle tunnels into the kernels (stones) of green unripe date fruit and lays its eggs there. The larvae and pupae develop and the adults leave the date host through a circular hole that they bore, after which they attack new fruit, specifically green unripe ones. A single date is able to support as many as 70 individuals. Each beetle can damage several fruit. Damage by *C. dactyliperda*

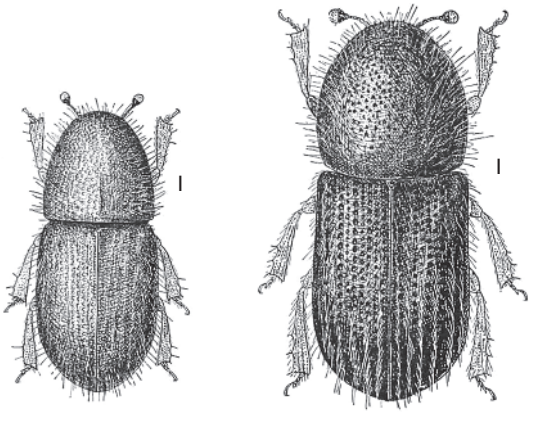


Figure 1.19 *C. dactyliperda* L., male (left side) and female (right side) (35× magnification) (from Lepesme 1947).

ultimately results in both reduced yield (fruit drop) and lower fruit quality (fruit infestation by sap beetles) (Blumberg and Kehat 1982).

Risks: The dropped and rotting dates serve as hosts for nitulid beetles such as *Carpophilus* spp. that attack ripe fruit in late summer.

1.6.9 *Carpophilus hemipterus* L. 1758 and *Carpophilus mutilatus* Erichson 1843 (Coleoptera: Nitidulidae)

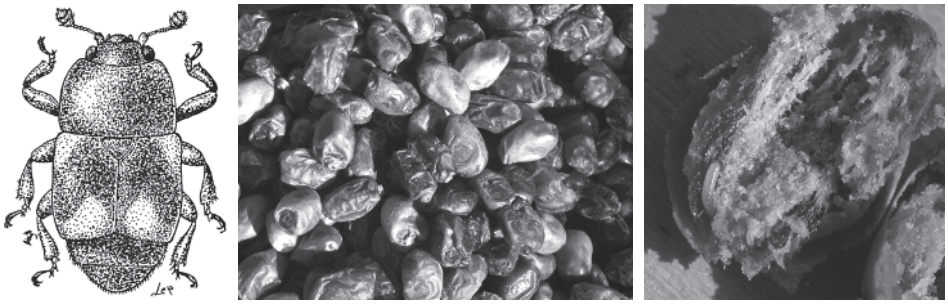
Sap beetles of the genera *Carpophilus* (e.g. *C. hemipterus* and *C. mutilatus*) and *Epuraea* (= *Haptoncus*) *luteola* are pests of several agricultural crops, including dates, throughout the world. They are minute (1.5–5.5 mm) beetles with short truncate, black-brown or black bodies. The larvae are whitish or yellowish with a brown head, final length 5–7 mm.

C. hemipterus adult length is 1.8–2.1 mm with obovate to subparallel body. It may be distinguished from other *Carpophilus* spp. by the presence of two pale humeral and apical patches on the elytra (Leschen and Marris 2005) (Fig. 1.20a). The adults are strong fliers, covering several kilometers a day in search of food. Mature larvae emerge from the fruit to overwinter as pupae in the soil.

C. mutilatus is 1.5–1.8 mm length with a parallel body, variable color, or unicolored light tan to brown. The antennal segment is three times less than 1× the length of segment 2; the male mandibles are asymmetrical with the right mandible strongly elbowed (Leschen and Marris 2005). This species has been described from western India, and the first record of it in New Zealand was by Hutton (1904). *C. hemipterus* (dried fruit beetle) and *C. mutilatus* (confused sap beetle) were re-described by Gillogly (1962), Audisio (1993), and by El-Shafie (2012) in a review on insect pests identified worldwide on date palm.

At least four species have been reported to occur abundantly in date orchards, in both the USA and the Middle East (Lindgren and Vincent 1953; Mashal and Albeidat 2006). In date orchards, sap beetles are considered primary pests, damaging the ripening fruit on palms and then later in storage (Bitton *et al*. 2007). Several species of nitidulid beetles attack ripened dates (Howard *et al.* 2001).

Distribution: Native area unknown. Present in California, North Africa, and the Middle East (Carpenter and Elmer 1978), including Egypt (Lepesme 1947). Also included is Australia (except for Arctic and colder temperature regions) (Connell 1991; Williams



(a) (b) (c)

Figure 1.20 (a) *C. hemipterus* (10× magnification) (from Lepesme 1947). (b) Dates damaged by *Carpophilus*. (c) Date infested with *Carpophilus* larvae.

et al. 1983) and New Zealand, where it has been introduced and has become established (Leschen and Marris 2005).

Host palms: *C. hemipterus* have been observed on rotting *Elaeis* and *Bactris* bunches in the Congo (Lepesme 1947; Mariau 2001). Ripening fruit of many commercial trees, especially those that have been previously damaged, and other fermenting plant material.

Harmful stage of the pest: Essentially the larvae, which typically feed on the pulp of dried fruit, such as ripening dates on the palm tree and on the ground (Fig. 1.20b, c). The eggs are laid in damaged fruit on the date palm or in rotting fruit lying on the ground in the shade. Mature larvae emerge from the fruit and complete their development in the soil.

Risks: The drop of green date fruit caused by *C. dactyliperda* enhances *Carpophilus* populations and increases their damage. Pest penetration into the fruit facilitates the development of microorganisms, resulting in rot and fruit fermentation that downgrade the date fruit.

1.7 Roots

1.7.1 Pest Ecology, Damage, and Management

Some insect species, mostly scarabs and moths, feed on palm roots. Damage is caused by the larvae, which consume either the aerial roots or those growing in the soil, or both equally. A few species are pests, and still fewer attack roots exclusively. For instance, the date palm beetle, *Oryctes agamemnon*, has been reported to feed on aerial roots in Tunisia as well as in Israel and the Arabian Peninsula (Soltani, Chaieb, and Ben Hamouda 2008), but it more generally feeds on old leaf bases where the dead and living tissues meet, as moist woody material is available there. Extensive feeding on the roots leads to weakening of the palm, which spends much energy in renewing the spoiled organs, with a potentially severe slowdown of growth and fruit production. Another consequence is toppling of the palms, particularly in windy areas or during storms. Control of these pests can be achieved using conventional insecticides when the pest is aerial, but is much less difficult when the larvae live exclusively underground.

