Chapter 5
Dynastid Beetle Pests

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Abstract Two main species of dynastid or rhinoceros beetle (Coleoptera: Scarabaeoidea: Scarabaeidae: Dynastinae: Tribe Oryctini) *Oryctes elegans*, and subspecies of *Oryctes agamemnon*, attack date palms causing significant and documented damage. Adults of *O. elegans* bore into the stalks of inflorescences and fruit bunches to feed, and oviposit in leaf axils where the larvae develop and may invade the trunk. *Oryctes agamemnon* larvae bore into frond bases, the trunk, and respiratory roots where their tunnelling may cause the palm to fall. It is difficult to distinguish the larvae of the two species in regions where both coexist. For control, annual servicing of palms includes cutting off old fronds at their bases using the correct technique which enables removal of larvae and their breeding places, and this may be integrated with light trapping for catching adults. Quarantine measures may hinder the spread of these pests to uninfested areas. In India, adults of a third species, *O. rhinoceros*, have been noted boring into the soft tissue of the growing point, and this species has also been reported from Yemen. Pheromone trapping is available for *O. elegans* but for effectiveness it requires the addition of fresh date palm tissue to

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the traps as a synergist. The entomopathogenic fungus *Metarhizium anisopliae* and the nematode *Rhabditis* sp. may have potential in integrated pest management but their possible natural occurrence in an area should be determined, prior to propagation and release. The pathogenic *Oryctes* Nudivirus, was successful against *Oryctes rhinoceros* in lowering its populations and damage to coconut palms when introduced into areas where this virus did not previously exist, and should be tested against date palm dynastids. *Oryctes agamemnon* and *O. elegans* adults attacking date palms do not appear to bore into the heart or meristem causing V-cuts to unfurling fronds or the death of the palm, in contrast to attacks by *O. rhinoceros* on coconut and young oil palms. Also *O. rhinoceros* larvae are found only in dead decomposing wood or other organic material, whereas larvae of date palm pests *O. elegans* and *O. agamemnon* may tunnel in living tissues.

5.1 Introduction

Dynastid or rhinoceros beetles may cause serious damage to date palms. Adults attack fruit bunches or frond bases. Larvae may tunnel into frond bases, the trunk or the root mass causing the death or collapse of the palm. The main pests are two species of *Oryctes*, namely *Oryctes elegans* (Prell), and subspecies of *Oryctes agamemnon* (Burmeister) (El-Shafie 2012). In Iraq, there is evidence that adults of *Oryctes* spp. act as vectors of the fungal pathogen *Fusarium proliferatum* (Matsushima) Nirenberg ex Gerlach & Nirenberg which causes wilt disease symptoms in date palms (Khudhair et al. 2014b). Adults of the well-known pest of coconut and oil palms *Oryctes rhinoceros* L. have been noted as attacking date palms in India (Butani 1974, 1975) and United Arab Emirates (UAE) (Gassouma 1991) and have also been reported from Yemen (Al-Habshi et al. 2006).

Taxonomic studies, with illustrations and a key to adults of the species *Oryctes* Illiger (Tribe Oryctini) have been provided by Endrödi (1985) and Dechambre and Lachaume (2001). In the order Coleoptera, species of *Oryctes* are members of the superfamily Scarabaeoidea, family Scarabaeidae, subfamily Dynastinae, and tribe Oryctini. In the field the three species mentioned above (Figs. 5.1, 5.2, and 5.3) can

Fig. 5.1 *Oryctes elegans* adult male (Dechambre and Lachaume 2001; with permission from Hillside Books, Canterbury, UK)

Fig. 5.2 *Oryctes rhinoceros*: male (*left* and *middle*), female (*right*) (Dechambre and Lachaume 2001; with permission from Hillside Books, Canterbury, UK)

Fig. 5.3 *Oryctes agamemnon arabicus* adult. Female (*top left*), female head with small tuber-like horn (*top right*), male (*bottom left*), and male head with big horn (*bottom right*) (Photos: Mohammad A. Al-Deeb)

be separated from each other based on leg morphology (Al-Deeb 2012). The apex of the hind tibia has two large fixed teeth in *O. rhinoceros*, while it has three fixed teeth in *O. agamemnon* and *O. elegans*. In turn these two species can be separated based on the presence of a fixed tooth on the underside of the front tibia in *O. elegans* and its absence in *O. agamemnon*. A description and illustrations of these features has been provided for *O. elegans* (Hurpin and Fresneau 1969).

Data on the larvae of *O. elegans* with illustrations were given by Hurpin and Fresneau (1969), and the larva together, with eggs and pupa, are shown in Fig. 5.4. The larva of *O. agamemnon arabicus* and eggs are shown in Fig. 5.5.

Fig. 5.4 *Oryctes elegans*: egg; larva; pupa (*left* to *right*) (Photos: Kazem Mohammadpour)

Fig. 5.5 *Oryctes agamemnon arabicus* larva (*left*), larval head showing big mandibles (*top right*), and eggs in dissected abdomen of female in dorsal view (*bottom right*) (Photos: Mohammad A. Al-Deeb)

However, a full description of the larvae of *O. elegans* and *O. agamemnon* using the method of Ritcher (1966), and a key for differentiating them are not available, causing difficulty in distinguishing larvae of each in regions where the two species coexist i.e. are sympatric. A full description of the larva of *O. rhinoceros* is available (Bedford 1974).

5.2 Distribution

Oryctes elegans is endemic in Iran and Iraq (Buxton 1920; Endrödi 1985; Rochat et al. 2004; Payandeh and Dehghan 2010); Northern Pakistan (Ratcliffe and Ahmed 2010); Saudi Arabia (Al-Deghairi 2007), UAE, Bahrain and Qatar (El-Haidari and Al-Hafidh 1986; Gassouma 1991). In Iran, locations where *O. elegans* has been reported (Gharib 1970; Endrödi and Petrovitz 1974; Mohammadpour unpublished) are shown in Fig. 5.6. The distribution of *Oryctes* species in Iraq is shown in Fig. 5.7.

Various subspecies of *O. agamemnon* are reported as attacking the date palm. In the Arabian Peninsula, *O. agamemnon arabicus* Fairmaire is endemic in Saudi Arabia (Endrödi 1985), Oman (Al-Sayed and Al-Tamiemi 1999). In the eastern part of UAE in the Al-Ain Region, it is the only species of *Oryctes* found (Gassouma 1991; Al-Deeb et al. 2012a). In Iraq, it coexists with *O. elegans* (Buxton 1920; Khalaf et al. 2013a, b) (Fig. 5.7). Subsequent research has clarified that the material referred to as *O. elegans* in Khalaf et al. (2010, 2011, 2012) is now identified as *O. agamemnon arabicus* (Khalaf, pers. comm. 2015), and the adjustment applies throughout this chapter.

