REVIEW: Date Palm Arthropod Pests and Their Management in Israel

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This review summarizes the current knowledge on the distribution, natural history, economic importance and management of 16 major species of date palm pests in Israel. Another 15, rarely occurring, pest species are also identified. Research on the date palm pests in Israel was initiated against a background of severe outbreaks of scale insects in the late 1950s. These outbreaks were caused mainly by unrestrained use of organophosphates. This situation led to the gradual development of an Integrated Pest Management (IPM) program, which was implemented first against scale insects and later against fruit pests. The IPM approach resulted in successful control of the scale insects, up to the present, whereas agrotechnical and crop management procedures, including covering the fruit bunches with plastic nets and early harvesting of several date cultivars, were successfully applied to achieve efficient control of the fruit moths. In addition, the use of chemical compounds in date plantations was drastically reduced and restricted to heavy foci of pest infestation. In time, microbial control, mainly application of *Bacillus thuringiensis* products against the lesser date moth, and the use of pheromone traps for monitoring and controlling red palm weevil, enabled further reductions in the use of synthetic insecticides. The overall change in pest management also significantly improved the preservation of natural enemies of the pests in the plantations. Whereas in the 1950s the major problems were caused by the parlatoria date scale and the green scale, in the early 2000s the key pests in date plantations in Israel are the lesser date moth and sap beetles in most of the date-growing areas, and spider mites which are restricted to the Arava Valley. Future management of the first two of these pests should rely on an improved monitoring system and integration of pheromone application for reduction of the population and damage. Efforts should be made to prevent the red palm weevil, which currently is a potential pest, from becoming an actual key pest in date plantations.

KEY WORDS: Biological control; chemical control; natural enemies; pest management; pheromones; *Phoenix dactylifera*.

INTRODUCTION

Many arthropod species are known as pests of the date palm (*Phoenix dactylifera* L.) worldwide (72,102). In their review of pests and diseases of the date palm, Carpenter and Elmer (45) reported on more than 50 species of insects and mites as pests of date palms in various countries. In Israel, however, approximately 25% of these species of insects and mites are considered serious pests (30,40,83,97).

Research on the date palm pests in Israel was initiated in the late 1950s, in response to the severe damage that resulted from the outbreaks of the parlatoria date scale, *Parlatoria blanchardi* Targioni-Tozzetti (Hemiptera: Diaspididae) and the green scale, *Palmaspis*

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(=*Asterolecanium*) *phoenicis* Ramachandra Rao (Hemiptera: Asterolecaniidae). The pioneers in that study, as well as in subsequent research on the date pests in Israel, were Prof. Eliahu Swirski and Dr. Moshe Kehat, both of the Department of Entomology, Agricultural Research Organization (ARO), The Volcani Center, Bet Dagan. Their studies undoubtedly enriched our knowledge of the biology, ecology, phenology and control of the major date palm pests, and they thereby laid the cornerstone of a comprehensive pest management strategy in the date plantations of Israel. Swirski and Kehat initially concentrated on finding solutions to the above-mentioned scale insects problems. Gradually, since the 1960s, they extended their efforts toward finding solutions to the other major date palm pest problems. Their work enabled the growers to cope with the pest problems, either by means of short-term solutions, such as insecticide applications, but mainly by establishing alternative, environmentally safer, control measures (97).

Date palm plantations in Israel cover an area of 3300 ha located along the Syrian-African rift, from Elat in the south to Lake Kinneret in the north; they contain 223,000 mature palms. The extremely high temperatures and the low relative humidity that prevail in those areas during spring and summer provide the optimal conditions for growth and development of the date palm, as well as for maturation of the fruits. The total planted area of organic date plantations in Israel in 2007 was approximately 370 ha, *i.e.,* approximately 11% of the total area planted with date palms in the country. The dominant (90%) cultivar in organic orchards is the 'Medjhool' (B. Glazner, pers. comm.). Other cultivars that are under consideration for planting in certified organic plantations include 'Hayany', 'Zahidi', 'Barhee', 'Khadrawy', 'Dayri', 'Helawy' and 'Amri'.

The arthropod fauna in Israeli date plantations is not entirely isolated from that of the neighboring countries, such as Jordan, Palestine and Egypt. The Jordanian plantations grown on the East Bank of the Jordan River, the Palestinian plantations on the West Bank and in the Gaza Strip, and the Egyptian plantations in the Sinai Peninsula may contribute to the Israeli fauna, through a corridor formed by the ornamental date palms planted in all Israeli residential areas.

The objective of this review is to summarize the knowledge accumulated on date palm pests and their management in Israel during almost half a century of research, in both the field and the laboratory. Much of the information presented in this review is based on the studies cited therein, as well as on the personal experience of the author.

This review is dedicated to the memory of Zvi Bernstein (1922 – 2006), the editor and the main contributor to the book "The Date Palm", published in 2004. For me, Zvi was a close colleague, a friend and a mentor. Like the date palm fruit, he was one of a kind, and was beloved by all his friends and colleagues. In his own words: "in all of the traditional date palm-growing countries, the date fruit is the preferred fruit consumed over any other kinds of fruits growing in those countries" (23).

In this work the various date palm pests are divided into two groups: (A) pests of frequent occurrence (major pests) and (B) pests of rare occurrence (accidental and/or minor pests).

A. PESTS OF FREQUENT OCCURRENCE (MAJOR PESTS)

The major date palm pests in Israel can be divided into several categories as related to their host specificity and preferred plant part (Table 1).

The following sections summarize information on the distribution, host range, natural

TABLE 1. Major date palm pests in Israel as related to their degree of specificity and their distribution within the palm according to their preferred organ (+ less preferred, +++ most preferred)

Pest species in taxonomical order (number of the section in the review)	Degree of specificity*	Parts of the palm attacked						
		Foliage	Bunch stalks	Green fruit	Ripening fruit	Shoots and/or palm bases	Stem	Roots
1. Dubas date bug	S	+++						
2. Issid date bug	S		+			++		
3. Green scale	FS	+++	++	+	+	+		
4. Red date scale	FS					+++		
5. Parlatoria date scale	O	+++	++	+	+	+		
6. Pineapple mealybug	P				+			++
7. Desert Locust	P	++						
8. Sap beetles	PP				+++			
9. Rhinoceros beetles	FS					+++	++	++
10. Red palm weevil	FS					+++	+++	
11. Date stone beetle	FS			+++				
12. Raisin moth	P				+++			
13. Carob moth	P				+++			
14. Greater date moth	FS		+++		++			
15. Lesser date moth	S			+++				
16a. Date mite	O	+++		++				
16b. Old world date mite	O			+++				

*S = High specificity to the date palm (*Phoenix dactylifera*).
FS = High specificity to the family Arecaceae.
O = Oligophagous species, attacking Arecaceae and a few other hosts.
P = Polyphagous species, attacking a wide range of plant species.
PP = Attacking all kinds of fermenting material.

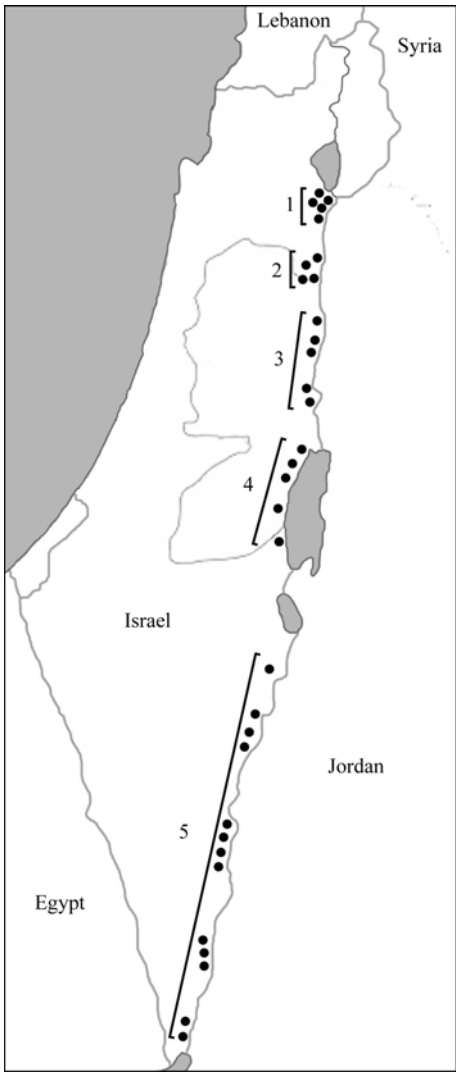

Fig. 1. Distribution of the main commercial date plantations in five growing areas in Israel (in parenthesis, the percentage of the total area): 1. Lake Kinneret area (29%); 2. Bet She'an Valley (31%); 3. Jordan Valley (5%); 4. Dead Sea area (14%); 5. Arava Valley (21%) (after B. Glazner, unpublished report).

history, damage, natural enemies, management and control of the major pests.

A.1 Dubas date tropiduchid (dubas date bug, Old World date bug), *Ommatissus lybicus* De Bergevin (Hemiptera: Tropiduchidae)

The Dubas date bug (DDB*)* was formerly referred to in the literature as the 'lybicus' variety of *O. binotatus*. It was raised to species status by Asche and Wilson in 1989 (5).

A.1.1 Distribution and host range

DDB is considered a major pest of date palms in several countries in the Near East,

North Africa and southeast Russia (72,73,100). The species is apparently restricted to date palms (72). It actually originated in the Tigris-Euphrates River Valley, from which it has spread to other areas in recent decades. In the late 1970s it was considered a serious pest in the Basrah area of Iraq and in some oases of Egypt and Libya. The spread of the insect to other locations has apparently been *via* transportation of offshoots that contained eggs (see 73). Damage by DDB in Israel was first reported in the early 1980s in the southern Arava Valley, where the 'Medjhool' and 'Deglat Noor' cultivars were attacked (100). In the late 1990s severe infestation and damage were recorded in the 'Medjhool' cultivar in the northern Dead Sea plantations.

A.1.2 Natural history

The adults are brownish-yellow in color, with clear wings with no distinct features. The females are 3.6–4.0 mm long, 1.2–1.6 mm wide; males are 2.5–3.0 mm long, 1.2–1.5 mm wide. The eggs are bright green when laid, later turning yellow. The developmental stages include five nymphal instars. The posterior segments of nymphs carry long thin waxy threads. The background color of young nymphs is whitish gray, changing to yellowish brown with distinct brown lines in later instars (100).

The females lay eggs singly, in straight compact rows on the lower leaflet surface. Most eggs are laid along the mid-veins of medium-aged leaflets, but in heavy attacks they are found on all veins and fronds. The DDB has two generations per year. The summer generation of young nymphs appears in mid- to late April. These nymphs mature after 2 months, and eggs of the second generation appear late in September. The number of eggs/female ranges from 100 to 130 (56). The eggs hatch within 18–21 days in summer and after over 170 days in winter. The latter eggs overwinter on the leaf pinnae, and they hatch in the spring (April) of the following year. Low temperatures (below 0°C) adversely affect the survival ability of the adults. Nymphs and adults find refuge within folded leaflets, or in the whorls of the palm. The 'Medjhool' palms, which have closed whorls, offer more hiding places and thus support heavier DDB infestations than the 'Deglat Noor' variety. The DDB usually avoids direct sunlight (100). Spread of the population is enhanced by transfer of infested offshoots as well as by wind.

A.1.3 Damage

The DDB excretes large amounts of sticky honeydew, which may almost completely cover the palms, and may drip to the ground. Development of sooty mold was not observed in the Arava Valley, probably because of the low relative humidity prevailing in that region (100). Heavy populations of the pest may cause yellowing of the infested palms and retard their development (46).

