Chapter 1

Insect Pests of Date Palm

1 Insect Pests of Date Palm

1.1. Order: Homoptera

1.1.1. Dubas Bug
(Old World Date Bug)

***Ommatissus lybicus* Bergevin**
(Hemiptera: Tropiduchidae)

Fieber (1875) was the first entomologist to describe and name species of the genus '*Ommatissus*' as *Ommatissus binotatus* from *Chamaerops humilis* palm, which grew as an ornamental plant in Spain and throughout the Mediterranean countries. Alfieri (1934) in Egypt, noticed and reported the first outbreak of Dubas bug on date palms in Oasis of Siwa. As well, in Iraq Dowson (1936) mentioned that it was a serious damage and attack of Dubas bug on seven million date palms in Basrah area.

De Bergevin (1930) described specimens of Dubas bugs collected from date palms in Siwa oasis in Egypt and gave it the name *Ommatissus binotatus* var. *lybicus*. This name continued until Asche and Wilson (1989) conducted a classification study of the genus '*Ommatissus*' and described four new species. They classified as species what was previously considered varieties. Thus, the current scientific name of the Dubas bug is "*Ommatissus lybicus* Bergevin". The Dubas bug is also known as "Old

World Date Palm Bug" as date palms are the main host of this insect. However, it can also infest some species of ornamental palms.

Distribution

Dubas bug, *Ommatissus lybicus* Bergevin, is distributed in North Africa (Morocco, Algeria, Tunisia, Libya and Egypt), Sudan, Iran, and Spain. In addition, it is widespread in Iraq, Kuwait, Bahrain, Qatar, Saudi Arabia, the United Arab Emirates and the Sultanate of Oman causing serious damage to date palms, (Waller and Bridge, 1978) and (El-Haidari, 1982).

Economic Importance

Dubas bug (Dubas = honeydew in Arabic), *O. lybicus* (Homoptera: Tropiduchidae), is a monophagous species in Oman that is considered as the most destructive sucking insect pest attacking date palms. This pest causes many direct and indirect damages to an infested date palm and nearby trees. The direct damages of this pest arise when the nymph stages and adults feed by sucking the sap from fronds (the green leaflets and rachis) and bunches (stalks, spikes and the fruits) in spring and autumn. While feeding, both the nymphs and adults excrete a thick substance or honeydew, Figs 1.1 and 1.2. However, the indirect damage caused by the females during depositing their eggs inside the tissue of the biaxial frond surfaces, seems to be as important as that caused by their feeding. Date palms infested with Dubas bug are easily recognised by the insect's copious honeydew production, which gives the Dubas bug its common name, i.e. in Arabic "dibs" means viscous syrup. The honeydew covers the fronds and fruit bunches and sometimes flows down to the trunks, and drops onto plants below the palms. The honeydew is rich in carbohydrates and low nitrogenous compounds. Data in Table 1.1 clarify the chemical composition of the honeydew secreted by nymphs and adults of Dubas bug.

Fig. 1.1. Honeydew secreted by nymphs and adults stages of Dubas bug.
Note how the honeydew almost completely covers the surface of the leaflets.

Fig. 1.2. A large drop of honeydew.

Fig. 1.3. Black sooty mould growth on honeydew.

Table 1.1. Chemical composition of the honeydew (Dibs) secreted by Dubas bug.

Compound	Concentration %	Compound	Concentration mg / kg
Nitrogen	0.21	Potassium	3649 - 4605
Proteins	1.30	Sodium	719 - 744
Reduced-sugars	< 2.0 - 4.5	Phosphorus	238 - 272
Sucrose	86.1 - 91.9	Calcium	378 - 472
Tri-oligosaccharides	3.0 - 3.8	Magnesium	198 - 213
		Iron	94 - 129
		Copper	1.4
		Zinc	< 0.1
		Manganese	< 0.1

On the other hand, the indirect damages arise from the growth of "sooty mould" on the honeydew, which is a suitable medium for fungal growth, Fig. 1.3. Dust particles affix to the honeydew covering the plant with thick layers of dust, which hinder the processes of photosynthesis, respiration and evaporation in the infested palms. This leads to weakening of the palms and change the colour of the affected fronds from green to yellowish green.

In addition to the above the dates from the affected bunches are slow to ripe and are smaller than normal dates because of the retarded development with lower sugar content. This contamination with honeydew and the attached dust, lower the marketable value of dates. The damages also extended to the surrounding plants grown under the date palms, as the honeydew droplets fall on them and on the ground. Moreover, Dubas bug causes nuisance to the farmers taking care of the date palms because of the stickiness of the honeydew excreted. Eventually, consecutive severe infestations year after year lead to great losses in the crop and decline of the infested date palms.

Fig. 1.4. Nymphs exuviae clustered on leaflets.

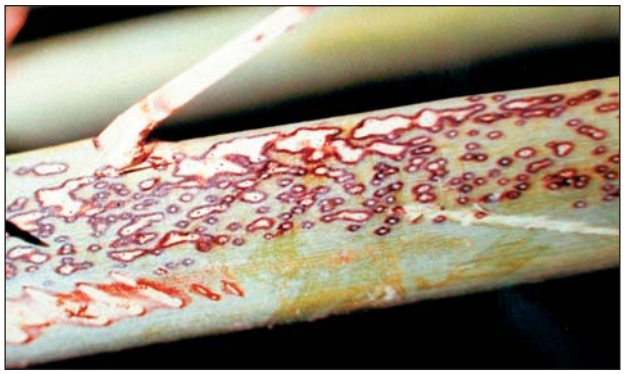

Fig. 1.5. The damage caused by the saw-toothed ovipositor.

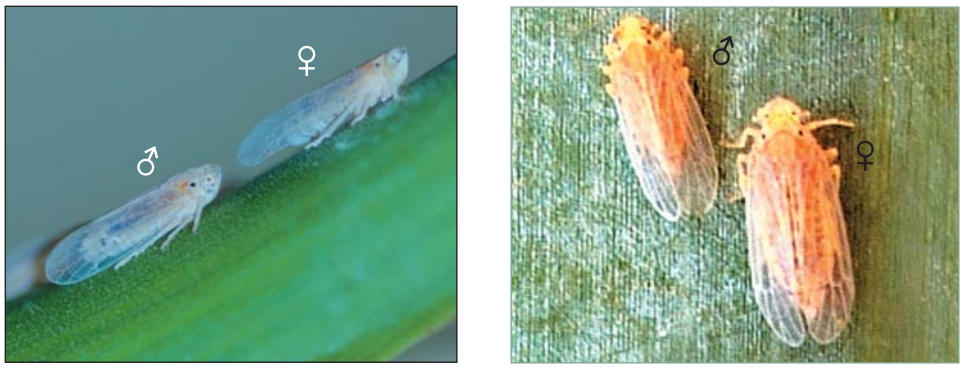

Fig. 1.6. Male and female of Dubas bug.

There are two visible key signs of infestation: the presence of exuviae clustered on the frond leaflets and egg depositing sites, as shown in Figs 1.4 and 1.5. The female of Dubas bug lays large numbers of eggs, (average of 140 eggs per female), on the midrib of the frond by inserting its saw-toothed ovipositor inside the plant tissues and borrows lane tunnels. Each tunnel is about 0.4 to 0.5 mm deep and containing only one egg. The top of the egg usually protrudes from the tunnel. Moreover, necrotic areas develop on the surface of fronds due to the development of scars caused during oviposition. The damages done in the frond tissue by the ovipositors and the egg depositing sites can be easily seen.

General Description

The adult is yellowish brown to greenish. The females distinguished by a strongly toothed-saw like ovipositor and are usually longer than the males, reaching 5-6 mm length compared to 3-3.5 mm of males. There are two black spots on the front of the heads of both sexes. The male is distinctive by its wings that are longer than its body and the pointed abdominal end as shown in Figs. 1.6 and 1.7. The egg is ellipsoidal with the anterior pole sharp and the posterior one rounded; the ventral surface is somewhat concave while the dorsal one is convex. Anteriorly, it has a large, subcircular respiratory area with the operculum and a short respiratory horn, Fig. 1.8. The egg is 0.5 to 0.8 mm long and 0.28 to 0.32 mm wide. At oviposition, it is light green in colour, but during embryonal development its colour turns to yellowish white, then bright yellow before hatching.

The nymph stage has five instars, each of which is yellow to greenish yellow. The five nymphal instars can be differentiated by the lengths of the wing buds (Hussain, 1985). Table 1.2 illustrates the general description of each of these five instars and the length of the wing bud in each instar.

There is a bunch of 6 to 24 long waxy caudal filaments at the end of nymph body, each about 3 mm long, Fig. 1.9. Al-Abbasi (1988) used the number of the waxy caudal filaments to differentiate between the five instars of the nymph stage as shown in Table 1.3. He also mentioned that the number of dorsal grey lines may assist in differentiation between the five instars and distinguish between male and female nymphs can be observed by the

Fig. 1.7. The adult male and female of Dubas bug under the stereomicroscope.

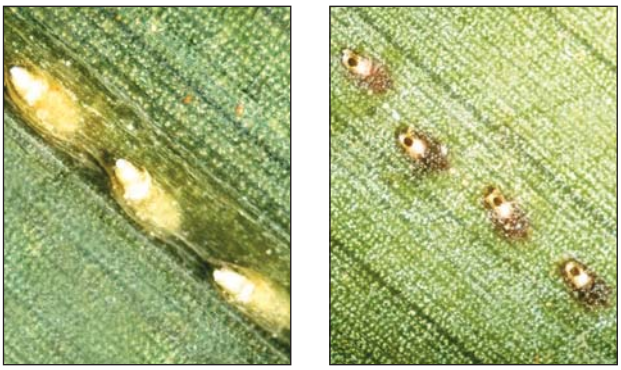

Fig. 1.8. Dubas bug eggs inside frond tissues, before and after hatching.

presence of the orange body on the abdomen of the male. Meanwhile, Abdallah *et al*. (1998a) indicated that one could rely upon the distribution of dots and dotted lines on the thorax and abdomen as well as the length of the wing buds to distinguish between the five instars of Dubas bug nymphs. As shown in Fig. 1.10, the following can be noticed in the five instars:

• **First instar:** There are dark brown batches on each side of thorax and abdominal segments. There are no lines on the dorsal surface of either the thorax or the abdomen. Body length 1.00 - 1.25 mm.

• **Second instar:** The early appearance of dark brown dotted lines as two parallel lines on the dorsal surface of the abdomen. Body length 1.30 - 1.70 mm.

• **Third instar:** These two dotted lines longitudinal on the dorsal surface of thoracic and abdominal segments. Body length 2.00 - 2.28 mm.

• **Fourth instar:** There are three lines on each side of the thorax. Body length 2.50 - 2.80 mm.

• **Fifth instar:** The buds of the first wings cover both the buds of the second wings and the third abdominal segment. Body length 3.00 - 3.50 mm.

Fig. 1.9. Bunch of the long waxy caudal filaments at the end of nymph body.

Table 1.2. The general description of the nymph instars.

Nymphal Instar	Wing Buds	General Description	Length (mm)
1st	Not present	White in colour with 3 dark black spots on the sides of the abdominal segments and with red compound eyes.	1.00 - 1.25
2nd	Present and directed downward.	White in colour with two blackish strands on the dorsal side of the body.	1.30 - 1.70
3rd	The wing buds cover the first segment entirely and part of the second segment.		2.00 - 2.28
4th	The wing buds cover the first and second segments completely, and part of the third segment.		2.50 - 2.80
5th	The wing buds cover the first, second and third abdominal segments completely and part of the fourth segment.		3.00 - 3.50

Table 1.3. Numbers of the waxy caudal filaments and the dorsal thoracic lines in nymph instars of Dubas bug.

Nymphal Instar	No. of waxy caudal filaments	No. of dorsal thoracic lines
1st	6	Nil
2nd	10	
3rd	16	2
4th	20	3
5th	24	

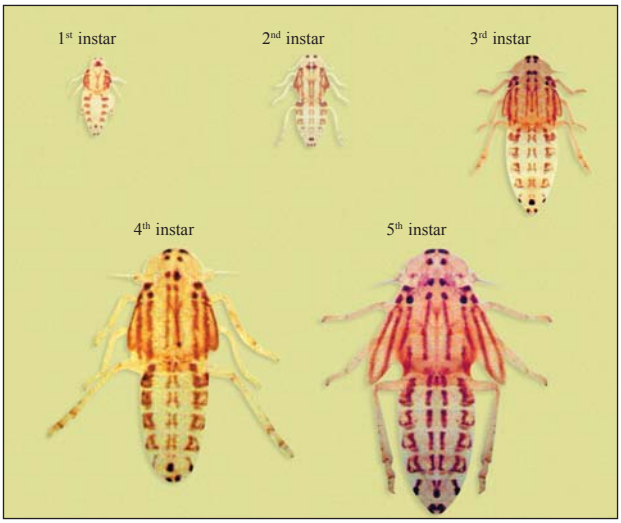

Fig. 1.10. The five nymphal instars of Dubas bug, *O. lybicus*

Life Cycle

Dubas bug, *O. lybicus*, is a bivoltine species and over winters has in the egg stage. It has spring and autumn generations each year. It was observed that the time of seasonal occurrence of each generation and the duration of each form; differing from country to country and regionally within the same country, according to the prevailing weather conditions. El-Haidary and Al-Tigany (1977) and El-Haidary (1979) found that the Dubas bugs start laying eggs in Oman and the United Arab Emirates 20-30 or more days earlier than in Iraq. The third, fourth and fifth frond whorl of the date palm fronds are the preferred sites for Dubas bug to lay eggs as it contains 76% of the total laid eggs compared to 24% found on the interior frond whorl. The nymphs of Dubas bug emerge in small numbers during early hatching, both in autumn or spring generations. The rate of hatching increases gradually day by day to reach up to 75% one month after first hatching.

• Spring Generation

The eggs, which lay in the autumn generation in October, start to hatch early February, in Oman, with some variations depending upon the prevailing climate conditions. The incubation period takes an average of 95 days. After hatching, the first instar nymphs of the spring generation emerge and start feeding avariciously by sucking the sap of young green leaves.

Abdallah *et al*. (1998a) reported that the total nymph duration of the spring generation lasts from 45 to 52 days with an average of 48.4 days. The average duration of the five consecutive nymph instars are 8.8, 8.8, 7.9, 10.1 and 12.4 days, respectively. Then the nymph transforms into an adult insect. Shortly thereafter, the female insects start laying eggs from the second week of April and continue laying eggs until the last week of June. The life span of the adult stage takes 82 days for the male and 72 days for the female, during which one female can lays up to 143 eggs.

Mokhtar *et al*. (2001a) reported that the female of Dubas bug in spring generation prefers to lay eggs on the fifth frond whorl from the top, which provides better protection for the eggs from the sunlight during the summer season, while during the autumn generation the insect females prefer to lay their eggs on the third frond whorl.

• Autumn Generation

The eggs, which lay in mid-April by the spring generation females, start to hatch in the second half of August and early September with slight variations between regions, depending on the prevailing climate conditions, with the incubation period taking an average of 120 days. The total lifetime of the five nymphs instars ranges from 37 to 47

days with an average of 44 days. The average duration of the five consecutive nymph instars are 6, 10, 7, 9, and 12 days, respectively. Then the nymph transforms into an adult insect where the female starts to lay eggs from the first week of October.

Behaviour of Nymphs and Adults

The nymphs of Dubas bug move little while sucking the sap from the green tissues and fruits, and from time to time they move the bunch of the waxy caudal filaments at the end of the abdomen. When sensing danger nymphs have a peculiar behaviour: they jump fast and for short distances, which may reach up to 50 cm for one jump. The nymphs prefer the shaded parts of the date palm and avoid the dry or dusty parts. They are present all-over the palm without preference but migrate to the innermost parts of the palm, hiding between the leaf sheaths and frond bases to escape the summer heat during the hottest hours of the daytime. During the evening to early morning, they redistribute themselves on the leaves and fronds.

The adults of Dubas bug prefer the shaded parts of the date palm tree and migrate, like the nymphs, to the central fronds of the crown of the palm when the temperature rises in the summer days, Fig. 1.11. Flock of adult insects can be seen gathering on certain parts like spathes and rachis to lay their eggs preferring the leaflets. The female starts laying its eggs in slits made inside the tissues of the leaves. The slits are done by the cutlass-like ovipositor, which looks like two saws at the end of the abdomen of the female. The diameter of each slit is about 0.2 mm, and it is 0.4 - 0.5 mm deep. The female lays one egg in each slit with the top end protruding outside the slit. Eggs are laid one by one in rows on all the green tissues, on stalks, fronds, rachis, pinnae, and spines, but they do not lay their eggs on the fruits. Just before hatching, the colour of the egg changes from pale yellow to transparent yellow and the two red compound eyes of the nymph can be seen underneath this transparent eggshell. To hatch, the nymph uses the hatching spike found on its head to push against the suture on the top end of the egg to separate from the shell to emerge.

Fig. 1.11. Adults of Dubas bug clustered to hide from sun heat

Relationship Between Population Density of Dubas Bug and Honeydew

Mokhtar *et al*. (2001b) studied the relation between the population density of different stages of the Dubas bug and the average number of honeydew droplets produced using a special water sensitive papers to collect and count the number of honeydew droplets that fall under the date palm trees. They found a positive proportional relation between the honeydew secretions and the population density of Dubas bug.

• Autumn Generation

Fig. 1.12 shows the population density of the Dubas bug estimated by the average count of the insects on the date palm leaflet and the corresponding number of honeydew droplets found on the water sensitive paper, during the autumn generation in the interior region of Oman. Through field studies, the presence of the first instar nymphs was recorded approximately from mid-September. However at this time the honeydew droplets cannot be detected because of their minute size. The honeydew droplets can be observed starting from the fourth week after egg hatching, i.e. early October.

The highest number of honeydew droplets counted in the autumn generation was in the ninth week after egg hatching. It was 24.5 droplets per paper per hour and corresponded to the highest count of insects on the date palm, 6.2 insects per palm leaflet. Here, the fourth and fifth nymph instars were the dominant among the insect population, representing 42 % and 34 % of population, respectively. These two nymph instars, the fourth and the fifth, are the most active stages in secreting the honeydew. It was also observed that the number of honeydew droplets markedly decreased with the increase of the percentage of the adult insects in the insect population, until the secretions stop completely in week 23 after hatching. This is because the adult insects secrete much less honeydew than the nymphs do, as most of their energies are directed to mating and reproduction.

The honeydew secretion is also related to the feeding activity because of the relation between the amount of plant sap sucked and the amount of honeydew secreted. So, the nymphs are feeding more than the adults and thus causing more immediate damages. The presence of the various stages of Dubas bug insects in the field during the autumn generation is shown in Fig. 1.13. The nymphs of the first to fifth instar were present in the field for 12, 11, 12, 14 and 18 weeks, respectively, in the autumn generation. The first appearance of the adult male insect was in the eighth week after eggs hatching and continued for 15 weeks. The adult female insects started to appear from the ninth week after the start of eggs hatching and lasted for 14 weeks. Based on these data, the pest control measures in the autumn generation should start in the eighth week from the start of eggs hatching.

• Spring Generation

Fig. 1.14 shows the population density of the Dubas bug in the spring generation estimated by the average count of Dubas insects on the date palm leaflet and the corresponding number of honeydew droplets. Through field studies, it was possible to record the presence of the first instar nymphs starting from approximately mid-February. Also, the honeydew droplets at that time cannot be detected because of their minute size. They can be observed starting from the third week after hatching, i.e. early March. The average count of the honeydew droplets was 32 droplets per paper per hour, which corresponded to 7.2 nymphs per leaflet at interior region of Oman (Mokhtar *et al*., 2001c).

The highest number of honeydew droplets counted in the spring generation in the same study was in the sixth week after hatching. It was an average number of 75.2 droplets per paper per hour and corresponded to the highest count of insects on the date palm, 15.3 insects per date palm leaflet. Here, the second and third nymph instars dominated the insect population, representing 23 % and 49 % of population, respectively. These two nymphal instars, the fourth and the fifth, were the most active in secreting honeydew. It was also observed that the number of honeydew droplets markedly decreased with the increase in the percentage of the adult insects in the insect population, until the secretions completely stopped in week 18 after hatching.

Fig. 1.15 shows that the nymphs of the first to fifth instars were present in the field for 9, 8, 8, 10 and 11 weeks, respectively, in the spring generation. The first appearance of the adult male insect was in the seventh week after hatching and continued for 17 weeks. The adult female insects started to appear from the eighth week after the start of hatching and continued until week 18. This means that both adult male and female insects coexisted in the field for 11 months. It is important to note that determining the appearance time of the adult female is crucial as it specifies the time of oviposition and reproduction. The pest control measures against the Dubas bug insects should start before that event. Based on the above data, the pest control measures in the spring generation should start in the seventh week after the start of eggs hatching.