In Tunisia, *O. agamemnon arabicus* was accidentally introduced into the oasis of Mrah Lahouar in the Djerid zone (Fig. 5.8) from the UAE in the late 1970s. The pest

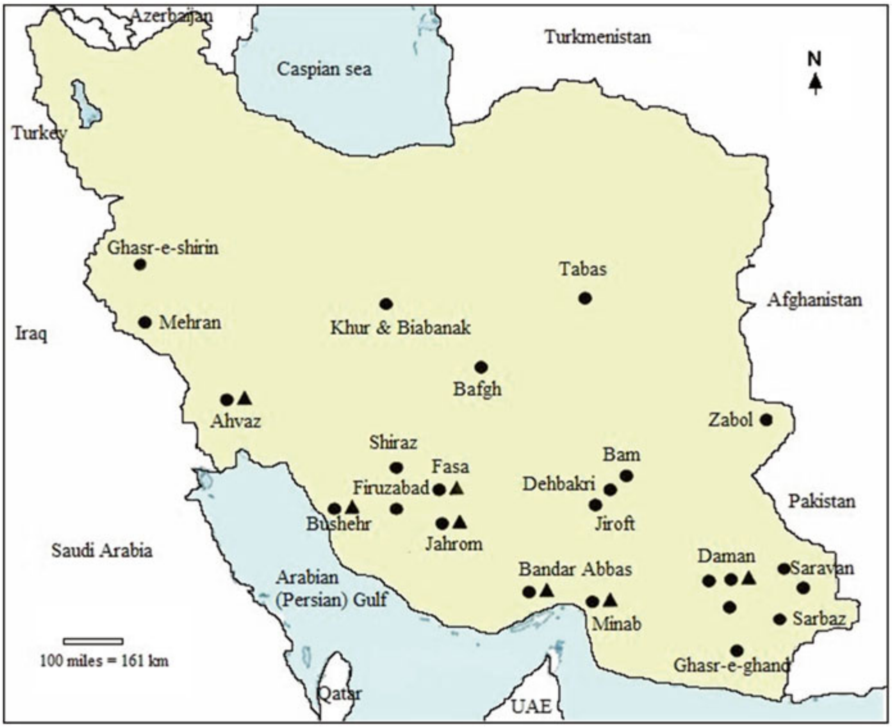

Fig. 5.6 Distribution of *Oryctes elegans* (●) and *Oryctes agamemnon* (▲) in Iran

Fig. 5.7 Distribution of *Oryctes* species in Iraq (indicated by *black spots*)

was concealed in offshoots, which was the part of the date palm involved in varietal exchange of material between the two countries (Soltani 2009). Lack of knowledge of this new species both by farmers and plant protection services, and the confusion of its larval stages, with larvae of other species of scarab beetles as no key was available, permitted its establishment and proliferation. The development of date palm cultivation in the oases of Djerid, with many immature young palms and offshoots also facilitated its establishment (Soltani 2009, 2010). The first recognition of its presence in Tunisia, and its potential as a threat to date palms, was in 1995 after the sudden falling over of productive trees in Mrah Lahouar (Khoualdia et al. 1997; Soltani et al. 2008a, b; Soltani 2004, 2009). As monoculture of the date palm is common in the oases, with which the beetle is closely linked, this association facilitates the beetle's survival and proliferation (Soltani 2009).

During the first years after its introduction, the infestation was limited to the northern edge of Chott El Djerid particularly in Mrah Lahouar (387 ha) and Dhraa El Janoubi (200 ha) oases. In 1987, with the emergence of date palm cultivation in the zone and the lack of offshoots, farmers used plants originating from these infested areas for new plantations in Ibn Chabbat oasis, located to the north of Mrah Lahouar and in the southern edge of Chott El Gharsa. This allowed the insect to spread and develop there, as the importance of sanitary and quarantine measures had been overlooked (Soltani 2010).

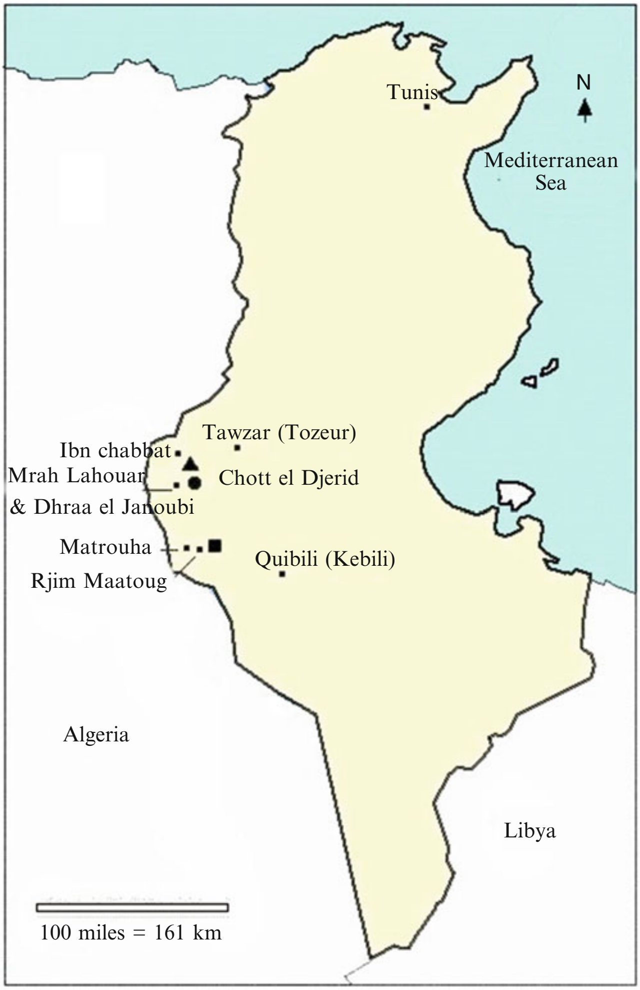

Fig. 5.8 Geographical distribution of *Oryctes agamemnon arabicus* in Southwest Tunisia. The main foci of infestation are the oases of Mrah Lahouar (●), Ibn Chabbat (▲) and Rjim Maatoug (■)

At the beginning of the 1990s, in offshoots originating from Ibn Chabbat, the pest reached the oases of Rjim Maatoug on the southern edge of Chott El Djerid and presently covers the entire border zone except eastern Matrouha oases (Soltani 2009, 2010). As the habits of this pest were not fully understood at that time, *O. agamemnon arabicus* was able to spread mainly through offshoots, as well as by flying adult beetles (Soltani 2010).

Analysis of DNA markers in *O. agamemnon arabicus* populations in Tunisia showed no significant differences in relation to location or host plant varieties, suggesting a limited number of genotypes would have been present at the start of the invasion. Substantial gene flow was revealed among populations, confirming the belief that much of the pest's spread is the result of transfer of planting material for propagation (Abdallah et al. 2012, 2013).

Oryctes agamemnon matthiesseni Reitter is reported from Southern Iran (Endrödi and Petrovitz 1974; Endrödi 1985; Mohammadpour unpublished) and Iraq (Khalaf unpublished). However, there is no information about its biology from these countries. It also occurs in Southern Afghanistan and North West Pakistan (Endrödi 1985). Another form of *O. agamemnon* (subspecies unknown) has been reported from Iraq (Khalaf unpublished).

5.3 Biology

5.3.1 Oryctes elegans

The adult bores a tunnel into the living parts of the palm such as the midrib (rachis) and leaf bases (petioles) of fronds, causing them to break off during wind, and into the stems of inflorescences and stalks of fruit bunches (Buxton 1920; Hussain 1963; Mohammadpour 2002).

Males produce a semiochemical, a male aggregation pheromone which attracts both sexes. It is 4-methyloctanoic acid (Fig. 5.9a), and its attractiveness is strongly enhanced by the presence of odor from fresh date palm tissue (Rochat et al. 2004). The laboratory protocols for the synthesis of these pheromones are reported (Ragoussis et al. 2007; Tabrizian et al. 2009; Sultanov et al. 2013).

The larvae are found in the axils of fronds and at the junction of dead and living tissue in crowns (Hussain 1963; Rochat et al. 2004) and may tunnel toward the growing point (Buxton 1920). Groups of larvae may tunnel in moist tissues inside dying or newly dead palm trunks forming a large hole (Gharib 1970), which may topple the palm (Hussain 1963).