A.1.4 Natural enemies

Little is known about the natural enemies of the DDB's, but Hussain (73) listed several, including an unidentified chalcidoid parasitoid, a predacious neuropteran and coccinellid beetles. These obviously do not provide adequate natural control everywhere the bug occurs; it is questionable whether coccinellids, in particular, are adapted to prey on this auchenorrhynchous insect or on its well-protected eggs. In the Arava Valley where the DDB appeared relatively recently, no natural enemies were detected (100).

A.1.5 Management and control

Control of the DDB is recommended only when dense populations occur, and various chemical treatments have been applied to control it, including aerial applications (54). In Israel in the mid-1980s, preliminary experiments were conducted to test systemic

carbamates, such as aldicarb and butocarboxim. Soil application of these compounds gave satisfactory control of DDB, and therefore growers began using them commercially (M. Klein, pers. comm.). Control treatments are applied at the beginning of a generation (early April or early August). In Iraq satisfactory control results were obtained in 1965, with a preparation of dichlorvos (DDVP) (54); injection of thiamethoxam at 1 g a.i. per palm was also very efficient in suppressing the pest population (2).

A.2 Issid date bug, *Asarcopus palmarum* Horvath (Hemiptera: Issidae)

A.2.1 Distribution and host range

The issid date bug (IDB) is native to North Africa and the Middle East, including Egypt (60) and Israel (109). It is probably specific to date palms (145). In the United States the IDB was first noticed in date plantings in 1922; it attacked young palms of the several species of *Phoenix* grown there (135). Large populations of IDB were found in Israel in 1990 and 1991, hiding and feeding at the base of whorls and fruit stalks in a date plantation near Lake Kinneret, but it attacks date palms all over Israel (109).

A.2.2 Natural history

IDB is a reddish-brown insect that feeds on inflorescence stalks, tender growth of the newest frond, and the lighter-colored tissue at the base of petioles. Occasionally, populations become dense and produce excessive honeydew, which attracts ants. The ant colonies build nests in the palms or within the soil near their food source. IDB is active throughout the year, although less so during the winter. Populations on date palms consist primarily of nymphal stages (46).

A.2.3 Damage

The injury consists of superficial, irregular brown areas of damaged tissues (72). At times, IDB become numerous enough on small, weak palms to cause the terminal leaves to drop (46). Young palms planted in the vicinity of older ones suffer from severe stunting or die because of the feeding of planthoppers. Damage caused to young palms is quite noticeable, whereas injury to large, healthy palms is not. It is possible that yields are affected by heavy infestation of fruit stalks. Damage is expressed in dryness of palm pinnae and in suppression of development of offshoots (109). Usually, IDB is not considered a serious pest of date palms in Israel.

A.2.4 Natural enemies

Not known.

A.2.5 Management and control

In spite of the damage caused by IDB, control of this pest in the USA is usually not necessary (46).

A.3 Green scale (date pit scale), *Palmaspis* (=*Asterolecanium*) *phoenicis* (Ramachandra Rao) (Hemiptera: Asterolecaniidae)

A.3.1 Distribution and host range

Up to the present, the green scale (GS) has been known as a pest only of the date palm (*Phoenix dactylifera*) (19). It is found in the Middle East, including Iran, Iraq, Saudi Arabia, Qatar and Sudan (46,72). In Israel it occurs in all the date-growing areas (97,136).

A.3.2 Natural history

The female bears concave armor, 1.2–1.5 mm long and 0.6–0.8 mm wide; its rear part is narrow, and pale yellow to bright green in color, whereas the front part is wide, and reddish

brown to dark, glossy purple. The crawler is elongated, elliptical and flattened; its body length is 0.4–0.6 mm, and its color is bright yellow to greenish (83,85).

In the Bet She'an Valley the GS produces three generations per year. The autumn–winter generation begins in November with the mass appearance of the crawlers, and lasts 7–8 months, until early summer (May–June). During the winter, the scale population comprises mainly 2^{nd} stage nymphs that develop slowly. In the spring, as temperatures rise, the nymphs turn into adult males or females. The second generation appears in June and terminates in September, and the third generation lasts from September to early November (83,85).

A.3.3 Damage

The GS infests the pinnae, the rachis, the basal parts of the leaves, and even the fruits, and may seriously damage the date palms. The infested plant parts (mainly the pinnae) turn yellow, and subsequently the entire leaf may degenerate. Heavy infestation by the scale may kill the palm (97).

A.3.4 Natural enemies

No natural enemies of GS have been reported in the literature (19). In Israel, however, high percentages of parasitized scales, with or without emergence holes, have often been observed in the field. Nevertheless, there has been no investigation of the natural enemies of this scale insect in Israel (97).

A.3.5 Management

Applications of organophosphate insecticides combined with mineral oils were very effective in minimizing GS infestation and damage (96). As regards biological control, emergence holes observed in many GS individuals suggest that parasitoids probably exercised efficient control of *P. phoenicis.* This may explain why no further outbreaks of GS since the early 1970s have been recorded in plantations that were not treated with insecticides.

A.4 Red date scale, *Phoenicococcus marlatti* Cockerell (Hemiptera: Phoenicococcidae)

A.4.1 Distribution and host range

The red date scale (RDS) frequently infests date palms in its native North Africa and the Middle East, and from there it has spread to Sicily and Spain. In the Western Hemisphere, it was introduced into Argentina on date offshoots and into the southwestern USA on infested date saplings (8,46,72,102). The RDS is highly specific to the Arecaceae (Palmae), and it is occasionally found on *Phoenix* spp. in Florida (USA). There is also a curious record of its occurrence on *Eucalyptus* (Myrtaceae) (21). In Israel, injury was recorded mainly in the Jordan and Bet She'an Valleys, but RDS is not usually considered a serious pest of date palms in Israel.

A.4.2 Natural history

The small, spherical body, $\sim$1.5 mm in length, is red or reddish brown in color and is embedded or nested in white wax. The wax is often rubbed, exposing the red color of the body. The scales occur on the white tissues at the base of fronds, and occasionally on exposed roots and fronds. The adult female is encircled by a band of whitish waxen flakes, and its antennae consist of only one segment. The 2^{nd} stage larva resembles the female in shape, but differs from the adult in the position of the anal orifice, which is situated at the extreme posterior end of the larval body, whereas in the adult it is further forward. The

male is very small and wingless, with clavate antennae (8).

The RDS normally avoids the light and is found massed on the white tissue at the bases of leaves and fruit stalks, where it is protected by fibers and leaf bases. Sometimes the scale also descends to the roots of the palm. According to Stickney *et al*. (135), the scale is partly viviparous, and in the USA was found to produce four generations each year.

A.4.3 Damage

With the extensive plantings of date palms in Israel, mainly in the northern valleys, and with the introduction of high-quality cultivars, the danger posed by this insect has risen, since it is likely to retard development of young palms. Dense scale populations may impair the survival prospects of newly planted young date shoots, and also may cause dryness and mortality of the infested palms. In cases of very heavy infestation the underlying tissues can be damaged to a depth of a few millimeters (8,46).

A.4.4 Natural enemies

Among a few general predators reported from North Africa is *Pharoscymnus anchorago* F. (Coleoptera: Coccinellidae), which is an active predator of RDS (135). Another coccinellid predator of RDS, found in Spain, is *Rhyzobius lophanthae* (Blaisdell) (67). No natural enemies have ever been recorded in Israel.

A.4.5 Management and control

Generally, chemical control of RDS is difficult and ineffective, because of the hidden sites in which the scales are located. Effective control measures include: (i) exposing infested offshoots that have been detached for transplanting to a temperature of 50°C for 65 h in an insulated room (46), or (ii) spraying to runoff into the bases of the offshoots with chlorpyriphos compounds (139).

A.5 Parlatoria date scale, *Parlatoria blanchardi* Targioni-Tozzetti (Hemiptera: Coccoidea; Diaspididae)

A.5.1 Distribution and host range

The parlatoria date scale (PDS) is widely distributed throughout most of the date-growing regions of the world (46,72,102,130). It is generally believed to be native to the Arabian Gulf countries (as is the date palm). Commerce in date offshoots over the centuries spread it into India, Central Asia, the Middle East, North Africa and Turkey, and later it was carried on offshoots to Australia and America (130). Date palms are the preferred host of PDS, but the latter also has been recorded on additional hosts belonging to four plant families: Arecaceae (Palmae), Apocynaceae, Oleaceae and Rhamnaceae (19). In Israel, it is widespread in all the date-growing areas (8).

A.5.2 Natural history

The female is covered with elliptical, convex armor, white-gray in color. Its body length is 1–1.5 mm and its width is 0.6–0.8 mm; its body (underneath the armor) is elongate, reddish, ∼0.8 mm in length. The female is neotenic and lays its eggs beneath the armor. The crawler is reddish, 0.23 mm in length. The male bears flattened and elongate armor, white in color, and its body is ∼0.8 mm in length.

In a 2-year survey at two locations in Israel, the population of PDS was found to increase substantially in spring and autumn. Reproduction in summer depended on climate, and was limited when heat and dryness were extreme. In winter, both development and reproduction were retarded. Three epidemiological generations per year were found, and only a small part of the population succeeded in establishing a fourth generation. A strong

overlapping of generations was observed (78).

A.5.3 Damage

The PDS infests all parts of the date palm. At high population densities, infestation covers the fruit bunches and the fruit stalks. Dense populations may impair development of the palm and cause the fruits to shrink, rendering them unmarketable. In extreme cases it may cause deterioration of the palm.

A.5.4 Natural enemies

Four main groups of natural enemies were found during a comprehensive survey of natural enemies conducted in unsprayed date plantations in Israel from the late 1950s to the early 1970s.

(i) Parasitic Hymenoptera: Two species of parasitic wasps were found in Israeli PDS populations: *Aphytis* n.sp. (Aphelinidae) (formerly recorded as *Aphytis* aff. *citrinus* Comp. (78); and *Archenomus arabicus* Ferriere (Encyrtidae) (formerly recorded as *Pteroptrix* sp. (78) and later described from Saudi Arabia (58). The first is widely distributed in groves in the North and in the southern Arava Valley, and is likely to be highly effective (78,95). The second species is rare and was found only in the southern Arava Valley (58). Noyes (114) reported seven aphelinid species (Chalcidoidea) that attack PDS. *Aphytis phoenicis* (DeBach & Rosen) (Aphelinidae) is one of a few species of parasitic Hymenoptera that is considered an important natural enemy of PDS in North Africa (72). Watson (143) claimed that it is also found in Israel, but its presence here is questionable.

(ii) Predatory Coccinellidae (Coleoptera): A rich fauna of predatory lady beetles was found associated with PDS. Among 25 coccinellid species recorded, seven were found frequently and, therefore, are regarded as important predators of the scale. They were: *Pharoscymnus* aff. *numidicus* Pic, *Ph. setulosus* Chevrolat, *Ph. ovoideus* Sicard, *Ph. pharoides* Marseu, *Chilocorus bipustulatus* (L.), *Rhyzobius lophanthae* Blaisdell and *Scymnus bipunctatus* Kugelann. The criteria for determining their usefulness were: searching ability, feeding behavior, distribution, population density, survival under extreme environmental conditions, and regularity of appearance on date palms (78-81). By these criteria, *Pharoscymnus* spp. were considered to be of great importance: except for *Ph. setulosus* they were widely distributed throughout the country; *Ph.* aff. *numidicus* was the most prevalent of them; it maintained very dense populations, and its seasonal predatory activity lasted longer than those of the other species. In the northern plantations (the Bet She'an and Jordan Valleys) *C. bipustulatus* seemed to be an important lethal predator in well-shaded, old plantations.