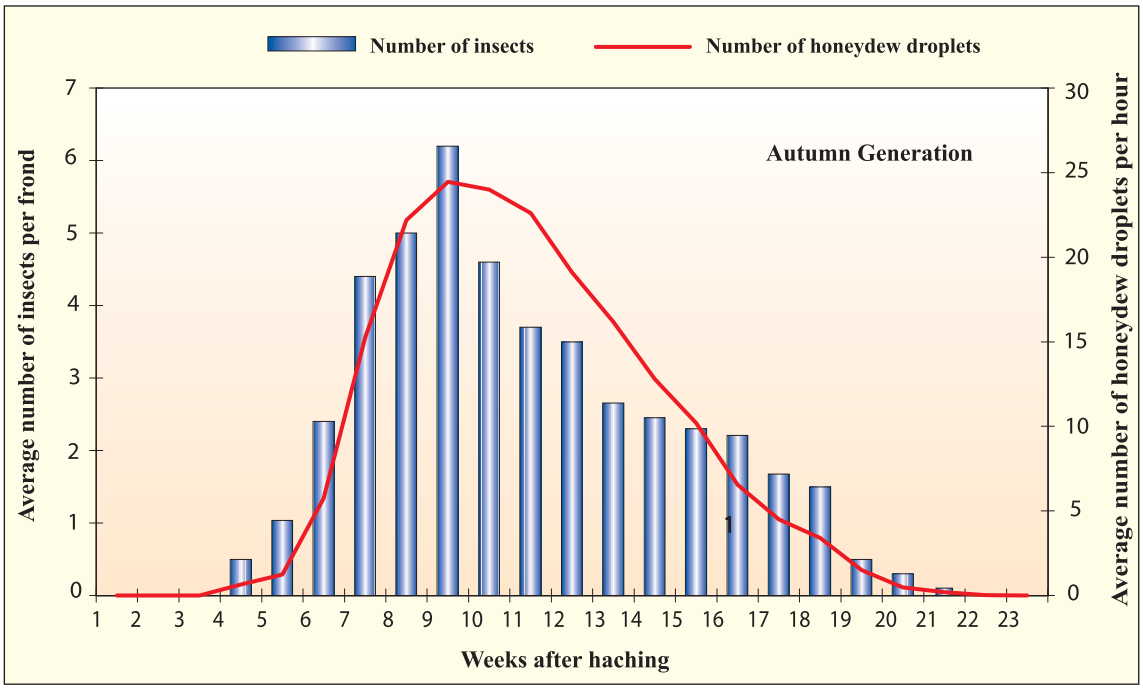

Fig. 1.12. The population density of the Dubas bug, estimated by the average number of insects on frond and corresponding numbers of honeydew droplets on sensitive test papers during autumn generation.

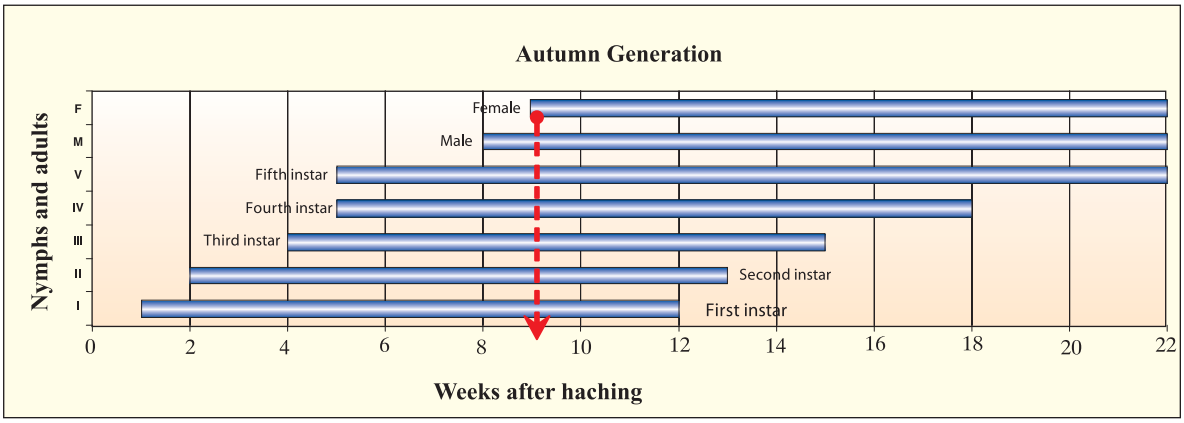

Fig. 1.13. Timeline chart: Showing the periods of different stages of Dubas bug in the field during the autumn generation (in weeks) starting from the day of eggs hatched.

N.B. The arrow indicates the time of appearance of the adult females of Dubas bug; the time just before which any successful pest controls measures should start.

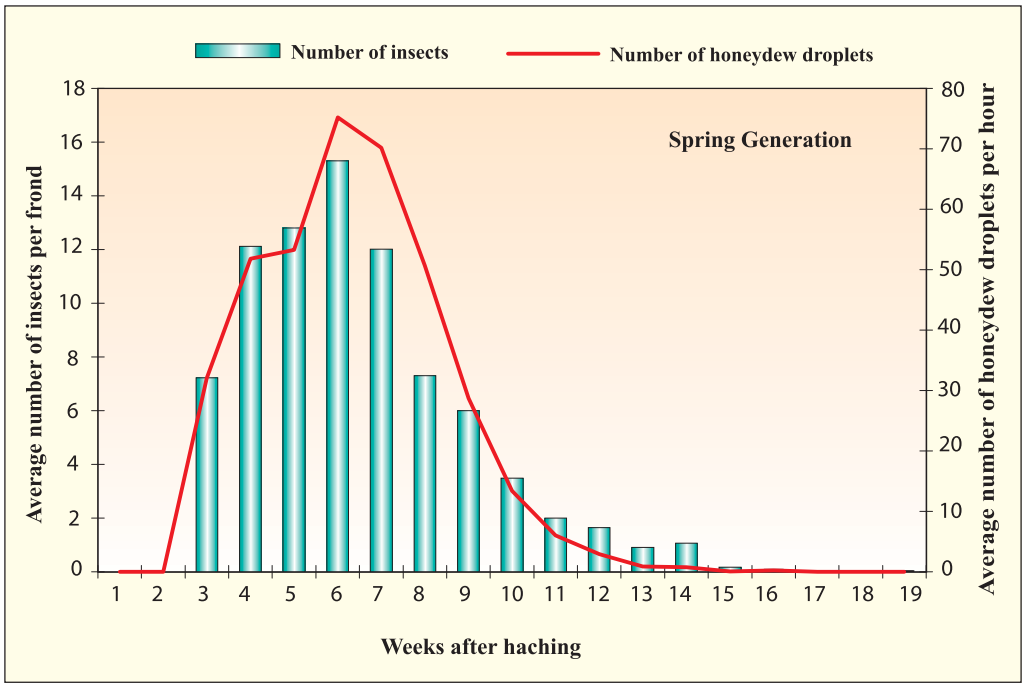

Fig. 1.14. The population density of Dubas bug, estimated by the average number of insects on frond and corresponding numbers of honeydew droplets on sensitive test papers during spring generation.

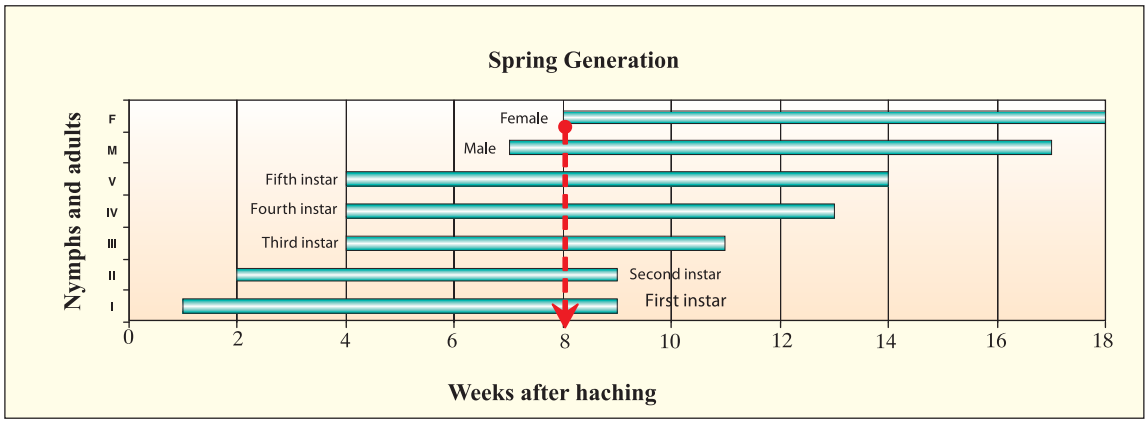

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Table 1.4. Summary of the most important bio-ecological characteristics of Dubas bug during autumn and spring generations*.

Characteristic Item	Autumn Generation	Spring Generation
Average Number of Insects / Leaflet	2.4	5.1
Average Number of Droplets/ Sensitive paper/ hour	10.1	24.2
Highest Number of Insects/ Leaflet	6.2	15.3
Highest Number of Droplets/ Sensitive Paper	24.5	75.2
Number of Droplets/ Number of Insects Ratio	4.2	4.7
Duration of Different Instar in the Field (in weeks)		
1st Instar Nymphs	12	9
2nd instar Nymphs	11	8
3rd Instar Nymphs	12	8
4th Instar Nymphs	14	9
5th Instar Nymphs	18	11
Adult Female Insects	14	11
Adult Male Insects	15	11
Total Period of Mobile Stages in the Field	22	18

* Source: Mokhtar, *et al*. (2000a).

Economic Threshold of Dubas Bug

As mentioned earlier, based on ecological studies of Dubas bug and the available knowledge of its activity, that the best time to initiate chemical control programs is during the period where the majority of the eggs are already hatched and the nymph stage is the predominant in the total population of the insect and before the appearance of the females, i.e. at the eighth and seventh week after eggs hatching for the autumn and spring generation, respectively.

In Iraq, Hussain (1985) identified the economic threshold of infestation of Dubas bug by counting the number of eggs on each date leaflet. He considered that the infestation was slight when five eggs were found on each leaflet and it was moderate with 5 to 10 eggs per leaflet, while with 10 or more eggs/leaflet indicated a heavy infestation.

In Oman, the economic threshold for Dubas bug was identified by indirect assessment of the size of the pest population. This was done by measuring the density of the honeydew secreted by the insects on special sensitive

test papers. In this method the number of insects, that can secrete enough amounts of the honeydew to cover the surface of the leaflet during one week, was counted and considered the Economic Injury Level. Hence, the number of insects that is expected to secrete enough honeydew to cover 10 % of the palm leaflet in a week was calculated, to give the economic threshold of infestation at which the chemical control measures should start to prevent the infestation from reaching the economic damage level (Mokhtar *et al*., 2001b).

This method is a much simpler and more accurate method than egg counting or other methods, in identifying the degree of infestation and consequently the economic threshold of infestation at which the chemical control should start. Table 1.5 shows that the economic threshold of infestation in the early season could be reached when the infestation rate reaches 10.9 first instar nymphs per palm leaflet. This number is also the number of insects needed to produce enough honeydew to cover 10 % of the surface area of the leaflet in one week. The economic threshold is reached if an average of 0.6 fifth instar nymphs is found on each leaflet.

Susceptibility of Date Palm to Dubas Bug Infestation

Dubas bug infests all the date palm varieties in Oman and so far, no resistant varieties have been identified. It is also noted that the infestation is higher in the eastern region 'Sharqiyah' and is somewhat lower in the coastal region 'Al-Batinah'. The reason behind this disparity is related to the cultural practices in date palm plantations. Most of the date palm plantations in the eastern region are densely planted, with narrow spacing between palms, which helps in increasing the relative humidity between palms, whereas in 'Al-Batinah' coast region most date palm plantations have wider spacing between palms. In addition, Klein and Venezian (1985) mentioned that Medjool palms were more highly infested than nearby Deglet Nour palms, possibly because in the former cultivar the whorls of fronds tended to be relatively closed.

Table 1.5. Number of honeydew droplets produced by various instars of Dubas bug nymphs and their relation to the economic threshold determination.

Nymphal instar	No. of honeydew droplets per hour	Droplet diameter (in microns)	Economic threshold (number of nymphs)
1st Instar	6.5	157	10.9
2nd Instar	6.4	256	4.2
3rd Instar	7.4	481	1.0
4th Instar	7.6	545	0.8
5th Instar	7.6	622	0.6

(Source: Mokhtar *et al*., 2001b).

Control Measures

The control of the Dubas bug in Oman as is the case in other affected neighbouring countries depends on chemical control as the cornerstone in controlling the population of Dubas bug and consequently limiting the damages. The chemical control and the alternative measures, which can be used to achieve desired Integrated Pest Management (IPM), shall be discussed below.

1. Cultural Control

The cultural control measures depend upon the following points:

• Spacing between date palms

The distance between the date palm should not be less than 8 × 8 metres to allow the wind movements and the sun light between the palms. This will help in preventing the increase in the relative humidity between and around the date palms thereby limiting the level of infestation by Dubas bug and other pests. In the already planted date groves, plans should be made to achieve this target even on the long run.

• Separating the offshoots from the mother palms

The offshoots should be separated from the mother palms at the right age as their presence around the parent palm increases the relative humidity, which increases the levels of infestation by the Dubas bug and other pests.

• Irrigation

Moderation in irrigation to prevent the increase in relative humidity around the palms, which encourages infestations.

2. Chemical Control

Chemical control of Dubas bug is still the basis of any control program to the present. However, through using the chemical control measure, we should not neglect the other complementary measures in the Integrated Pest Management (IPM). The use of chemical pesticides is only one aspect of this management and should be done in liaison and with precise scientific implementation with other measures. In Oman, the chemical control is done through ground based spraying or aerial spraying.

The advantages of ground-based spraying are:

1. The possibility to spray the offshoots and young trees grown under the date palm trees.
2. The possibility to spray areas inaccessible to aeroplanes.

The disadvantages of ground-based spraying are:

1. The pesticides do not reach the crowns of the tall palms thus greatly decrease the efficiency of spraying.
2. Ground based spraying consumes more time compared to the aerial spraying.

The chemical control by aerial spraying of pesticides is done by using two types of aeroplanes:

1. **The ordinary fixed wing aeroplanes:** have advantages of spraying vast open fields quickly. Unfortunately, it is risky and difficult to operate in canyons (In Arabic: Wadis) between high mountains.

2. **Helicopters:** The biggest advantage of using helicopters fitted with micron air spraying heads is the ability to spray the canyons flanked by high mountains. However, the helicopters are relatively slower than the ordinary fixed wing aeroplanes.

In general, the disadvantages of the aerial spraying are the difficulty of delivering the pesticide to Dubas bug in cases of dense plantations, the difficulty, and the risks involved in flying over and spraying the date palm plantations near the high mountains.

3. Biological Control

In nature, the Dubas bug has many natural enemies that feed on their different stages. There are some parasitoids on the Order: Hymenoptera that parasitoids on the eggs of Dubas bug. In addition, some predator insects are found to naturally prey on the nymphs and adults of Dubas bug. Among the most important of these predators are the larvae of the common green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae).

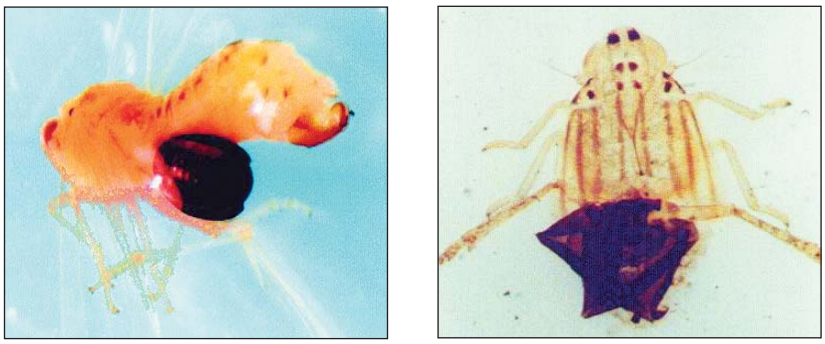


Fig. 1.16. External parasitoids, *Bocchus hyalinus* Olmi (Hymenoptera: Dryinidae), on nymph and adult of Dubas bug.

In addition, there are three species of lady beetles (Coleoptera: Coccinellidae) reported to prey on the nymphs and adults of Dubas bugs:

1. *Coccinella septempunctata* L.
   (The seven-spotted lady beetle)
2. *Coccinella undecimpunctata* L.
   (the eleven-spotted lady beetle)
3. *Chilocorus bipustulatus* L.

In Saudi Arabia, Hammad *et al*. (1983b) recorded a species of mites called *Bdella* sp., which devours the eggs of Dubas bug. Talhouk (1983) reported another species of Coccinellidae called *Exochomus nigripennis* (Erichson), which also preys on the nymphs and adults of Dubas bug.

In Oman, the following predators and parasitoids have been identified and recorded on Dubas bug:

1. *Chrysoperla carnea* Stephens
   (Neuroptera: Chrysopidae)
2. *Cheilomenes* (=*Menochilus*) sexmaculata (Fabricius)
   (Coleoptera: Coccinellidae)
3. *Runcinia* sp. (Araneae: Thomisidae)
4. *Bocchus hyalinus* Olmi (Hymenoptera: Dryinidae)
5. *Bochartia* sp. (Acari: Erythraeidae)

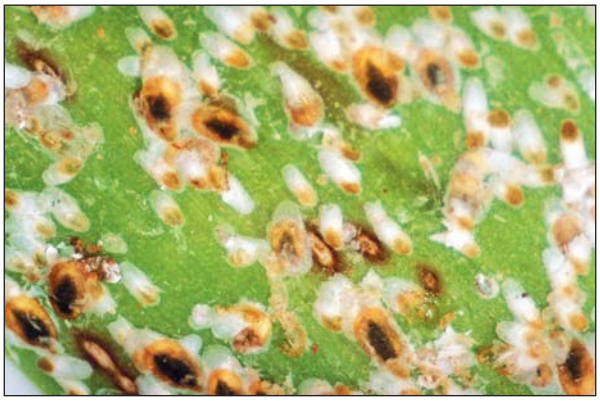
Recently very important egg parasitoid was recorded on Dubas bug eggs, *Pseudoligosita babylonica* (Hymenoptera: Trichogrammatidae), which was first reported and named as *Oli*gosita sp., Fig. 1.17, (The Natural History Museum, 2002). Viggiani (2008) then confirmed *Oligosita* sp. as *Pseudoligosita babylonica*, while the first identification of *Pseudoligosita babylonica* n. sp. was recorded from Iraq (Hassan, *et al*. 2004). In Oman, the egg parasitoids, *P. babylonica* has shown more than 70% parasitism in some locations and can be considered as a potential biological control agent of Dubas bug, *O. lybicus*. In addition, the parasitoids *Aprostocetus* sp., (Hymenoptera: Eulophidae), was recorded on Dubas Bug in Oman.

Fig. 1.17. The egg parasitoid, *Pseudoligosita babylonica* Viggiani (Hymenoptera: Trichogrammatidae).

Generally, because many date palms in Oman are in relatively scattered villages and valleys, from an ecological point of view such areas are probably perfectly suited for implementing biological control programs. More research should be carried out in this domain to rear and import one or more of the above-mentioned natural enemies and to release them according to specific programs to decrease the levels of infestation and to control the numbers of Dubas bug in an Integrated Pest Management Program.

1.1.2. Parlatoria Date Palm Scale

***Parlatoria blanchardi* (Targioni- Tozetti)**
(Homoptera: Diaspididae)



Distribution

Parlatoria date palm scale, *Parlatoria blanchardi*, is also called the armoured scale insect or the white scale. It is widely distributed throughout tropical and subtropical regions where palms grow. It is present in all date palm growing areas and regions worldwide except in the USA, where previously heavy infestations were eradicated completely since 1934. It was accidentally introduced to the USA in 1890, was subsequently found in Arizona, California and Texas, and was successfully eradicated in 1914 in Arizona, in 1919 in Texas and in the 1930s in California (Boyden, 1941 and Gill, 1997).

This scale insect spreads widely on the date palms in all the areas and provinces of Oman and other countries like: Yemen, Bahrain, Qatar, Kuwait, UAE, Iraq, Iran, Afghanistan, Palestine, Egypt, Sudan, Somalia, Libya, Algeria, Morocco, Mauritania, Niger and as far as Argentina in the South American continent. The primary hosts of *P. blanchardi* are palms in the genera *Hyphaene*, *Latania*, *Neowashington*, *Phoenix*, *Pritchardia* and *Washingtonia*. It is worth mentioning that, *P. blanchardi* besides infesting many palm species, is also found on some ornamental plants such as *Jasminum* and *Vinca* sp.