In laboratory studies in which the larvae were reared on a food mixture of decayed wood or compost and cow dung at 28–30 °C, the average duration of development was: egg, 10 days; larva, 91 days (three instars); prepupa, 7 days and pupa, 31 days (Hurpin and Fresneau 1969). Larvae were also able to feed on living plant

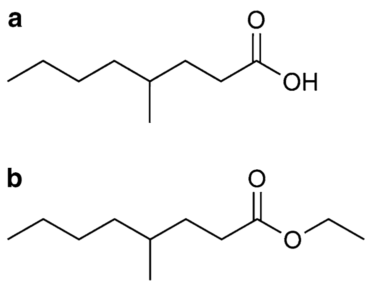

Fig. 5.9 4-methyloctanoic acid (4-MO) pheromone of *Oryctes elegans* (**a**), ethyl-4 methyloctanoate (E4-MO) (**b**) (Bedford 2013; with permission from Annual Review of Entomology Volume 58. © 2013 by Annual Reviews)

material e.g. apple, but development time was longer and the resulting adults were smaller sized (Hurpin 1970). In another laboratory study, at 27 °C, somewhat longer development times were observed, with mortalities of 5, 23 and 3 % recorded for the egg, larval and pupal stages, respectively (Payandeh and Dehghan 2010).

Adult life span was about 4 months, and egg-laying began 2–3 weeks after individuals were brought together as couples, with an average of 60 eggs laid by a single female per life cycle (Hurpin and Fresneau 1969).

5.3.2 *Oryctes agamemnon arabicus*

In Tunisia, no attacks by adults on the inflorescence and green fronds were registered and little sign of feeding was found under laboratory rearing conditions (Soltani et al. 2008a, b; Soltani 2009, 2010). However, in Saudi Arabia, adults attacked fruit bunch stalks and the rachis of fronds (Al-Sayed and Al-Tamiemi 1999).

In Tunisia, the larvae are found feeding in the dead respiratory roots around the base of date palm trunks (Soltani et al. 2008b), but no attacks on the inflorescences and green fronds by larvae were reported (Soltani et al. 2008a, b; Soltani 2009, 2010). In Tunisia, Saudi Arabia and Oman, it breeds in dead dry bark, dry frond petioles, fiber masses in axils, and offshots (Khoualdia et al. 1997; Al-Sayed and Al-Tamiemi 1999; Soltani et al. 2008a, b), while in Iraq they occur in debris in the bases of lower fronds and in tunnels in dead frond bases, where there may be up to 12–13 larvae per tree (Khalaf et al. 2010).

The life cycle of *O. agamemnon arabicus* in Iraq is illustrated in Fig. 5.10. Here at 25 °C, the average durations of the stages are; eggs: 13 days; total larval stages: 196 days and pupae 29 days (Khalaf et al. 2014). In Tunisia, laboratory rearing at 23 °C resulted in average durations of egg, first-, second-, third-instar larva, total larval stages, pupa, and total immature stages of 14, 35, 51, 141, 227, 24 and 266 days, respectively; at 27 °C, 12, 35, 44, 118, 197, 22 and 231 days, respectively; and at 30 °C, 9.5, 36, 45, 142, 223, 21 and 254 days, respectively (Soltani et al. 2008a; Soltani 2012).

Males of *O. agamemnon arabicus* emitted a blend of four compounds: (1) ethyl 4-methyloctanoate (Fig. 5.9b), (2) 4-methyloctanoic acid (Fig. 5.9(a), (3) 4-methyloctanyl acetate, and (4) 4-methyloctanol. Laboratory observations using an olfactometer showed that compounds 1 and 3 attracted both sexes but females were more attracted by compound 1, virgin females by compound 2, and males by compound 3. Field studies revealed that a mixture of compounds 1 and 2 with date palm core odor was the most effective in attracting both sexes, with females pre-dominating (Saïd et al. 2015). Ethyl 4-methyloctanoate (E4-MO, Fig. 5.9b) is the pheromone of the coconut and oil palm pests *O. rhinoceros* and *O. monoceros* (Olivier), and is commercially available and widely used in trapping and IPM (Integrated Pest Management) programs directed against them (Bedford 2013).

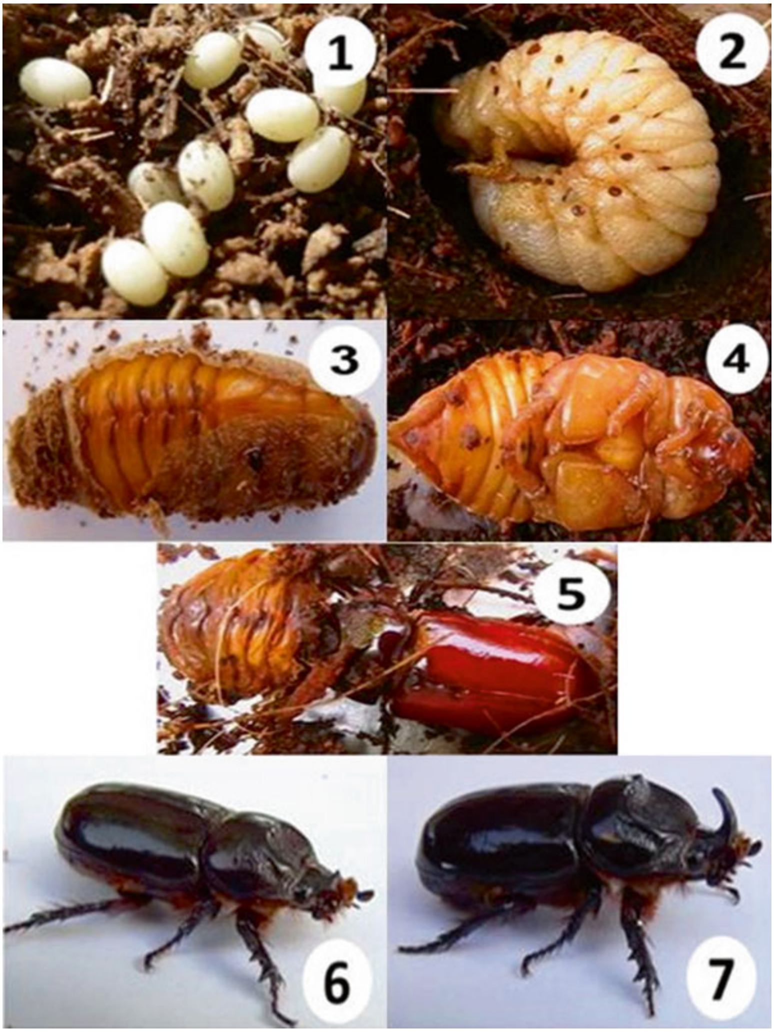

Fig. 5.10 Life cycle of Arabian rhinoceros beetle, *Oryctes agamemnon arabicus*; *1*: eggs, *2*: larva, *3–4*: pupae, *5*: emerging adult, *6*: adult female, *7*: adult male (Photos: Mohammed Z. Khalaf)

5.4 Seasonal Incidence

In Iraq, adults of *O. elegans* are attracted to light from April to September, but especially during April and May (Buxton 1920; Hussain 1963). Light trapping in three orchards showed that flying activity of *O. agamemnon arabicus* started during April (Khalaf et al. 2013b) and peaked during July (82 individuals caught per trap and month). Population densities as measured by light trap captures then decreased dramatically in October (Khalaf et al. 2011, 2012).