1.7.2 *Sufetula sunidesalis* Walker (Lepidoptera: Crambidae)

Oil palm is affected by several Lepidopteran root miners, which can sometimes damage the root system to such an extent that palm development is slowed and the palm tree topples (Desmier de Chenon 1975). *S. sunidesalis* is a moth with a wingspan of 15–20 mm. The male presents a dark color overall, and the wings vary from yellowish to black-brown and are decorated with several more or less complete sawtooth stripes. In the female, the body is shorter and thicker. The wings appear darker and are less clearly marked by transversal stripes (Desmier de Chenon 1975). *S. sunidesalis* is a typical species of these pest moths.

Distribution: Southeast Asia: Indonesia (Mariau, Desmier de Chenon, and Sudharto 1991), Malaysia.

Host palms: *C. nucifera* and *E. guineensis*.

Harmful stages and damage: The caterpillar (Fig. 1.21a) destroys root extremities growing out from the base of the stem into the open air when the palm has been

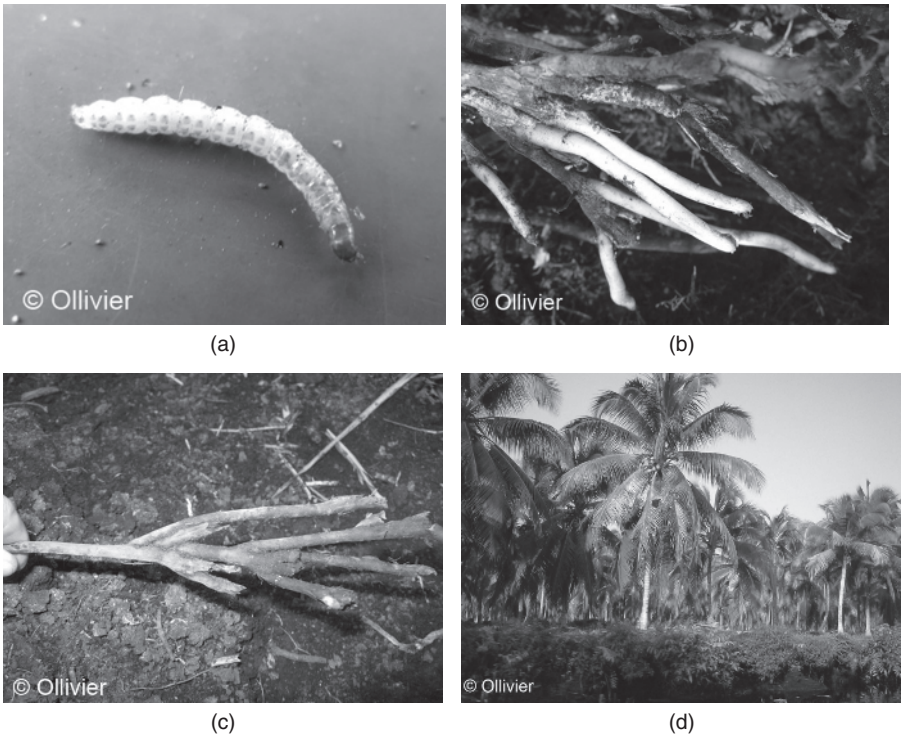


Figure 1.21 (a) *S. sunidesalis* last-instar larva. (b) Repeated reiterations of oil palm root system. (c) Typical symptoms on oil palm primary roots attacked by *S. sunidesalis*. (d) Coconut palms affected by *S. sunidesalis*.

incorrectly planted, or the roots underground. The attacks cause successive and repeated iterations of the root system (Fig. 1.21b). The most severely attacked plots on peat displayed very typical symptoms of highly branched root tips (Fig. 1.21c). The primary roots become stumped, delaying palm growth and resulting in loss of production (Fig. 1.21d).

Risks: Plantations on peat soil and neglected plantations.

1.8 Conclusion

This chapter describes the many insect species that are common to palms. They are classified into groups based on their preferred palm organ. However, some species are not highly specific to a particular organ. They may infest more than one part at the same time, and can attack foliage as well as fruit or inflorescences, depending on the severity of the infestation and prevailing weather conditions (*A. destructor*, for example). Damage is worse on young palms and rare on palms older than 3–4 years, although damage has been recorded on palms 15 years after planting and on isolated palms.

The interactions between palm pests, such as *S. australis* (or *O. rhinoceros*) and the weevil *Rhynchophorus*, or between *P. archon* and *R. ferrugineus*, must be seriously considered. The damage inflicted to the palm by the first pest is often exacerbated by the

effects of a secondary pest (e.g. *P. archon* attacks create sites that are highly propitious for weevil reproduction).

Specific insect problems vary with geographic area and location. Particular conditions may dispose palms to infestation by insect pests, such as weakened palms, presence of other insects, poor management or field sanitation, lack of or excess irrigation, and fertilization. The nature and severity of the attacks also vary with cultivar, weather, and cultural practices, and may also aggravate the situation and lead to an increase in a specific pest population. Effort should be made to prevent invasive pests from causing outbreaks and becoming established.

References

Abbas, M.S.T., Razvi, S.A., Rashid, H.S. and Al-Khatry, S.A. (2008) Role of egg parasitoids in controlling the pomegranate butterfly, in Virachola livia. 2nd Arab Conference of Applied Biological Pest control April 7–10, 2008, Cairo, Egypt.

Abe, F., Hata, K. and Sone, K. (2009) Life history of the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae), in southern Japan. *Florida Entomologist*, **92**, 421–5.

Ali, M.A.M., Metwally, M.M. and Hussain, A.E. (2003) Infestation levels and population density of insect pests attacking stored date under the conditions of El-Baharia Oasis, Egypt. *Bulletin of the Entomological Society of Egypt*, **80**, 133–46.

Alibert, H. (1946) Etude sur deux insectes parasites des noix de palme en Afrique occidentale. *Agronomie Tropicale*, **1**, 173–6.