Economic Importance

P. blanchardi, is one of the most serious pests on date palms worldwide with the highest infestations observed on the young date palms ranging from three to ten years of age. It also opts for the areas with high humidity and shaded spots away from the direct sunrays. *P. blanchardi* infests the date palm leaflets, fronds, midribs, spines, bunches and fruits where the nymphs and adults feed by sucking the sap from the green parts and the dates of the attacked palm most of the year. As a result, the colour of the infested parts changes from dark green to pale or light green or to the yellow colour with the appearance of several spots. A discoloured area of injured tissue develops where scales settle and feed. These spots start as light green in colour then turns tawny (tan or brownish) in colour. The affected areas gradually wither. Severe infestation leads to the death of the leaflets, dry fronds and premature death by inhibiting transpiration and photosynthesis. All these together cause general weakness in the date palm tree and deterioration in the produced crop both qualitatively and quantitatively.

When *P. blanchardi* infests the date fruits it causes many deformities, which greatly reduce their market value,

particularly because this insect species infests the dates in all their ripening stages, i.e., Khalal (Colour stage), Rutab (Soft ripe stage) and Tamer (Full ripe stage). The scales cannot be removed from the infested dates during cleaning and packaging of the dates. Smirnoff (1957) reported date fruits losses of 70-80% resulting from direct feeding by the Parlatoria date scale. Hussain (1985) noted that the economic damages caused by Parlatoria date scale insects depend upon their numbers on both the date palm fronds and the fruits, and that the degree of infestation can be categorized as follows;

Infestation	Number of insects per leaflet
Very low	3
Low	3 - 10
Moderate	< 10
Severe	Insects found on less than half of the number of leaflets in each frond
Extremely severe	Insects found on most of the leaflets in each frond

To illustrate the intensity of infestation, it was reported that the number of different stages of *Parlatoria blanchardi* on the severely infested date palms might reach up to thirty million insects on a single tree. Each affected date palm leaflet may have around 500 to 1200 insects. It was also observed that these insects are not distributed evenly on the leaflets, but may be typically distributed as follows;

Leaflets area	Distribution of *P. blanchardi* on date palm leaflet
Basal part	68 %
Middle part	26 %
Apical part	6 %

Another observation is that, the degree of infestation is directly proportional to the age of the fronds, as the number of insects on each leaflet of a heavily infested date palm tree varied as shown in Table 1.6.

The dispersal stage of *P. blanchardi* is the first instar crawler, but this can only walk a short distance. In Niger, Stansly (1984) observed that the infestations spread only 30-90 cm per month, depending on the season. Dissemination to new hosts is due to many factors, such as movement by wind, birds, insects and the transport of infested plants from one area to another. Movement of *P. blanchardi* into new areas has commonly been due to the import of infested date offshoots.

Table 1.6. Variations in severity of infestation by Parlatoria date palm scale insects, *P. blanchardi*, according to the age of the fronds on the same date palm.

Frond Age	Number of *P. blanchardi* per leaflet
Old	1163 - 2129
Middle aged	120 - 168
Young	14 - 89
Very young	Usually have no insects

General Description

The adult female insect is pink-coloured or dark red and 0.8 mm long and oval-shaped with a flat scale, that is white in colour with a brown tint. There is a dark coloured spot in the centre, which is actually the exuviae of the last nymphal instar. The female scale of *P. blanchardi* is subcircular, 1-1.2 mm long.

Ghauri (1962) recorded that both winged and wingless forms of the adult male have been observed. The adult males are of three kinds; some have well developed wings, some are apterous and some are brachypterous. In Egypt, El-Kareim (1998) mentioned that alate males predominate in the spring when they fly at early dawn, while apterous males predominate in the summer generation. The adult

male is 0.7 mm long; its scale is thin, elongated with parallel sides and smaller than that of the female, which is 1 mm long and 0.4 mm wide. It is white in colour with a dark spot on one of its ends, being the terminals exuviae as shown in Fig. 1.18 and. Males tend to aggregate in clusters.

The egg of P. *blanchardi* is oval in shape, shiny rose in colour and 0.4 mm long. The nymph is dark rose or deep red in colour and 0.6 mm long, when fully grown. The scale of the nymph is round in shape and dirty white in colour.

Life Cycle

Reproduction of *P. blanchardi* is sexual and oviparous throughout the year, (Bénassy, 1990). Females lay from 4 to 13 eggs in clusters underneath their cover with a mean of 9.6 eggs. Hussain (1985) mentioned that each adult female of *P. blanchardi* lay from 10 to 29 eggs under its scale. Upon laying of its eggs, the female dies leaving the eggs under its scale. The eggs hatch and tiny-sized (around 0.3 mm long), rose coloured nymphs emerge, which remain under the scale of their mother for a period that varies according to the weather conditions. Later, the nymphs wander about or crawl, looking for shaded palm leaflets or fruits. Hence, they are named "Crawlers". Once they find a suitable place, i.e. shaded and humid, they fix themselves to it by their stylets, feed on the plant sap and start to secrete a waxy substance.

P. blanchardi prefers to settle on the lower surfaces of the leaves in the lowest part of the canopy. Highest numbers are found near the base of the leaves, where they feed on the white succulent tissue protected by layers of other tissues and fibres. The female nymph moults twice, in situ, to develop into the mature adult female form, while the male nymphs moult four times to reach the adult form. It was observed that the female insects remain under their scales during their lifetime, while the male insects emerge from their scales when fully grown to mate and copulate. Upon reaching adulthood, males live 2-3 days. Bénassy (1990) mentioned that the sex ratio favours females, with males generally forming less than 25% of the population.

The number of generations of *P. blanchardi* per year differs depending on the geographical region; in Iraq it was reported to have four overlapping generations; in Morocco, 3-4 generations; in Pakistan and Saudi Arabia, 3-5 generations. In Oman, it is expected that *P. blanchardi* has four generation each year, Hussain (1985). In Iran, *P. blanchardi* has 3-4 generations per year, Abivardi (2001). Generally, this species is recorded to have three to five

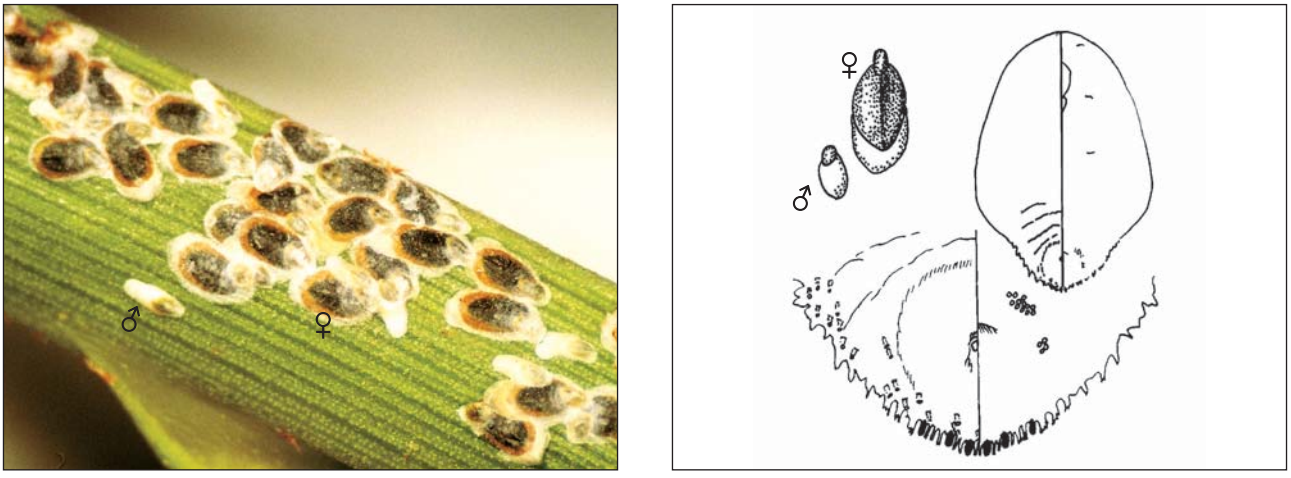


Fig. 1.18. An enlarged photo and an illustration of both sexes of *P. blanchardi.*

overlapping generations annually (Gharib, 1973; Abdul Ahad and Jassim, 1983; Bénassy, 1990; Khoualdia *et al*., 1993). In Iraq, according to Hussain (1985), descriptions of the four overlapping generations of *P. blanchardi* are as follows:

• **The First Generation (Spring Generation)**

The adult female deposits its eggs during the first week of April, which are incubated for 10 to 12 days, and then hatch releasing tiny nymphs (Crawlers) which crawl looking for suitable places. About 95% of the eggs hatch in the third week of April. The eggs of this generation continue to hatch for a long period of nearly 46 days. After one week of hatching, the crawlers are fixed in their places and cover themselves with scales. The nymphs in this generation last 66 days, and are mostly found on the old green leaflets although some crawlers may migrate to young date leaflets. During the third week of June, the adult insects start to appear. One week later, the adult females oviposit once again. The adult female insect lives for around 43 days. Thus, the spring generation takes approximately four months.

• **The Second Generation (Summer Generation)**

The adult female insects begin to oviposit in the last week of June. The eggs hatch after about 7 days and continue to do so for approximately 33 days. Nearly 97% of the eggs hatch during the first week of August. The emerging nymph is covered with its scale after 9 days of hatching. The nymph stage in this generation lasts 41 days. They are usually present on both the upper and lower surfaces of the basal part of frond. Later, the adult insects appear and mate during the second week of August, and the adult females begin to deposit their eggs after four days of their appearance. The adult female insects live for 55 days. Therefore, the summer generation lasts around three and a half months.

• **The Third Generation (Autumn Generation)**

The adult female insects begin to oviposit in the third week of August, and then the eggs hatch after about 6 days and continue to do so for approximately 47 days, as nearly 90% of the eggs hatch during late August and early September. The emerged nymph covers itself by a scale after 5 days of hatching. The nymph stage in this generation lasts 58 days. The adult insects appear and mate during the third week of August, and the adult females begin to deposit their eggs after two weeks of their appearance. The adult female insects live for 66 days, thus the autumn generation lasts around four and half months.

• **The Fourth Generation (Winter Generation)**

The adult females deposit their eggs during the first week of November, which hatch after around 16 days of their emergence. The eggs of this generation continue to hatch for a period of two months, and nearly 87% hatch during the second week of December. The nymphs cover themselves with their scales after about 5 days of hatching. The nymph stage in this generation lasts about 117 days. Later, in the third week of March, the adult insects start to appear and after one week, the adult females' starts oviposit again. The adult female insect lives around 64 days, thus the winter generation takes approximately six and a half months.

It is worth mentioning that the second and third generations of this insect infest in particular the date fruits. They are firmly attached to the surfaces of dates that they are very difficult to be removed by washing with water during cleaning. Table 1.7 showing dates and duration of the four overlapping generations of the Parlatoria date scale insects around the year.

Table 1.7. Timings and durations of the four overlapping generations of *Parlatoria blanchardi* throughout the year.

Stage	1st Generation	2nd Generation	3rd Generation	4th Generation
Incubation Period (days)	10 - 12	7	6	16
Eggs Hatching	95 % 3rd week of May	97 % 1st week of August	90 % late Aug. and early Sept.	87 % 2nd week of December
Nymph Duration (days)	66	41	58	117
Female Lifespan (days)	43	55	66	64
Generation (months)	4	3.5	4.5	6.5
Period of Generation	April - July	June - Sep.	Aug. - Dec.	Nov. - Apri

Susceptibility of Date Palm to *P. blanchardi* Infestation

Madkour (1979) and Hussain (1985) reported the existence of differences in the susceptibility of date palm varieties to infestation by the Parlatoria date palm scale insect. In Libya, it was observed that Deglet Nour variety is more susceptible than the local varieties while in Iraq, the most susceptible varieties were Sayer and Dayeri. In Tunis, Khoualdia *et al*. (1993) found that the cultivar Kentichi was significantly more resistant to the Diaspidid than Deglet Nour, Aligue or Khouaet Alig. In India, Swaminathan and Verma (1991) mentioned that the cultivars Khadrawy and Medjool were susceptible and that Al Zahdi and Migraf were tolerant to infestation.

Control Measures

1. Cultural and Mechanical Methods

Cultural control can achieve by performing the following steps:

- Removing the infested fronds and burning them.
- Taking good care of the date palms and continuously removing the old fronds by pruning.
- Giving attention to the agricultural cleaning and ploughing the soil around the palm trunk and the offshoots.
- Moderation in irrigation.
- Inspection of offshoots before planting in new groves is considered one of the best methods to restrict the spread and outbreak of this pest.

2. Chemical Control

The date palm trees should be sprayed after the fruit-setting season and at the beginning of winter, twice each time, to eradicate the insects that would remain until the spring of the following year (March-April). Here one of the following organophosphorus insecticides could be used:

- **First Spraying:** Malathion or Pirimiphos-methyl (Actellic®) at 1.5-2 litres per thousand litres of water, these insecticides could be mixed with a mineral oil.
- **Second Spraying:** starts with the beginning of spring season, late March and early April using the same insecticides mentioned earlier without adding any mineral oils because of the high temperature at this

time of the year. When using high-pressure spraying machines, the spraying nozzles should be modified i.e. elongated to ensure that the insecticide reaches all the green parts of the palm. The aerial spraying Program can be combined with the Dubas bug control Program as both timings and the insecticides used in both programs are perfectly matched.

3. Biological Control

Biological control is the most useful and most successful measure to control Parlatoria date palm scale, *P. blanchardi*, and it was implemented with great success in many countries. However, this pest was completely eradicated from the USA, its distribution has been limited through implementing a successful quarantine, and control procedures Program that started in 1914 and continued until 1934.

In Mauritania, Tourneur and Lecoustre (1975) reported that the Coccinellid lady beetle predator, *Chilocorus bipustulatus* L., could control the numbers of Parlatoria insects in six months of release into new areas with a consequent significant reduction in infestation, if a permanent vegetation cover is available in the groves. The predator is released at a rate of 400 beetles per 60-100 date palm trees, or per half a hectare. Stansly (1984), Montaigne *et al*. (1986) and Khoualdia *et al*. (1993 and 1997) reported that the release of the Coccinellid predators *Chilocorus bipustulatus* and *Chilocorus bipustulatus* var. *iranensis* into date palm groves in Mauritania, Niger, and Tunisia, respectively, provided an acceptable level of control for *P. blanchardi*. The adult beetle of *C. bipustulatus* is 3.3-4.5 mm long, spherical and convex in shape and shiny black in colour with red spots on its wings. It can be imported from Iran, where a variety of this beetle called *Chilocorus bipustulatus* var. *iranensis* is present and can hence, effectively control the numbers of Parlatoria date palm scale and limiting their damages.

In India, Swaminathan and Verma (1991) reported that, *Pharoscymnus horni* was the most effective predator against the Parlatoria date palm scale in a comparison study of three species of Coccinellid reported preying on the Diaspidid.

In Oman, two predators were recorded to prey on the Parlatoria date palm scale insect, i.e. *Pharoscymnus numidicus* Pic. (Coleoptera: Coccinellidae) and *Cybocephalus rutitrons* Rtl. (Coleoptera: Nitidulidae).

There are also several others predators and parasitoids recorded as natural enemies to the white scale or the Parlatoria scale insect in Iraq, USA, Iran, Mauritania, Morocco, Algeria, Tunisia and Libya. Table 1.8 shows list of the most important predators and parasitoids recorded in different places worldwide as natural enemies to Parlatoria date palm scale insect.

Table 1.8. The predators and parasitoids recorded in different places worldwide as natural enemies to Parlatoria date palm scale, *P. blanchardi*.

Country or Region	Natural enemies
Predators	
I. (Coleoptera: Coccinellidae)	
Iraq and Morocco	1. *Chilocorus cacti* L.
Iran, Iraq and Mauritania	2. *Chilocorus bipustulatus* L.
Iraq	3. *Pullus ebner* Wse.
	4. *Nephus puadrimaenlatus* Hbst.
	5. *Pharoscymnus smirnovi* Dobzha.
In Different Places	6. *Pharoscymnus anchorago* (Fairmaire)
Oman and Many other Places	7. *Pharoscymnus numidicus* Pic.
Morocco	8. *Pharoscymnus flexibilis* Mulsant
India	9. *Pharoscymnus horni* (Weise)
II. (Coleoptera: Nitidulidae)	
Oman and Iraq	1. *Cybocephalus rutitrons* Rtl.
Algeria	2. *Cybocephalus seminulum* Bau.
North African Countries	3. *Cybocephalus tlavieeps* RH.
	4. *Cybocephalus palmarum* Peyesh.
	5. *Cybocephalus nigriceps* (J. Sahlbiesg)
III. (Neuroptera: Chrysopidae)	
In Different Places	*Chrysopa vulgaris* Schon.
IV. (Acarina: Sascoptidae)	
North African Countries	*Hemisareoptes malus* Shimer
Parasites	
(Hymenoptera: Aphelinidae)	
Iraq, Mauritania	1. *Aphytis mytilaspidis* Lebaron
Iraq	2. *Aphytis phoenieis* Debaels & Rosen

1.1.3. Red (wax) Date Palm Scale

***Phoenicococcus marlatti* Cockerell**
(Homoptera: Phoenicococcidae)

Distribution

The red (wax) date palm scale, *Phoenicococcus marlatti*, is widespread in almost all date growing areas in the world. It was recorded in Egypt, Palestine, Jordan, Iraq, Saudi Arabia, Bahrain, Qatar, United Arab Emirates, and the Sultanate of Oman as well as Tunisia, Algeria and Morocco. In addition to the date palm, the red date palm scale also infests several species of ornamental palms, e.g. Doum palm (*Hyphaene thebaica*, the gingerbread palm, Thebaica or Doum in Arabic), Canary Island palm (*Phoenix canariensis*) and the California fan palm (*Washingtonia filifera*).

Economic Importance

The different stages of *P. marlatti* are found on the bases of date fronds, which are covered with fibre sheaths, in the cracks on some midribs of fronds and on date fruits spikelet's. *P. marlatti* insects appear in deep pink to dark red in colour and partly or entirely covered with white waxy secretion that forms a cottony mass, Nixon and Carpenter (1978). It is not as easy to detect the infestation of the red date palm scale, as is the case with most other scale insects because of its natural behaviour to hide.

The adult females and nymphs feed on the frond bases and spikelet bases especially the white tender tissues covered with fibres preferring the hidden parts of the palm. They suck the sap from the infested parts causing dark coloured spots and excreting white waxy substance that can be easily detected on the infested part. The darker spot is oval in outline, which is the body of the scale insect itself. The symptoms of infestation can be observed after the process of cutting the dry frond bases where tiny floury white spots can be seen on the inner surface of the frond base, as seen in Fig. 1.19. Generally, the infestation by *P. marlatti* leads to withering and general weakness in the palm's growth. The incidence of infestation may be as high as 91% of the frond bases as was the case in Basra area in south Iraq, where each infested base contained from 3 to 3.6 insects and an average 77 insects per each frond base on both the inner and outer surfaces of the base, Hussain (1985). Frequently, the red date palm scale is found underground on roots of the infested palm. Fortunately, although the date palm red scale insect is widely spread all over date palm groves in Oman, it is not causing serious economic damage to the infested date palms up to date.

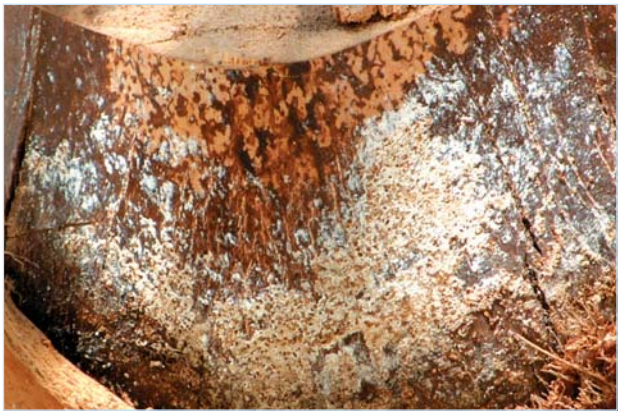


Fig. 1.19. Date palm red scale, *P. marlatti.*

Susceptibility of Date Palm to *P. marlatti* Infestation

In Libya, Martin (1958) noted that the red date palm scale infests all date palm cultivars, existing on the frond bases. The infestation is more concentrated in the interior oases than the coastal oases.

General Description

The adult of the red date palm scale, *P. marlatti*, is red in colour. The female is 0.5-1 mm long, while the male is a little shorter, 0.5-0.6 mm. The adult male is apterous, which is unusual in males of the scale insects. The egg is shiny rose in colour, has smooth surface and is 0.2 mm long. Nymph of *P. marlatti* is oval in shape, around 0.5 mm long and rose in colour. It is light rose colour in the first instars, while the late instars of the nymphs are darker. The red date palm scale insect does not cover itself with a scale like most of the armoured scale insects. Instead, the first and second instars of both the male and female nymphs and the adult female insects release a white waxy substance covering their bodies. This wax is made of convoluted shiny white coloured threads that resemble a piece of cotton around the body of the insect.

Life Cycle

In USA, Stickney *et al*. (1950) mentioned that the female of the wax date palm scale, *P. marlatti*, deposits its eggs posteriorly inside the waxy mass during spring. After hatching, the crawlers migrate to infest new places in the palm. The female undergoes three nymphal instars, while the male has five nymph instars before developing into adult insects. These adult insects appear in the period from March to June, then disappear to re-appear again during the month of November of each year.