In Iran, *O. elegans* is univoltine, having one generation per year. Here this species and *O. agamemnon matthiesseni* are sympatric; *O . elegans* adults are nocturnal and attracted towards light. Light trapping revealed that the adults emerged from March and April (spring) to late September, and were most abundant in June and July (summer) (Fasihi 2011), and were not found in late autumn. The female of *O. elegans* makes a small cavity and lays eggs individually in palm fiber in the axils of fronds and inflorescences, or living tissue where petioles join the trunk, or in damp dead half-rotten trunks. The larvae overwinter in their feeding sites in the palm, and each larva weaves a cocoon of fiber (6 × 2 cm). The pupal period in March and early April lasts for 3–4 weeks (Gharib 1970). Pheromone trap catches also showed the population of *O. elegans* reached to a maximum during summer season (mid-July to mid-August) (Rochat et al. 2004).

In Oman, light trapping showed that *O. agamemnon* appeared from mid-April to early May, with maximum catches recorded from early June to early July, the warmest and driest season, and then catches fall and cease from late August to early October (Al-Sayed and Al-Tamiemi 1999).

In the Al-Ain region of the UAE, *O. agamemnon arabicus* adults were attracted to street lights and found crawling on the grass of gardens and parks under lights after sunset (Al-Deeb unpublished). In a 2-year study using light-trapping in UAE, Al-Deeb et al. (2012a) found that *O. agamemnon arabicus* males and females appeared in the field around April and May and the population continued to build until maximum numbers were reached in mid-June. However, at the end of July and early August, the numbers declined sharply and no adults were found after the end of September. *Oryctes agamemnon arabicus* has one generation per year (Al-Deeb 2012; Al-Deeb et al. 2012a) unlike the red palm weevil *Rhynchophorus ferrugineus* (Olivier), which has several overlapping generations per year. In Saudi Arabia, Al-Deghairi (2007) reported that the highest activity of *O. elegans* occurred from April to July and the peak monthly activity was observed during June, and no beetle activity during January and February. In date orchards in Riyadh Province (Saudi Arabia) 58 % of scarabs light-trapped were *O. elegans* and reached highest abundance in August (Al Dhafer and Alayeid 2014).

In Tunisia, light trapping showed a single peak – indicating that *O. agamemnon arabicus* has one generation per year (univoltine). The adults emerged from the date palm breeding sites in late May/mid-June and flights continued to mid-October/early November, with the peak flight activity between mid-July and mid-August, the warmest part of the year. Females were the most numerous in the catches overall. The trap captures decreased afterwards, becoming rare in late September/early October, and then ceasing from mid-October/early November until June of the following year (Soltani 2009; Ehsine et al. 2014). Nocturnal activity started about 40 min after sundown and continued until 1 h before sunrise. Most beetles were caught in the first 2 h of flight activity, females dominating in the first hour, and males the second hour (Ehsine et al. 2014). Adults spend most of their time within the green parts of the palm, from where they emerge to seek breeding sites and disperse. In oases, both adult and immature stages also occur in compost heaps (Soltani 2009).

In Yemen, when light traps were used to monitor the *O. rhinoceros* population, it appeared in March, increased in April, peaked in June, decreased to low numbers by September, with very low numbers caught from October to February. The single peak of adult captures (sex ratio male: female 1:1.3) indicated there was one generation per year (Al-Habshi et al. 2006). In coconut-growing areas of the South Pacific, it is considered that *O. rhinoceros* is only occasionally attracted by light (Gressitt 1953).

5.5 Damage and Losses

5.5.1 Oryctes elegans

When the adult bores into the stalk of the fruit bunch (Fig. 5.11), it makes a tunnel on one side of the stalk and the dates on that side of the bunch remain undersized, while on the other side of the bunch, fruit is of normal size. A heavily attacked stalk can cause all the dates on a bunch to shrivel, or the stalk breaks and the whole bunch falls. In Iraq, the stalks were attacked straight after fruit set in April.

In the early 1960s in Iraq the infestation of bunches was less than 2 %, so it was not regarded as a serious pest at that time (Hussain 1963) whereas heavy damage to bunches was reported in 1918 (Buxton 1920). Similar damage to fruit stalks occurs in Saudi Arabia (Al-Deghairi 2007).

Fig. 5.11 Damage from *Oryctes elegans* adults on base of fruit bunch (Photo: Kazem Mohammadpour)

In Iran, *O. elegans* damage is more significant in young date palms (aged around 10–20 years) than in old plantations, and was more severe where planting distance between palms was less than 5 m (Latifian et al. 2012). The long feeding tunnels in the stalks of inflorescences (especially during the pollination period) and bunches, weaken them and cause them to break. They also feed on other living parts of the palm such as the base (petiole) and midrib (rachis) of fronds, causing them to break off during wind. In some areas the damage caused by *O. elegans* represents 5–20 % of the total harvest (Gharib 1970).

The larval feeding sites of *O. elegans* may also serve as the egg deposition sites by *R. ferrugineus*, however only a weak correlation between the abundance of both species was observed in 16 date palm orchards of Saudi Arabia monitored from June 2007 to May 2008 (Al-Ayedh and Al Dhafer 2015). In areas where both *O. elegans* and *O. agamemnon* (regardless of subspecies) coexist e.g. Iraq, at times it is not only difficult to attribute damage to the larval or the adult stages, but also to ascribe it to one or other of the species. Moreover, the morphological differentiation of the larvae of both species is also difficult as no key is available. In Iran, *Oryctes* larvae live in the crown and trunk, feeding on petioles and rachis of fronds, and this injury may allow entry of fungi and secondary insect pests. When tunnelling in the trunk they may reach the central bud and kill the palm. They also attack the base of the palms to feed on sap.

5.5.2 *Oryctes agamemnon arabicus*

In Oman, adults were reported as attacking fruit bunch stalks and the rachis of fronds and, in Saudi Arabia, fruit stalks and the rachis and bases of fronds (Al-Sayed and Al-Tamiemi 1999).

In Iraq, all ages of date palm are infested by *O. agamemnon arabicus* larvae, but the trees aged over 30 years scored the highest level of infestation in comparison with middle age and young trees in all experimental date palm orchards, in different provinces. However, infestation level varied among provinces as Wasit (Al-Numaniyah) (Fig. 5.7) had the highest infestation level leading to breakdown of trunks, especially during wind storms (Khalaf et al. 2013a, b, 2014; Khalaf and Al-Taweel 2014).

In situations where *O. agamemnon arabicus* is clearly involved, it can infest most parts of the tree. In the young date palm it infests aerial roots at the base of the trunk, due to the presence of frond bases that are close to the soil surface, leading to yellowing and drying of the crown (Khalaf et al. 2014; Khalaf and Al-Taweel 2014). However, this type of infestation does not occur in middle aged and old trees. The lower part of the trunk (about 1 m above the soil surface) is infested in palms of all ages. The insect infests the middle of the trunk in the middle-age and old palms (Khalaf et al. 2013a, b, 2014). No infestation has been recorded in the upper stem part, close to the crown region in the case of young trees, but severe infestation was recorded here on middle aged and old date palm trees. The upper crown, stalk and fronds have not been infested by this species on palms of all ages. The date palm parts that are attacked, in relation to the age of the palm, are summarized in Table 5.1.

In Tunisia, outbreaks of *O. agamemnon arabicus* develop inside plantations from those that are newly planted up to about 35 years old, with regular spacing between trees of 9×9 m. This pest does not occur in plantations cultivated in the traditional system where palms are irregularly spaced and intercropped with other crops (Soltani 2009). The feeding activity of larvae causes damage to offshoots, and to aerial roots and dry petioles of young palms beyond the offshoot stage (Soltani 2009, 2010).