(iii) Predatory Cybocephalidae (Coleoptera): Five species of these predatory beetles were found to be associated with PDS: *Cybocephalus nigriceps nigriceps* (J. Sahlberg), *C. micans* Reitter, *C. mediterraneus* Endrödy-Younga, *C. aegyptiacus* Endrödy-Younga and *C. pullus* Endrödy-Younga. Their distribution, phenology, biology, and survival under extreme climatic conditions were studied (25-27,29,41-43). The most prevalent species was *C. nigriceps*. In plantations where dense populations of *P. blanchardi* existed, *Cybocephalus* spp. also appeared in very large numbers, especially in the Arava Valley but also, to a lesser extent, in the northern plantations. Adults of *C. nigriceps nigriceps* were present in date plantations all year round; their populations peaked during summer, whereas eggs and larvae were abundant only during spring and summer. In autumn and winter the adults entered a diapause (aggregating in the bases of pinnae), development of their ovaries was arrested, oviposition stopped and predatory activity decreased. The predominance of *C.*

nigriceps in local habitats is attributed to the fact that all stages of this predator displayed high survival capacity under extreme conditions of high temperatures and relative humidity (25). *Cybocephalus* spp. survived well at a very low prey population density, as well as in insecticide-treated plantations, where coccinellids were destroyed (97). On the other hand, its disadvantage as a predator was reflected in its low predatory activity - as compared with the Coccinellidae, its inability to feed on adult scales, and its low activity during the winter, when PDS nymphs are most abundant (41). Comparative biological studies of several cybocephalid species explained their different distribution according to the climatic conditions and prey species prevalent in their specific habitats (41,43).

(iv) Green lacewings (Chrysoperla spp.): These lacewings were found mainly during spring and autumn; their significance in the control of PDS was not investigated.

The predacious mite *Hemisarcoptes coccophagus* Meyer (Hemisarcoptidae) was also found to attack PDS (61).

A.5.5 Management and control: Integrated pest management (IPM)

Following the severe outbreaks of the PDS in date plantations in Israel in the late 1950s and during the 1960s, chemical control was used to provide an immediate solution to the scale problem. Concomitantly, a program for IPM was initiated, first against the PDS and the green scale, and later against the other major pests, especially those of the ripening date fruits (30,97).

During the 1960s and 1970s date growers used chemical control against all major date palm pests. However, the behavior and biology of PDS, *i.e.*, extended oviposition period, overlapping generations, and constant infestation of axils and leaves beneath dry fibers, reduced the effectiveness of chemical control (78). Insecticides used in the 1960s were based on organophosphate compounds among which dimethoate, alone or in combination with a 2% mineral oil emulsion, was the most effective; combinations of other organophosphates with oil also gave satisfactory control (95).

The IPM program developed in date plantations against the PDS was based on the following principles.

(i) Survey of local natural enemies of PDS in insecticide-untreated plantations: see the above section on 'Natural enemies' of PDS).

(ii) Re-establishment of local natural enemies: The re-establishment of parasitic wasps and cybocephalid beetles involved mainly transferring these natural enemies from unsprayed plantations, where they were abundant, to plantations from which they had been eliminated. However, the re-establishment of coccinellids relied mainly on supply from laboratory mass-rearing cultures. During 1960–1965, approximately 50,000 adults of *Ph. numidicus* and 5,000 of *Ch. bipustulatus* were reared in the laboratory and distributed in date plantations in the southern Arava Valley. *Ph. numidicus* successfully re-established in all plantations where it was distributed, whereas repeated efforts to establish *Ch. bipustulatus* failed. The latter species was limited to its natural distribution in the northern plantations (97).

(iii) Establishment of a less toxic environment in date plantations: This was a prerequisite for enhancing the activity and survival of natural enemies of the PDS, and thereby ensuring the successful biological control of PDS and green scale. Establishment of a less toxic environment in date plantations was achieved in several ways: (*a*) restricting chemical applications to heavily infested foci, or parts of a plantation, to ensure the continued existence of natural enemies; (*b*) using insecticides with a low toxicity to the

natural enemies (95); (*c*) ensuring considerable reduction of PDS populations prior to the beginning of the IPM program, to avoid the need for disruptive treatments afterwards: this was achieved either mechanically – by removing old, heavily infested, unproductive palm leaves – or chemically; (*d*) improving the micro-environmental conditions for survival of natural enemies, and thereby reducing the need for chemical treatments. Thus, the frequent dust storms in the Arava Valley, and the extreme environmental conditions that prevail there (82), impaired the efficacy of natural enemies. Procedures such as the introduction of drip irrigation, covering the soil with weeds, and reducing the number of cultivations lessened the amount of dust, and probably resulted in other micro-environmental changes in temperature and relative humidity, and increased the availability of alternative foods – all of which led to increased survival and efficacy of the natural enemies. The effect of enhanced micro-environmental conditions was reflected also in the relationship between plantation age and the density of PDS: provided there were no chemical applications, the PDS population density was inversely related to the age of the plantation.

(iv) Maintaining satisfactory phytosanitary conditions in the plantations: Maintenance of satisfactory phytosanitary conditions in date plantations by, *e.g.* cutting and removing old, PDS- and green-scale-infested palms, greatly reduced re-infestation of trees.

The implementation of the IPM program against scale insects resulted in the successful control of the PDS and the GS. Thus, scale density was reduced from 96.6 in l962 to 0.02 scales/cm^2 in 1972 (97). As a result, PDS changed from the status of a key pest to a very rare and unimportant pest of dates in Israel: from the early 1970s to the present (2008), there has been almost no need for any control measures against scale insects in date plantations in Israel. Nonetheless, in recent years (early 2000s), occasional outbreaks of PDS and GS have been reported in a few date plantations in Israel (S. Bitton, pers. comm.).

A.6 Pineapple mealybug, *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae)

A.6.1 Distribution

The pineapple mealybug (PAM) is cosmopolitan, generally occurring in tropical and subtropical areas of the Australasian, Afrotropical, Nearctic, Oriental, Palaearctic and Neotropical regions (17-20). In the Middle East the PAM was previously known from Egypt and Israel (17). It has been known in Hawaii, especially as a serious pest of pineapples and to a lesser extent of sugarcane and bananas. However, PAM attacks a wide range of other host plants (including various Arecaceae), and its major wild habitats in Hawaii comprise roots of grasses and foliage of numerous native weeds. PAM is always attended by ants, which are largely responsible for its spread (14).

A.6.2 Natural history

In Hawaii, PAM reproduces parthenogenetically, about 25 days after the third molt, and males do not exist there. The life span of the mealybug ranges from 78 to 111 days, averaging 95 days. *D. brevipes* is ovoviviparous and the crawlers constitute its primary dispersal stage. There are three instars of larvae, which extend over a total of about 34 days. A female can produce up to 1000 crawlers during an average of 25 days. The adult female lifespan ranges from 31 to 80 days, averaging $\sim$56 days.

A.6.3 Damage

In the arid Arava Valley of Israel, populations of this mealybug occur throughout the year on the adventitious roots at the trunk base of date palms, apparently without damaging

the palms (17). Nevertheless, in late summer (August–September) mealybugs occasionally wander upwards to the ripening bunches, where they infest the dates and sometimes cause total loss of bunches. This occurred in several date plantations in the southern Arava Valley during 1980–1982 (17). Small colonies were observed on date palm trees in the early 2000s in various date-growing areas (Y. Ben-Dov, pers. comm.).

A.6.4 Natural enemies

Many natural enemies have been recognized in Hawaii, but none is known in Israel. According to Noyes (114), 30 parasitoid species, comprising 28 encyrtids and two signiphorids, attack *D. brevipes*. Predators include the coccinellids: *Cryptolaemus montrouzieri* Mulsant, *Lobodiplosis pseudococci* Felt, *Nephus bilucernarius* Mulsant, *Scymnus (Pullus) unicatus* Sicard and *S. pictus* Gorham; and a cecidomyiid, *Lobodiplosis pseudococci*. These natural enemies exhibit minimal control if protective ants are tending the mealybug colony (105).

A.6.5 Management and control

In Israel, no control measures have been taken against the PAM in date plantations. In Hawaii considerable reduction in the abundance of the pest has been achieved through the combined activity of several natural enemies: the cecidomyiid *Dicrodiplosis pseudococci* Felt, and the encyrtids *Anagyrus coccidivorus* Dozier and *Hambletonia pseudococcina* Compere.

A.7 Desert Locust, *Schistocerca gregaria* (Forskal) (Orthoptera: Acrididae)

The desert locust occurs in date-growing areas throughout the Old World (45). Heavy migrations into palm plantings are sporadic, but may be devastating. The locust swarms are measured in terms of square kilometers. The insects eat leaves and fruit, and may destroy an entire crop (46). During the winter of 1958–59, an invasion of this locust occurred in Israel and lasted 14 days (48), during which palms were completely defoliated and did not renew growth until the following April. Heavy defoliation of palms is undoubtedly reflected in reduced crops for several years, because renewal of an acceptable crown of leaves takes at least 3 years under optimal growing conditions.

Chemical control is effective if applied properly and timed to kill the locusts before they attack the palms. The coordinated use of baits and dusts in breeding and swarming areas and the use of serial spraying on both ground and flying swarms of locusts have been successful. Since 1959 aerial spraying has come into widespread use. The numerous factors that affect the success of the various control methods were reviewed in detail by Carpenter and Elmer (46).

A.8 Sap beetles (Coleoptera: Nitidulidae)

The sap beetles found in Israel belong to four sub-families that include a total of 44 species (47). Four species are regarded as date plantation pests of economic importance in Israel: they belong to two sub-families, the Carpophilinae and the Epuraeinae. The Carpophilinae comprise ten species, of which three are of economic importance: the dried fruit beetle, *Carpophilus hemipterus* (Linnaeus); the confused sap beetle, *C. mutilatus* (Erichson); and the pineapple beetle, *Urophorus (=Carpophilus) humeralis* (Fabricus). The Epuraeinae comprise five species, of which the yellow nitidulid, *Epuraea (=Haptoncus) luteola* (Erichson), is the most prevalent.

A.8.1 Distribution and host range

Sap beetles are regarded as pests of many agricultural crops, including dates, throughout the world (46,144). In Israel they are found primarily in date plantations (30,39,90).

A.8.2 Natural history

The adults are chestnut brown, brown-black or black, with short truncate elytra that only partially cover the abdomen; the legs are yellow-red. The antennae are 11-segmented. The body is 2–4 mm in length. They can be distinguished easily from other species by the presence of two bright, pale spots on the elytra. The larvae are whitish or yellowish, with brown heads, and grow to a final length of 5–7 mm. The larvae usually pupate in the soil, and the pupae are white or yellow, 3–4 mm in length. The eggs are white, elliptic in shape and 0.7 mm in length.

Sap beetles are attracted to all kinds of rotten plant material; they develop on a variety of substrates, such as decaying fruits and vegetables, pollen and flowers (11,70,103,129,144). The abundance of the four main species in Israeli date plantations varied in different years, as well as the relative abundance of each of them (39,93).

Some Nitidulidae are known to vector a variety of disease-causing microorganisms (3,50,141). Nitidulid beetles are also considered to be important pollinators of Annonaceae (59,121).