Control Measures

As mentioned earlier, the red date palm scale insects are not economically important at present. However, the best measures to control this pest are:

1. Mechanical Control

Carpenter and Elmer (1978) reported that the best measure to control this insect is subjecting the infested offshoots and those separated from the parent palm to a temperature of 50°C for 65 hours in a heat-insulated room.

2. Chemical Control

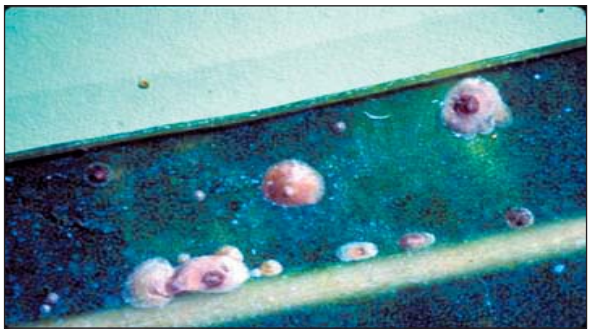
The red date palm scale, *P. marlatti*, can be controlled, if absolutely necessary, by spraying the infested palms with one of the Organophosphorous compounds; Malathion 57% at 2-3 litres or Diazinon 60 % at 1.5 litres per thousand litres of water.

3. Biological Control

Many species of the Coccinellidae lady beetles are found to prey on the red date palm scale, *P. marlatti*, e.g. *Cheilomenes sexmaculata* (Fabricius), *Chilocorus nigritus* (Fabricius), *Pharoscymnus flexibilis* Mulsant, *Pharoscymnus anchorago* (Fairmaire) and *Pharoscymnus horni* (Weise).

1.1.4. Oriental yellow scale

***Aonidiella orientalis* (Newstead)**
(Homoptera: Diaspididae)



Distribution

The oriental yellow scale, *Aonidiella orientalis*, is a highly polyphagous insect. According to Williams and Watson (1988), the oriental yellow scale attacks many plant families except conifers. It can be an economic pest of crops from diverse families. These include many species of Citrus (especially Omani Lime, Sweet Lime and Grapefruit) and Ficus (*Ficus benghalensis*), Benjamina Fig (*Ficus benjamina*) and Fig (*Ficus carica*). In addition, it attacks Mango (*Mangifera indica*), Tea (*Camellia sinensis*), Guava (*Psidium guajava*), Papaya (*Carica papaya*), Bananas (*Musa* sp.), Sapodilla (*Manilkara zapota*), Indian tamarind (*Tamarindus indica*) and other fruits as well as palm trees, including Date palm (*Phoenix dactylifera*), Coconut palm (*Cocos nucifera*) and Arecanut (*Areca catechu*).

The oriental yellow scale, *A. orientalis*, is present on date palms in many countries like Saudi Arabia, UAE, Iraq, Pakistan, India, Somalia and Sudan and Oman. In Oman, it was recorded in Khabourah and Saham districts. It was also found, in small numbers, on the date palm fronds in Al Hamra district (Elwan, 2000). *A. orientalis* is also recorded on citrus trees in all areas and on Neem trees (*Azadirachta indica*) in several locations. *A. orientalis* is considered in Oman as the most serious pest of Neem.

Economic Importance

The oriental yellow scale, *A. orientalis*, does not cause great economic damages to date palms in Oman. Moreover, in Saudi Arabia, Nixon (1954) reported that its infestations were slight in most years in the regions of Ahsa and Qateef. The oriental yellow scale attacks both the date palm fronds and fruits. The damages are incurred by sucking the plant sap from the infested areas, leaving dark coloured spots on the affected green parts and fruits. Direct feeding damage on leaves and removal of plant sap reduces plant vigour. Feeding often causes depressions, discoloration and distortion of palm fronds.

Crawlers and females of the oriental yellow scale, *A. orientalis*, feed on sap. Surplus carbohydrates and nitrogenous compounds are used in the production of material to construct the scale cover and not into honeydew as in other scale insect families.

General Description

As with all armoured scale species (Diaspididae), adults of *A. orientalis* are covered with a scale or a cover that is morphologically separate from the body. The adult female is light yellow in colour and covered with a round, shield-shaped scale. The colour of the scale cover is almost white to pale brown or yellow, with yellow to dark brown

exuviae positioned more or less centrally and is 1.0-1.4 mm in length, Fig. 1.20. Adult female of *A. orientalis* is prosoma pyriform, expanding to sub circular and becoming moderately sclerotized around the margins at maturity. The Pygidium is quite well sclerotized dorsally.

Male scales are elongate to oval in shape and similar to females, but smaller, with yellow exuviae near one end. They can be differentiated as being mussel-shaped after two weeks of the emergence of the nymphs. The mature adult male insect is winged and fragile. It has three pairs of legs, a pair of antennae and only one pair of wings as the other two wings are modified into two hook shaped appendages. The relatively long aedeagus is clearly visible at the end of abdomen of males, being long enough to aid in copulation with the female while it is under its scale cover.

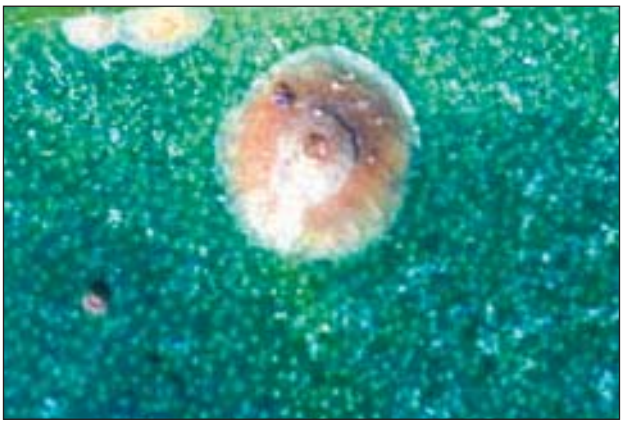


Fig. 1.20. The oriental yellow scale, *A. orientalis*.

Life Cycle

The adult females of *A. orientalis* deposit their eggs under the female scale cover. The first instar larvae (crawlers) are yellowish cream coloured and too small to be seen by the naked eye. They emerge from under the female scale cover and crawl for several hours until they find suitable host plant tissue into which to insert their stylets.

The female larvae subsequently remain immobile, with successive moulting adding to the size of the scale. Females have two moults before attaining maturity. The male larvae have additional prepupal and pupal moults before attaining a winged adult stage. Adult males lack mouthparts, do not feed and are relatively short-lived. It was found that the male insects die immediately after mating. Mating and the laying of eggs is the most important route by which crawlers are produced (Rajagopal and Krishnamoorthy, 1996).

Hussain (1985) mentioned that the adults of the yellow oriental scale insects, *A. orientalis*, emerge during spring, summer and autumn seasons and probably have three or four generations per year on date palm in Iraq.

Hammad *et al*. (1983a) studied the fluctuation of the populations of *A. orientalis* on date palm variety Razeez, in Qateef area in Saudi Arabia. They mentioned that it had four generations each year, with the maximum population density in the first, third and fourth generations. In their study, they found that the peak of the population density in the first generation was during December, the peak of the second generation's was during February and March and the third generation was during June while in the fourth generation the highest recorded count was during August and September.

In Iran, Khalaf and Sokhansanj (1993) found that reproduction of *A. orientalis* was most frequently viviparous, but Farid (1994) has also observed oviparous and ovoviviparous reproductions. He recorded five generations per year with the maximum population density in the fourth and fifth generations. In India, *A. orientalis* has only three generations per year (Glover, 1933).

Under laboratory conditions, Elder and Smith (1995) observed that males of *A. orientalis* took an average of 19.5 days from the crawler stage to adult and females took an average of 44.2 days from the crawler stage to production of the first crawler of the subsequent generation.

Control Measures

1. Cultural Control

The oriental yellow scale insects, *A. orientalis*, can be controlled by:

• Avoiding to plant other host plants near the date palms.

• Planting the date palm with suitable spacing and leaving enough room for aeration. The adjacent fronds of the crowded palm should not touch each other to prevent the crawlers from moving freely.

• Taking care in cleaning the farms and removing weeds because their presence increases the humidity under the date palms.

• Trimming and cutting off the infested fronds and burning them.

2. Chemical Control

Currently, oriental yellow scale insects do not cause enough economic damages to the date palms to warrant chemical control. Khalaf and Sokhansanj (1993) mentioned that the usual chemical treatment is mineral oil sprays, although these are not routinely recommended because they interfere with the natural biological control of pest insects in orchards and plantations. Malathion, Dimethoate, Diazinon or Monocrotophos have also been recommended for dealing with severe infestations to control the oriental yellow scale insects in different crops, (Rajagopal and Krishnamoorthy, 1996).

3. Biological Control

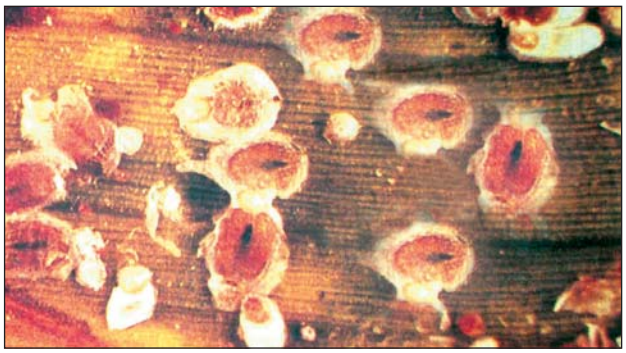
Although, *A. orientalis* has a wide distribution, its natural enemies have only been reported from a few countries, most notably India, Pakistan and Saudi Arabia (Rajagopal and Krishnamoorthy, 1996). *Comperiella bifasciata* Howard and *Comperiella lemniscata* Compere & Annecke (Hymenoptera: Encyrtidae) are probably the only two parasitoids that are naturally effective at checking populations of *A. orientalis* over most of its range. The same authors also indicated the potential of the parasite *Comperiella bifasciata* and the Coccinellid predator beetle *Chilocorus nigritus* (Fabricius) as important biological control agents of *A. orientalis*. Mani and Krishnamoorthy (1996) mentioned that the Coccinellidae beetles and lacewings are frequent predators of *A. orientalis* on a variety of crops.

In Australia, Elder *et al*. (1998) mentioned that the role of three parasitoids in controlling *A. orientalis* in Papaya in coastal areas of central and northern Queensland was assessed during 1989-95. *C. lemniscata* was introduced from Hainan Island in China and from the Torres Strait in northern Queensland and was released during 1991. Within 12 months, parasitism rates rose as high as 80% and rejection of fruit for market dropped from 20-30 to 1-2 %. *Aphytis melinus* DeBach (Hymenoptera: Aphelinidae) was also augmentative released in Papaya plantations in central and northern Queensland at a rate of 25000 individuals per hectare. Parasitisation mainly of the third-instar scales was boosted by these releases from 0% to between 10 and 30%, but these levels persisted for only a few months and the parasitoid had to be continually re-released. They also stated that *Encarsia citrina* Craw occurred naturally, producing levels of up to 80% parasitism, and was therefore important in the biological control of *A. orientalis*.

In Oman, successful biological control Program was applied to control the oriental yellow scale, *A. orientalis* on citrus and mango orchards during 1994. In this Program, two parasitoids and two predators species were imported from Australia and released. The two parasitoids are *Aphytis lingnanensis* Compere (Hymenoptera: Aphelinidae) and *Comperiella leminscata* Compere & Annecke (Hymenoptera: Encyrtidae). While the two efficiently predators of the Coccinellidae lady beetles are *Chilocorus circumdatus* (Gyllenhal) and *Chilocorus baileyii* Blackburn.

1.1.5. Date Palm Brown Flat Scale

***Fiorinia phoenicis* Balachowsky**
(Homoptera: Diaspididae)



Distribution

The date palm brown flat scale, *Fiorinia phoenicis*, is present on date palms in Iran, Saudi Arabia and United Arab Emirates, while in Oman it is sparsely distributed in small numbers in different areas in Oman.

Economic Importance

In Oman, the date palm brown flat scale, *F. phoenicis*, is considered to be of limited economic importance because it is present in small numbers in scattered areas. Moreover, it attacks a confined number of leaflets in each infested frond so that the damages caused by sucking the plant sap are limited.

General Description

The most characteristic feature in the brown flat scale insect is its transparent scale through which all the instars of the insect can be observed. The typical scale is elongated oval in shape and little convex. The pointed end is lighter in colour than the rest of the scale cover. The scale is 1.25-1.50 mm long, 0.75 mm wide and yellowish green in colour with a dark brownish spot on the dorsal surface. There are several white waxy threads on the fringes around the scale margins.

The adult female insect under the scale cover is flat with a pointed end, 1-1.25 mm long and red in colour. It is legless with rudimentary antennae and has long piercing and sucking stylets that looks like a hair. The body is encapsulated in a transparent capsule in which it lays the eggs to remain until hatched. The male insects are present in large numbers among the female congregations. The male insect has a waxy white coloured scale, which is elongated in shape in the early instars. All the developmental stages of the male exist under the scale cover.

Another species of the same genus *Fiorinia* called *Fiorinia fioriniae* (Targioni & Tazzetti), which spreads on the date palm trees in Egypt, Libya, Tunisia, Algeria, Morocco and the USA. *F. fioriniae* is known as palm fiorinia scale and is a highly polyphagous species. It has been recorded from hosts belonging to 45 genera in 23 plant families (Davidson and Miller, 1990). These hosts include species of: *Anthurium*, *Araucaria*, *Buchanania*, *Camellia*, *Cinnamomum*, *Citrus* spp., *Cocos nucifera*, *Cupressus*, *Cycas*, *Decaspermum*, *Dictyosperma*, *Eucalyptus*, *Eugenia*, *Ficus* spp., *Hedera*, *Howea*, *Larix*, *Laurus nobilis*, *Leptospermum*, *Livistona*, *Mangifera indica*,

Myristica, *Olea*, *Palmae*, *Persea americana*, *Phoenix*, *Phytelephas*, *Pinus*, *Podocarpus*, *Salix*, *Santalum*, *Sida*, *Taxus* and *Ulmus*.

The palm fiorinia scale, *F. fioriniae*, does not produce waxy secretions, and its female scale cover is elongated oval, 1.0-1.5 mm long, transparent light or yellowish brown with a slight median ridge and a single, terminal yellowish exuviae. The adult female of *F. fioriniae* is pupillarial, i.e. remaining enclosed in the enlarged and sclerotized cast skin of the second instar, so there is almost no difference in appearance between the adult and the second instar scale covers. The males rarely or never exist and if present, the male scale covers dull white, nearly transparent, with transparent terminal exuviae (Gill, 1997).

Johnson and Lyon (1988) mentioned there are five species of the genus *Fiorinia* found in the USA on different crops, Table 1.9. They also mentioned that the species *Fiorinia fioriniae* was most abundant in the south of the USA, where it was recorded in the following states; California, Oklahoma, Texas, Georgia in addition to Florida where it caused no measurable economic damages to the date palms. This species was reported to infest 23 different genera of plants as it primarily infests many genera of *Phoenix* as well as others like, *Persea*, *Gardenia*, *Camellia*, *Podocarpus* and *Mangolia*. *Aphytis* spp. and *Encarsia lounsburyi* (Berlese & Paoli) (Hymenoptera: Aphelinidae) and *Signiphora* spp. (Hymenoptera: Signiphoridae) were recorded as parasitoids of *F. fioriniae*. In addition, the following natural enemies were recorded as predators of *F. fioriniae*: *Karnyothrips flavipes* (Jones) (Thysanoptera: Phlaeothripidae) and *Rhyzobius pulchellus* (Montrouzier) (Coleoptera: Coccinellidae).

In Oman, a new species of the genus *Fiorinia* was identified for the first time as *F. linderae*. Ghabbour *et al*. (1996) described this species in details and determined the key taxonomical characteristics of the first instar of nymph and the adult female insect of *F. linderae*, Figs. 1.21 and 1.22. Takagi (1970) was the first entomologist to describe *F. linderae* as a new species found in China and Taiwan.

Fig. 1.21. *Fiorinia linderae* Takagi.

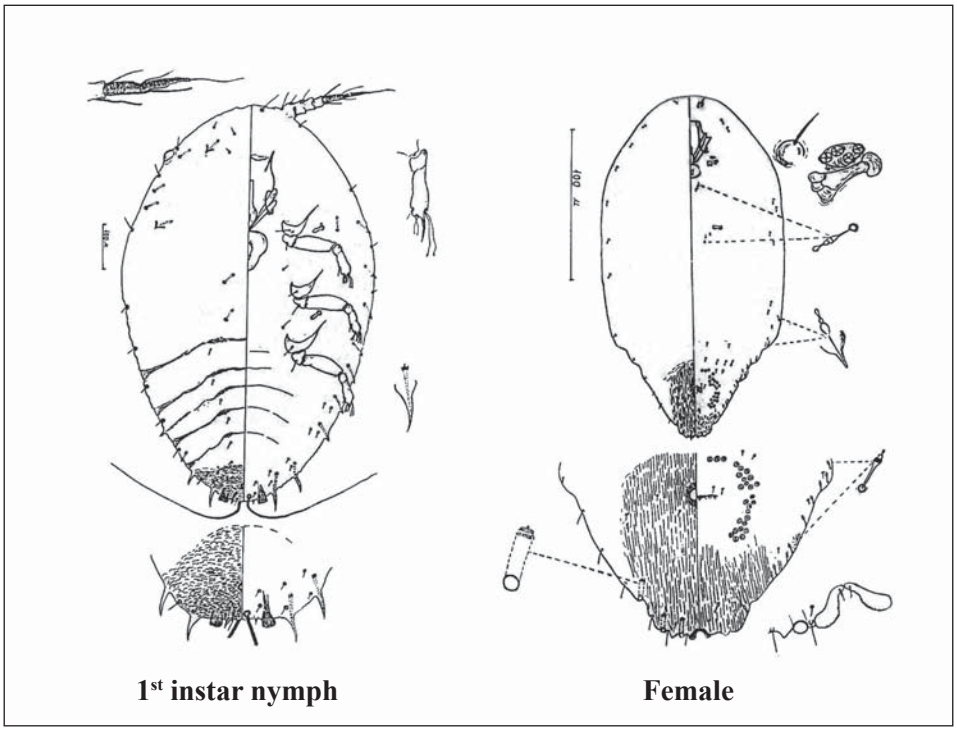


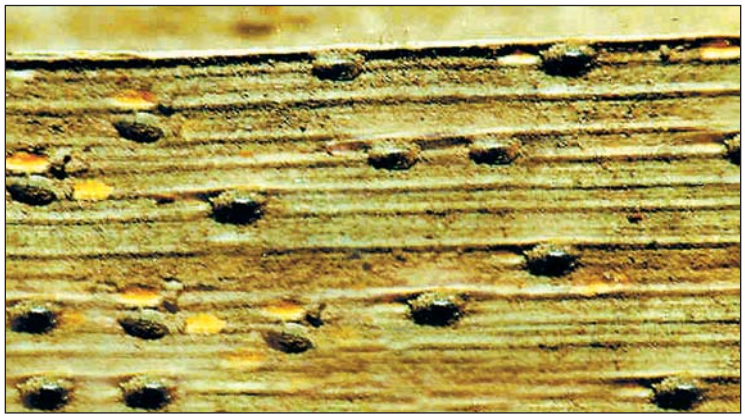
Fig. 1.22. A schematic diagram illustrating the adult female and the first instar nymph of *Fiorinia linderae.*

Table 1.9. Fiorinia species in the USA.

Fiorinia species	Common name
Fiorinia fioriniae (Targioni & Tozzetti)	Palm fiorinia scale
Fiorinia theae Green	Tea scale
Fiorinia juniperi (Bouche)	Juniper fiorinia scale
Fiorinia japonica Kuwana	Japanese fiorinia scale
Fiorinia externa Ferris	Elongate hemlock scale

1.1.6. Green Soft Scale

***Asterolecanium phoenicis* (Ram. - Rao)**
(Homoptera: Asterolecaniidae)



Distribution

Rao was the first entomologist to record the green soft scale, *Asterolecanium phoenicis*, in 1929 on date palms in Iraq. Later on it was also found in Iran, Egypt, Palestine, Saudi Arabia and the USA. *A. phoenicis* was recorded also in Oman as a pest on citrus trees and was found in many regions in Oman infesting the Neem trees, *Melia azadirachta* L.

In Oman, Greathead (1977) noted another species of the same genus called *Asterolecanium pustulans* (Cockerell) on the olive trees (*Olea europaea* L.) in Nizwa district. List of hosts plants of *A. pustulans* are Akee apple (*Blighia sapida*), pigeon pea (*Cajanus cajan*), coconut (*Cocos nucifera*), coffee (Coffea), mango (*Mangifera indica*), aubergine (*Solanum melongena*) and cocoa (*Theobroma cacao*).