Allou, K., Morin, J.P., Kouassi, P. *et al.* (2006) *Oryctes monoceros* trapping with synthetic pheromone and palm material in Ivory coast. *Journal of Chemical Ecology*, **32**, 1743–54.

André, N. and Tixier Malicorne, P. (2013) Le papillon palmivore en Languedoc-Roussillon: Son impact, ses conséquences et les plans d'action envisagés, in *Proceedings of the Palm Pest Mediterranean Conference, AFPP* January 16–18, 2013, Nice, France, pp. 157–69.

Anglade, P. (1972) Les *Sesamia*, in *Entomologie Appliquée à l'Agriculture, Traité, Tome II, Lépidoptères* (ed. A.S. Balachowsky), Masson et Cie, Saint Germain, Paris, pp. 1389–1400.

Anon (1966) Distribution maps of pests, in Aspidiotus destructor *Signoret*, Series A. map N° 218, Commonwealth Institute of Entomology.

APG (Angiosperm Phylogeny Group) (2009) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society*, **161**, 105–21.

APPPC (1987) *Insect pests of economic significance affecting major crops of the countries in Asia and the Pacific region*, Technical document N° 135. Bangkok, Thailand. Regional FAO Office for Asia and the Pacific (RAPA).

Asselbergs, J.E.F. (1999) *Arenipses sabella* Hampson, 1901, from South Spain: New to the European fauna; *Thylacoptila paurosema* Meyrick, 1885, new to the fauna of the Canary Islands; *Ancylosis* (Ancylosis) *albidella* Ragonot, 1888, new to the Spanish fauna (Lepidoptera: Pyralidae, Galleriinae, Phycitinae). *SHILAP Revista de Lepidopterologia*, **27**, 125–9.

Audisio, P. (1993) *Fauna d'Italia. Vol XXXII. Coleoptera: Nitidulidae: Kateretidae*, Calderini, Bologna, Italy.

Avidov, Z. and Harpaz, I. (1969) *Plant Pests of Israel*, Universities Press, Jerusalem, Israel.

Badawi, A., Kamel, A.H. and Saleh, M.R.A. (1977) Seasonal fluctuation and the population dynamics of certain pests attacking date bunches in the New Valley (Egypt). *Agricultural Research Review*, **55**, 1–7.

Balachowsky, A. (1972) *Entomologie Appliquée à L'agriculture*, Masson et Cie, Paris.

Barranco, P., de la Peña, J., Martín, M.M. and Cabello, T. (2000) Rango de hospedantes de *Rhynchophorus ferrugineus* (Olivier, 1790) y diámetro de la palmera hospedante. (Coleoptera, Curculionidae). *Boletín de Sanidad Vegetal, Plagas*, **26**, 73–8.

Beaudoin-Ollivier, L., Morin, J.P., Prior, R.N.B. *et al.* (1999) Le complexe *Scapanes-Rhynchophorus*, principal problème entomologique du cocotier en Papouasie-Nouvelle-Guinée. *Plantations, Recherche, Développement*, **6**, 46–55.

Beaudoin-Ollivier, L., Prior, R.N.B., Morin, J.P. *et al.* (2001) The larval development sites of the Melanesian coconut beetle *Scapanes australis* Boisduval (Coleoptera: Scarabaeidae: Dynastinae) in Papua New Guinea. *Science in New Guinea*, **26**, 52–60.

Beaudoin-Ollivier, L., Streito, J.C., Ollivier, J. *et al.* (2004) *Aleurotrachelus atratus* Hempel (Hemiptera: Aleyrodidae) and its emergence as pest of coconut (*Cocos nucifera* L.), in the Comoro Islands2nd European Whitefly Symposium. Cavtat, Croatia, October 5–9, 2004.

Bedford, G.O. (1974) Descriptions of the larvae of some rhinoceros beetles (Coleoptera, Scarabaeidae, Dynastinae) associated with coconut palms in New Guinea. *Bulletin of Entomological Research*, **63**, 445–72.

Bedford, G.O. (1976) Observations on the biology and ecology of *Oryctes rhinoceros* and *Scapanes australis* (Coleoptera: Scarabaeidae: Dynastinae): Pests of coconut palms in Melanesia. *Journal of the Australian Entomological Society*, **15**, 241–51.

Bedford, G.O. (1980) Biology, ecology and control of palm rhinoceros beetles. *Annual Review of Entomology*, **25**, 309–39.

Bedford, G.O. (2013) Biology and management of palm dynastid beetles: Recent advances. *Annual Review of Entomology*, **58**, 353–72.

Besse, S., Panchaud, K. and Gahlin, S. (2013) Palmiers: Encore un nouveau ravageur. *Phytoma*, **661**, 14–17.

Bitton, S., Nakash, Y., Soroker, V. and Blumberg, D. (2007) Control trials of sap beetle in date plantation. *Alon Hanotea*, **62**, 974–7.

Blumberg, D. (2008) Review: Date palm arthropod pests and their management in Israel. *Phytoparasitica*, **36**, 411–448.

Blumberg, D. and Kehat, M. (1982) Biology studies of the date stone beetle: *Coccotrypes dactyliperda*. *Phytoparasitica*, **10**, 73–8.

Bondar, G. (1940) *Insetos nocivos e molestias do coquero (*Cocos nucifera *L.) no Brazil*, Tipografia Naval, Salvador.

Borowiec, N., Quilici, S., Martin, J. *et al.* (2009) Increasing distribution and damage to palms by the Neotropical whitefly: *Aleurotrachelus atratus* (Hemiptera: Aleyrodidae). *Journal of Applied Entomology*, **134**, 498–510.

Bourquin, F. (1930) Algunas observaciones sobre castniidae. *Revista de la Sociedad Entomológica Argentina*, **3**, 173–4.

Buhl, O., Falck, P., Karsholt, O. *et al.* (2009) Records of Microlepidoptera from Denmark in 2008 (Lepidoptera). *Entomologiske Meddelelser*, **77**, 65–81.

CABI (2015) *Invasive Species Compendium* Datasheet on Sesamia cretica http://www.cabi.org/isc/datasheet/49749.