In offshoots eggs are laid in the mass of fibers in the axils of fronds, and here young larvae feed unnoticed until the third instar larvae bore into the heart. Most often, the attacked palms are killed in the first year after planting, and losses can reach up to 100 % (Fig. 5.12).

In palms that are past the offshoot stage, adults bore holes into the aerial root mass to oviposit, where damage is mostly due to the subsequent tunnelling by feeding larvae which produces cavities. These cavities provide access to subsequent generations of adults for entry and oviposition. Groups of adults, mainly ovipositing females, can coexist in these cavities, along with larvae, and the continuous feeding and tunnelling activity by larvae (Fig. 5.13) can lead to collapse of the palm after a few years (Fig. 5.14) (Ehsine et al. 2009, Soltani 2009).

When eggs are laid in the mass of fiber in frond petioles, the early larval stages feed here, and the third instar larvae tunnel into the dry petioles, feeding on the soft wood and pupate at the end of the tunnels (Fig. 5.15). Any attack to the trunk itself is less important, as only external dead wood is affected (Soltani et al. 2008b; Soltani 2009) - it is unlikely to cause the palm to fall, but provides an ongoing breeding site (Ehsine et al. 2009) (Fig. 5.16).

Table 5.1 Parts of the date palm infested by *Oryctes agamemnon arabicus* in Iraq

Date palm tree part	Young trees (4–10 years)	Middle age trees (10–20 years)	Old trees (over 30 years)
Stem base close to the root i.e. aerial roots at base of trunk	+	−	−
Lower stem or trunk, about 1 m above soil	+	+	+
Middle of the stem (Trunk)	−	+	+
Upper stem (when the old fronds are present)	−	+	+
Lower crown	−	+	+
Upper crown	−	−	−
Fronds	−	−	−
Stalks (frond bases i.e. petioles)	−	−	−

(−) No infestation, (+) Infestation

Fig. 5.12 Damage caused to offshoot by a third instar *Oryctes agamemnon arabicus* larva (*left*), and offshoot death after larval attack (*right*) (Photos: Rasmi Soltani)

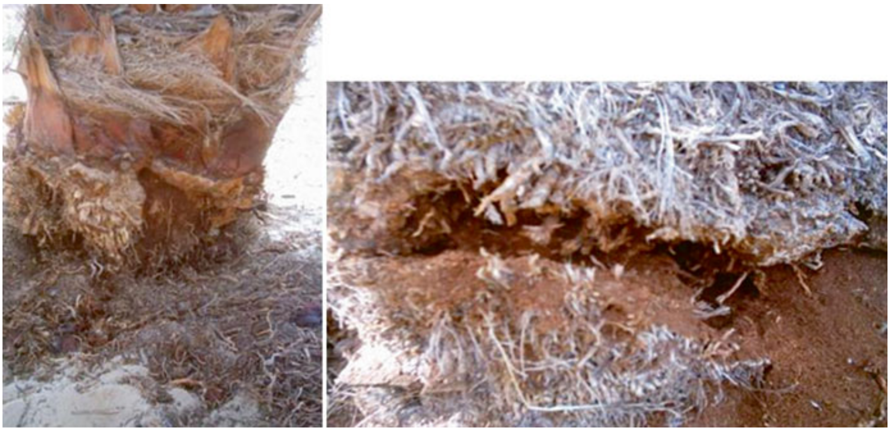

Fig. 5.13 Aerial roots attacked (*left*) and damage due to *Oryctes agamemnon arabicus* larvae (*right*) (Photos: Rasmi Soltani)

Fig. 5.14 Date palm highly liable to collapse following severe attack by *Oryctes agamemnon arabicus* larvae at the collar region (Photo: Rasmi Soltani)

Fig. 5.15 Damage due to *Oryctes agamemnon arabicus* larvae and adults on dry petioles (Photo: Rasmi Soltani)

Fig. 5.16 Attack by larvae of *Oryctes agamemnon arabicus* on fiber masses in axils and on bark of the trunk (Photo: Rasmi Soltani)

5.6 Management

5.6.1 Physical Control

This approach is very important in all date growing regions. Old and almost dried frond bases are pruned and removed from the palm trunk in an annual servicing by cutting them at a downward sloping 45° angle, the cut ends allowing the farmer to climb the tree. Layers of fiber between fronds, frond thorns, and old dried bunch stalks are also removed (Figs. 5.17, 5.18, and 5.19). This eliminates sites for beetles to hide and oviposit, and for larvae to develop, and allows hand picking of any larvae found (Figs. 5.20 and 5.21). The number of larvae found later on serviced i.e. pruned palms was significantly less than the number present on unpruned control palms (Khalaf and Al-Abid 2013). Pruning also reduces humidity around the trunk and frond bases so discouraging oviposition. Disinfecting any wounds on trees with approved pesticides may deter adults (Mohammadpour 2002). Plantation sanitation is recommended to remove potential breeding sites such as dead palms or rotting trunks along with clippings and fronds after pruning, and to try to reduce excess humidity due to irrigation in palm groves (Gharib 1970).

Fig. 5.17 A climbing harness being used in annual servicing of a middle-age date palm (Photo: Mohammed Z. Khalaf)

Fig. 5.18 Young date palm showing a stage in annual servicing (Photo: Mohammed Z. Khalaf)

Fig. 5.19 Previously pruned trunk showing frond bases cut off at the recommended 45° angle (Photo: Mohammed Z. Khalaf)

5.6.2 Trapping and Monitoring

5.6.2.1 Light Trapping

This technique has been used for monitoring populations of *O. elegans* and *O. agamemnon* in Iran (Fasihi 2011), *O. agamemnon arabicus* in Iraq (Khalaf et al. 2010, 2011, 2012), UAE (Al-Deeb et al. 2012a) and Oman (Al-Sayed and Al-Tamiemi 1999), *O. elegans* in Saudi Arabia (Al-Deghairi 2007) and *O. rhinoceros* in Yemen (Al-Habshi et al. 2006). Where electricity supply is not available light traps with solar panels can be used (Fig. 5.22). In UAE and Saudi Arabia, light traps emitting white light from a mercury vapour bulb may be used for mass trapping (Al-Deghairi 2007; Al-Deeb et al. 2012a).

In Iraq, the light traps, in conjunction with hand removal of larvae, have proven very efficient as a control method against *Oryctes attacks*, reducing beetle numbers by 90 % (Khalaf et al. 2011). In fields where hand picking of immature stages from old frond bases is neglected, the subsequent catch of adults by light traps was found to be high.

Moonlight affected the light trap catches of adult beetles. During the nights of bright moon light, adult captures (considered to be *O. agamemnon arabicus)* decreased compared to nights with less moon light (Khalaf et al. 2011). A similar trend was also suggested by the data collected using coconut wood traps (i.e. non-light traps) for monitoring *O. rhinoceros* in New Britain (Bedford 1975).

Fig. 5.20 Larvae of *Oryctes agamemnon* detected in their tunnels in frond bases during important annual servicing in Iraq. *Top right* picture shows black tunnels (Photos: Mohammed Z. Khalaf)

Fig. 5.21 *Oryctes* spp. larvae collected during annual servicing of date palms in Iraq (Photo: Mohammed Z. Khalaf)

Fig. 5.22 Solar light trap (Magna Trap with lamp of 320–420 nm wavelength, Russell IPM Limited, UK) used for monitoring and controlling *Oryctes* spp. in date palm orchards in Iraq (Photo: Mohammed Z. Khalaf)

5.6.2.2 Pheromone Trapping

In Iran, monitoring of population fluctuations of *O. elegans* was conducted for 25 weeks in the Saravan region between April and September, 2002. Ten traps baited with a piece of date palm core and the male aggregation pheromone 4-methyloctanoic acid were placed about 5 m above the ground on trunks of date palms in groves. The traps consisted of 24 l plastic buckets with lids perforated by eight radial 8 × 5 cm openings (Fig. 5.23).