Economic Importance

The green soft scale insect, *A. phoenicis*, attacks the date palm leaves, rachis, bunches and fruits (dates). The nymphs and adult insects of *A. phoenicis* suck the sap from the affected areas causing light yellow coloured spots on the green parts and fruits. When the infestation is heavy, the colour of the infested leaflets turns yellow with green spots. The infestation was found to be most severe in the areas of high humidity. In severe infestation, the fronds will wither and eventually die due to the effect on the process of photosynthesis, while the infested date fruits will be distorted which will decrease their market value.

General Description

The female insect of *A. phoenicis* has a yellowish green coloured convex scale, which is 1.3-1.5 mm long. Its margins are surrounded with several fringes of white coloured waxy threads. The female scale is elongated in shape, 1-1.3 mm long, 0.7 mm wide and light red in colour. While the male scale has green colour, oval, elongated and flat scaled. The male insect is winged which has light green or yellowish green colour. The egg is elongated in shape, white coloured and 0.3 mm long.

Life Cycle

Carpenter and Elmer (1978) mentioned that the green scale insect, *A. phoenicis*, has three generations per year

in the USA. In spring and summer, the female insect life span ranges from 85 to 95 days, while in autumn and winter it is extended up to 150 days or even 180 days. Meanwhile, the male insect lives for 50 to 60 days only comprising 25 % of the total number of insect population. While in Iraq, Hussain (1974) noted that the green scale insect, *A. phoenicis*, had one generation only every twenty months or more.

The eggs of the green scale insects hatch inside the female insect. The number of eggs ranges from 7 to 22 eggs per female insect with an average of 13 eggs. It was also noted that the newly hatched nymphs stay inside the adult female insect for almost one week before being released in a small chamber that constitutes a part of the posterior end of the scale. The nymphs stay inside for almost three days before emerging through a cleft at the end of the scale cover. The emerged crawlers are characterised by their high activity and speed while crawling to look for suitable places for food. The crawlers keep moving on the leaflets for about two days, and when they find a suitable feeding place, they insert their stylets in the leaf tissue and settle down to feed on the plant sap.

In Iraq, Hussain (1985) found that the duration of the nymph stage is dependent on the time of birth. The nymphs born in the period from June to August have a shorter lifespan than those born in the period from September to December. To differentiate between both of them, the nymphs born in the hot months are called the summer nymphs while those born in the moderate seasons are called the autumn nymphs. A summer nymph would start to cover its body with the scale after one month of leaving the scale of the parent female insect. The scale takes almost one week to be completed making the duration of the nymph stage around 2-2.5 months. An autumn green scale nymph overwinters without a scale in a quiescent state and starts to form the scale in early spring. In this case, the nymph stage completes in a period of eight to ten months. It was reported that the adult female insects' lives for about one year, while the adult male insects begin their appearance in the late summer season and last till the end of the autumn.

Control Measures

The green scale insect, *A. phoenicis*, does not necessitate a control Program except if the infestation is heavy. In that case, the control Program can implement the following points:

- Spraying the heavily infested date palms with one of the Organophosphorus insecticides, e.g. Malathion 57% or Diazinon 60 %.

- Timing of Spraying: the infested palms should be sprayed during the summer months to kill and eradicate the new crawlers and nymphs before they attack the date fruits. It is also mandatory to spray the infested date palms once more in the autumn season, when about 75 % of the nymphs have left the parental scales.

1.1.7. Date Palm Mealybug

***Pseudaspidioproctus hyphaeniacus* Hall.**
(Homoptera: Margarodidae)

Distribution

Giant mealybug and false mealybug are among the synonyms of the date palm mealybug, *Pseudaspidioproctus hyphaeniacus* Hall. Abu Thuraya (1979) found that the infestation by the date palm mealybug, *P. hyphaeniacus*, was moderate in Al Dawaser valley in Saudi Arabia. Earlier, Martin (1958) recorded *P. hyphaeniacus* in Al Wahat region in Libya. The date palm mealybug was also recorded in the UAE and in Oman, where it was recorded for the first time near Rumais in Al-Batinah Coastal region in 1983 and near Nizwa in 1986 (MAF,1992). It is important to note that this insect pest is monophagous because it infests only date palms and no other hosts have been noticed yet.

Economic Importance

The date palm mealybug, *P. hyphaeniacus*, usually infests neglected date palms and newly transferred offshoots with bundled and roped fronds. The mealybugs feed on the petiole base and are rarely found on the leaflets, although in some areas they were found on the fruits. The nymphs of this species secrete honeydew copiously on which black sooty mould grows leading to contamination of the dates thereby greatly decreasing their market value. On the green fronds, the presence of the honeydew secretions and the black sooty mould hinder the process of photosynthesis, as shown in Fig. 1.23.

It is interesting to note that the date mealybug lives in symbiosis with a black ant species, Fig. 1.24. The ants surround and protect the mealybug colony with small pieces of plant debris cemented together with their secretions. The ants live inside the mealybug colony feeding on their honeydew secretions. Without the ants, the date palm mealybugs would suffocate in their own copious honeydew secretions.

General Description

The segments of the female body of date palm mealybug, *P. hyphaeniacus*, are not clearly visible. The body is big in size and covered with dense white wax. Legs and antennae

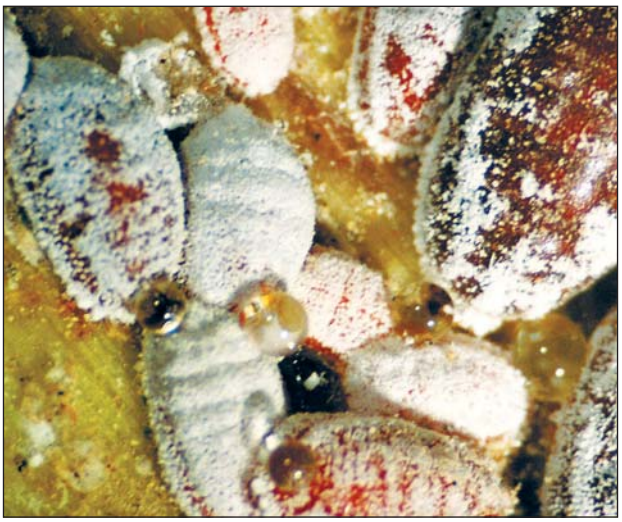


Fig. 1.23. Honeydew secreted by the mealybug colony, *P. hyphaeniacus*.

are present in all developmental stages. The adult female moves like the nymph. No males have been observed in the date palm mealybug, *P. hyphaeniacus*.

Life Cycle

No male insects of *P. hyphaeniacus* have been identified so that they may not exist, which would explain why the date palm mealybug, *P. hyphaeniacus*, reproduces asexually, i.e. by parthenogenesis. The adult female lays up to several thousands of eggs. The eggs are covered with waxy secretions. During the winter season, the date mealybugs migrate to the roots of the palm where they live and feed by sucking the sap (phloem). When the temperature rises and the weather conditions are suitable, they return to their preferred sites on the frond bases.

Control Measures

1. Cultural Control

As already mentioned the date mealybug, *P. hyphaeniacus*, lives symbiotically with the black ants. By preventing the black ants from reaching the colonies of the date mealybug, the mealybugs will suffocate in their own copious honeydew secretions. This can be achieved by painting the palm trunks with an insecticide.

2. Chemical Control

When the infestation is heavy, any of the following insecticide can be used to spray the infested date palms; Malathion 57 % or Pirimiphos-methyl (Actellic® 50 %).

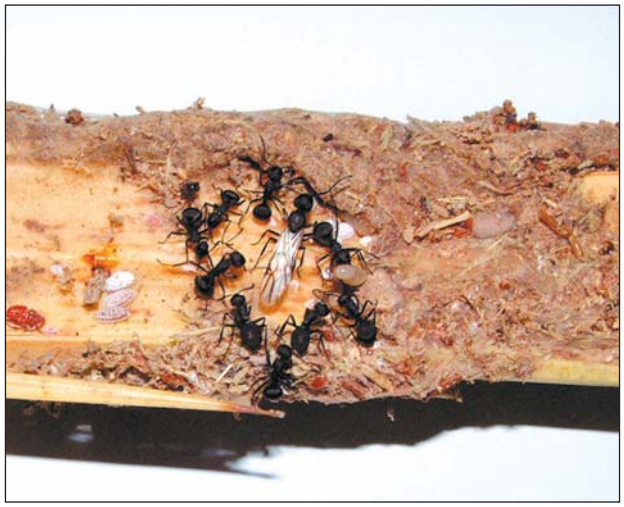


Fig. 1.24. Black ants live symbiotically with mealybug, showing the queen in centr.

1.1.8. Pink Hibiscus Mealybug

***Maconellicoccus hirsutus* (Green)**
(Homoptera: Pseudococcidae)

Distribution

The Pink Hibiscus Mealybug, *Maconellicoccus hirsutus*, was first recorded in Oman in 1977 (Greathead, 1977) and it is considered one of the most abundant species of mealybugs on many types of fruit trees; citrus, guava (*Psidium guajava*), mango (*Mangifera indica*), jujube (*Ziziphus mauritiana*), avocado (*Persea americana*), carambola (*Averrhoa carambola*) and fig (*Ficus carica*) trees. It might also infest many ornamental plants like Hibiscus (rosemallows), (*Hibiscus cannabinus*), China-rose (*Hibiscus rosasinensis*), Jamaica sorrel (*Hibiscus sabdariffa*), and croton (*Codiaeum variegatum*), some vegetables like eggplant and okra (*Abelmoschus esculentus*) and even wild acacia spp. trees like umbrella thorn (*Acacia tortilis*) and Albizzia trees (*Albizzia julibrissin*). In addition, it is infested acerola (*Malpighia glabra*) and sapodilla (*Manilkara zapota*). The pink hibiscus mealybug, *M. hirsutus*, was found attacking date palm (*Phoenix dactylifera*) in Egypt, UAE and Oman.

Economic Importance

Because of the habits and behaviour of the pink hibiscus mealybug in reproducing in large numbers and its high fecundity, it can cause visible damage to the infested palms, if left to reproduce in an area that lacks its natural enemies. The pink hibiscus mealybug, *M. hirsutus*, attacks the fruit stalks and fruit bases in areas of high humidity. It sucks the plant sap, excretes substances causing shrivelling and dryness in the date fruits especially those present in the centre of the bunch.

M. hirsutus, also heavily secretes honeydew on the attacked areas encouraging the growth of black sooty mould. Together, the honeydew and the mould prevent sun light from reaching the affected areas. As a result, the fruits may fall prematurely or may ripen into malformed dates, which greatly decreases their market value. When the infestation is heavy, the growth of the date palm tree may be stunted.

General Description

The adult female of the pink hibiscus mealybug, *M. hirsutus*, is small in size, 3 mm long and the original colour of its body is pink. However, the body is always covered with white coloured waxy secretions in the shape of short threads, Fig. 1.25.

Immature females and newly matured females have greyish-pink bodies dusted with mealy white wax. The adult female is soft-bodied, elongate oval and slightly flattened. On maturation, it begins to secrete sticky, elastic, white wax filaments from abdomen to form a protective ovisac for her eggs. As its pinkish-grey body fills with salmon-pink eggs, the female attains a pink colour, but this is often not immediately visible because the entire colony tends to become covered by white, waxy ovisac material. When the sticky ovisac wax is parted with a needle, clusters of pink eggs and pink to grey females become visible. On the other hand, the adult male insect is smaller than the female and is characterised by its pink colour and a pair of very simple wings and lack mouthparts. It also has long antennae and a pair of long caudal filaments made of white wax threads projecting posteriorly, as shown in Fig. 1.26.

It is noticed that when an insect of the pink mealybugs is crushed, a pink coloured fluid is released from its body, which is the key element to identify this species. As is the case with other mealybugs, the first instar nymphs are called the crawlers being able to disperse and move from a place to another either by walking or by the wind, which carry them away to other places suitable for them to feed and complete the life cycle. Crawlers are pink and very small, varying from 0.3 to 0.4 mm in length.

Life Cycle

The female insects lay their eggs in ovisacs, as shown in Fig. 1.27, which are present inside their abdomen. The number of eggs laid by each female, ranges between 300 and 600 eggs. The eggs are initially orange in colour but turn pink on maturity immediately before hatching. Crawlers are very small (0.3 mm long), light in colour and can survive a day or so without feeding. They cannot walk far by themselves, but are ideally suited to transport by water, wind and animal agents including domestic animals and man.

Crawlers settle in cracks and crevices, usually on new growth, which becomes severely stunted and distorted, in which densely packed colonies develop. The would be female nymphs moult twice, thus have three instars while the nymphs that will develop into males moult three times having four instars. The adult male insects of the pink hibiscus mealybug live for few days only, do not

Fig. 1.25. The adult female of *M. hirsutus.*

Fig. 1.26. The adult male of *M. hirsutus*.

Fig. 1.27. Eggs in the ovisac.

feed and are attracted to a sex pheromone secreted by the unfertilised female when it becomes ready to start mating. It was found that, the pink hibiscus mealybug needs from 23 to 30 days to complete its life cycle. There may be as many as 15 generations per year (Pollard, 1995).

Reproduction is reported as mostly parthenogenetic in Egypt (Hall, 1921) and in India (Singh and Ghosh, 1970). In West Bengal, India, *M. hirsutus* is recorded as being biparental (Ghose, 1971, 1972) and it seems likely that populations in the West Indies are also biparental (Williams, 1996). Males are reported to have a pupal stage capable of locomotion (Bartlett, 1978).

Control Measures

1. Cultural Control

To prevent the dispersal of the pink hibiscus mealybug, *M. hirsutus*, between date palms, we should consider the following aspects:

- Hibiscus plants should not be planted near date palms.
- Landscape plants known to be hosts of the pink hibiscus mealybug, *M. hirsutus*, such as *Acacia* spp. should not be cultivated near date palm groves to limit the spread of the pest.
- Wildly- grown trees near the date palm groves which are considered as host plants, should be removed, e.g. umbrella thorn, *Acacia tortilis*.
- Cutting down infested plants aids dispersal by scattering the crawlers into the air, where the wind may cart them away. Pruning of infested plants, and the clothing, tools and vehicles of agricultural workers can become contaminated with the crawlers and so aid in their dispersal.
- In India, Mani (1989) mentions that sticky banding such as "Tree Tanglefoot Pest Barrier" has been used to protect grape bunches from infestation by *M. hirsutus*. The Tree Tanglefoot Pest Barrier is a brown paste and consists of organic materials (castor oil, waxes, and resins). It can be applied around the trunks of trees and shrubs to block access of crawling insects to leaves, buds, and fruits.

2. Chemical Control

Pesticide sprays tend to be of limited effectiveness against the pink hibiscus mealybug, *M. hirsutus*, because of its habit of hiding in crevices and the waxy covering of its body (Williams, 1996), although systemic insecticides are more likely to be effective. Chemical control cannot be relied upon to eradicate this pest especially in the case of heavy infestations or at fruit setting and near ripening. However, one may resort to use insecticides in some cases to control the number and to limit their damages. When insecticides are used, one should comply with the allowance and safety periods for each insecticide until fruits harvesting. Any insecticide used against *M. hirsutus* should be carefully selected to avoid any disturbance to its natural enemies, because they are likely to be important in helping to keep its populations at low levels in the long term.

In India, (Jalaluddin and Sadakathulla, 1998) found that inorganic oil emulsion sprays gave good control of *M. hirsutus* on guava trees. Anitha *et al*. (1999) tested the alkaloid abrine, isolated from seeds of Abrus precatorius, on *M. hirsutus* and found evidence that abrine could have a drastic effect on the population density of the mealybug.

3. Biological Control

Biological control of the pink hibiscus mealybug, *M. hirsutus*, is considered one of the best measures to decrease its populations. Biological control programs have been implemented successfully in many parts of the world like Egypt, Caribbean Sea Islands and Florida and the Hawaii Islands, in the USA. The biological control of the pink hibiscus mealybug have relied on importing the natural enemies of the insects from different places and releasing them in the infested areas, in what is called the classical biological control or importation.

There are many natural enemies of *M. hirsutus*, which have been imported, reared, released and settled in their new habitat. These natural enemies have been greatly successful in controlling the numbers of the pink hibiscus mealybug and significantly reducing their damages. Among the most notable are:

***Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae)**

Cryptolaemus montrouzieri Mulsant (Coleoptera: Coccinellidae), the Mealybug Destroyer, is one of the most important predators used since long in the control of the different species of mealybugs. Generally, the mealybug destroyer, *C. montrouzieri*, has been imported into more than 40 countries, where it preys on at least 17 species of mealybugs as mentioned by Leeper (1976), Bartlett (1978) and Booth & Pope (1986). As known, the mealybug destroyer was imported into the United States in 1891 from Australia by one of the early biological control pioneers, Albert Koebele, to control citrus mealybug in California. In a few countries, it was unable to become permanently established and to survive during the winter except in coastal areas, Sadof (1995).

In India (Karnataka state), on acid lime two releases of 25 beetles of *C. montrouzieri* per plant in January and February 1999 reduced the population of *M. hirsutus* to economically unimportant levels by mid-March (Mani and Krishnamoorthy, 1999). Similarly releases in guava orchards reduced the mealybug population to insignificant levels within one month (Mani and Krishnamoorthy, 2001).

Meyerdirk and De Chi (2003) mentioned that the great success of the biological control Program against *M. hirsutus* in the Caribbean by using the predatory beetle *Cryptolaemus montrouzieri* and the hymenoptern endoparasitoids *Anagyrus kamali* and *Gyranusoides indica*, is largely attributable to these insects, which reproduce at least twice as fast as the mealybug populations which reduced by 82 - 97 %.

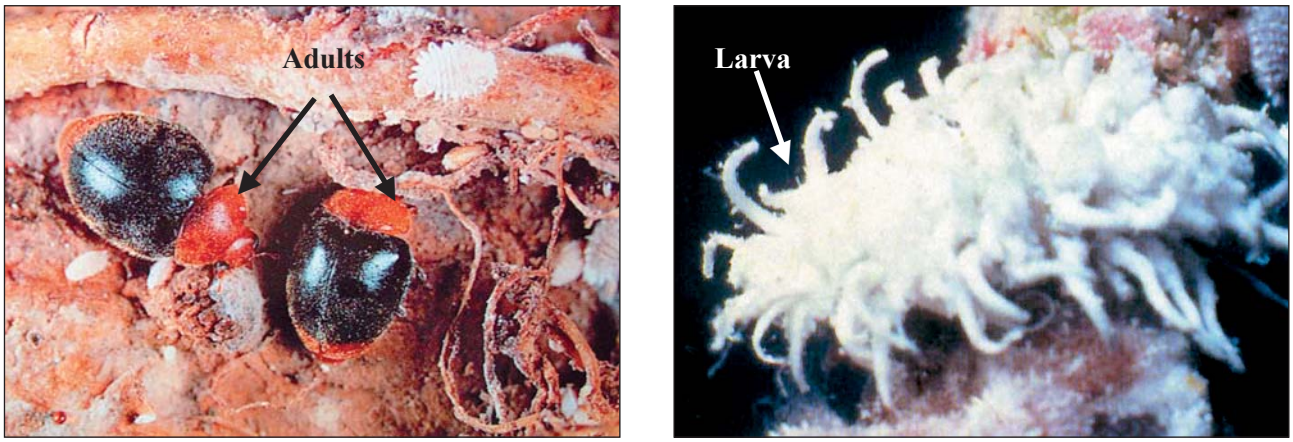


Fig. 1.28. The mealybug destroyer, *Cryptolaemus montrouzieri*.

Fig. 1.29. *Anagyrus kamali*.

In addition, public awareness programs were also important. Public co-operation avoided heavy use of pesticides that might have impaired establishment of the biological control agents, and the public helped to disseminate the natural enemies (Kairo *et al*. 2000).

Kinawy *et al*. (2008), in Oman, mentioned that 14,000 adult beetles of the mealybug destroyer, *C. montrouzieri*, were released during 1994 and 1997 in Dhofar province. The mealybug destroyer was established in the area and significantly contributed toward controlling the main common species of mealybugs, in Dhofar province, i.e.: the Egyptian or breadfruit mealybug, *Icerya aegyptiaca* (Douglas), the citrus mealybug, *Planococcus citri* (Risso) and the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green). The mealybug destroyer not only established in the release site but also spread all-over the coastal region in Dhofar plain and provided effective control of the mealybug pests in both fruit trees and ornamental plants. They also took the view that the *C. montrouzieri* establishment in Dhofar region can be utilised in other parts of Oman by transporting the predators to those areas, which have been infested by pink hibiscus mealybug such as date palms, which are common in north Oman.

In addition, it should be noted that the nymphs of the predator, *C. montrouzieri*, and the pink hibiscus mealybug, *M. hirsutus*, are so similar that only specialists can differentiate between them. The predator nymphs cover their body with white waxy secretions in the shape of long filaments, as shown in Fig. 1.28, making it difficult to distinguish from the mealybugs, which they prey upon.