Cachan, P. (1957) L'Hispine mineur *Coelaenomenodera elaeidis* Maul: Parasite du palmier à huile dans la zone guinéenne. *L'Agronomie Tropicale*, **XII**, 610–632.

Carpenter, J.B. and Elmer, H.S. (1978) Pests and diseases on the date palm, in *Agricultural Handbook*, 527 edn N°, US Department of Agriculture, Washington, pp. 1–42.

Chapin, E. (2006) *Paysandisia archon*: Situation 5 ans après son signalement. *PAFPP: 1ère Conférence sur l'entretien des espaces verts, jardins, gazons, forêts, zones aquatiques et autres zones non agricoles*. Avignon, France, October 11–12, 2006: 157–63.

Chapin, E. and Germain, J.F. (2005) Des ravageurs des palmiers en France, espèces établies, introduites ou interceptées. *AFPP*7ème Conférence Internationale sur les ravageurs en Agriculture. Montpellier, France, October 26–27, 2005.

Cock, M. J. W., Godfray, H. C. J., and Holloway, J. D. (1987) Slug and Nettle Caterpillars: The biology, taxonomy and control of the Limacodidae of economic importance on palms in South-East Asia. CAB International.

Commonwealth Institute of Entomology (1979) *Distribution Maps of Pests*, Series A (Agricultural), Map no. 339 *S. nonagrioides* (Lef.), Commonwealth Agricultural Bureau, UK.

Connell, W.A. (1991) Sap beetles (Coleoptera: Nitidulidae), in *Insect and Mite Pests in Food: An illustrated key*, Volume 1. United States Department of Agriculture Handbook No. 655 (ed. J.R. Gorham), US Government Printing Office, Washington, pp. 151–74.

Corley, R.H.V. and Tinker, P.B. (2007) *The Oil Palm*, 4th edn, Blackwell Publishing, Oxford.

Cotterel, G.S. (1925) The hispid leaf miner (*Coelaenomenodera elaeidis* Mlk.) of oil palms (*Elaeis guineensis* Jacq.) on the Gold Coast. *Bulletin of Entomological Research*, **16**, 77–83.

Dabbour, A.I. (1981) Distribution of the scale insect *Parlatoria blanchardi* Targ. On date-palm trees. *Mededelingen van de Faculteit Landbouwwetenschappen. Rijksuniversiteit Gent*, **46**, 553–8.

Delle-Vedove, R., Beaudoin-Ollivier, L., Hossaert-McKey, M. and Frérot, B. (2012) Reproductive biology of the palm borer *Paysandisia archon* (Lepidoptera: Castniidae). *European Journal of Entomology*, **109**, 289–92.

Delvare, G., Genson, G., Borowiec, N. *et al.* (2008) Description of *Eretmocerus cocois* sp. n. (Hymenoptera: Chalcidoidea): A parasitoid of *Aleurotrachelus atratus* (Hemiptera: Aleyrodidae) on the coconut palm. *Zootaxa*, **1723**, 47–62.

Desmier de Chenon, R. (1975) Presence in Indonesia and Malaysia of a Lepidoptera oil palm root miner, *Sufetula sunidesalis* Walker, and its relationship to attacks by Ganoderma. *Oléagineux*, **30**, 449–56.

Djerbi, M. (1994) *Précis de Phéniculture*, vol. **191**, FAO, Rome.

Doumandji, S. E. (1981) Biologie et écologie de la pyrale des caroubes dans le Nord de l'Algérie, *Ectomyelois ceratoniae* Zeller (Lepidoptera-Pyralidae). Thèse doctorat ès science, Université de Paris VI.

Doumandji-Mitiche, B. (1983) Contribution à l'étude bio-écologique des parasites et prédateurs de la pyrale des caroubes *Ectomyelois ceratoniae* en Algérie en vue d'une éventuelle lutte biologique contre ce ravageur. Thèse de doctorat ès science, Université de Paris VI.

Dowson, V.H.W. (1982) Date production and protection: Food and Agricultural Organization of the United Nations. *Plant Production and Protection Paper*, **35**, 1–294.

Drescher, J. and Jaubert, R. (2003) *Paysandisia archon* continue sa progression. *PHM: Revue Horticole*, **445**, 49–51.

Drescher, J. and Martinez, M. (2005) Le coléoptère *Pistosia dactyliferae* menace les palmiers du sud de la France. *PHM: Revue Horticole*, **468**, 34–8.

Eiserhardt, W.L., Svenning, J.C., Kissling, W.D. and Ballslev, H. (2011) Geographical ecology of the palms (Arecaceae): Determinants of diversity and distributions across spatial scales. *Annals of Botany*, **108**, 1391–416.

Eizaguirre, M. and Fantinou, A.A. (2012) Abundance of *Sesamia nonagrioides* (Lef.) (Lepidoptera: Noctuidae) on the edges of the Mediterranean Basin. *Psyche: A Journal of Entomology* article 854045, doi: 10.1155/2012/854045.

El-Haidari, H.S. and Al-Hafidh, E.M.T. (1986) *Palm and date arthropod pests in the Near-East and North Africa* (in Arabic), in *Project for Palm and Date Research Center in the Near East and North Africa*, *FAO Bulletin*, Baghdad, p. 17.

El-Mergawy, R.A.A.M. and Al-Ajlan, A.M. (2011) Red palm weevil, *Rhynchophorus ferrugineus* (Olivier): Economic importance, biology, biogeography and integrated pest management. *Journal of Agricultural Science and Technology B*, **1**, 1–23.

El-Sayed, A.M., Suckling, D.M., Wearing, C.H. and Byers, J.A. (2006) Potential of mass trapping for long-term pest management and eradication of invasive species. *Journal of Economic Entomology*, **99**, 1550–1564.

El-Shafie, H.A.F. (2012) Review: List of arthropod pests and their natural enemies identified worldwide on date palm: *Phoenix dactylifera* L. *Agricultural and Biology Journal of North America*, **3**, 516–524.

Eloja, C.N. and Abad, R.G. (1981) Evaluation of six insecticides against the greater coconut spike moth *Tirathaba* sp. *Philippine Journal of Coconut Studies*, **1**, 1–6.

eMonocots (2013) Kew Royal Botanic gardens: University of Oxford: Natural History Museum: National Environment Research Council, United Kingdom, http://www.emonoct.org/

EPPO (2014) PQR database. Paris: European and Mediterranean Plant protection Organization, http://www.eppo.int/DATABASES/pqr/pqr.htm.