Sap beetles develop and survive very well under the extreme climate conditions (especially high temperatures) that prevail during the summer in date-growing areas. At 27°C development from egg to adult takes 16–21 days, whereas at 32°C only 12–15 days are required. It follows that if ripe dates remain on the palm or in the warehouse for a long time they are likely to become heavily infested with sap beetles, since several generations could develop during prolonged storage. The beetles fly readily and may cover distances of up to 4 km. Nitidulid adults can live for 6–12 months, during which time each female may lay 500–1000, and sometimes 2000 or more eggs (8). During most of the year the beetle population survives on fallen date fruits and kernels that are decaying on the ground, and only towards the beginning of the ripening season do the adult beetles start to attack the date bunches (46,90,103).

A.8.3 Damage

In dates, sap beetles damage the ripening fruits on the palms, on the ground and in storage. They do so by entering the fruits, usually at the calyx end, and feeding on the pulp. The hatching larvae develop rapidly inside the fruits, contaminating them with their excretions. Fruit infestation by sap beetles is usually accompanied by generation of secondary pathogens, which accelerate fermentation and rotting of the fruits, rendering them unsuitable for marketing. In some fruit orchards sap beetles are usually regarded as secondary pests. However, in date and fig plantations they are also primary pests, attacking the ripe fruits on the palms and trees. Most date cultivars are susceptible to attack by sap beetles (8,46,103).

A.8.4 Natural enemies

(i) Parasitoids: In Israel the only known local parasitoid that attacks sap beetles is *Zeteticontus utilis* Noyes (Hymenoptera: Encyrtidae), which is a solitary internal parasitoid of larvae of *Carpophilus* spp. Its development, fecundity, survival and host preference were studied by Blumberg *et al.* (31). In the laboratory, successful development occurred in *C. hemipterus* and in *C. mutilatus*, but not in *C. humeralis* or in *E. luteola* (31). In field populations of *Carpophilus* spp., *Z. utilis* was always quite rare, and therefore its contri-

bution to the reduction of sap beetles is probably not significant. To promote biological control of sap beetles in Israel, trials were conducted during the early 1980s to acclimatize additional species of parasitoids. Two species of hymenopteran parasitoids were introduced from the USA: *Microctonus nitidulidis* Loan (Braconidae), which parasitizes the adult stage, and *Brachyserphus abruptus* Say (Proctotrupidae), which attacks the larvae. These parasitoids were released in date plantations in the northern valleys, but no evidence of their establishment was ever recorded (40).

(ii) Nematodes: Entomopathogenic nematodes received attention through their use as alternatives to chemicals for insect biological control (77). Preliminary laboratory studies suggested that local species of sap beetles are susceptible to entomopathogenic nematodes (65), especially strains of *Heterorhabditis* sp. (64).

A.8.5 Management and control

Control of sap beetles in Israeli date plantations is based mainly on application of insecticides. Agrotechnical and crop management measures, such as covering bunches with plastic nets, phytosanitation procedures, and early harvesting of certain cultivars, help to reduce populations and damage, as in the case of fruit moths (see section A.12, on control of the raisin moth).

(i) Chemical control: A single application of an appropriate insecticide in midsummer and a second one 3–4 weeks before harvest were used as routine measures for control of sap beetles, similarly to the measures against all moth species that attack the ripening fruits. Since the 1960s, date growers have used various organophosphates for controlling fruit pests, and malathion provided the most satisfactory control of nitidulids (35,40,87). During the early 1980s, malathion was replaced with azinphosmethyl (a wettable powder) that was more effective against sap beetles. In addition, selective and supposedly more environmentally friendly insecticides of various groups were tested. The synthetic pyrethroids cypermethrin and cyhalothrin, and the Insect Growth Regulators (IGRs) diflubenzuron, hexaflumuron and teflubenzuron were found effective, and these three IGRs were recommended for commercial use (24,89,93,139,140). The IGRs, although they do not affect the adult stage of the beetles, cause sterilization of their eggs and high mortality of the beetle larvae (6,32). Additional trials, carried out during 2003–2006, indicated that the pyrethroids lambda-cyhalothrin and bifenthrin, the neonicotinoid imidacloprid, and the chloronicotinoid thiacloprid were highly effective in controlling sap beetles (S. Bitton, pers. comm.). The control of sap beetles in organic plantations is problematic and at present it should be based on the agrotechnical measures described below.

(ii) Covering the fruit bunches with plastic netting: This agrotechnical measure was first developed for the control of fruit moths (see details in section A.12, related to the raisin moth). In the mid-1970s, in some date plantations in the Jordan Valley, 'regular' plastic netting (2-mm mesh size) was replaced with 'dense' plastic netting (0.8×0.5 mm mesh size) to cover fruit bunches as protection against sap beetles, and it was found very efficient (88). However, following several years of successful use of these 'dense' nettings, a significant increase in fruit infestation by the greater date moth, *Arenipses sabella* Hampson, occurred in many plantations, for reasons that were not clear. As a result, the use of the 'dense' nettings was no longer recommended (35). In 2006, in the Bet She'an Valley, additional experiments with the same dense plastic netting demonstrated once again the high efficacy of these covers in preventing infestation and damage by sap beetles, so far without any damage by the greater date moth (24).

(iii-iv) Phytosanitation and early fruit harvest: As with the raisin moth (see details in section A.12), both phytosanitation of the plantation and early harvesting of certain date cultivars, are very helpful in reducing sap beetle populations and infestation in date plantations (40).

(v) Activation of pheromone traps: Male-produced aggregation pheromones, to which both males and females respond, were identified for several *Carpophilus* species (11-13), including those that are widely distributed in Israel. These pheromones are not entirely species-specific; pheromones emitted by one species also attracted other *Carpophilus* spp., but not *E. luteola* (36,148). The first series of studies with aggregation pheromones of sap beetles in Israel were conducted during the early 1990s, in both the laboratory (with the aid of an olfactometer) and date plantations. The aggregation pheromones acted synergistically in attracting C. *hemipterus, C. mutilatus* and *C. humeralis* to host volatiles. The pheromones were obtained from Great Lakes IPM, Inc. (Vestaburg, MI, USA). Captures in traps baited with combinations of the pheromone and host volatiles were much higher than in traps baited with either attractant alone. In further experiments, during 2002–2003, it was found that sap beetle capture was largely dependent on the type of trap used. For example, captures were significantly higher in IPS white-yellow, Magnet Funnel traps (distributed by AgriSense BCS Ltd., Mid Glamorgan, UK) in California, than in MacPhail traps (Shabtieli, Tel-Aviv, Israel), originally designed for mass-trapping of flies.

Use of pheromone traps revealed that the relative abundance of the four species of sap beetle in date plantations varied among regions but not among date cultivars: *C. hemipterus* was always trapped in the smallest numbers, and any of the three other nitidulids might be dominant in different sites. The relative prevalence of the studied sap beetles in ripening date fruits on the ground and in fruits collected from the bunches, in two date plots in the Bet She'an Valley, did not match the trap-capture figures: in the fruits the most abundant species were *C. hemipterus* and *E. luteola,* whereas beetle capture rates were significantly affected by the suspension height of the traps on the date palms. Near ground level (0.2 m) *E. luteola* was most abundant, whereas at the level of the fruit bunches (16 m), *C. hemipterus* was the dominant species. Thus, capture rates in traps suspended near the ground may not necessarily indicate which species are responsible for most of the injuries to the fruits on the palm. The abundance patterns of the studied nitidulids in other orchard crops, such as figs, pomegranates, nectarines, citrus, apples and vines, were somewhat different from those in date plantations (39).

A.9 Rhinoceros beetles (Coleoptera: Scarabeidae: Dynastinae)

A.9.1 Distribution and host range

Many species of rhinoceros beetles are borers of palms in different regions of the world; the most economically important species are members of the genus *Oryctes* (15,46,63). *Oryctes* spp. specialize on different parts of the palm. A subspecies, *Oryctes agamemnon sinaicus* Walker (V. Chikatunov, pers. comm.), is abundant in Israel, where it was first recorded in the late 1980s, and rapidly became an important pest in date plantations in the Arava Valley and the southern Jordan Valley (52). *O. agamemnon* also occurs in the Sinai Peninsula (Egypt), Saudi Arabia, the Persian Gulf coast of Iran (15) and Tunisia (98).

A.9.2 Natural history

Most of the rhinoceros beetles are large (30–60 mm), and black or dark brown in color,

with a velvety reddish-brown pubescence on the ventral surface. Both males and females of many species of the Dynastinae possess a dorsal horn on the head and a forward facing pronotal concavity; both features are larger in the male than in the female of the same size (63). *O. agamemnon sinaicus* produces one generation per year. Adult activity begins in early May, peaks during June–July, and ends in September. The female lays approximately 100 eggs that hatch in approximately 2–3 weeks; they are white when laid, but within a few days their color changes to glossy brown and they reach their final size of 4 x 3 mm. The grub-shaped larva has a soft, transparent cuticle, through which the internal white-brown organs can be seen. The three grub instars differ clearly in the size of the head capsule, which grows from 2.5–3.0 mm in the first instar to ∼9 mm in the third. At the end of its 2-month development the larva measures 50–70 mm in length and ∼10 mm in width. Grubs are found from late June, and most reach the third and final instar by early September. The beetle overwinters as a fully grown grub and pupates in spring for 3–4 weeks. The pupae are caramel-brown in color and occupy cells in the soil (52).

A.9.3 Damage

The major injury to the palm is caused by the grubs, which feed on the roots, and bore into the underground bases and even the trunks. Severe damage is inflicted particularly to offshoots and young palms, in which the mortality rates may be very high. Mature and old palms, also, may be infested with grubs, which results in yellowing of the palms and reduction in yield. This rhinoceros species is an opportunistic feeder and easily survives by feeding on roots of grasses also (52). An attack by rhinoceros beetles may facilitate lethal secondary attacks by palm weevils (*Rhynchophorus* spp.) and by pathogens (15).

A.9.4 Natural enemies

So far, none has been recorded in Israel. Several arthropod parasitoids, such as scoliid wasps (Hymenoptera: Scoliidae), and predators such as carabid beetles (Coleoptera: Carabidae), attack rhinoceros beetles, but they seem to have little effect on *Oryctes* numbers (15).

A.9.5 Management and control

(i) Chemical control: Application of the organophosphate diazinon around the palm trunk at the beginning of August effectively controlled young borer larvae in date plantations in the Arava Valley of Israel (52).

(ii) Cultural and biological methods: Traditional methods of controlling rhinoceros beetles include removal of beetles from feeding holes in young palms and mass capture of adults in light traps (15,146). In the Philippines the effects of baculoviruses in suppressing populations of *O. rhinoceros* larvae have been studied since the mid-1980s. Introduction of the baculovirus into disease-free islands lowered the pest population density to 10–20% of the pre-release levels, and over 40% of the adult beetles became infected (147). Palm snags can play important roles, both in spreading the pathogen and in regulating *O. rhinoceros* populations.

A.10 Red palm weevil (red strip weevil, coconut weevil, Asiatic palm weevil), *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae)

A.10.1 Distribution and host range

The red palm weevil (RPW) originated in South–East Asia, where it attacks a wide range of tropical palms, including date, oil and coconut palms, and ornamentals; it is now widely distributed in Oceania, Asia, Africa, Europe (Spain) and the Middle East (63). The

weevil first appeared in the Middle East during the 1980s, since when it has caused severe damage to date production, destroying thousands of trees (108). It was first detected in Israel in 1999 (84); among all insect pests affecting date palms, it poses the most serious threat to date palms in the Middle East (38,132).

In Egypt during 1992–2000, over 216,000 infested palms were recorded, of which approximately 60,000 were removed (55).