Another natural enemy of the mealybugs is the parasitoids *Anagyrus kamali* Moursi (Hymenoptera: Encyrtidae), which according to Kamal (1951) is considered one of the significant solitary endoparasitoids, which can achieve complete control of the pink hibiscus mealybugs, *M. hirsutus*, after being introduced into Egypt from Java.

In Egypt, almost total control of the mealybug is maintained using the parasitoid *Anagyrus kamali*, (Williams, 1996). It has been imported in some places like Egypt and Hawaii Islands where it had a dramatic effect in controlling the populations of the pink hibiscus mealybugs, *M. hirsutus*, in a short period of time. It is important to note that *Anagyrus kamali* can complete a full generation in half the time needed by its host, which gives it an advantage over the hibiscus mealybug.

1.1.9. Citrus Mealybug

***Planococcus citri* (Risso)**
(Homoptera: Pseudococcidae)

Distribution

The citrus mealybug, *Planococcus citri*, is distributed in many countries in the world. It is most abundant in Saudi Arabia, Libya, Egypt, Lebanon, Palestine, Syria, Tunisia, Morocco, Jordan, Iran as well as Cyprus and USA especially in Florida. In Oman, the citrus mealybug, *P. citri*, is present where it infests several crops including date palm trees, though without noticeable economic damage.

The citrus mealybug, *P. citri*, is polyphagous and occurs on a wide range of flowering plants (Gravitz and Wilson, 1968; Bartlett, 1978). In the tropics, Entwistle (1972) mentioned that *P. citri* occurs mainly on the aerial parts of crops such as citrus, cocoa, bananas, pomegranate, tobacco and coffee and on wild trees such as: *Ceiba pentandra* and *Leucaena strickland*. Le Pelley (1968) reported that *P. citri* occurs in nearly all coffee-growing countries of the world, and occurs in the Mediterranean basin, in South Africa and in some of the southern United States.

In the South Pacific region, *P. citri* has been recorded on 20 host plants, including Brassicae, Ceiba, Citrus, Cocoa, Cyrtosperma, Cucurbita, Gardenia, Inocarpus, Ipomoea, Leucaena, Morinda, Ocimum, Psidium, Pueraria and Solanum spp., (Williams and Watson, 1988). In India, *P. citri* occurs on mandarin (Amitava Konar, 1998) and has been recorded for the first time on soybean by Jadhav *et al*. (1996).

Economic Importance

The citrus mealybug infests the fronds, bunches and fruits of the date palm as the nymphs and adult insects suck the plant sap and the juices from the green leaves and fruits. Small masses of the white coloured, mealy wax substance, secreted by the insects, can be spotted on the affected parts. These secretions hinder the process of photosynthesis in the photosynthetic palm leaflets affecting plant growth. Moreover, the honeydew is a suitable substrate for black sooty moulds to grow on the infested dates thus greatly diminishing their market value.

General Description

The mature adult female of the citrus mealybug, *P. citri*, is oval shaped, 1.6-3.2 mm long and 1.2-2.0 mm wide (Cox, 1989). It is covered with fine particular white wax with faint but distinct stripe from first thoracic to mid-abdominal segments. Body colour beneath wax is

a characteristic yellow. On the margins of the body of the adult female, there are 17 pairs of stout wax filaments of almost equal length. The anal and two preceding pairs are slightly approximately ten times longer than the rest. The antennae in the adult female consist of eight segments. The egg of the citrus mealybug is small, 0.3 mm long, oval shaped and light yellow in colour.

The adult male of the citrus mealybug is dark yellow or brown in colour and has a single pair of light blue wings. The antenna consists of ten segments and the mouthparts are rudimentary. There are two long filaments at the posterior end of the abdomen.

The first instar nymphs are light brown, while the second instar nymphs are reddish brown with a pair of six-segmented antennae. The third instar nymphs that would develop into adult female insects have antennae consisting of seven segments, while the male-to-be nymphs have antennae consisting of nine segments. The adult male needs one more nymphal instar than the females. The fourth instar is a pupa inside a chamber (sac) of waxy secretions.

Life Cycle

The citrus mealybug, *P. citri*, is oviparous. The adult female starts to lay eggs about two weeks after mating. The eggs are amber and laid in a fluffy posterior ovisac, which is about equal in length to the body of the female adult. The total number of eggs laid by each female insect during its lifetime ranges between 200 and 580 eggs, a number that fluctuates according to the host and the weather conditions particularly the temperature and the relative humidity. It was found that at a temperature of 16°C the adult female insect deposited around 200 eggs. While at 27°C, the number of eggs laid increased to 350 eggs, the maximum number of eggs was laid at 27°C and 60% relative humidity. Arai (1996) mentioned that the higher developmental threshold temperatures must be around 30°C, while the lower developmental threshold temperatures and thermal constants for *P. citri* were 7.7°C and 401 DD (Degree Days) during the nymphal stage and 8.0°C and 378 DD during the pre-oviposition period. It is noteworthy that the reproduction in the citrus mealybug is by parthenogenesis. However, when both male and female insects develop in the same place, they may reproduce sexually as well. Betrem (1936) found that males were rare and believed parthenogenesis might occur.

On the other hand, other researches such as (James, 1937; Entwistle, 1972; Padi, 1996) have found that males and females are produced in approximately equal numbers: the specific sex ratio established from 11413 progeny from 43 females was 101.6 ±1.5 males per 100 females (James, 1937) and 82 males to 106 females (Myres, 1932). It is reported that the adult male citrus mealybugs lives for few days, almost a week. The adult female may live 22-47 days, so that the length of a whole generation of the citrus mealybug ranges from one month to three months. The citrus mealybug *P. citri* has eight generations each year. Abdelkhalek *et al*. (1998) found that *P. citri* had six to eight overlapping generations annually and the high population levels occurred during June-December.

It was found that the males of the citrus mealybug, *P. citri*, are attracted to females by a sex pheromone, dextro-cis-planococcyl acetate, produced by the female, (Rotundo and Tremblay, 1974; Bènassy *et al*. 1976; Panis, 1979). Moreno *et al*. (1984) applied monitoring experiments by using the synthetic pheromone and they found that the male of *P. citri* is an early morning flier with a flight range in the field of up to 183 m compared to a maximum of 2 cm direct flight to the virgin female.

Control Measures

1. Chemical Control

The same measure taken against other mealybugs can be applied against the citrus mealybugs.

2. Biological Control

Many natural enemies, both predators and parasitoids, have been evaluated for the biological control of the

citrus mealybug, *P. citri*. Predators like the larvae and adult insects of lady beetles, the green lacewings and other species of predating mites and thrips are among the natural enemies to the citrus mealybugs. In addition, there are some parasitoids from order Hymenoptera.

Here is a list of the most important natural enemies, which have been successfully used in biological control of the citrus mealybug, *P. citri*;

1. *Cryptolaemus montrouzieri* Mulsant
   (Coleoptera: Coccinellidae)

The Mealybug Destroyer, *C. montrouzieri*, is originally from Australia. It is known and has been deployed since 1892. It is highly effective in controlling the populations of several mealybug species through its larvae and adults, which prey on the mealybugs.

2. *Exochomus flavipes* Thunberg
   (Coleoptera: Coccinellidae).
3. *Rodolia* (*Vedalia*) *cardinalis* Mulsant
   (Coleoptera: Coccinellidae).
4. *Hyperaspis pumila* Mulsant
   (Coleoptera: Coccinellidae).
5. *Dicrodiplosis pseudococci* Felt.
   (Diptera: Cecidomyiidae).
6. *Anagyrus pseudococci* (Girault)
   (Hymenoptera: Encyrtidae).
7. *Leptomastix dactylopii* Howard
   (Hymenoptera: Encyrtidae).

P. citri was successfully controlled by the introduced predator *Cryptolaemus montrouzieri* and by the parasitoid *Leptomastix dactylopii* in France (Panis and Brun, 1971), Sicily (Liotta *et al*. 1976), Queensland in Australia (Smith *et al*. 1988), India (Reddy *et al*. 1992; Mani, 1994), Italy (Fronteddu *et al*. 1996) and Morocco (Abdelkhalek *et al*. 1998).

The Encyrtid wasp, *Leptomastix dactylopii*, a parasitoid of South American origin, gave excellent results in limiting the spread of the citrus mealybug. When it was imported and released in designated areas, the *L. dactylopii* spread and established itself feeding on the citrus mealybugs. The Encyrtid wasp, *L. dactylopii*, is present in Oman and attack the citrus mealybug, *P. citri*, in north Oman, Fig. 1.31. The third instar of larval stage of the citrus mealybug, *P. citri*, is the sole prey of the Encyrtid parasitic wasp, *L. dactylopii*, which is a native of Brazil. Under favourable conditions, (25°C and 60-65% humidity), the females lay about 60-100 eggs within 10-14 days inside the mealybug. Once the larvae hatch, they completely consume their host. The pupae swell and harden into a yellow-brown (striped) mummy. The adult parasitic wasp emerges through a round hole at the rear of the mummy. Approximately two weeks after introduction, the first mummies can be seen in the crop.

The life cycle of the Encyrtid wasp *L. dactylopii* is about 25 days. The body of *L. dactylopii* is orange and the back of head is dark brown. The scape (the basal segment of the Antenna) is long and cylindrical with dorsal margin darker than venter, flagellum with all funicles longer than wide and generally brownish. The adult male is smaller than the female and has hairy antennae. The other stages of the wasp develop inside their host. The recommended release rate is 1-2 wasps per square meter or five wasps per heavily infested plant and the minimum release rate is 7500 wasps per hectare. In addition, multiple releases may be required where there is a history of mealybug problems.

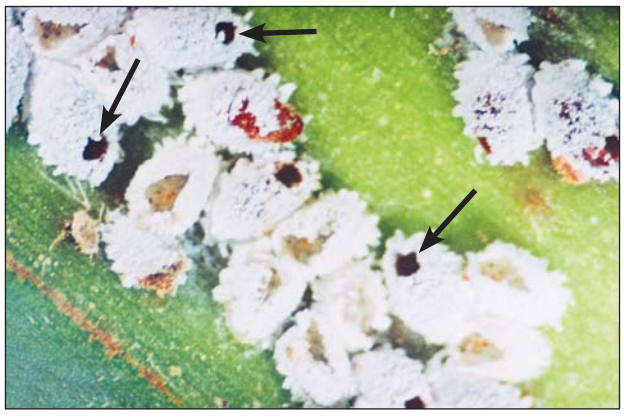


Fig. 1.30. Emerging hole of Encyrtid wasp, *L. dactylopii*, parasitoid of the citrus mealybug, *P. citri*.

1.1.10. Spherical Mealybug

***Nipaecoccus viridis* (Newstead)**
syn. *Nipaecoccus vastator* (Maskell)
(Homoptera: Pseudococcidae)

Distribution

The spherical mealybug, *Nipaecoccus viridis*, is widespread in many countries worldwide and has been recorded on date palm in Egypt, Iran, Iraq, and Pakistan, in addition to Oman. It is not considered a damaging pest to the date palm and does not require a specific pest control Program. It is worth to note that the spherical mealybug, *N. viridis*, is a polyphagous pest with a wide range of plant hosts. It infests many species of trees like date palms (*Phoenix dactylifera*), lime (*Citrus aurantiifolia*), sour orange (*Citrus aurantium*), lemon (*Citrus limon*), pummelo (*Citrus maxima*), navel orange (*Citrus sinensis*), grapefruit (Citrus x paradisi), arabica coffee (*Coffea arabica*), jujube (*Ziziphus mauritiana*), fig (*Ficus carica*), mango (*Mangifera indica*), pomegranate (*Punica granatum*), and grapevine (*Vitis vinifera*). The list of hosts also includes apricots, apples (*Malus domestica*), pears (*Pyrus communis*) as well as cotton (*Gossypium hirsutum* L.).

Economic Importance

In the date palms, the spherical mealybug, *N. viridis*, attacks the fronds, bunches and fruits. Like many mealybug species, the nymphs and adult insects feed by sucking the plant sap from the infested parts. These insects also secrete the honeydew that covers the palm leaflets and dates leading to the accumulation of dust and the growth of black sooty mould. In addition, the leaves and other parts of the tree shine because they are wetted with honeydew. In general, a heavy infestation causes deformities in the dates affecting their quality and subsequently lowering their market value.

General Description

The adult female has extremely short legs and is approximately 4 mm long by 3 mm wide with body colour black, purple to blue green with thick white or pale yellow wax. The young ones are covered in mealy white wax with short projecting filaments arranged around the margin. The mature females become covered in abundant white or pale yellow waxy threads that form a smooth globular ovisac. The wax threads are very elastic and if the ovisac is grasped and pulled with the fingers, it can be drawn out for 150 mm or more. The body contents are purple and this can be observed when individuals are squashed. The egg is light brown in colour, elongated in shape, 0.26 mm long and 0.17 mm wide.

The mature adult male insect is reddish in colour, with a single pair of wings and rudimentary mouthparts. There are two long filaments on the posterior end of the abdomen. The length of a mature adult male is nearly 0.9 mm. It is very short-lived.

The male and female insects can be differentiated in the nymphal stage. The "female" nymph is pale yellow in colour with two long filaments at the abdomen's end. The "male" nymph is rose in colour and spins a cocoon around its body after the first moult. Generally, the nymphs are 0.75 to 1.3 mm in length.

Life Cycle

Hussain (1985) mentioned that the spherical mealybug, *N. viridis*, had 6-7 generations per year in Iraq. Each generation lasted from 28 to 56 days. In the spherical mealybug, overwintering took place mostly as eggs with few nymphs and adults. Early in the spring, the eggs begin to hatch and the crawlers emerge to disperse on the various parts of the plant until they settle down and feed by sucking the plant sap. Later, the female nymph moults thrice and the male four times before they develop into mature adult insects. The adult female insects begin to oviposit three days after the last moulting. The female forms a white waxy sac in which it deposits the eggs. Each female can deposit from 113 to 1524 eggs during its lifetime. The incubation period of the eggs is about 7 days. The duration of the nymphal stage is ranging from 18 to 22 days. The adult female lives longer than male, its lifespan ranging from one week to five weeks, whereas the males live only for 5 days.

Jarjes *et al*. (1989) stated that there were significant positive correlations between population density of *N. viridis* and temperature, and negative correlations with relative humidity. They also mentioned that each female of *N. viridis* laid 90-138 eggs on rosebay shrubs, and the egg and nymphal stages lasted 10-13 and 31-43 days, respectively.

Control Measures

1. Chemical Control

Sharaf (1996), in Egypt, mentioned that the life-table studies indicate that *N. viridis* should be controlled on lemon trees by means of insecticide applications during the first half of July instead of the traditional control operations in spring, summer and autumn.

2. Biological Control

There are several natural enemies, whether predators or parasitoids, which help in controlling the number of the spherical mealybug. Should the spherical mealybug insects inflict noticeable economic damages on the date palm, citrus trees or other plants, here is a list of the most important of parasitoids and predators reported in Iraq. One or more of them can be imported and released if the need arises to implement what is called the classical biological control.

a. Predators of the spherical mealybug

***Chrysoperla carnea* Stephens**

(Neuroptera: Chrysopidae)

Which known as green lacewings. The larvae prey on the eggs, nymphs and adult forms of many pest insects including the various forms of the spherical mealybug, *N. viridis*, which attack date palms.

***Diomus rubidus* Motsch.**

(Coleoptera: Coccinellidae)

It was found that the larvae and adult insects of this lady beetle species prey on the nymphs and adult insects of the spherical mealybug, *N. viridis*.

***Exochomus nigripennis* Erichson**

(Coleoptera: Coccinellidae)

Hussain (1985) noted that this predator beetle is specialised in devouring the eggs of the spherical mealybug. A single larva can consume approximately 1,735 eggs of the spherical mealybug while the adult beetle can eat as much

as 17,443 eggs. As a result, *E. nigripennis* is one of the most important natural enemies to the spherical mealybug on date palms. The adult beetle of this Coccinellid beetle, *E. nigripennis*, overwinters in a diapause state and becomes active again in early spring when each female insect may lay 300 eggs in average. This predator has several generations per year.

***Hyperaspis pumila* Mulsant**
(Coleoptera: Coccinellidae)
The larvae and adult forms of this lady beetle, *H. pumila*, feed on the eggs, nymphs and adults of mealybug insects.

In addition to the above predators, there are another three species of lady beetles, genus *Nephus*, which prey on spherical mealybug. These three species are *Nephus bipunctatus* Kugelann, *Nephus nigricans* Weise and *Nephus hiekei* Fürsch.

***Dicrodiplosis pseudococci* Felt.**
(Diptera: Cecidomyiidae)
The larvae of this fly species feed on the eggs and nymphs of the mealybugs. This fly overwinters in diapause usually in the pupal stage and occasionally in the larval stage.

b. Parasitoids of the Spherical Mealybug.
Meyerdirk *et al*. (1988) showed that *Anagyrus indicus* Shafee, Alam & Agarwal (*Anagyrus agraensis* Saraswat), (Hymenoptera: Chalcidoidea) which was released into the Jordan River Valley from Guam, greatly reduced infestations of the spherical mealybug, *N. viridis*, in areas where *A. indicus* was abundant.

In addition, the larvae of several parasitoids feed on the nymphs and adults of the spherical mealybug. Here is a list of these parasitoids:

1. *Neochrysocharis formosa* (Westwood)
   (Hymenoptera: Eulophidae)
2. *Chartocerus kurdjumovi* Nikol'skaya
   (Hymenoptera: Chalcidoidea)
3. *Prochiloneurus aegyptiacus* (Mercet)
   (Hymenoptera: Encyrtidae)
4. *Anagyrus bohemanni* Westwood
   (Hymenoptera : Encyrtidae)
5. *Anagyrus diversicornis* Howard
   (Hymenoptera: Encyrtidae)

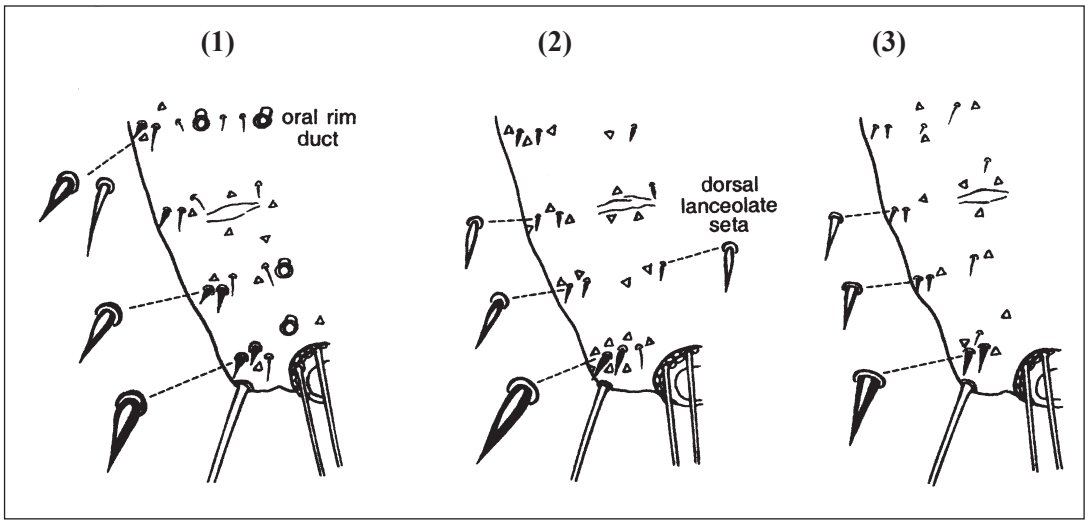


Fig. 1.31. Dorsum of the posterior abdomen of second-instar females of three mealybug species. (1) *Planococcus citri.* (2) *Nipaecoccus viridis.* (3) *Maconellicoccus hirsutus.*

Fig. 1.31 and Table 1.10 illustrates a summary of the study carried out by (Gullan, 2000) to distinguish between six morphological types of mealybugs that infect citrus in Australia and can take advantage of this study to distinguish between three types of mealybugs, which affect the date palm in the Sultanate of Oman and many other parts of the world, i.e., *Planococcus citri, Maconellicoccus hirsutus* and *Nipaecoccus viridis.*

Table 1.10. Morphological features that distinguish nymphal instars of *Planococcus citri*, *Maconellicoccus hirsutus* and *Nipaecoccus viridis.*

Species	Antennae		Anal ring (µm)	Dorsal oral rim ducts	Anal lobe bar and cerarian sclerotisation	Cerarian setae
	No. of segments	Length (µm)				
First instar						
P. citri	6	--	30-32	Absent	Bar but no sclero	Robust in anal lobe cerarii only
M. hirsutus	6	--	28-33	Absent	Bar but no sclero	Robust in anal lobe cerarii only
N. viridis	6	--	30-35	Absent	Bar but no sclero	Robust in anal lobe cerarii only
Second instar						
P. citri	6	200-220	40-45	Absent in females (a few oral collar tubular ducts mostly on dorsal margins plus dorsal multilocular pores, approximately 5 µm in diameter, in males).	No cerarii sclerotised; distinct anal lobe bar.	Conical in most abdominal cerarii but most robust on anal lobes, more slender anteriorly; robust flagellate setae on thoracic and head cerarii.
M. hirsutus	6	180-190	40-45	Most segments with two or more ducts dorsally females (usually only oral collar tubular ducts on dorsum in males).	No cerarii sclerotised; anal lobe bar present.	Robust lanceolate only in last 4–5 pairs of abdominal cerarii of females, only in anal lobe cerarii of males.
N. viridis	6	180-200	43-50	Absent in females (scattered oral collar tubular ducts only in males).	No cerarii sclerotised; anal lobe bar barely discernible.	Robust lanceolate in all abdominal and most thoracic cerarii; robust lanceolate setae (approximately 10 µm long) also on dorsum.
Third instar (females only)						
P. citri	7	270-300	50-60	Absent	No cerarii sclerotised; anal lobe bar present	Conical in all 18 cerarii; no auxiliary setae.
M. hirsutus	7	250-270	55-60	Present in transverse rows	No cerarii sclerotised; lightly sclerotised anal lobe bar present.	Robust lanceolate in 4–6 pairs of cerarii on posterior abdomen only; auxiliary setae sometimes present
N. viridis	6	220-250	60-65	Absent	No cerarii sclerotised; broad, lightly sclerotized anal lobe bar present	Robust lanceolate in 10–12 pairs of cerarii on abdomen and posterior thorax only; no auxiliary setae; robust lanceolate setae (approximately 15 µm long) also on dorsum.