Weekly captures of *O. elegans* between April and September increased gradually from mid-April until the beginning of June (5.3 ± 1.4 beetles per trap), reaching a peak in mid-July to early August (11.5 ± 1.9 beetles per trap), then the catch fell (Fig. 5.24).

Considering the mean captures per trap calculated on monthly basis, the population reached a maximum in summer (mid-July to mid-August: 5.9 ± 0.8 beetles). Both sexes seemed to emerge simultaneously in spring and were reported until the temperature dropped in late autumn. The sex ratio of catches fluctuated through the trial, being approximately balanced in spring and then showing an excess of females through summer, especially in August. The female excess recorded in summer may reflect a shorter life span of the males or a greater mobility of females (Rochat et al. 2004). Furthermore, a trial with traps using 4-methyloctanoic acid and the odor from fresh date palm tissue as synergist, caught in Saravan more than 4000 *O. elegans* over the two trapping seasons during which the synthetic pheromone was evaluated. The captures averaged 6.3 beetles per trap and week (Rochat et al. 2004).

Fig. 5.23 Plastic bucket pheromone trap for trapping *Oryctes elegans* (Photo: Kazem Mohammadpour)

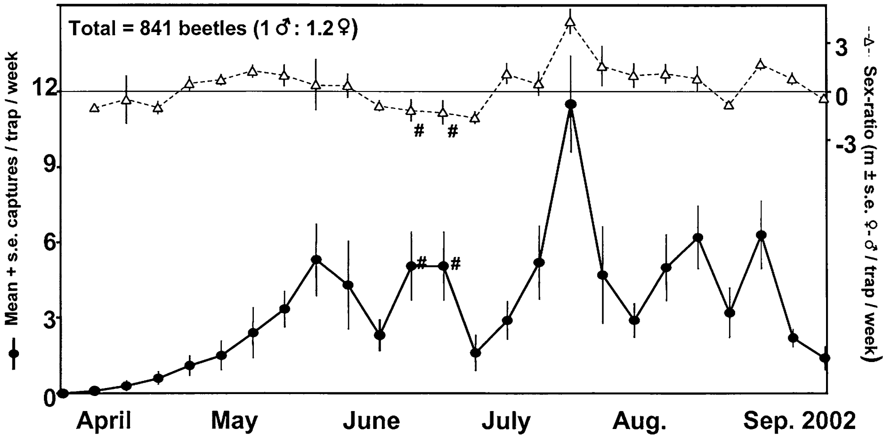

Fig. 5.24 Weekly captures of *Oryctes elegans* per trap (*bottom, left* scale) with corresponding sex-ratios (*top, right* scale) from ten traps baited with a piece of date palm core and 4-methyloctanoic acid, the major component of the male aggregation pheromone, emitted at a rate of 2.2 ± 0.1 mg/day (mean ± SE) for 25 weeks between April and September 2002 in Eastern Iran (Rochat et al. 2004)

Monitoring by traps could be integrated with insecticide application at the time of leaf-pruning around fruit bunches, and could reduce the beetle population and hence the need for insecticide use.

Experiments on the possibility of co-mass trapping of red palm weevil, *R. ferrugineus* and *O. elegans*, using pheromone traps, were carried out in infested date palm groves of the Saravan Region in the Sistan and Baluchistan Province of Iran, during the years 2004–2005. Results showed that the traps baited with separate dispensers of aggregation pheromones of the two insects, when compared with traps that were baited with pheromone mix (50:50) in one dispenser, attracted significantly more *O. elegans*. But all forms of the baits were equally attractive for *R. ferrugineus*. Also in this trial there was no significant difference in the number of *O. elegans* caught by traps placed at different heights i.e. at ground level, or 1.5 or 4 m above, but the traps placed on the ground attracted significantly more *R. ferrugineus* weevils in comparison with traps placed about 1.5 and 4 m above ground. The placement of traps on the ground is hence convenient for catching both species (Mohammadpour and Avand-Faghih 2008). However, placing traps at a higher level (4 m) gave a higher catch for *O. elegans* and, depending on the main target, the technique has to be adapted consequently (Rochat et al. 2004). A similar benefit, i.e. improved catch by elevating the trap, has been noted in the pheromone trapping of *O. rhinoceros* in young oil palm plantations (Bedford 2014, Oehlschlager 2007). The effect of date palm core tissue ageing on the catch of *O. elegans* and *R. ferrugineus* was similar. Captures in traps where replacement of date palm core tissue was done every week, were significantly greater than in traps where replacement of date palm core was done every 2–3 weeks. Increasing age of the date palm core, hence, decreased captures in traps. These results indicated that pheromone traps with separate dispensers of pheromone of *R. ferrugineus* and *O. elegans*, and placed on the ground, can be used for co-mass trapping of these beetles (Mohammadpour and Avand-Faghih 2008). Pheromone traps may also be used against *O. elegans* in Iraq.

To date, neither *O. agamemnon matthiesseni* in Iran nor *O. agamemnon arabicus* in Iraq were reported to be attracted to traps using the *O. elegans* pheromone (Khalaf and Mohammadpour unpublished).

5.6.3 Host Plant Resistance

Different varieties of date palm have varying susceptibility to *Oryctes* attack. In Iran, *O. elegans* damage is more prominent in young date palms (10–20 years) and on short varieties (Mozafati) than in old plantations and tall varieties (i.e. Halili, Krout and Mordarsang) (Gharib 1970). No other plant species are reported as hosts (Mohammadpour 2002).

In Iraq the date varieties Brem and Ustaomran (Umrani) were the most susceptible to attack and infestation by *O. agamemnon arabicus*, and 10 and 9 larvae per tree, respectively, were found in the parts exposed during the annual frond pruning of palms (Khalaf et al. 2011, 2014). Date palm varieties show much difference in their morphological characters e.g. length and orientation of leaves, type of growth and shape of frond etc. In Iraq, a study on the characteristics of the dried base of fronds for different commercial date palm varieties in relation to borer infestation showed that varieties having fragile textured fronds are preferred by *Oryctes*, compared to the varieties with solid and hard textured fronds (Khalaf et al. 2010).

5.6.4 Quarantine Measures

Females of *Oryctes* spp. are attracted to the odors of animal manure or organic compost for oviposition (Ehsine et al. 2009). In the UAE organic fertilizer in bags or loose piles on the farm can serve as good breeding sites. They were found to chew holes in the fertilizer bags to enter and lay eggs. Therefore, proper storage and handling of the organic fertilizer on the date palm farm is very important to reduce infestation. In addition, importing organic fertilizer from countries infested with *Oryctes* beetles can serve as a new source of infestation. Thus, it is not recommended to bring in organic fertilizers from infested farms or countries. In this regard, internal and national quarantine procedures are a legislative method to prevent the spread of *Oryctes* infestation by helping in examination, detention, treatment or disposal of infested organic fertilizers.

In Tunisia, after defining infested areas, quarantine protocols were applied by plant protection services and law enforcement authorities at checkpoints to prevent the spread of infested offshoots (Soltani 2010).