A.10.2 Natural history

The adult is reddish-brown with a long proboscis that comprises one-third of the entire body length; it measures approximately 35 $\times$ 12 mm. The male weevil has a tuft of soft reddish-brown hairs. The egg is creamy white in color, long and oval in shape, and has an average size of 2.6 $\times$ 1.1 mm. The fully grown larva is a conical, legless, fleshy grub, measuring 50 $\times$ 20 mm on average. It appears yellowish brown, whereas the newly hatched larva is yellowish white, with a brown head; its mouth parts are well developed and strongly chitinized, enabling the grub to burrow into the palm trunk. The pupa is brown-white, with an average size of 15 $\times$ 35 mm. After emergence, the adult weevil stays inside the cocoon for $\sim$ 8 days, until attaining sexual maturity. The pre-oviposition period lasts 1–7 days, after which the female lays 300–500 eggs over a period of 8–10 weeks, in separate holes in the bases of young palm leaves, mainly in the soft damp tissues of wounds caused by cutting and by other pests such as rhinoceros beetles (*Oryctes* spp.). The RPW preferentially digs its burrows in the palm transport tissues and in the apical growing point. The eggs hatch in 2–5 days into legless grubs which bore into the interior of the palms, moving by peristaltic muscular contractions of the body, and feed on the soft succulent tissues, discarding all fibrous material. The larval period varies from 1 to 3 months. The grubs pupate in elongate, oval, cylindrical cocoons made out of fibrous strands. The pre-pupal and pupal stages last 3 and 12–20 days, respectively. At the end of 14–21 days of pupation the adult weevils emerge. Thus, the life cycle is approximately 4 months (63,108).

The adults live for 2–3 months and feed on the palm; they are not able to survive for more than 1 week without food. The threshold temperature for development ranges between 12° and 14°C. The weevils may fly relatively long distances, $\sim$1 km per day, usually in the daytime, and are active for most of the year (115).

Mating in RPW is mediated by an aggregation pheromone produced by the male weevil. The pheromone is composed of a major component – ferrugineol (4-methyl-5-nonanol), and a minor component – 4-methyl-5-nonanone (122). The adults are strongly lured by the combination of aggregation pheromone and volatiles secreted by palms. In Israel the weevil raises two generations each year (132).

A.10.3 Damage

The RPW is attracted to dying and damaged parts of palms, but also attacks undamaged palms. Visible symptoms of infestation are difficult to detect, because the penetration sites are usually covered with offshoots and fibers. Generally, infestation is detected only after the palm has been severely damaged. Careful observation may reveal several indications of the presence of the pest: holes in the crown or trunk, from which chewed-up fibers are ejected, sometimes accompanied by oozing brown viscous liquid; crunching noises produced by the feeding grubs; and the presence of a withered bud/crown. The immature stages develop within the trunk, destroying its vascular system (63). Heavily infested palms may contain 80 or more simultaneously developing larvae, and more than one generation may develop in the same palm (134). Infestation may adversely affect

the potential yield, lower the palm's growth rate, and eventually cause its collapse and death. Since its discovery in Israel, almost no economic damage – in terms of numbers of infested palms – was reported, either in date plantations or in any ornamental plants of the family Arecaceae. This is due to the efficient management practices conducted in Israel (see *A.10.5*).

A.10.4 Natural enemies

Reginald (127) reported a fortuitous occurrence of the predatory bug *Platymeris laevicollis* Distant (Reduviidae) which was imported into Sri Lanka for use against *Oryctes rhinoceros* (L.) and was found to prefer *R. ferrugineus*. In India various species of mites have been reported to be predators of the red palm weevil (124), but their harmful effects on the weevil are not known. Various pathogens are known to affect the weevil larvae (22,68). Laboratory studies found that several strains of the entomopathogenic fungus *Metarhizium anisopliae*, were highly virulent to larvae of the RPW (133).

A.10.5 Management and control

Efficient control of RPW can be achieved by combining several means, such as: prophylactic measures, chemical control, and routine monitoring with aggregation pheromone traps.

(i) Prophylactic measures

(a) Quarantine regulations: To prevent spread of the RPW to new plantations, strict quarantine regulations are recommended to prohibit the trade and transport of palms and offshoots outside the infested areas (38,132).

(b) Early detection of infestation: This is the most important stage in preventing distribution of the weevil, and the subsequent damage it can cause. Experimental data suggested that early detection can be achieved partially by: regular inspection and visual checking of the palms by experts; the use of trained dogs (110); or using sound equipment that amplifies the burrowing noises of the weevil larvae in palm offshoots (125,134). Emergence holes of adults in the trunk are a significant sign of infestation.

(c) Phytosanitation: Maintaining satisfactory phytosanitary conditions in the plantation is important and can be done by removing damaged palm parts, and burning or removing them.

(ii) Chemical control

Early symptoms of RPW damage are difficult to detect; therefore, emphasis generally is placed on prevention which, however, is not always possible. The common and most practical curative measure is the use of insecticides. Preventive and curative measures include: injection of systemic insecticides such as monocrotophos into the trunk (126); treatment of wounds with repellents and filling leaf axils with insecticide dusts, such as BHC or chlordane mixed with sand (104); and drenching of the crown of infested palms with insecticides (101). High mortality of RPW was obtained in the United Arab Emirates when the insecticides carbosulfan and pirimiphos-ethyl were injected into small date palms (*P. dactylifera*) that had been artificially infested with larvae (53). In India, trunk injections of fenthion or carbaryl, or use of Phostoxin tablets (aluminum phosphide, which releases phosphine) were effective (126). Applications of sevin (carbaryl) effectively controlled RPW in Indonesia (131). Successful prophylactic and curative experiments were conducted in Israel during the early 2000s. In the prophylactic treatments offshoots and trunk received applications of the organophosphates: azinphos methyl, diazinon and chlorpyriphos. The curative method involved trunk infusion with dichlorvos and/or soil

application of Confidor (imidacloprid). Laboratory experiments with potted young date palms indicated that imidacloprid was effective in preventing development of RPW larvae (133).

In Egypt during the years 1992–2000, more than 270 tons of insecticides were applied against the RPW. However, this intensive use of chemicals did not prevent the weevils from overtaking the plantations in the northern areas of the country (55).

A method to control RPW larvae on young date palm seedlings by disinfection with methyl bromide (bromomethane) has recently been developed in Israel (125).

(ii) Monitoring with aggregation-pheromone traps

Since 1999, traps baited with a combination of the synthetic aggregation pheromone of RPW and fruit volatiles have been used regularly in most of the date plantations in Israel for monitoring and mass trapping (132). The traps are loaded with the commercial pheromone Ferrugineol (4S5S-ferrugineol), supplemented with ethyl acetate and a fermenting mixture of dates and sugarcane molasses; they are posted at a high density of about ten traps per hectare (132). Approximately 700 weevils were caught in pheromone traps during 1999–2005; 72% of them were females. Significant decreases in the numbers of trapped beetles and of infested palms in Israel were observed during 2001 and the following years. No infested palms have been found since 2002, indicating a decrease in the RPW population (133). The decrease in the number of weevils caught in traps baited with aggregation pheromone since the initiation of the use of such traps, and the small number of infected palms recorded are attributed to the mass capture of adults in the traps. This finding suggested that pheromone traps might have played a significant role in the suppression of RPW populations in date plantations (132). Coping with RPW is especially difficult in the organic plantation, because of the lack of effective chemical compounds permitted for use in these plantations (66).

A.11 Date stone beetle, *Coccotrypes dactyliperda* Fabricius (Coleoptera: Scolytidae)

A.11.1 Distribution and host range

The date stone beetle (DSB) is widespread in most of the date-growing areas of the world: North America, North Africa, the Middle East and India (46,102). In Israel it is prevalent mainly in the Jordan and Bet She'an Valleys. It is also common in the Gaza strip. The absence of the DSB from date plantations in the Arava Valley, as well as from the northern areas of the Dead Sea, is probably due to the low humidity and low precipitation in those two regions, conditions that lead to desiccation of the date kernels, making them unsuitable for development of the beetle (10). Evidence of the presence of DSB, as well as other stored product pests, in the Dead Sea area in the past, was provided by the discovery of almost 2000-year-old date kernels from the Roman and Byzantine periods in archaeological excavations at Masada (99). This discovery is indicative of the long-established presence of the pest in the area. The date stone beetle is probably specific to the family Arecaceae (Palmae). Species belonging to 18 genera of palms have been reported as hosts for DSB (107).

A.11.2 Natural history

The adult beetle is elongate, 1.5–2.5 mm in length, chestnut-brown in color. The female is longer than the male (102). The reproduction mode is arrhenotoky, and females are predominant (85–93%) in both field and laboratory populations. The threshold temperature for development is 12.3°C. At 28°C the average egg incubation period is approximately 6

days, larval duration 12–15 days, and pupal development period 4 days. Development from egg to adult is slightly longer for females than for males: ∼25 and 22 days, respectively. The mean number of progeny per mated female (30.4) was significantly higher than that recorded for unmated females (6.6), but the latter lived significantly longer: approximately 73 and 63 days, respectively (34). During spring, early summer and summer (April to August), the DSB can develop three or four generations. Date fruits that fall to the ground from mid-June onwards are the most suitable for development of the beetles, which develop on fresh kernels of both mature and immature fruits, and of those that dried up during the summer and absorbed water during the rainy season. The beetle population level is, therefore, directly affected by the number of fresh kernels in the plantation (10).

A.11.3 Damage

The DSB is known as a primary pest of green, unripe date fruits. Considerable damage has been reported from North Africa, India and Israel (34,94). Observations of attacks on unripe fruits revealed that the beetles chewed a round hole, 2–3 mm deep, but rarely reached the seed. In most observed cases fluids coming from the wound ejected or even killed the boring individuals and thereby stopped the attack (10,34). The injured fruits usually drop from the bunches, but some of them remain and complete ripening. However, a scar is formed around the penetration site, rendering the infected fruits unmarketable. Yield losses as a result of the beetle attacks can reach 30–40% (88). Feeding on the unripe fruit contributes to maturation of the beetles; it is not clear whether the individual beetles benefit from feeding on the green fruits in the bunches, but the dropped unripe fruits serve for reproduction during periods when kernels are scarce (10). The beetles feed on the green fruits between May and July, and the fruit flesh is injured when the beetles fly to the fruit bunches to feed. In most cases the hole burrowed into the injured fruit does not reach the seed. A single female is able to injure several fruits and cause them to drop, before she penetrates the seed to reproduce. In Israel heavy damage was recorded in the following varieties: 'Khadrawy', 'Hayany', 'Helawy', 'Barhee', 'Zahidi' and 'Deglat Noor' (34). The damaged fallen fruits are also suitable for reproduction of sap beetles (Nitidulidae), and therefore support the build-up of the latter's population as early as midsummer. Damage caused by DSB may, therefore, indirectly enhance infestation of the fruit by sap beetles during the ripening season (August to October) (40).

A.11.4 Natural enemies

Not known.

A.11.5 Management and control

(i) Chemical control: An effective chemical control program for DSB would require several applications of organophosphate insecticides throughout the season. However, such a program is not acceptable, because it would interfere with the biological control in the date plantation (88). In fact, chemical treatments applied against other pests that attack the green unripe fruit, especially the lesser date moth, may contribute considerably to the control of DSB.

(ii) Agrotechnical measures: The removal of fallen dates and kernels from the plantation (phytosanitation) may reduce the level of the overwintering population of DSB and, consequently, the potential damage expected in the subsequent season (40).