EPPO/OEPP (2008) Data sheets on quarantine pests *Paysandisia archon*. *OEPP/EPPO Bulletin*, **38**, 163–6.

Evans, G. A. (2007) Whitefly taxonomic and ecological website: An on-line interactive catalogue of the whiteflies (Hemiptera: Aleyrodidae) of the world and their parasites and predators. United States Department of Agriculture, http://www.fsca-dpi.org/homoptera_hemiptera/whitefly/whitefly_catalog.htm.

Faleiro, J.R. (2006) A review on the issues and management of red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. *International journal of tropical Insect Science*, **26**, 135–54.

FAO (1966) *FAO Technical Working Party on Coconut Production, Protection and Processing*. Colombo, November 30 to December 8, 1964. Rome: FAO, Working Paper 33.

Farazmand, H. (2002) Investigation on the reasons of food preference of red palm weevil, *Rhynchophorus ferrugineus* (Oliv.). *Applied Entomology and Phytopathology*, **70** (11), 49–61(in Persian).

Fenner, T. L. (1984) *Palm Leaf Beetle*. Agnote 84/16. Northern Territory of Australia: Department of Primary Production.

Ferreira, J.M.S., Warwick, D.R.N. and Siqueira, L.A. (eds) (1994) *Cultura do coqueiro no Brasil*, EMBRAPA-SPI, Aracaju, Brazil.

Foldi, I. (2001) Liste des cochenilles de France (Hemiptera, Coccoidea). *Bulletin de la Société Entomologique de France*, **106**, 303–8.

Frigimelica, G., Pozzebon, A., Duso, C. and Pellizzari, G. (2012) Pathogenic fungi on *Trachycarpus fortunei* palms infested by *Paysandisia archon*. *Proceedings of the XVIII*

Convegna Nazionale Societa Italiana di Patologia Vegetale, Sassari, Italy. *Journal of Plant Pathology*, **94**, 47.

Frogatt, J.L. and O'Conor, B.A. (1941) Insects associated with the coconut palm. Pt. II. *New Guinea Agricultural Gazette*, **7**, 125–33.

Genty, P., Desmier de Chenon, R., Morin, J.P. and Korytkowski, C.A. (1978) Les ravageurs du palmier à huile en Amérique latine. *Oléagineux*, **33**, 326–420.

Gillogly, L.R. (1962) Insects of Micronesia: Coleoptera: Nitidulidae. *BP Bishop Museum, Honolulu*, **16**, 133–88.

González, J.M., Domagala, P. and Larysz, A. (2013) The giant butterfly-moths (Lepidoptera Castniidae) of the Upper Silesian Museum (Muzeum Górnośląskie) in Bytom, Poland, with notes on the history of the Museum. *Biodiversity Journal*, **4**, 219–228.

Goodey, J.B. (1960) *Rhadinaphelencus cocophilus* (Cobbe 1919) n. comb., the nematode associated with "red-ring" disease of coconut. *Nematologica*, **5**, 98–102.

Gough, L.H. (1917) Notes on an Ephestia: An insect injurious to stored dates in Khargeh Oasis. *Bulletin of the Entomological Society of Egypt*, **5**, 133–40.

Gries, G., Gries, R., Perez, A.L. *et al.* (1994) Aggregation pheromone of the African rhinoceros beetle, *Oryctes monoceros* (Olivier) (Coleoptera: Scarabaeidae). *Zeitschrift für Naturforschung*, **49**, 363–6.

Griffith, R. (1974) The use of the smaller palm weevil *Rhynchophorus palmarum* L. in the forecasting of red ring disease outbreaks. *Journal of the Agricultural Society of Trinidad and Tobago*, **74**, 149–58.

Guglielmino, A. (1997) Biology and postembryonic development of *Ommatissus binotatus* Fieber: A pest of Dwarf Palm in Sicily. *Spixiana*, **20**, 119–130.

Haddad, L. (2000) Quelques données sur la bio-écologie d'Ectomyelois ceratoniae dans les régions de Touggourt et Ouargla, en vue d'une éventuelle lutte contre ce déprédateur, in *Mémoire d'ingénieur*, ITAS, Ouargla, p. 2000.

Hallett, R.H., Gries, G., Gries, R. *et al.* (1993) Aggregation pheromones of two Asian palm weevils. *Rhynchophorus ferrugineus and R. vulneratus. Naturwissenschaften*, **80**, 328–31.

Hallett, R.H., Perez, A.L., Gries, G. *et al.* (1995) Aggregation pheromone of coconut rhinoceros beetle, *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae). *Journal of Chemical Ecology*, **21**, 1549–70.

Hargreaves, E. (1928) Some insect pests of Sierra Leone, in *Proceeding of 1st W. Africa Conference* March 1927:, Ibadan, Nigeria, pp. 113–128.

Henderson, A. (1986) A review of pollination studies in the Palmae. *Botanical Review*, **52**, 221–59.

Hernandez-Suarez, E., Carnearo, A., Aguiar, A. *et al.* (2003) Parasitoids of whiteflies (Hymenoptera: Aphelinidae, Eulophidae, Plastygastridae; Hemiptera: Aleyrodidae) from the Macaronesian archipelagos of the Canary Islands, Madeira and the Azores. *Systematics and Biodiversity*, **1**, 55–108.

Howard, F.W., Moore, D., Giblin-Davis, R.M. and Abad, R.G. (2001) *Insects on Palms*, CABI Publishing, Wallingford.

Huguenot, R. and Vera, J. (1981) Description and control of *Castnia daedalus* Cr. (Lepidoptera Castniidae), oil palm pest in South America. *Oléagineux*, **36**, 543–8.

Hussain, A.A. (1974) *Date palms and dates with their pests in Iraq*, University of Baghdad. Ministry of Higher Education and Scientific Research, Iraq, p. 166.

Hutton, F.W. (1904) *Index Faunae Novae Zealandiae*, Dulau, London.

Idder, A. (1984) Inventaire des parasites d'*Ectomyelois ceratoniae* Zeller dans les palmeraies de Ourgla et lâchers de *Trichogramma embryophagum* Hartig contre cette pyrale, in *Mémoire ingénieur agronome*, INA El Harrach, Alger, p. 1984.