5.6.5 Biological Control

5.6.5.1 Entomopathogenic Fungus

In Iran, laboratory studies using *Metarhizium anisopliae* (Metchnikoff) Sorokin showed that it killed *O. elegans* adults 6–11 days post-infection (LT50 values). Additionally, the adults fed less and females laid fewer eggs compared to untreated insects (Latifian and Rad 2012). It is the second most frequently found entomopathogenic fungus in Iraq, occurring in 18 % of soil samples collected from date and date/citrus orchard sites (Khudhair et al. 2014a). The fungus infects *Oryctes* under laboratory conditions (Fig. 5.25).

Spraying of spore suspensions against larvae, or light traps allowing automatic infection by spores followed by release of the contaminated adults, may have potential for incorporating the fungus in future IPM programs against *Oryctes* spp. in the date palm environment.

5.6.5.2 Nematodes

In the UAE infective juveniles of the entomopathogenic nematode *Steinernema riobrave* (Cabanillas, Poinar and Raulston) at various concentrations caused a range of 44–100 % mortality in third instar larvae of *O. agamemnon* under laboratory conditions, and 33–78 % mortality when applied to soil in a fig orchard (Abbas and Mahmoud 2009).

Rhabditis sp. has been isolated in Southern Iraq from *Oryctes* larvae which had developed an abnormal brown color. It is being propagated and investigated for its possible potential in pest control (Khalaf unpublished). *Rhabditis* spp. and *Heterorhabditis* spp. Poinar in Iran (Mohammadpour unpublished) are potential candidates as biological control agents. However, there are no data on their natural incidence in the field.

Fig. 5.25 Adult of *Oryctes* infected by *Metarhizium anisopliae* fungus under laboratory conditions (Photo: Mohammed Z. Khalaf)

5.6.5.3 *Oryctes* Nudivirus

This non-endemic virus was introduced into Oman and significantly lowered the damage caused by *O. rhinoceros* to fronds of coconut palms (Kinawy 2004; Bedford 2013). It is not known if *O. elegans* or *O. agamemnon* are susceptible to this pathogen, but its introduction into Oman means it is now present in the Arabian Peninsula, and free to disseminate.

5.6.5.4 Mites

In the UAE, *O. elegans* adults often carry a large load of the phoretic mites *Sancassania* sp. and *Hypoaspis rhinocerotis* Oudemans on their body and under the elytra (Fig. 5.26) (Al-Deeb and Enan 2010; Al-Deeb et al. 2012b). However, it has

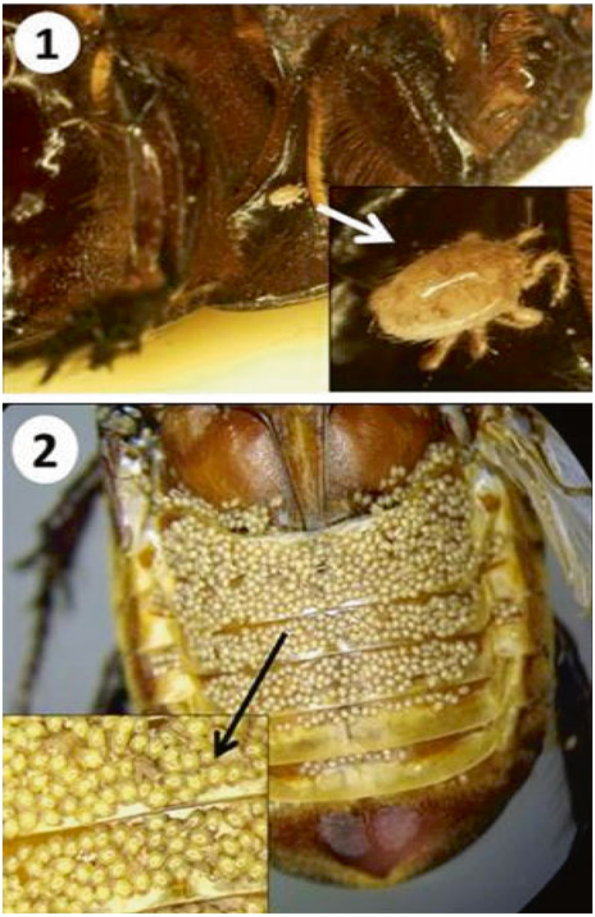

Fig. 5.26 Mites on *Oryctes agamemnon* adult in UAE; (*1*) *Hypoaspis* sp. Adult, (*2*) *Sancassania* sp. deutonymphs on abdominal tergites (Photos: Mohammad A. Al-Deeb)

not yet been established if the mites have a harmful effect on the pest, or are only phoretic. The same holds for *Hypoaspis* sp. in Iraq (Figs. 5.27 and 5.28).

5.6.5.5 Vertebrates

In Iran a species of squirrel, *Funambulus palmarum* L. inhabits the palm groves of Baluchistan Region (its local name is Herdak) and feeds on larvae of *O. elegans.* The average body length is 142 mm, general body color is gray with three strips of

Fig. 5.27 *Hypoaspis* sp. mite (Photo: Mohammed Z. Khalaf)

Fig. 5.28 *Hypoaspis* mites on adult *Oryctes* (to *left* of base of front legs) (Photo: Mohammed Z. Khalaf)

bright yellow color on the back, while the abdomen is yellowish to white (Gharib 1970). However, its effect on the pest population is unknown.

5.6.6 Chemical Control

In Iran, as the adult beetles were usually active in the inflorescence of palm trees, chemical control of dynastid pests was difficult and expensive. In areas where control measures consisted of insecticides against the lesser date moth, *Batrachedra amydraula* Meyrick and the dubas bug, *Ommatissus lybicus* De Bergevin, Asche & Wilson, adult beetles of *O. elegans* that were active and flying in this season, may also be eliminated.

Placing a bran bait with insecticide in the crowns was recommended in the past (Gharib 1970). In Tunisia, chemical control was difficult due to the concealed behavior of the pest, the cost and high quantities of pesticide that would be needed, and the risk of pollution. However, treatment by dipping of offshoots in insecticide solution for 5 min is recommended to kill larvae, prior to the transfer of the offshoots to new areas (Soltani 2010). In Iraq, a trial comparing three insecticides and a control showed spraying was not effective against *Oryctes* larvae in their concealed habitat (ICARDA 2011). In the UAE, chemical control was not recommended as a major control method however, the use of chemical control can be applicable in certain situations: (1) soil insecticides can be used on infested farms where light traps are not available, (2) animal manure or organic compost could be treated with soil insecticides as a pre- or post-application treatment, and (3) insecticides can be applied to treat the root systems of infested trees.

5.6.7 Integrated Pest Management

Combining hand picking of larvae and light trapping of adults in orchards south of Baghdad (Iraq) from 2009 to 2012 compared to control orchards (without integrated control) reduced adult numbers caught in the location by about 90 % and increased yield by about 28 and 31 % in 2011 and 2012, respectively (Table 5.2) (Khalaf and Al-Abid 2013; Khalaf et al. 2011, 2013a, b, 2014; Khalaf and Al-Taweel 2014).