A.12 Raisin moth, *Cadra* (= *Ephestia*) *figulilella* Gregson (Lepidoptera: Pyralidae)

A.12.1 Distribution and host range

The raisin moth (RM) is widely distributed in date plantations in California and in North Africa including Egypt (46). In California, the RM is a pest of the growing fruit only, whereas in North Africa and the Middle East it attacks the stored fruit (107). In Israel, especially in the Arava Valley, it is prevalent in most of the date plantations, where it attacks the ripening fruit.

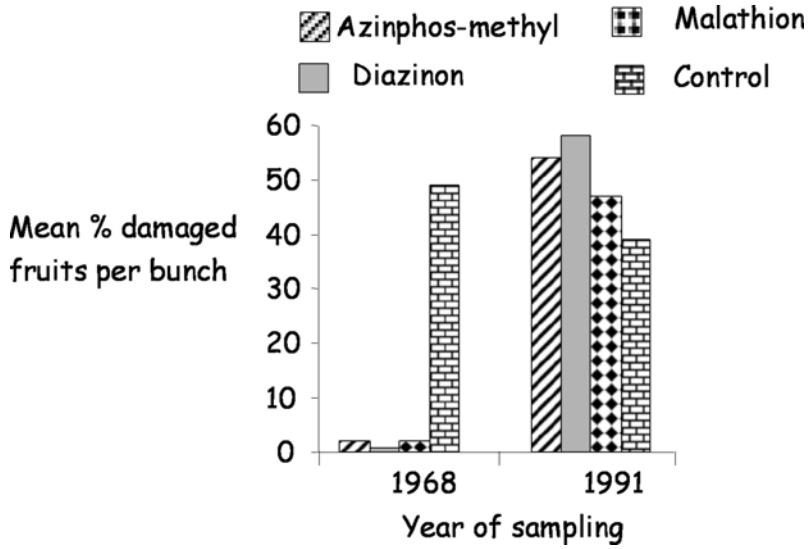

Fig. 2. Infestation of 'Deglat Noor' fruits with moth larvae (mainly of the raisin moth) in Yotvata plantation (southern Arava Valley) in 1968 and 1991. The data indicate the moth's development of resistance to organophosphate compounds.

A.12.2 Natural history

The adult RM is gray in color and ∼1 cm long, with a few obscure dark bands and spots on the forewings. The pupa is brown and is covered in a silken cocoon, which it spins in hiding places on the palm, in topsoil, or in convenient cracks. The adults are most active in the early evening and remain in shaded, protected areas during the day (46,92). If present, they can usually be found in hidden places in the date palm and in fallen fruits. The year-round presence of larvae in decaying fruits enables continuous development in the plantation without the need for alternative host plants. At 30°C, the RM requires 54 to 65 days for complete development. The female lays 100–200 eggs on the surface of the dates, most of them in the second and third day after her emergence. At 30°C, incubation of the eggs takes 3–4 days, and that of the larva and the pupa 51–61 days.

A.12.3 Damage

In Israel and the USA, the RM is considered an important pest of date fruits, both in the plantation and in storage (8,46,49). It attacks fruits still on the palms as they begin to ripen and, if the fruits are not fumigated, the larvae may feed in the dates and develop into adults even after harvest. Ripe fruits are attacked both on the ground and in bunches on the palms. The inside of the fruit is gnawed and filled with feces, and dead larvae are left in the fruit even after fumigation.

The larvae open the way for secondary organisms, and infestation rates may exceed

50%. Injury inflicted on the fruit within a relatively short period is of great economic importance and necessitates control measures. Larvae can be found year round in the plantation, in fallen and decaying fruits; fruits on bunches are attacked only after they are completely ripe (45,92,87).

A.12.4 Natural enemies

No specific parasitoids of RM have been reported in the literature. Several hymenopteran parasitoids were surveyed in a chilled fig warehouse in California; among them were *Habrobracon hebetor* (Say) (Braconidae), *Venturia canescens* (Gravenhorst) (Ichneumonidae), and a *Goniozus* Förster sp. (Bethylidae) (76).

A.12.5 Management and control

(i) Chemical control: The first experiments on controlling the RM were conducted in date plantations in Israel's southern Arava Valley in the late 1960s. Spraying with the organophosphates azinphosmethyl and diazinon, when the color of the fruit changed and again 3 weeks later, gave satisfactory control and reduced fruit damage considerably (87). However, the continuous use of these compounds created two problems: organophosphate residues on the harvested fruits, and development of resistance in the RM in the mid 1980s. Experiments indicated that a single treatment of azinphosmethyl during the season, instead of two, and washing the fruits in the packing house after harvest, significantly decreased the level of residues (37). In the early 1990s, after about 20 years of use, organophosphates lost their efficacy against date moths, a phenomenon that was reflected also in the development of resistance to the organophosphates used, and also in the raisin moth (Fig. 2) (33). Since then, pyrethroids such as cypermethrin and cyhalothrin have displaced the organophosphates in the management of all fruit moths that attack ripening fruits (33,139).

(ii) Agrotechnical measures: Several agrotechnical methods and crop management procedures have been developed and are currently employed in date plantations in Israel. These methods, developed mainly for enhancing profitability of the date palm crop, also indirectly play an important role in protecting the ripening date fruit from injury by various fruit pests, among which is the RM. The agrotechnical measures used were: covering fruit bunches with plastic nets, phytosanitation, and early harvesting.

Plastic nets were first used to protect the ripening date fruits from casual large pests, such as birds, lizards, etc. Later, various types of nets were used also to protect the ripening fruits from infestation by the raisin moth, the carob moth, the greater date moth, and sap beetles (33,87). Among the various types of covers tested, a 'regular' type of wire or plastic netting, with 2.0×2.0 mm mesh size, proved to be the most efficient agrotechnical measure for preventing damage by RM and other moth species (30,33,87). The fruit bunches are usually covered with nets in mid August when the fruit color starts to change. Besides protecting the date fruits from insect pests, the net also enables easy gathering of dates that drop before harvest time (87).

Phytosanitation, *i.e.*, maintaining a satisfactory phytosanitary level in the plantation, by removing waste, and especially fruit waste, from the ground helps to reduce RM damage, as well as that of other pest species that attack the ripening fruit. In some cases such sanitation is achieved by grazing animals, especially and mainly horses and donkeys, in date plantations (30).

Early harvesting has recently been applied to several date cultivars, such as 'Deglat Noor', 'Medjhool', 'Barhee' and 'Hayany' , with the aim of enhancing the growers'

incomes. This procedure was found very effective in preventing infestation and damage by all fruit moths (including RM) and sap beetles, since it shortens the period during which the ripening fruits are subjected to attack by each of the above pest species from 4 weeks to approximately 1 week. Thus, early fruit harvest of the above cultivars prevents, almost entirely, the need to use any control measures against pests that attack the ripening fruit (30).

In plantations where early fruit harvest is not usual, covering the bunches with 'regular' (2×2 mm mesh) plastic nets may provide good protection from infestation by fruit moths, but not from sap beetles, which can penetrate through these covers.

(iii) Sex pheromone traps: The results of preliminary field studies with synthetic RM sex pheromone in a date plantation in the southern Arava Valley in the early 1990s indicated that the pheromone component (Z,E)-9,12-tetradecadienyl acetate (Z9,E12-14:Ac), at a load of 1 mg, impregnated into a rubber dispenser, was most effective in attracting males of the moth to funnel traps of the IPS type (see A.8.5 subsection (*v*)). These traps serve as an effective tool for monitoring moth populations in the field, and for determining the necessity for and timing of insecticide application (91). It was found that pheromone strands of the moth *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae), whose acetate component is also the main pheromone component of RM, can be effective in mating disruption of RM (86).

A.13 Carob moth, *Spectrobates (= Ectomyelois) ceratoniae* (Zeller) (Lepidoptera: Pyralidae)

A.13.1 Distribution and host range

The carob moth (CM) is a polyphagous fruit pest widespread in many tropical and subtropical regions. It is known as a pest of citrus, dates, figs, carob and almonds in Mediterranean countries, of almonds in Australia, of citrus in South Africa, and of dates in California (69,111). It is also found in Florida, Central America and in northern South America and, as a pest of date palms, in North Africa (Algeria and Morocco) (46).

A.13.2 Natural history

The body length of the CM is 8–10 mm. Its wings are creamy white to gray, brownish, or even dark brown in color, with a spread of 22–24 mm; across their width there are two bright stripes with dark margins. The rear wings are white-gray with light-brown veins. The egg is elliptical and elongate in shape, measuring 0.75×0.5 mm; its color is white at oviposition, becoming brown-red later. The larva is pink, with brown head and front dorsum; its length can reach 15 mm; on its back are small dark-brown bumps.

The eggs hatch in 3–7 days. The larval stage may last from 1 to 8 months, and pupation usually occurs at the feeding sites of the larvae. In summer, the females start to oviposit the day after their emergence, and may lay 60 to 120 eggs during the adult lifespan of 3–6 days. Three to four generations are produced annually, in the approximate sequence of April–May, June–July, August–November, and November–March (46). Calcat (45) noted that only the last two of these generations develop on dates in the bunch. The CM can develop in dried fruits in storage. Mean development time from egg to adult ranges from 45 to 62 days according to fruit (almond) condition (111).

A.13.3 Damage

Damage by the CM in date plantations in Israel was first recorded during the late 1980s, in the southern Arava Valley (40).

A.13.4 Natural enemies

In southeast Morocco, CM is parasitized by hymenopteran parasitoids *Phanerotoma ocuralis* Kohl *[Phanerotoma leucobasis*] on the bunch and by *Bracon hebetor* on fallen fruits (71).

A.13.5 Management and control

Chemical control and agrotechnical measures applied for the raisin moth (section A.12) are also effective against the CM.

Sex pheromone traps: The sex pheromone of the CM was isolated and identified in 1989 (9). Preliminary trials with traps baited with this pheromone in date plantations in the southern Arava Valley in 1994, did not yield satisfactory results (86). ISCA Technologies Inc. (Riverside, CA, USA) (74) recently announced the successful synthesizing of carob moth mimic to attract the moths to monitoring traps in dates in California.

A.14 Greater date moth, *Arenipses sabella* Hampson (Lepidoptera: Pyralidae)

A.14.1 Distribution and host range

The greater date moth (GDM) generally occurs throughout the date-growing regions of North Africa, the Middle East and northern India (1,46,92,138). In Israel it is found in all date-growing areas, and so far the date palm is its only known host.

A.14.2 Natural history

The adult has gray wings, and its body length is 15–20 mm. The larvae are hairy; gray-black in color, and reach a length of 30–35 mm. Egg incubation lasts 4–5 days at 30°C. Development times of the larva and the pupa are each approximately 34–40 days. At 27°C adult survival is 7–8 days, and the female lays 200–400 eggs. Between April and September each year, four generations may develop. The spring generation is characterized by the massive population of larvae in April; larvae of the summer generation are found mainly in unripe fruits on the plantation floor, whereas those of the autumn generation are found in the ripening fruit on the bunches. Overwintering larvae can be found hidden at the base of the trunk and in fruits on the ground (46,92); they pupate in the following spring and establish the spring generation.

A.14.3 Damage

Damage is caused by both the spring and the summer generations. Larvae of the spring generation infest mainly tender fronds of young leaves; they feed upon inflorescences and immature dates, and burrow through fruit stalks at the point where the fruit strands arise. In addition to the burrows, which sometimes reach a depth of 10 cm, their activity can be recognized by the presence of considerable amounts of silken threads with dark brown pellets of frass attached to them. Attacked bunches gradually wither and degenerate. Larvae of the summer generation attack mainly the ripe dates; they burrow through the center of the date bunch, spoiling the entire bunch, which decays.