(Source: Gullan, 2000)

1.1.11. Arabian Cicada

***Platypleura arabica* Myers**
(Homoptera: Cicadidae)

Distribution

There are about 3000 species of cicada around the world. The name "Cicada" is a direct derivation from Latin, which meaning "buzzer". Cicadas live in temperate to tropical climates where they are among the most widely recognized of all insects, mainly due to their large size and their conspicuous acoustic signals or "songs", which the males make using special structures called "tymbals" or "timbals" , found on the abdomen.

The Arabian Cicada, *Platypleura arabica*, pervades in Arabian Gulf in Qatar, United Arab Emirates and Oman. The local name for Cicada insect in Oman is Saroukh (Arabic: high sound). The males of Cicada species sing through issuing continuous and noisy loud sounds throughout the day stopping only when disturbed or approached.

Songs of Cicadas

Each Cicada species has its own distinctive song. The males produce these sounds or "Songs" through two organs found on both sides of the first abdomenal segment known as "tymbals", i.e. the shell-like drum at the base of the abdomen. The tymbals are regions of the exoskeleton that are modified to form a complex membrane with thin membranous portions and thickened "ribs". Contracting the internal tymbal muscles produces a clicking sound as the tymbals buckle inwards. As these muscles relax, the tymbals return to their original position producing another click. The interior of the male abdomen is substantially hollow to amplify the resonance of the sound. A cicada rapidly vibrates these membranes, and enlarged chambers derived from the tracheae make its body serve as a resonance chamber, greatly amplifying the sound. The females of Cicada insect cannot sing or produce sounds, but gravitate towards sounds produced by the males. Moreover, it is possible to benefit from Cicada in phenomenology, which seeks the relation between the climate and one of the periodic biological phenomena, in the appearance of the insect, which is deemed a clear indicator for the start of the summer season in the Sultanate of Oman.

Fig. 1.32. The ova of the Cicada arranged on the palm midrib (right) and an enlarged photo of the ova depositing slit (left).

Economic Importance

In Oman, the Arabian Cicada, *P. arabica*, exists in wild trees such as Acacia trees. It deposits its eggs in the twigs of wild trees, citrus and mango trees and date palms. The most important damage from the Cicada insects on date palms are due to the digging as well as the scratches made by females on rachis of the fronds in order to deposit their eggs, which are severely injured causing topical dryness of the fronds. Sometimes fungi invade the tissue of the middle vein and turn the areas where females have dug into dark brown colour, Fig. 1.32. Sometimes the fronds, where the Cicada females have laid their eggs break, Fig. 1.33. Close up of Cicada eggs under stereomicroscope are showing in Fig. 1.34. Generally, the damage caused by Cicada is limited in date palms, as it spends most of time on the wild trees for feeding via sucking the juice from the wood.

General Description

The adult of the Arabian Cicada, *P. arabica*, has a strong body, which is large at the front end. It is a big insect, as its length from head to tip of wings reaches 35-40 mm, Fig. 1.35. Its body is wedge-shaped, the head very broad, eyes slightly bulging at the sides, the abdomen tapering rapidly behind. The forewings are longer than the body, lens shaped, glistening, prominently veined; the hind pair half as long. The adult face is prolonged downward and backward V-shaped to the base of the slender, stiff labium. The upper surface of the body is black in colour with a wide light black strip at the end of the transparent wings. The egg is elongated and 3 mm in length. The nymph is brownish in colour and has strong forelegs adapted for digging the soil. The fully-grown nymph is about 35 mm long.

Fig. 1.33. Frond breaking due to eggs.

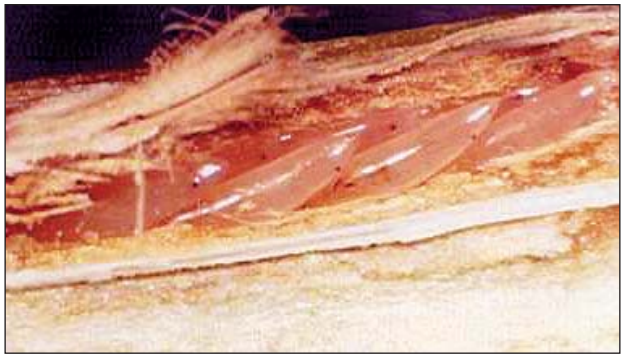


Fig. 1.34. Close up of Cicada ova deposited by Cicada females.

Fig. 1.35. Adult of Cicada insect, *P. arabica.*

Life Cycle

After mating, the females of the Arabian Cicada, *P. arabica*, begin to deposit their eggs in slits made by their strong ovipositors. They cut the surface of the rachis of the fronds to deposit the eggs along the main vein of the lower surface of the frond. Each female may do so repeatedly, until she has laid several hundred eggs. The eggs hatch after 4-6 weeks into nymphs, which fall to the ground and burrow into the soil.

Cicadas live underground as nymphs for most of their lives, at depths ranging from about 30 cm up to 2.5 m. The nymphs feed on root juice and have strong front legs for digging. They live underground by hiding between the tree roots and feeding on them for up to two years. In the final nymphal instar, they construct an exit tunnel to the surface and emerge from the soil at the end of March or early April. They crawl up on the side of the nearest trees, then moult (shed their skins) on a nearby plant for the last time and emerge as adults. The abandoned skins remain clinging to the bark of trees and can be easily noticed on the trees, such as a Casuarina tree (*Casuarina tenuissima*), Fig. 1.36.

The seasonal activity of the Arabian Cicada, *P. arabica*, in Oman extends from April to August. Depending on ecological studies that were conducted in Oman about the seasonal activity of the Cicada insect via light traps, (Mokhtar *et al*., 1991), it was found that the biggest number of the Cicada adults appear within the second and the third weeks of June, as it is illustrated in Fig. 1.37.

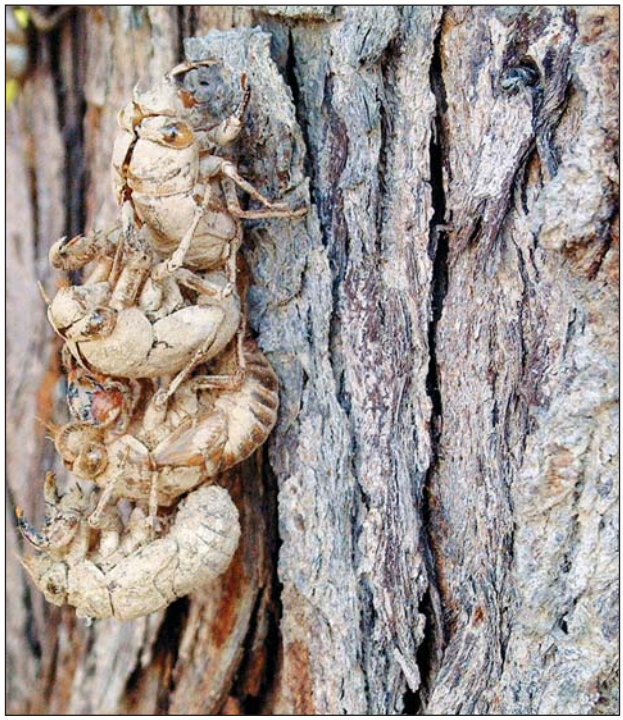


Fig. 1.36. The discarded Cicada skins suspended from a Casuarina tree.

Control Measures

Because of the limited damage by Cicada on the date palms, it is not necessary to follow any measure to control it. Birds commonly feed on Cicadas and are considered important predator for Cicada. In addition, there is a fungal disease, (*Massospora cicadina*), which is the significant pathogen of Cicadas thereby helping to reduce the population of Cicada.

Another known predator is the Cicada killer wasp, (*Sphecius* sp.), which is a large, solitary, ground dwelling, predatory wasp. Cicada killer wasps are so named because they hunt Cicadas and store them in their nests after stinging and paralyzing them. There are 21 species of this killer wasp, (*Sphecius* sp.), worldwide. The highest diversity occurs in the region between North Africa and Central Asia.

Furthermore there are some parasitoids of the order Hymenoptera that have been recorded on the Arabian Cicada in Oman (MAF, 1994), which are *Archirileya femorata* (Boucek) (Eurytomida), *Eupelmus* sp. nr. *elongatus* Risbec (Eupelmidae) and *Pseuderimerus* sp. (Torymidae).

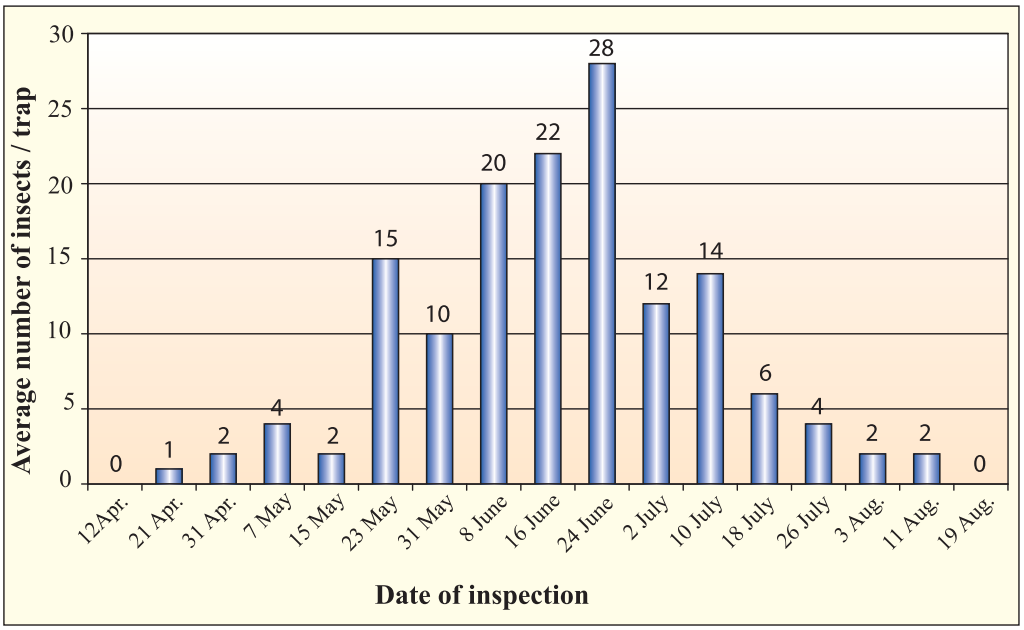


Fig. 1.37. The adult's activity of the Arabian Cicada, *P. arabica*, throughout the year in Oman.

1.1.12. Date Palm Offshoots Leafhopper

***Perindus binudatus* Emeljanov**
(Homoptera: Cixiidae)

General Description

The adult insect of the date palm offshoots leafhopper, *P. binudatus*, is usually found on the leaves. No nymphs are found and they probably feed on the roots inside the soil. The adult insect, like other species of leafhoppers, can jump (hop) or fly for short distances in most instances to escape from a danger or to wander among the date palm offshoots. The female insect has a sharp, dagger-like ovipositor, Fig. 1.38 shows the female insect with the sharp dagger-like ovipositor. It was possible to differentiate the female from the male by the venation of the forewing Fig. 1.39.

The date palm offshoot leafhopper, *Perindus binudatus* Emeljanov, was first recorded in Oman on date palm offshoots (Mokhtar *et al*., 2001d) inside the cooled greenhouses of the Agricultural Research Station in Jimmah in interior region. This insect pest was also recorded in some of the mountain villages in the North of Al-Batinah area of "Wadi Hibi".

Life Cycle

Not much is known about the life cycle of the date palm offshoots leafhopper, *P. binudatus*. This species of leafhopper was also recorded on date palm in the south west of Iran. It is important to mention that the Cixiidae family is distributed worldwide and approximately 1500 species of this family have been described. In New Zealand, Lariviere (1999) recorded eight genera and 25 species of family Cixiidae. He mentioned that most of these species have similar life cycles with the following stages: the egg stage, the nymphal stage (5 instars) and the adult stage. He also stated that the majority of these species have one generation annually except *Oliarus atkinsoni* which was found to have only one generation every two years.

The females of the family Cixiidae of leafhoppers are characterized by secreting wax in the form of white wool, which is carried in the abdominal end and placed around

the eggs deposited in the soil. In addition, the nymphs grow around the roots on which they feed. The adult insect is usually active during the day and can be found on the date offshoots as well as on the grass situated under these offshoots.

Mokhtar *et al*. (2001d) studied the seasonal fluctuation of the adult population of *P. binudatus in Oman*, for one year by using yellow colour sticky traps. These traps were suspended in a cool greenhouses used for producing date palm offshoots. The peak population of the adult insects was recorded during the third week of August, while the lowest number adult insects was recorded during the second week of December.

Fig. 1.38. Female ovipositor of *P. binudatus*, which resembles a dagger

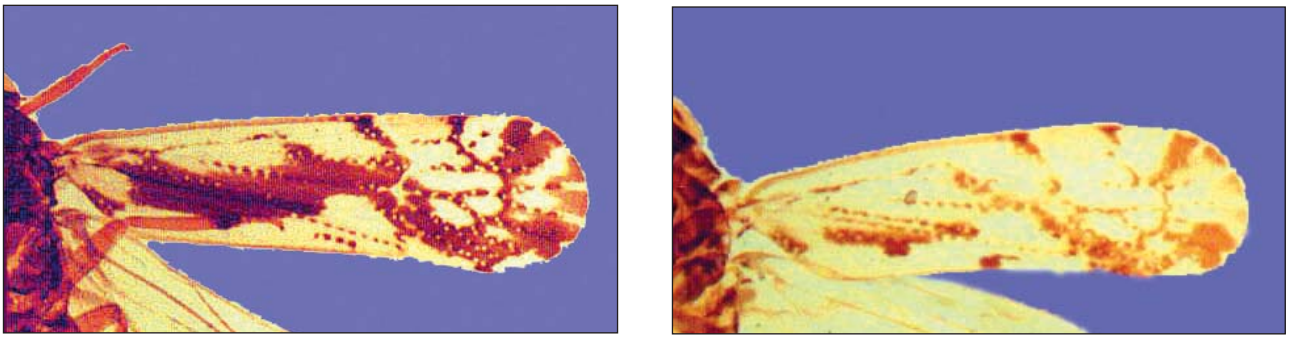


Fig. 1.39. The forewing of a female (left) and a male (right) of the date palm offshoots leafhopper, *P. binudatus*

1.2. Order: Lepidoptera

1.2.1. Lesser Date Moth

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

Distribution

The Lesser Date Moth (LDM), *Batrachedra amydraula* Meyrick, is distributed in all date producing countries and has been recorded in Saudi Arabia, Egypt, Libya, Palestine, Kuwait, Bahrain, Iran, India, UAE and Oman. El-Haidari and Tijani (1977) stated that the rate of infestation with the lesser date moth in Oman ranged between 1-15 %. Saaidi (1992) demonstrated by survey that the lesser date moth insect is one of the main pests attacking the date fruits in Oman, and he added that the date varieties have different susceptibility to infestation by the LDM. He noted that the variety Khalas is one of the most susceptible varieties.

Economic Importance

LDM, *B. amydraula*, is a pest of date fruits. The larvae of the first generation feed on the small fruits after fruit setting, i.e. "Hababouk" stage. The larvae enter from top between the three carpels inside the young fruit. Each larva has its independent entry pore in the fruit and may attack from three to four fruits during its lifetime. Usually, each larva eats more than a third of the fruit and it may sometimes feed on the entire content and consume seed in varieties in which this is tender, leaving only the outer fruit skin. These infested fruits wither and are suspended from the stalks by the silk threads secreted by the larvae or they fall on to the ground as in Figs. 1.40 and 1.41.

The larvae of the second and third generations enter inside the fruits near the calyx or through the calyx and they feed on the placenta, fruit flesh and the fruit kernel. After some time these fruits become reddish in colour. Hence, the name Homera is given to the insect, which means red in Arabic. The damaged fruits begin to drop from bunches whichever stage they are in, (Kimri, Khalal, Rutab or Tamar). The infestation of the dropped fruits can be differentiated by the pore present on each infested fruit filled with the faeces of the larvae and by the presence of the silk weaving secreted by the larvae. It was found that the fruit infestation in both Kimri and Khalal stages led to their fall to the ground, as shown in Fig. 1.42.

Fig. 1.40. Signs of infestation by *B. amydraula*

Fig. 1.41. Visible faeces of the larvae and the fruits still attached to the stalks

It is important to differentiate between this drop of fruits and the normal physiological one, which occurs in most species of fruits, which called the June drop. In some regions in Iraq, almost 70 % of the dropped fruits of date palms were not infested by the LDM.

The degree of infestation with the LDM, *B. amydraula*, can be assessed using the ratio of the infested fruits to the total drop fruits. It is considered a mild infestation if the percentage of the infested fruits is 5% of the total drop fruits, moderate if between 25-30% and severe if it is more than 30%. Carpenter and Elmer (1978) stated that the loss in the date palm fruits due to the infestation with the LDM might reach up to 75% in some regions.

Fig. 1.42. A Group of dropped fruits infested with *B. amydraula*

General Description

The adult female of *B. amydraula* is a minute moth around 13-15 mm in length and it is dull yellow-white speckled with grey, with a wingspan of about 10-13 mm, Fig. 1.43. The forewings are covered with white scales and have extremely small brown coloured spots. The hind wings are narrow and light brown in colour. The wings are surrounded with long brownish brittle hairs. The abdomen is silver in colour, the compound eyes are brown and the antennae are silvery with brown spots. The adult female lays its tiny eggs on the fruit stalk, and after hatching the larvae enters the young fruit from the calyx end. The egg is white in colour, circular in shape and around 0.3 mm long. The fully-grown larva is about 20 to 22 mm in length and milky white or pink in colour. The head and the first prothorax segment are dark in colour, Fig. 1.44.

The larval stage has five instars. Each segment of the larval body carries the following tubers:

- Two adjacent tubers with dark colouration on each of the two sides with one hair emerging from each tuber.

- Two tubers near the centre of the segment on the back. From each tuber emerges a bristle that is twice as long as the previously mentioned side tuber bristles.

Fig. 1.43. Adult of *B. amydraula*

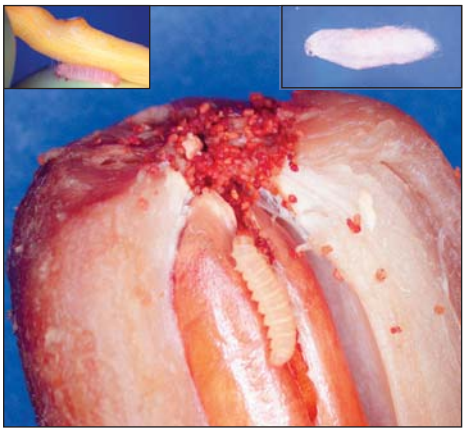


Fig. 1.44. Larva and pupa of *B. amydraula*, note the faeces in the fruit calyx

- Two distant tubers far from the centre of the segment on the back as well. The bristle from the posterior tuber is long and one of the anterior tubers is short.

The pupa has a thin and elongated body shape with yellowish brown colour. It lives inside a silk cocoon, which is pale yellow or silvery white in colour. The cocoon is tip-ended from both ends and around 15 mm in length.

Life Cycle

Gharib (1968) in Iran, Michael and Habib (1971) in Egypt, Hussain (1974) and El-Haidari *et al*. (1975) in Iraq studied the life cycle of *B. amydraula*. They observed that it had from two to three generations per year in Iraq, Egypt and Iran. Hussain (1985) also stated that *B. amydraula* had three generations each year in Basra region in the south of Iraq.