5.6.8 Comparison of *Oryctes* spp. on Date Palms with *Oryctes rhinoceros* on Coconut and Oil Palms

It is of interest to compare the biology and damage caused by the two species of *Oryctes* on date palms, with that caused by the well-known pest *O. rhinoceros* on coconut (*Cocos nucifera* L.) and oil palms (*Elaeis guineensis* Jacquin). Adults of *O.*

Table 5.2 Effect of IPM program against *Oryctes* on yield of Barhee date palms

	No. of bunches per tree		Yield (kg per tree)	
Treatment	2011	2012	2011	2012
Control (no hand collection of larvae)	10.91	10.7	104.00	106.00
Almost complete control, with hand collection of larvae and light traps	11.27	11.1	133.36	139.00
Yield/bunch increase (quantity)	0.36	0.40	29.36	33.00
Yield increase (%)	3.3	3.74	28.20	31.13

Fig. 5.29 Coconut palm in Fiji showing damaged V-cut fronds resulting from *Oryctes rhinoceros* adults boring into the immature fronds (Bedford 2013; with permission from Annual Review of Entomology, © 2013 by Annual Reviews)

elegans bore into fruit bunch stalks of the date palm to feed, while *O. agamemnon* adults apparently feed little, or not at all. On coconut or oil palms *O. rhinoceros* adults crawl down frond axils to bore into the heart or meristem feeding on sap as they go. This tunnelling damages the still immature fronds which as a result display V-shaped cuts when they unfurl (Fig. 5.29).

Such attacks by adult *O. rhinoceros* if continued and repeated, kill the growing meristem and the coconut palm dies (Fig. 5.30).

Coconut palms of all ages may be attacked and killed, while young oil palms in particular may be thus killed while older oil palms seem less affected. This type of damage is not reported in the case of date palms attacked by *Oryctes* spp. However, *O. rhinoceros* adults boring into young oil palms can cause the rachis of fronds to

Fig. 5.30 Coconut palms killed and reduced to poles due to repeated heavy attacks by *Oryctes rhinoceros* at Drauniivi, Fiji. Breeding now occurs in the tops of the dead poles (Bedford 2013; with permission from Annual Review of Entomology, © 2013 by Annual Reviews)

break and the upper section of the frond to hang down, as has been noted with *Oryctes* spp. damage in date palms.

In date palms *Oryctes* spp. oviposit in leaf axils, or debris or fiber therein, and from here the larvae may penetrate into the leaf bases and trunk. Oviposition also occurs in the masses of respiratory roots at the base of the trunk. These attacks occur in the living date palm.

Oryctes rhinoceros only oviposits, and the larvae only develop, in dead wood e.g. the tops of dead standing coconut poles (often those killed by adults' attacks, Fig. 5.30), decaying coconut logs and stumps, shredded pulverised oil palm trunk material, and a variety of other breeding sites consisting of various types of decaying organic matter (Bedford 2013). However, it has been reported as breeding in debris in coconut palm leaf axils in Guam (University of Guam, 2010; http://www.biologynews.net/archives/2010/06/21/unusual_rhino_beetle_behavior_discovered.html), perhaps similar to *O. elegans*.

Adults of subspecies of *Scapanes australis* Sternberg in Melanesia attack only young low coconut and oil palms, but in a manner similar to *O. rhinoceros*. Its breeding sites are at soil level under decaying bush logs or in decaying tree roots. Larvae are not found in living coconut or oil palms (Bedford 1980, 2013).

5.7 Future Research

A full description of the larvae of *O. elegans* and *O. agamemnon* and its subspecies, with a key to identify them, would be very useful so they can be reliably distinguished in locations where both species coexist.

The virus *Oryctes* Nudivirus (OrNV) has been successful in lowering populations and damage by *O. rhinoceros* to coconut palms in a number of countries where this virus did not occur prior to its introduction (summarised in Bedford 1980, 2013). It kills larvae and adults, and infected adults act as vectors spreading it before they succumb. It would be of interest to test whether larvae or adults of *O. elegans* and *O. agamemnon* are susceptible to this virus. If found susceptible, prior to any release it would be important to observe samples of larvae and adults taken from the field to see if any other endemic viruses already exist in their natural habitat. As regards the Arabian Peninsula, it would be important to note that this virus has now been introduced and established in Oman (Kinawy 2004) to lower damage by *O. rhinoceros* on coconut palms. Starting from there it is free to self-disseminate elsewhere, and would be available for introduction into locations where this species is attacking date palms.

The fungus *M. anisopliae* is ubiquitous so it would be important to observe samples of field-collected date dynastid larvae and adults for its presence to obtain data on its natural incidence in an area, prior to wide scale release against date palm dynastids. This would provide a base line from which the effect of releases may be assessed. Possibly, light traps may be adapted to auto-infect adults with the fungus allowing their release to disseminate it. A pheromone trap (utilising the already widely-used commercially available pheromone ethyl 4-methyloctanoate) has been adapted for trial use in oil palm plantations to capture and auto-infect *O. rhinoceros* adults with *M. anisopliae*, followed by theirrelease in the field (Ramle et al. 2011). Perhaps pheromone traps for *O. elegans*, or light traps for *O. elegans* and *O. agamemnon*, could be adapted for capture, infection of adults with *M. anisopliae*, then allow their release to disseminate the entomopathogen.

As the components of the male aggregation pheromone of *O. agamemnon arabicus* have now been identified (Saïd et al. 2015) as primarily a mix of 2 already known *Oryctes* spp. semiochemicals, ethyl 4-methyloctanoate and 4-methyloctanoic acid, can this discovery be developed for trapping and future use in an IPM program (Vuts et al. 2014)? For *O. elegans*, the odor or volatiles from fresh date palm tissue, usually from shoots, is synergistic with the pheromone 4-methyloctanoic acid in traps, but as offshoots are sold for propagation, a cheap substitute for date palm offshoots is needed. So extraction and identification of date palm volatiles is needed, which might then be synthesized and added to the pheromone so trapping can be more fully developed, enhanced and utilised. In locations where *O. rhinoceros* attacks date palms, use of the commercially available male aggregation pheromone ethyl 4-methyloctanoate for trapping may be applicable (Bedford 2013).

Are there volatiles common to date, coconut and oil palms which attract *Oryctes* species e.g. *O. elegans* and *O. rhinoceros* to feed, or to oviposit in the case of *O. agamemnon*, and thus these *Oryctes* species are attracted to palms and not to other plants ? Is it a similar question to that which applies to *O. rhinoceros* – do date palm volatiles attract date palm *Oryctes* spp. pests, and then the release of the male produced aggregation pheromone promotes intraspecific competition thence mating, and possibly subsequent oviposition?

While males of *O. elegans* confined in traps, or 4-methyloctanoic acid lures in traps, attract both sexes to traps (Rochat et al. 2004), there is lacking information or observations on where or when during their adult life span, males in the wild emit the pheromone, or both sexes respond (Vuts et al. 2014). Does this occur, with subsequent mating, in feeding sites, or breeding sites, or both? This question also applies to *O. agamemnon arabicus* where more than one key pheromone molecule are produced (Saïd et al. 2015).

A prior assessment of the natural incidence of entomopathogenic nematodes in an area would be advisable if their propagation and widespread release is envisaged.

5.8 Summary

Adults of *O. elegans* cause damage to date palms by boring into the stalks of inflorescences, fruit bunches and frond bases. Their larvae bore into frond bases and trunks. Larvae of subspecies of *O. agamemnon* bore into frond bases thence trunks and into aerial root masses and may thus cause the palm to fall subsequently. Physical control measures such as pruning off old frond bases removes oviposition sites and hence ensuing damage by larvae.

Light trapping enables monitoring of both species and may be used as a component of IPM. Pheromone trapping is also an important tool available in IPM for control of *O. elegans*. Various entomopathogens and other biological control agents may well be investigated as potential or possible components in IPM against these date palm pests.

The damage caused by adults of *O. rhinoceros* which bore into the heart of coconut and oil palms causing the emergence of typical V-cut fronds, and the death of the palm if repeated attacks destroy the meristem, does not seem to occur with the two species of *Oryctes* attacking date palms. *Oryctes rhinoceros* only breeds in dead decomposing woody or organic material whereas immature stages of date palm dynastids may tunnel into living date palm tissue.

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