Damage to palms is more severe in the southern Arava Valley than in the northern valleys. The intensity of infestation fluctuates widely from year to year (92). In the northern area of the Dead Sea, high infestation rates were sometimes observed in female inflorescences that burst in male palms during the summer.

A.14.4 Natural enemies

Several species of the Braconidae parasitize the GDM (73). In Israel unidentified braconids were frequently observed in association with GDM during the high-density period of the moth. In Iraq, pseudoscorpions are abundant among the fibers at the bases of

petioles, and are thought to be important in the control of the caterpillars (73).

A.14.5 Management and control

(i) Chemical control: In most cases, infestation by *A. sabella* does not require a specific application of insecticides. Chemical treatments applied against the date stone beetle or the lesser date moth (see section A.15) during April–May may also be efficient in preventing damage by the spring generation of GDM. Likewise, treatments applied during September–October against other fruit moths and sap beetles, may also reduce GDM populations and their damage.

(ii) Agrotechnical measures: Covering bunches with plastic nets, phytosanitation activities, and early harvesting of certain varieties, almost entirely avert the need to use control measures against the GDM.

A.15 Lesser date moth, *Batrachedra amydraula* Meyerick (Lepidoptera: Batrachedridae)

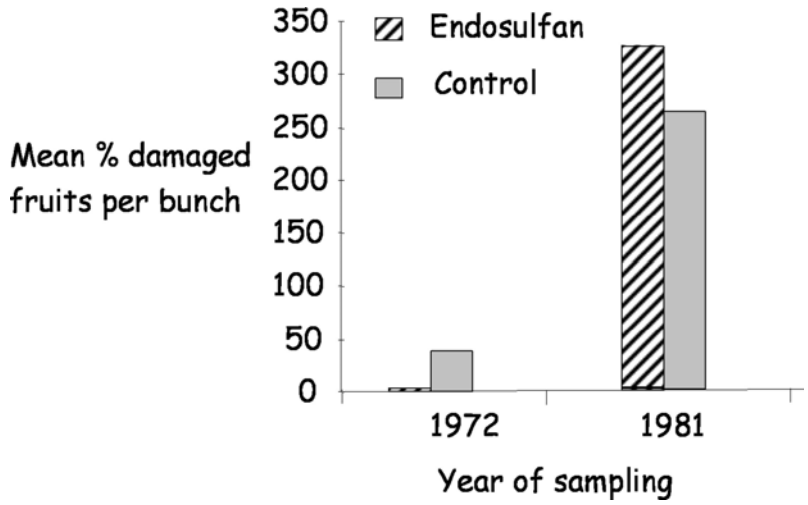

Fig. 3. Infestation of 'Deglat Noor' fruits by the lesser date moth, *Batrachedra amydraula* in Eilot plantation (Arava Valley) in 1972 and 1981. The data indicate the moth's development of resistance to thionex (endosulfan).

A.15.1 Distribution and host range

The lesser date moth (LDM) is distributed mainly in Libya, Egypt, Iran and Iraq (46). In Israel, it was first observed in 1970 in the Arava Valley, where it probably had invaded from the Sinai Peninsula (Egypt). In the following year, extreme damage was caused in two date plantations in the area: Eilot (southern Arava Valley) and En Gedi (Dead Sea region) (28). Since the 1980s, it has gradually spread throughout most of the date-growing plantations of the country, where it has become a major pest of newly set and young green date fruits. The LDM is highly specific to the date palm, and no reports are known of infestation of other host plants by this moth. Attempts to rear the moth on artificial diets in the laboratory were so far unsuccessful.

A.15.2 Natural history

The adult moth is gray-brown in color; its length is 8–10 mm, and its wingspan 11–14 mm. The wings are characterized by a marked longitudinal gray stripe in their center. The egg is white-yellow, with a diameter of 0.7 mm. The larva is white-gray and reaches a length of 12 mm.

Three annual generations of LDM were recorded in date plantations in the Arava Valley (142). Larvae of the first generation were observed in the field from late March to late April; those of the second generation, from early to late May; and those of the third generation from about mid- to end of June. During August the number of larvae observed in the field diminished considerably, and all were in the third stage. From the end of August no larvae or further damage were detected, nor were larvae found on bunches or on decaying fruit during autumn or winter. Thus, the occurrence of larvae and the damage they inflict on the trees are restricted to a relatively short period (April to early July) (142). Observations in the southern Arava Valley showed that LDM undergoes diapause in the larval stage. Larvae of the last generation of each year construct elongated white cocoons which are well hidden inside the fibers at the bases of the palm fronds; they apparently remain in this condition during the second half of the summer and the winter (late August to early March), pupate in the following spring (probably during early to mid March), and give rise to the first generation adults of the new year. The larvae of this first generation attack the newly set date fruits. The shortening of the insects' exposure to daylight during late summer is probably the main factor in inducing diapause in the larvae and, conversely, the increase in day length in early spring probably triggers the termination of the larval diapause (28).

A.15.3 Damage

The larvae attack newly formed inflorescences, but the main injury is to the young green fruits. Approximately 80% of the fruits are attacked while between 0.6 and 1.0 cm in diameter. The larva chews a hole near the calyx, through which it penetrates the fruit and feeds on the pulp and the soft immature seed. A damaged fruit is easily recognizable by the black feces attached to the penetration site. The larvae can move from fruit to fruit within the bunch, thus increasing the damage; a larva seldom eats more than one-third of a fruit before seeking another one, and can damage three or four fruits during its lifetime. About 4 weeks are required for the attacked fruits to darken, dry and fall to the ground. In severe infestation most of the infested fruits drop to the ground; the bunch ceases to grow, and then dries. Thus LDM injuries to the palms cause considerable fruit drop and losses of up to 75% of the yield (28,106). Late-season infestation of large fruits may cause fruit decay and fermentation, which may accelerate the build-up of sap beetle (Nitidulidae) populations.

A.15.4 Natural enemies

The parasitic wasp *Parasierola swirskiana* Argaman (Hymenoptera: Bethylidae) attacks the LDM. The parasitoid is common in date plantations in the Arava Valley, and is known also from Jordan and Afghanistan (4). In the Arava Valley the parasitoid was reared mainly from larvae of the second generation. Laboratory studies suggest that *P. swirskiana* is not an efficient control agent (51). *Bracon* sp. (Hymenoptera: Braconidae) attacks larvae of LDM as well as those of other fruit moths, but its contribution to the control of LDM has not yet been studied (40). Artificial releases of the egg parasitoid *Trichogramma cacoeciae* Marchal (Hymenoptera: Trichogrammatidae) and the entomophagous fungus *Beauveria bassiana* (Balsamo) Vuillemin (Deuteromycotina: Hyphomycetes) were tested against *B. amydraula* during the last decade (113), but so far have not shown any promise.

A.15.5 Management and control

(i) Chemical control: Among several insecticides tested against the LDM, endosulfan (thionex) was the most effective, and when the first application was timed with the first detection of infestation and the second 3–4 weeks later, the treatments usually provided season-long control and a marked yield improvement (44). In the early 1980s, however, the moth became resistant to endosulfan, which no longer provided satisfactory control (Fig. 1) (142), probably because of its excessive use (30). The growers replaced endosulfan with organo-
phosphates, mainly chlorpyriphos. Later, additional compounds, mostly IGRs such as triflumuron (Alsystin) and teflubenzuron (Molit), were added to the arsenal (30,139). A study conducted in 2006 revealed that in the Bet She'an Valley, triflumuron, applied with a mixture of date pollen during pollination, effectively controlled LDM larvae (S. Bitton, pers. comm,). In Egypt, in 1999 and 2000, spinosad (Tracer) at 10 ml 100 l^{-1} gave 94% and 86% control of *B. amydraula*, respectively (128).

(ii) Microbial control: Several commercial products based on the bacterium *Bacillus thuringiensis* Berliner (*Bt*) were found to be effective against the LDM, and they are used for control, mainly in organic plantations (112). These products are used either in spraying or in dusting formulations; the latter offers better capability of penetrating into the center of the date bunches (40). The compound Bitayon (Rimi Chemicals Co.), applied with a sub-species of the bacterium, *B. kurstaki,* or on feeding bait for the larva, was found effective in controlling the pest larvae (113), especially when applied together with the date pollen. The mixture of Bitayon and date pollen protects the young setting fruits against first generation moth larvae immediately at the time of pollination. The efficiency of *Bt* compounds is higher at the beginning of the season, when a larva consumes more than one fruit to complete its development. Later in the season, when the fruits are bigger, the larvae usually complete their development in a single date fruit, and are not exposed to the *Bt* compounds (30,40).

(iii) Biological control: An experiment conducted in the late 1990s, involving an inundating release of the egg parasitoid *T. cacoeciae*, at approximately 1000 adults per palm, together with an application of a commercial product of the fungus *B. bassiana*, indicated a potential for use of each of these two control agents against the moth (113; J. Nakash, pers. comm.).

In organic plantations the LDM is controlled by application of several permitted insecticides, such as *Bt* compounds and Kryocide (cryolite), which is an inorganic stomach and contact poison. Since 2001 in a young organic 'Hayany' plot at the Eden Experiment Station (Bet She'an Valley), and since 2005 in organic plantations in Samar (southern Arava Valley), experimental inundating releases of the egg parasitoid *T. cacoeciae* gave effective control of *B. amydraula* (J. Nakash, pers. comm.).

A.16 Spider mites (Acarina)

Several species of phytophagous mites damage date palms throughout the world (46). Mite infestation and damage to date palms were first recorded in Israel in the southern Arava Valley during the late 1970s (62,117). Several species of mites, belonging to two families, were found on date fruits, mainly of cv. 'Deglat Noor'. They were: *Raoiella indica* Hirst, *Phyllotetranychus aegyptiacus* Sayed, *Tenuipalpus pareriophyoides* Meyer and Gerson (all Tenuipalpidae, false spider mites); *Eutetranychus palmatus* Attiah,

Oligonychus afrasiaticus (McGregor) and *Oligonychus senegalensis* Gutierrez and Etienne (Tetranychidae, spider mites) (62). Only *O. afrasiaticus* and *E. palmatus* caused economic damage.

A.16a Old world date mite, *Oligonychus afrasiaticus* (McGregor)

A.16a.1 Distribution

This is a serious pest of dates in North Africa and the Near East (45,116). In Israel it is the dominant spider mite pest of date fruit in the southern Arava Valley (120).

A.16a.2 Natural history

The adult mite is 0.4 mm long, greenish in color, and the body bears 13 pairs of simple dorsal setae. The mites infest the fruits during the summer, as long as they are green. During a 1999–2002 survey of mites on 'Deglat Noor' and 'Barhee' date palms in the Arava Valley of Israel, other spider mites were rarely collected (118). Infestation of 'Medjhool' starts in early May, whereas infestation of 'Deglat Noor' was detected only during the first week of July. The initiation of infestation on 'Barhee' varied between plots and years, ranging from the second half of May to the beginning of July, but was always earlier than on 'Deglat Noor'. Mite populations on the pinnae remained low from June through October. The sex ratio of *O. afrasiaticus* on fruits of all cultivars was highly female-biased, usually above 0.85. The mite is not specific to date palms and was found also on Bermuda grass (*Cynodon dactylon*) in the orchard ground cover, as well as on fronds of all three above-mentioned cultivars (119).