Idder, A., Idder-Ighili, H., Saggou, H. and Pintureau, B. (2009) Taux d'infestation et morphologie de la pyrale des dattes *Ectomyelois ceratoniae* (Zeller) sur différentes variétés du palmier dattier *Phoenix dactylifera* (L.). *Cahiers Agricultures*, **18**, 63–71.

Jacquemard, J.C. (2011) *Le palmier à huile*, Quae/CTA /Presses agronomiques de Gembloux, Montpellier, France.

Jover, H. (1950) Note technique sur la lutte contre *Coelaenomenodera* sp., parasite des palmiers à huile à La Mé. *Oléagineux*, **5**, 156–60.

Kalshoven, L.G.E. and van der Laan, P.A. (1981) *Pests of Crops in Indonesia*, Ichtiar Baru, Jakarta, Indonesia.

Kehat, M. and Greenberg, S. (1969) The biology and phenology of *Arenipses sabella* Hmps. and *Cadra figulillella* (Gregson) (Lepidoptera, Pyralidae) on date in Israel. *Bulletin of Entomological Research*, **58**, 411–419.

Kehat, M., Stoller, S., Meisner, J. and Greenberg, S. (1966) Development of population and control of *Carpophilus dimidiatus* F., *C. hemipterus* L. and *Coccotrypes dactyliperda* F. in dates. *Israel Journal of Agricultural Research*, **16**, 173–6.

Khoo, K.C., Ooi, P.A.C. and Ho, C.T. (1991) *Crop Pests and Their Management in Malaysia*, Tropical Press, Kuala Lumpur, Malaysia.

Klein, M. and Venezian, A. (1985) The dubas date Tropiduchid: *Ommatissus binotatus lybicus*: A threat to date palms in Israel. *Phytoparasitica*, **13**, 95–101.

Labonne, G. and Bonfils, J. (1998) Présence en France du Tropiduchidae *Ommatissus binotatus* (Fieber, 1876), parasite du palmier nain *Chamaerops humilis* (Hom., Fulgoroidea). *Bulletin de la Société Entomologique de France*, **103**, 33–5.

Lamas, G. (1995) A critical review of J. Y. Miller's checklist of the Neotropical Castniidae (Lepidoptera). *Revista Peruana de Entomologia*, **37**, 73–87.

Le Berre, M. (1978) Mise au point sur le problème du ver de la datte *Myelois ceratoniae* Zeller. *Agricultural Bulletin of Sahara Desert*, **1**, 1–35.

Lepesme, P. (1947) *Les Insectes des Palmiers*, Paul Lechevalier, Paris.

Leschen, R.A.B. and Marris, J.W.M. (2005) *Carpophilus* (Coleoptera: Nitidulidae) of New Zealand with notes on Australian species. *MAF: Contract FMA*, **121**.

Lever, R.J.A.W. (1969) *Pests of the Coconut Palm*, FAO Agricultural Studies N° 77, Food and Agricultural Organization of the United Nations, Rome.

Liao, C.T. and Chen, C.C. (1997) Primary study the insect pests, hosts and ecology of weevil attacking ornamental palm seedlings. *Bulletin of Taichung District Agricultural Improvement Station*, **57**, 43–8.

Lindgren, D.L. and Vincent, L.E. (1953) Nitidulid beetles infesting California dates. *Hilgardia*, **22**, 97–118.

Maddison, P. A. (1983) Coconut hispine beetle. Advisory Leaflet, South Pacific Commission, N° 17.

Malumphy, C. and Moran, H. (2007) Plant pest notice: Red palm weevil *Rhynchophorus ferrugineus*. *Central Science Laboratory*, **50**, 1–3.

Manciot, R. (1965) Lutte chimique contre le Brontispa du cocotier. Pratique agricole, conseils de l'IRHO 41. *Oléagineux*, **6**, 369–71.

Mariau, D. (2001) *The fauna of oil palm and coconut insect and mite pests and their natural enemies*, CIRAD, Montpellier, France.

Mariau, D. and Julia, J.F. (1977) Nouvelles recherches sur la cochenille du cocotier *Aspidiotus destructor* (Sign.). *Oléagineux*, **32**, 217–224.

Mariau, D., Desmier de Chenon, R., Julia, J.F. and Philippe, R. (1981) Les ravageurs du palmier à huile et du cocotier en Afrique occidentale. *Oléagineux*, **36**, 170–228.

Mariau, D., Desmier de Chenon, R. and Sudharto, P.S. (1991) Les ravageurs du palmier à huile et leurs ennemis en Asie du Sud-Est. *Oléagineux*, **46**, 400–476.

Martin, J.H. (2005) Whiteflies of Belize (Hemiptera: Aleyrodiae): Part 2: A review of the subfamily Aleyrodinae Westwood. *Zootaxa*, **1098**, 1–116.

Mashal, M. and Albeidat, B. (2006) A survey on insect pests of date palm trees in Jordan (Research Note). *Jordan Journal of Agricultural Sciences*, **2**, 94–104(English abstract).

Menon, K.P.V. and Pandalai, K.M. (1958) *The coconut palm: A monograph*, Indian Central Coconut Committee, Ernakulam, India.

Meyer, J.Y., Lavergne, C. and Hodel, D.R. (2008) Time bombs in gardens: Invasive ornamental palms in tropical islands, with emphasis on French Polynesia (Pacific Ocean) and the Mascarenes (Indian Ocean). *Palms*, **52**, 71–83.

Miller, J.Y. (1986) The taxonomy, phylogeny, and zoogeography of the Neotropical moth subfamily Castniidae (Lepidoptera: Castnioidea: Castniidae). *Dissertation Abstracts International, B (Sciences and Engineering)*, **47**, 2289.

Montagud Alario, S. (2004) *Paysandisia archon* (Burmeister, 1880) (Lepidoptera, Castniidae): Nuevas localizaciones en la Península Ibérica y su gestión. *Boletín de la Sociedad Entomológica Aragonesa*, **34**, 237–46.

Moore, D. (2001) Population regulations of palm pests, in *Insect on Palms* (eds F.W. Howard, D. Moore, R.M. Giblin-Davis and R.G. Abad), CABI, Wallingford.

Morin, J.P. and Mariau, D. (1971) La biologie de *Coelaenomenodera elaedis* Mlk. III. La reproduction. *Oléagineux*, **26**, 373–8.

Morin, J.P., Rochat, D., Malosse, C. *et al.* (1996) Ethyl 4-methyloctanoate, major component of *Oryctes rhinoceros* (L.) (Coleoptera, Dynastidae) male pheromone. *Comptes Rendus de l'Académie des Sciences: Série III: Sciences de la vie*, **319**, 595–602.

Mound, L.A. and Halsey, S.H. (1978) *Whitefly of the World: A systematic catalogue of the Aleyrodidae (Homoptera) with host plant and natural enemy data*, John Wiley & Sons, British Museum (Natural History). Chichester.

Nay, J.E. and Perring, T.M. (2005) Impact of ant predation and heat on carob moth (Lepidoptera: Pyralidae) mortality in California date gardens. *Journal of Economic Entomology*, **98**, 725–31.

O'Meara, B. (2001) *Bacterial symbiosis and plant host use evolution in Dryophthorinae (Coleoptera, Curculionidae): A phylogenetic study using parsimony and Bayesian analysis*, Harvard University, BSc thesis.

Ohler, J.G. (1984) *Coconut: Tree of life*, FAO Plant Production and Protection Paper 57.

Palmweb (2011) *Palmweb: Palms of the World Online*, http://palmweb.org.

Panchaud, K. and Dusoulier, F. (2013) Observations de terrain et premiers éléments de biologie chez *Pistosia dactyliferae* (Maulik, 1919): Nouveau danger pour les palmiers. *Actes de la 3ème conférence sur l'entretien des espaces verts, jardins, gazons, forêts, zones aquatiques et autres zones non agricoles*. Toulouse, France, October 15–17, 2013: 215–219.

Panchaud, K. and Dusoulier, F. (2014) *Pistosia dactyliferae* (Maulik, 1919): Nouveaux résultats sur la connaissance de l'insecte. *AFPP: Colloque ravageurs et insectes invasifs et émergents*, Montpellier, France, October 21, 2014.

Perthuis, B., Desmier de Chenon, R. and Merland, E. (1985) Mise en évidence du vecteur de la Marchitez sorpresiva du palmier à huile, la punaise *Lincus lethifer* Dolling (Hemiptera Pentatomidae Discocephalinae). *Oléagineux*, **40**, 473–76.

Peyron, G. (2000) *Cultiver le Palmier-Dattier. Guide illustré de formation*, Quae, Paris.

Prior, R., Morin, J.P., Rochat, D. *et al.* (2000) New aspects of the biology of the Melanesian Rhinoceros Beetle *Scapanes australis* (Col., Dynastidae) and evidence for field attraction to males. *Journal of Applied Entomology*, **124**, 41–50.

Psirofonia, P. and Niamouris, K. (2013) First infestations by the Lepidopterous pest *Paysandisia archon* in Cretan palm tree (*Phoenix theophrasti*). *Agricultural and Animal Husbandry*, **1**, 32–6.

Raache, A. (1990) Etude comparative des taux d'infestation de deux variétés de dattes (Deglet-Nour et Ghars) par la pyrale des dattes *Ectomyelois ceratoniae* (Lepidoptera: Pyralidae) dans deux biotopes différents (palmeraies moderne et traditionnelle) dans la région de Ouargla, in *Mémoire ingénieur*, *ITAS*, Ouargla.

Rahalkar, G.W., Harwalkar, M.R. and Rananavare, H.O. (1972) Development of red palm weevil, *Rhynchophorus ferrugineus* Oliv. on sugarcane. *Indian Journal of Entomology*, **34**, 213–215.

Rai, B.K. (1973) *Brassolis sophorae* and *Castnia daedalus* chemical control of these major pests of coconut in Guyana. *Journal of Economic Entomology*, **66**, 177–80.

Reid, S. (2008) Recent quarantine interceptions of *Paysandisia archon* Burmeister. *Atropos*, **33**, 25–7.

Riolo, P., Isidoro, N. and Nardi, S. (2005) Prime osservazioni sul ciclo biologico di *Paysandisia archon* (Lepidoptera, Castniidae) nelle Marche, in *Atti Incontri Fitoiatrici, Difesa delle Colture Ortoflorofrutticole* February 24–25, 2005 (ed. Ace International), Torino, Italy, pp. 82–3.

Riolo, P., Nardi, S., Carboni, M. *et al.* (2004) *Paysandisia archon* (Lepidoptera, Castniidae): Prima segnalazione di danni del pericoloso minatore delle palme sulla riviera adriatica.). *Informatore Fitopatologico*, **54**, 28–31.

Riolo, P., Nardi, S., Carboni, M., *et al.* (2007) Insetti associati ad Arecaceae nelle Marche. *Proceedings XXI Congresso Nazionale Italiano di Entomologia*, June 6–11, 2007, Campobasso (Italia): 216.

Rival, A. and Levang, P. (2013) *La Palme des Controverses: Palmier à huile et enjeux de développement*, Quae.

Rochat, D. (2006) Olfactory trapping of red palm weevil: Drawbacks and prospect, in Proceedings of the 1st International Workshop on Red Palm Weevil, Rhynchophorus ferrugineus, IVIA, Moncada, Spain, Agroalimed et Generalitat, pp. 99–104.

Rochat, D., Desouhant, E. and Menu, F. (2013) Exploitation de la plante-hôte pour l'alimentation et la reproduction, in *Interactions insectes-plantes, Partie 4: Des stratégies d'exploitation de la plante aux stratégies mutualistes* (eds N. Sauvion, P.A. Calatayud, D. Thiéry and F. Marion-Poll), Editions Quae, Versailles, France, pp. 263–70.

Rugman-Jones, P.F., Hoddle, C.D., Hoddle, M.S. and Stouthamer, R. (2013) The lesser of two weevils: Molecular-genetics of pest palm weevil populations confirm *Rhynchophorus vulneratus* (Panzer 1798) as a valid species distinct from *R. ferrugineus* (Olivier 1790), and reveal the global extent of both. *PLoS ONE*, **8**, e78379 doi: 10.1371/journal.pone.0078379.