A.16a.3 Damage

The mite feeds on the green fruits, causing them to become reddish-brown, and their skins to display numerous minute cracks that emit gum-like exudations. The mites remain active even at 45°C, and spin copious amounts of whitish webs in which dust accumulates. Heavy infestations can cause significant yield reductions, because the scars and the webs that are formed on the exocarp of the unripe fruits render them unfit even for processing, and thereby impair their commercial value (62,118).

A.16b Date palm mite, *Eutetranychus palmatus* Attiah

A.16b.1 Distribution

Prior to its discovery in Israel, *E. palmatus* had been known only from Egypt, where it was found on date palms (7). Recorded hosts included the Washington palm, *Washingtonia filifera,* the African doum palm, *Hyphaene thebaica,* the Canary Island date*, Phoenix canariensis* and the date palm, *Phoenix dactylifera*. In Israel it is distributed all over the Arava Valley, and also infests ornamental palms in the southernmost Israeli town of Elat (62; E. Palevsky, pers. comm.)

A.16b.2 Natural history

Eutetranychus palmatus is 0.4–0.5 mm long, reddish-brown in color; the body is oval and the legs are longer than the body. The eggs are round, pale brown in color. Sporadic observations indicated that *E. palmatus* occurs on date fronds throughout the year, infests the fruit during mid summer, and then, as the dates turn yellow, is restricted to the fronds. This species does not spin webs. Little is known about its biology (62).

A.16b.3 Damage

The mite is a minor pest of date fruits; its feeding results in exudates that become covered with dust, as well as with the shed whitish exuviae of the mites. It has been

suggested that, under certain conditions, *E. palmatus* should be considered a potential pest of date fruit, at least on cv. 'Barhee', and that it could become a more important pest in areas where *O. afrasiaticus* does not occur.

A.16b.4 Natural enemies

Not known.

A.16b.5 Management and control

Date growers in Israel have dusted fruit bunches prophylactically with sulfur since 1990. As many as five treatments per year were applied in the past, but the efficacy of sulfur has recently declined. Several alternative control techniques were investigated: reducing the density of the overwintering populations by burning tree trunks; deploying physical barriers to prevent ambulatory and airborne mites from reaching fruit bunches; and using indigenous phytoseiid mites to control the pest. None of these methods yielded satisfactory results (119). On the other hand, a single treatment with the acaricides fenbutatin oxide, hexythiazox, or abamectin, applied when the first mites were found on the fruit, provided seasonal pest control. A post-harvest re-hydration treatment, intended to mitigate any evidence of mite damage was also effective; it increased the amount of marketable fresh fruit of the economically important Medjool cultivar by approximately 20% (120).

In organic plantations mites are controlled by dusting the fruit bunches with sulfur compounds. The recommended steps for decreasing mite injuries include maintenance of highly phytosanitary conditions by methods such as eradication of weeds and removal of fruit waste and kernels, as well as control operations in the packing house after fruit harvesting.

B. PESTS OF RARE OCCURRENCE (OCCASIONAL AND/OR MINOR PESTS)

Pests clustered in this group are considered accidental or minor pests of the date palm in Israel (Table 2).

SYNTHESIS AND CONCLUSIONS

Since the early 1960s, major efforts have been dedicated to generating knowledge on the ecology of date palm pests in Israel and on means to manage them. Most of the major arthropod pests attacking the date palm in Israel are native to the Near East, and the key pests among them are host-specific. Those that display wide host ranges are either fruit pests or stem borers. This pattern of host-plant range is typical of the pest fauna of other native fruit trees such as stone fruits and olives (Table 1).

Chemical control

Outbreaks of scale insects in Israeli date plantations since the late 1950s resulted from the application of synthetic nonspecific insecticides, which led to adverse effects on their natural enemies. This had happened due to the application of organophosphates against invasive swarms of the desert locust, *Schistocerca gregaria,* or treatments with synthetic insecticides in the plantation or on adjacent field crops, such as cotton.

The seasonal outbreaks of the lesser date moth and date stone beetle on unripe fruits are related to insecticide applications during the previous season and the level of phytosanitation. Poor phytosanitation also may cause outbreaks of sap beetles and date stone beetle, which develop on the fruits and kernels on the plantation floor.

TABLE 2. Date palm pests of rare occurrence

Pest species	Remarks	References
1. ***Monolepta lepida*** Reiche (Coleoptera: Chrysomelidae)	Known as a pest of mango. Found on palms during April–June in most date-growing areas, attacking green fruit.	30, 137
2. ***Potosia angustata*** Germar (Coleoptera: Scarabaeidae) (flower chafer)	Damaging fruits of litchee, pear, and graftings of avocado. Larvae were found at the base of date palm leaves in the Coastal Plain.	75
3. ***Chrysomphalus aonidum*** Linnaeus (Coccoidea: Diaspididae) (Florida red scale)		137
4. ***Vespa orientalis*** Linnaeus (Hymenoptera: Vespidae) (Oriental hornet)		137
5. ***Cadra*** (=*Ephestia*) ***calidella*** Guenée (Lepidoptera: Pyralidae) (dried fruit moth)	Mainly known as stored-product pest	8, 46, 107
6. ***Cadra cautella*** Walker (Lepidoptera: Pyralidae) (almond moth)	Mainly known as stored-product pest	8, 46, 107
7. ***Cadra elutella*** Hübner (Lepidoptera: Pyralidae) (cacao moth)	Mainly known as stored-product pest	8, 46, 107
8. ***Plodia interpunctella*** (Hübner) (Lepidoptera: Pyralidae) (Indian meal moth)	Mainly known as stored-product pest	8, 46, 107
9. ***Pseudophilus testaceus*** Gahan (=*Jebusaea hammerschmidti*) (Coleoptera: Cerambycidae) (date palm trunk borer)		30
10. ***Prionus unipectinatus*** White (Coleoptera: Cerambycidae)		30
11. ***Acanthophorus arabicus*** Thomson (Coleoptera: Cerambycidae)	This species develops in the trunks of date palms. Found in the Arava Valley and the northern areas of the Dead Sea	30
12. ***Antipa nigrocincta*** Lacordaire (Coleoptera: Chrysomelidae)	Adults of this beetle were observed in 2001, on date inflorescences in the Bet She'an Valley	30
13. ***Apate monachus*** Fabricius (Coleoptera: Bostrychidae) (black borer)		30
14. **Thrips** (Thysanoptera: Thripidae)	Three species were collected from date flowers in the Coastal Plain: ***Holarthrothrips josephi*** Bhatti; ***H. tenuicornis*** Bagnall; ***Palmiothrips palmae*** (Ramakrishna). Damage to the palms was never recorded.	L.A. Mound (pers. comm.)
15. **Termites** (Isoptera)	***Microcerotermes diversus*** Sil. was reported from date palm. Minor damage by termites (probably of the genus ***Reticulitermes*** Rossi) was recently reported in young date palms in the northern areas of the Dead Sea.	8; S. Bitton (pers. comm.)

Integrated Pest Management

An IPM program was developed in date plantations in Israel during the second half of the 20^{th} Century. It was first implemented successfully against the parlatoria date scale, and later against fruit pests, also with satisfactory results (30,97).

In most cases date palm pests can be controlled efficiently by chemical insecticides. During the 1960s and 1970s, date growers used non-selective insecticides, mainly organophosphate compounds, as a routine measure for the control of scale insects, fruit moths and sap beetles. Since the early 1980s, selective insecticides gradually replaced the non-selective ones. They included mineral oils, IGRs, pyrethroids, carbamates, nicotinoids and acaricides – all considered to be selective compounds, 'friendly' to the environment, and less toxic to humans. Chemical treatments can be effective against several pests simultaneously. Thus, for example, insecticides applied during April to June can efficiently control the lesser date moth, the date stone beetle and the greater date moth. Similarly, insecticides applied during mid August to late October can efficiently control fruit moths and sap beetles that attack the date fruits during the ripening season (30). This procedure may, therefore, prevent unnecessary applications of insecticides. Fruit moths and beetle pests are not well controlled by biological agents. Most of these are cryptic feeding species and are protected from contact insecticides (30). Hence, chemical control of these pests is aimed at preventing an attack rather than reducing their population by direct control.

Decades of upgrading the chemical treatments have resulted in a decrease in the overall amount of insecticide residues in the ripening fruits at harvest time. This was achieved by: (i) improving application precision so as to enable reduction of the chemical concentration, *e.g.* from 0.5% to 0.01–0.02%, and lowering the number of treatments applied during the growing season, from two or more to one; and (ii) washing the fruit in the packing house (89,93). Nevertheless, in spite of the significant reduction of azinphosmethyl residues in the harvested fruits, the use of this compound and others of the same group was banned under the regulations issued in 2002 by the European Trade Corporations (EUREP-GAP) (57). This new situation called for the examination of alternative compounds to replace those that were no longer permitted (30).

Agrotechnical measures, such as the use of plastic nets to cover the fruit bunches at the beginning of the ripening season, maintaining a satisfactory level of phytosanitation in the plantation, and early fruit harvest of certain date cultivars, all constitute an important part of the IPM program.

Biological control

Biological control of most of the major date palm pests is problematic. The reason is the paucity of local natural enemies; some usually are not host-specific and are not effective. An exception is the case of the parlatoria date scale, biological control of which was achieved by intentional manipulation and management of local natural enemies. However, this is true only as long as the use of chemical treatments is considerably reduced. The parlatoria date scale represents the only example of achievement of successful control of a date palm pest in Israel by manipulation of local natural enemies. Trials to introduce natural enemies of sap beetles and acclimatize them in date plantations were not successful (40).

With regard to application of microbial products such as *Bacillus thuringiensis* (*Bt*): these were found to be useful against lepidopterous insects, either in spraying or in dusting formulations (112). In local plantations, commercial *Bt* preparations are used against the

lesser date moth, mainly in organic plantations.

Pheromones

Traps baited with synthetic sex pheromones are commercially available for use against the raisin moth (123) and the carob moth (74). However, the use of these pheromones for monitoring and control (96) became almost unnecessary because of the successful application of nettings, or of the early harvest procedure that is widely used in date plantations. Traps baited with aggregation pheromones are commercially available for use against the red palm weevil and in Israel they have been used since 1999 for preventive and monitoring purposes (132). For sap beetles, aggregation pheromones are commercially available; however, this group of insects needs more study before a suitable monitoring and mass-trapping system can be developed that could be commercially employed in date plantations in Israel.

Prospects

No satisfactory solutions are yet available for some of the major pests, especially the lesser date moth, sap beetles (in all areas where there are date plantations) and spider mites (in the Arava Valley). The control of the remaining major pests depends greatly on their abundance and the amount of damage they cause. An exception is the red palm weevil, which has the potential to inflict very extensive damage, and which therefore necessitates preventive measures on a regular basis.

In the coming decade the date growers in Israel will need to cope with several different challenges. Because of the banning of the routinely applied insecticides, the damage inflicted by the lesser date moth is likely to increase. Therefore, future management of this pest should rely on an improved monitoring system and integration of pheromone applications in the form of mating disruption or lure and kill techniques, with employment of biological agents and techniques such as inundating releases of egg parasitoids, *e.g. T. cacoeciae*, and entomopathogenic fungi, *e.g. B. bassiana*. Since the control of sap beetles is still problematic, the R&D efforts should focus on: (i) re-examination of entire-bunch netting; (ii) upgrading the use of aggregation pheromones in mass trapping and lure and kill techniques; and (iii) placing more emphasis on botanical insecticides and micro-organism-based formulations. The red palm weevil still poses a major threat, not only because of its aggressiveness, but especially because of the intensive use of systemic insecticides as protective measures. Intensive monitoring is required in all date palm areas.

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