Salama, H.S. and Abdel-Razek, A.S. (2002) Development of the red palm weevil *Rhynchophorus ferrugineus* (Olivier) (Coleoptera, Curculionidae) on natural and synthetic diets. *Journal of Pest Science*, **75**, 137–9.

Salama, H.S., Zaki, F.N. and Abdel-Razek, A.S. (2009) Ecological and biological studies on the red palm weevil *Rhynchophorus ferrugineus* (Olivier). *Archives of Phytopathology and Plant Protection*, **42**, 392–9.

Sarto i Monteys, V. (2013) *Paysandisia archon* (Castniidae): Description, biological cycle, behaviour, host plants, symptoms and damages. *Proceedings of the Palm Pest Mediterranean Conference AFPP*. Nice, France, January, 16–18, 2013: 33–50.

Sarto i Monteys, V. (2002) The discovery, description and taxonomy of *Paysandisia archon* (Burmeister, 1880): A Castniid species recently found in south-western Europe (Castniidae). *Nota Lepidopterologica*, **25**, 3–15.

Sarto i Monteys, V., Aguilar, L., Saiz-Ardanaz, M. *et al.* (2005) Comparative morphology of the egg of the castniid palm borer, *Paysandisia archon* (Burmeister, 1880) (Lepidoptera: Castniidae). *Systematics and Biodiversity*, **3**, 179–201.

Sayed, A.A.A., Temerak, S.A., Gameel, S.M.M. and Moussa, A. (2014) Alternate two different modes of actions of green chemicals to combat *Batrachedra amydraula* Meyrick and *Cadra cautella* Walk on date palm fruit, Egypt. *Journal of Agricultural Science and Technology A*, **4**, 529–34.

Schuiling, M. and van Dinther, J.B.M. (2009) Ecology and control of *Castnia daedalus*: A major pest of oil palm in Brazil. *Journal of Applied Entomology*, **90**, 161–74.

Sharma, S. and Gupta, S.G. (1988) Rhinoceros beetle. *Oryctes rhinoceros* (Coleoptera: Dynastidae) on banana from Nagaland. *Bulletin of Entomology (New Delhi)*, **29**, 228–30.

Smirnoff, W.A. (1957) La cochenille du palmier dattier (*Parlatoria blanchardi* Targ.) en Afrique du Nord: Comportement, importance économique, prédateurs et lutte biologique. *Entomophaga*, **2**, 1–99.

Soltani, R., Chaieb, I. and Ben Hamouda, M.H. (2008) Descriptive study of damage caused by the rhinoceros beetle, *Oryctes agamemnon*, and its influence on date palm oases of Rjim Maâtoug, Tunisia. *Journal of Insect Science*, **8** Article 57.

Streito, J.C., Etienne, J. and Balmès, V. (2007) Aleyrodidae des Antilles et de la Guyane Française (Hemiptera, Sternorrhyncha). *Revue Française d'Entomologie*, **29**, 57–72.

Streito, J.C., Ollivier, J. and Beaudoin-Ollivier, L. (2004) Two new pests of *Cocos nucifera* L. from Comoro Islands: *Aleurotrachelus atratus* Hempel, 1922, and *Paraleyrodes bondari* Peracchi, 1971 (Hemiptera: Aleyrodidae). *Bulletin de la Société Entomologique de France*, **109**, 67–72.

Talhouk, A.S. (1977) Family Tropiduchidae, *Ommatissus binotatus* Fieb. Var. *lybicus* de Berg, in *Diseases, Pests and Weeds in Tropical Crops* (eds J. Kranz, H. Schmutterer and W. Koch), John Wiley & Sons, Chichester, pp. 304–5.

Thomas, R. (2013) L'anatomie des palmiers et les techniques d'endothérapie: Quelles conséquences physiologiques? *AFPP, Colloque Méditerranéen sur les ravageurs des palmiers*, Nice, January 16–18, 2013: 73–88.

Uribarrena, B. S. (2013) Local intervention procedure providing the coordination of support, control and handling activities of the red palm weevil in the municipality of Valencia, Spain. *Proceedings of the Palm Pest Mediterranean Conference, AFPP*. Nice, France, January 16–18, 2013 (in French): 179–96.

Wagner, M., Atuahene, S.K.N. and Cobbinah, J.R. (1991) *Forest Entomology in West Tropical Africa*, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Warner, R. L. (1988) Contributions to the biology and management of the carob moth *Ectomyelois ceratoniae* (Zeller), in Deglet Noor date gardens in the Coachella Valley of California. PhD dissertation, University of California, Riverside.

Waterhouse, D.F. and Norris, K.R. (1987) *Biological Control: Pacific prospects*, Inkata Press, Melbourne, Australia.

Wattanapongsiri, A. (1966) A revision of the genera *Rhynchophorus* and *Dynamis* (Coleoptera: Curculionidae). *Department of Agriculture Science Bulletin (Bangkok)*, **1**, 328.

Willcocks, F.C. (1922) A survey of the more important economic insects and mites of Egypt. *Sultanic Agricultural Society of Cairo: Technical Section Bulletin*, **1**.

Williams, R.N., Fickle, D.S., Kehat, M. *et al.* (1983) *Bibliography of the genus* Carpophilus *Stevens (Coleoptera: Nitidulidae)*, Ohio State University Ohio Research and Development Center: Research Circular 278..

Wong, L., Boesch, R.A., Okada, C.L. and Reimer, N.J. (2006) *Annual Report FY 2006* Hawaii Department of Agriculture http://hawaii.gov/hdoa/meetings_reports/legislative-reports/2007Leg-Reports/Appendix%204%20–%20PI%20Annual%20Rpt.pdf.

Wood, B.J. (1968) *Pest of Oil Palms in Malaysia and their Control*, Incorporated Society of Planters, Kuala Lumpur, Malaysia.

Yaseen, M. (1981) Report on a visit to Guyana for biological control of *Brassolis sophorae* and *Castnia daedalus*. Consultant report, FAO, TCP/GUY/001 (Mi).

Zaid, A., de Wet, P.F., Djerbi, M. and Oihabi, A. (1999) *Date Palm Cultivation*, Chapter XII: Diseases and pests of date palm. FAO Plant Production and Protection Papers, pp. 223–87.