In Oman, Abdallah *et al*. (1998b) studied the seasonal fluctuation of the population of *B. amydraula* and found that the adult insects began to appear in late February. They mentioned that the peaks of infestation with *B. amydraula* were recorded at the second weeks of March, April and May. They found that the infestation ceased from the beginning of June and this indicates that *B. amydraula* has three generations per year. In addition, they conducted biological studies on the LDM, *B. amydraula,* under laboratory conditions and found that the first generation of *B. amydraula* extended from the fourth week of February to the first week of April, the second generation extended from the fourth week of March to the first week of May, while the third generation extended from the first week of May to the second week of March of the following year.

They reported that the incubation period of the eggs in the three generations ranged from 4 to 5 days and the larval duration ranged between 8 to 17 days. On the other hand, the pupal duration ranged between 12 and 15 days, during the first and second generations, while during the third generation it was extended to between 271-300 days with an average of 292 days. The following is a general summary of the three generations of the LDM, *B. amydraula*, in respect to the duration of each generation and the sites of infestation of its different growth stages:

First Generation

The duration of the first generation is about one month. The adult moths of the first generation start to appear at the end February as the females deposit their eggs on the calyx end and date stalks. Each female lay from 6 to 35 eggs throughout its lifetime. The eggs hatch after 4 to 5 days into tiny larvae that attack the young fruits after fruit setting. Usually, one larva exists inside the fruit, but sometimes two larvae may be found inside one fruit. It is worth mentioning that when the infested fruits fall off to the ground, the larvae remain on the crown of the palm tree and do not fall off with them. The duration of the

larval stage is around two weeks and when fully-grown the larva leaves the fruit looking for a suitable place to spin its silken cocoon, inside which it turns into a pupa. The pupal stage lasts around two week.

Second generation

The duration of the second generation is around one month like the first one. The peak of this generation is during the second week of April. The larvae of this generation also feed on the dates at "Kimri" stage. The larval stage of this generation lasts two weeks, while the duration of the pupal stage is the same as the first generation, i.e. two weeks or slightly less.

Third Generation

The longest among the generations is the third as it extends from the first week of May until the first week of March of the following year. Accordingly, the duration of this generation ranges between 9.6 and 10.4 months. The larvae in this generation feed on the dates at "Khalal" and "Rutab" stages. The larvae feed on the Khalal stage first, which is starting to change into Rutab stage in at the end of July. Then the fully-grown larva searches for a suitable place to spin the pupal cocoon. It remains inside the cocoon, hibernating, during the autumn and winter seasons. The LDMs of the first generation appear at the end of February. Thus, the pupal stage duration in this generation is as long as 9 to 10 months. It was found out that, the adult of *B. amydraula*, live for an extremely short time, ranging between 4 and 8 days and that they start to lay eggs after one or two days from emerging from the pupal stage.

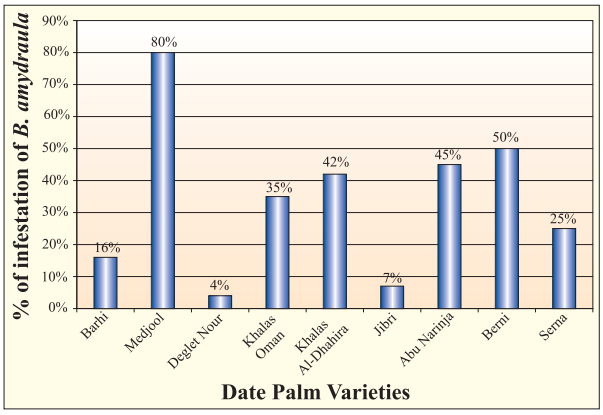


Fig. 1.45. The percentages of infestation with *B. amydraula*, among some date palm varieties

Susceptibility of Date Palms to *B. amydraula* Infestation

Hussain (1974) mentioned that there had been no recorded date palm varieties, which are resistant to the infestation with the LDM, *B. amydraula*, in Iraq. However, in Oman, El-Haidari *et al*., (1992) conducted studies on some Omani date palm varieties to determine their resistance to the LDM infestation. Fig. 1.45 demonstrates the summary of the results of this study. It was found that the Medjool variety was the most susceptible to be infested with the LDM among all varieties and had 80% infestation. The varieties of Deglet Nour and Jibri were the least susceptible with infestation percentages of 4% and 7%, respectively. As for the moderate susceptible varieties: these were Berni, Abu Narinja, Khalas Al-Dhahira and Khalas Oman with infestation percentages of 50%, 45%, 42% and 35%, respectively.

Control Measures

1. Mechanical and Agricultural Control

The mechanical and agricultural control measures of the LDM, *B. amydraula*, rely on executing the following measures:

- Collecting the infested fruits, which are present on the leaves and fruit dropped on the ground between the date palms and the weeds and then burning them.
- Regular pruning, fibres removal and cleaning the remains of the previous crop in palm crown.
- Removing the offshoots or aggressively cutting them.
- When planting a new date palm grove it is recommended to cultivate the varieties that flower during the same period in one place or sector. This would help in facilitating the implementation of the control measures against the larvae of the first generation of LDM on the early varieties, hence decreasing the population of this pest in the subsequent two generations.

2. Chemical Control

In Oman, chemical control against *B. amydraula*, is recommended in the heavy affected areas by using one of the recommended Organo-phosphorus pesticides. This could be done through a Program of two consecutive sprayings, with 15-21 days interval, and the first spraying must be applied around 15 days after fruit setting (during March). In Oman, the best time for spraying against the LDM is in the second week of March. Any of the following pesticides may be used in the chemical control program as they were proven effective in controlling LDM, (Abdallah *et al*., 1998b); Trichlorfon (Dipterex® 80% WP), Fenitrothion (Sumithion® 50% EC), Deltamethrin (Decis® 2.5) or Carbaryl (Sevin® 85% WP).

3. Biological Control

There are many natural enemies known to attack *B. amydraula*. Abdul Wahab (1975) recorded the following parasitoids from family Braconidae (Hymenoptera) on LDM, in Iraq, these parasitoids were *Bracon brevicornis* Wesmael, *Bracon hebetor* Say and *Phanerotoma ocularis* Kohl. In addition, another two parasitoids were recorded on *B. amydraula, i.e. Parasierola* sp. (Family: Bethylidae) and *Habrocytus* sp. (Family: Pteromalidae). It is believe that the previous parasitoids control the caterpillars of the LDM naturally in many areas. He also discovered that the larvae of the common green lacewing, *Chrysoperla carnea* Stephens, attack and prey on LDM larvae. In Egypt, Michael (1970) recorded *Hymenobosmina* sp. (Hymenoptera: Ichneumonidae) as a parasitoid on *B. amydraula*.

In Oman, Abbas *et al*. (2008) found that the parasitoid *Goniozus* sp. (Hymenoptera: Bethylidae), Fig. 1.46, was the most common parasitoid of *B. amydraula*. They mentioned that this parasitoid was reared successfully in the laboratory on larvae of *Galleria mellonella* L. (Lepidoptera: Pyralidae) and released in three date palm orchards as a bio-control agent against *B. amydraula*. Efficacy of *Goniozus* sp., released in the three date palm orchards against *B. amydraula*, was assessed using the ratio of "*Batrachedra*: *Goniozus*" (B: G) obtained from the samples of infested date fruits collected from releasing orchards and control orchards. Their study revealed that the (B: G) ratio in the *Goniozus*-released orchards ranged from 1: 1.1 to 1: 3.1, while this ratio ranged from 1: 0.1 to 1: 0.05 in the control orchards. The results suggest that the parasitoid *Goniozus* sp. could be utilized within an IPM program against the LDM, *Batrachedra amydraula*, which attacks date palms in Oman.

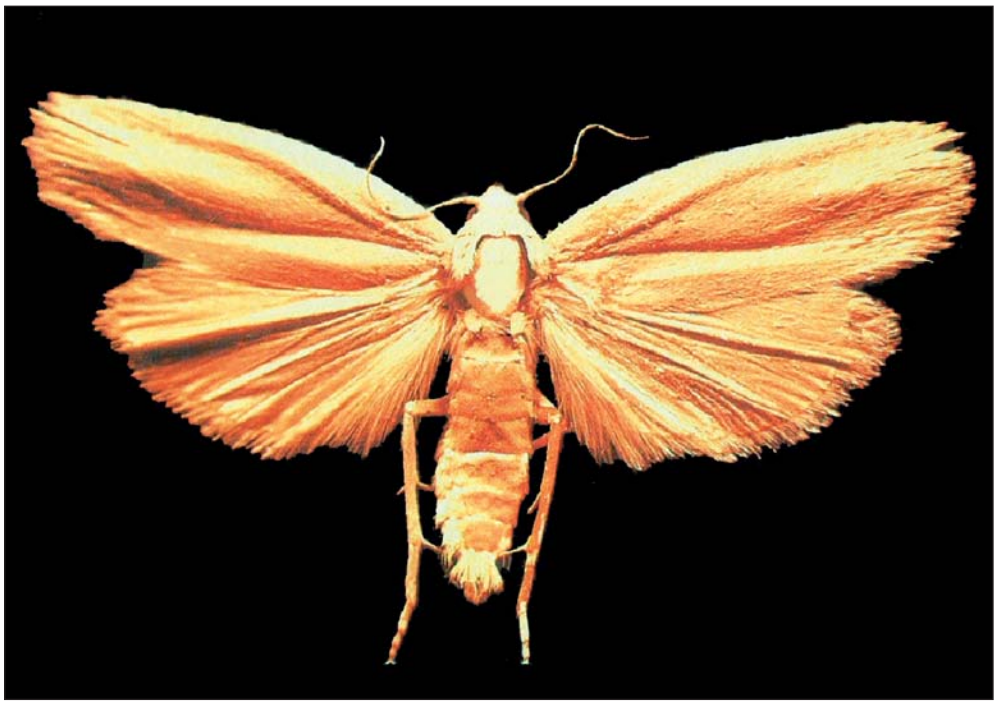
Fig. 1.46. *Goniozus* sp. (Hymenoptera: Bethylidae).

In addition, the farmers in the Arabian Peninsula used species of predatory ants to control LDM in the past. This species is *Crematogaster* sp. (Hymenoptera: Formicidae). This predatory ant was extremely effective in controlling *B. amydraula*, and is still present in the region but in small numbers because of the extensive use of chemical pesticides.

Generally, more attention should be given and necessary research should be conducted in order to use the parasitoids and predators on a wider scale in the biological control programs against the LDM, *B. amydraula*, through an IPM program of date palm pests and in the scope of the biological control of this economically significant pest. In addition, use of the egg parasitoid of the genus *Trichogramma* spp. should be investigated against LDM.

1.2.2. Greater Date Moth

***Arenipses sabella* Hampson**
(Lepidoptera: Pyralidae)



Distribution

The Greater Date Moth (GDM), *Arenipses sabella*, is also called Spathe Borer and is widely distributed in the date palm-growing countries of North Africa, the Middle East and northern India (Carpenter and Elmer, 1978; Al-Azawi, 1986; Talhouk, 1991). It has been recorded in Oman, Iraq, Saudi Arabia, Qatar, Libya, Egypt, Palestine, Iran and India.

Economic Importance

The GDM, *A. sabella*, causes serious economic damages to date palms in several countries. In Iran, the percentage of damage among the fruits was found to be between 5-15%, while in Iraq, it reached 70% among the date palms in some regions and the incidence among the spathes was about 49%.

The infestation starts in spring and the adult females lay their eggs on or near unopened spathes. After hatching, the young larvae bore into spathes or petioles of young soft fronds. If spathes are open, the larvae bore into the non-swollen inflorescence. After the inflorescence is swollen, the larvae bore and feed on the small flowers and fruits while they are formed. Thus, the infested fruit stalks appear without fruits. The most significant sign of infestation with this pest is the presence of tunnels filled with the larvae faeces and other plant matter. During feeding on the palm parts, the larvae spin silk threads in which the dark coloured faeces are suspended.

The newly hatched larvae stay in groups biting the leaflets and the midribs of the young fronds, until they become

corky and the leaflets and palm fronds disfigure. After the opening of the spathe, the larvae make tunnels in the spathe and attack the small fruits. The active larvae consume the inner fruits of the strand and may cause damages to as much as 40% of the fruits on the fruit stalks. At the same time, the infested fruit stalks may appear intact from the outside. When the larvae are fully-grown, they seek safe places among the dead fruits to spin white cocoons. Inside the cocoon, the larva changes into a pupa then into an adult insect during the summer months, and this is the second generation (July to September). The subsequent second-generation larvae overwinter in a white cocoon located in the crown of the palm.

From the above it is obvious that the main damage of this pest leads to complete or partial wilt of the spathes as well as wilt of the infested fruits as they lose their green colour and turn yellowish or grey while remaining suspended on the spikes between the silk threads to rot. Fig. 1.47 illustrates the sign of infestation by the larvae of the GDM in the spikes base.

General description

The greater date moth is a medium sized and 18 mm long. Its light brown head and thorax and silvery white abdomen characterize it. The wingspan is about 33-35 mm in the male and wider in the female 40-42 mm. The egg of GDM is creamy white in colour, spherical in shape and 0.2-0.3 mm in diameter.

The larva is reddish brown with black or reddish brown colour head. The first and second thoracic rings are dark brown with a long bristle on each. The second abdominal segment has lateral yellow spots and the remaining segments each have four dark brown spots dorsally each with a long seta. The fully-grown larva is 20-23 mm long and moves quickly, Fig. 1.48.

The pupa of the GDM is reaching up to 18 mm in length. The larva pupates inside a cocoon spun by the larva in the cracks on the palm's trunk, the soil surface and under the wooden logs and boxes in the stores. It is elongate in shape and white or very pale brown in colour.

Life Cycle

Gharib (1969) in Iran and Hussain (1974) in Iraq studied the life cycle of the GDM, *A. sabella* and found that it has two generations each year, one in spring and other in autumn.

Fig. 1.47. Sign of infestation by larvae of *A. sabella* in the spikes base.

Fig. 1.48. Larva of *A. sabella.*

• Spring Generation

The moths of the spring generation emerge during the months of March and April. They live for a period of one to three weeks. The female moth deposits its eggs singly inside and outside the spathe sheath with some eggs being deposited on the green young fronds. The incubation period is around 10 days, but in regions with high temperature, the eggs hatch after 4-5 days. The larval stage lasts between 5-6 weeks. When the larva is fully grown, it spins a silk cocoon inside which it becomes a pupa. Some pupae are present in dry inflorescence sheath or among fibres in the palm canopy. The duration of the pupal stage lasts between 6-7 weeks, after which the autumn generation moths emerge. Thus, the duration of the spring generation ranges between 3-3.5 months.

• Autumn Generation

In autumn generation, the moths start to emerge in July and continue during the months of August and September. It is interesting that the females of this generation deposit their eggs only on the vegetative parts of the palm, opting for the new green fronds. The incubation period is about 5 to 10 days. When the larva is fully-grown, it leaves the fronds to the palm crown in between the petiole bases and fibres, where it spins a silken cocoon to overwinter as a larva. As a result, the larval stage lasts about 28 weeks.

In addition, during the autumn generation, some larvae may not complete their growth or may not be able to spin the cocoon for hibernation. Such not fully-grown larvae spend their hibernation in a slumber state, suspended from the palm crown until next spring season. The duration of the pupal stage lasts between 2 to 4 weeks. Therefore, the duration of the autumn generation ranges between 8 to 9 weeks.

Control Measures

1. Chemical Control

The chemical control program using against The Lesser Date Moth, *Batrachedra amydraula* can be used also against the Greater Date Moth, *Arenipses sabella* because both insect pests are present on date palms at the same time. The same pesticides in that program can be used as well.

2. Biological Control

Hussain (1974) found that there are plentiful of pseudoscorpiones, which prey on the larvae of the GDM, *A. sabella*, e.g. *Chelifer spinipalpis* Redikorzev (Family: Cheliferidae). In addition, he mentioned that there are several species of Braconidae parasitoids were recorded on the GDM, *A. sabella*, such as *Phanerotoma ocularis* Kohl., *Macrocentrus* sp. and *Apanteles* sp.

1.3. Order: Coleoptera

1.3.1. Red Palm Weevil

***Rhynchophorus ferrugineus* (Olivier)**
(Coleoptera: Curculionidae)

Distribution

It is believed that the origin of the Red Palm Weevil (RPW), *Rhynchophorus ferrugineus*, is India, therefore it is called the Indian Palm Weevil. It is essentially a pest of different species of palms. The major hosts of the RPW, *R. ferrugineus*, are sugar palm (*Arenga pinnata*), toddy palm (*Borassus flabellifer*), coconut (*Cocos nucifera*), African oil palm (*Elaeis guineensis*), sago palm (*Metroxylon sagu*) and date palm (*Phoenix dactylifera*). It is one of the most important and destructive pests that attack the date palms. Menon and Pandalai (1960) mentioned that some ornamental palms have also been reported to be attacked by the RPW, *R. ferrugineus*, such as Washingtonia Palms (*Washingtonia* spp.).

Barranco *et al*. (2000) and EPPO (2008) mentioned that the RPW, *R. ferrugineus*, has been reported on 19 palm species belonging to 15 different genera. In Spain, Dembilio *et al*. (2009) found that the California fan palm, *Washingtonia filifera*, and the European fan palm, *Chamaerops humilis*, are resistant to the RPW, *R. ferrugineus*. They also reported that the resistance in *W. filifera* is based on antibiosis whereas in *C. humilis* resistance is based on antixenosis.

RPW is common in the Indian peninsula as well as South East Asia that is why it is sometimes called, "Asiatic Palm Weevil". It is present in India, Pakistan, Bangladesh, Malaysia, Laos, Cambodia, Indonesia, Sri Lanka, Thailand, Vietnam, Taiwan, Burma, Philippines and China. During the last two decades, this pest began to spread into many areas in the world. It is recorded in Iran, Bahrain, Saudi Arabia, United Arab Emirates, Egypt, Algeria and Spain. Recently, it was recorded in Japan, Jordan and Palestine (Bitton and Nakache, 2000).

RPW was recorded from the Canary Islands since 2007; from Italy since 2004, from Turkey since 2005, from Cyprus since 2006, from France since 2006 and from Greece since 2006, Li (2009). In Oceania, RPW was

recorded from Australia (isolated record in Queensland), Papua New Guinea, Solomon Islands, Western Samoa and New Caledonia, Wattanapongsiri (1966).

In East Asia, RPW was recorded from Japan in 1975 in horticultural palms (Matsuura 1993). In the Mediterranean Sea rim, Egypt first recorded the weevil's distribution in 1992 from Ismaelyia and Sharkyia governorates. Spain reported its presence in 1996 from Andalucía and continuously from Comunidad Valenciana since 2004.

RPW was reported from the Canary Islands (Murcia, Islas Baleares, and Islas Canarias) since 2007; from Jordan and West Bank since 1999; from Italy since 2004 (Campania, Lazio, Puglia, Sardegna, Sicilia, Toscana), from Turkey since 2005 (Mersin province), from Cyprus since 2006, from France since 2006 (Corse, Provence-Alpes-Côte d'Azur), and from Greece since 2006 (Kriti, Rhodos). In Oceania, RPW was recorded from Australia (isolated record in Queensland), Papua New Guinea, Solomon Islands, Western Samoa, and New Caledonia (Wattanapongsiri 1966).

Table 1.11. illustrates the first record of the red palm weevil in the Gulf Cooperation Council (GCC) countries and Egypt. The first records of the RPW in the GCC countries were during 1985 in United Arab Emirates, 1986 in Saudi Arabia, 1989 in Qatar, 1993 in Oman and Kuwait and 1995 in Bahrain. It is probable that the pest reached United Arab Emirates (UAE) through importing infested offshoots from South East Asia. It also prevailed in Saudi Arabia where ornamental palm and coconut offshoots were imported from India and Pakistan by commercial nurseries in order to plant the parks and gardens for urban beautification.

In Egypt, Cox (1993) has mentioned that near the end of 1992, the first record of the pest was in Al Salhia area in Sharkyia governorate and Al Qasaseen in Ismaelyia governorate. Since then, the infestation spread to all the centres in the mentioned two governorates. It was also recorded in several other governorates like Qalioubia, Alexandria, Menoufia, Giza, Suez, and Cairo. At present, it is found in all the Delta governorates as well as the Sinai Peninsula.

In Oman, the first record of an infestation by the RPW, *R. ferrugineus*, was in 1993 in the border areas with UAE in Governorate of Al Buraimi in Wilayats (Al Buraimi and Mahdhah). Later on, other infestations with the RPW were recorded in both Musandam governorate and in some of the mountain villages in Wilayat Shinas in Al Batinah region. It is certain that transporting the offshoots from these areas led to the spread of the attacks to other areas as some infestations with this pest were recorded in some villages in Al Batinah region in Wilayats (Liwa, Sohar, Saham and Al Khabourah) as well as in A'Dhahirah region (Wilayat Yanqul).

In addition, Zaid (1999) demonstrated that the species *Rhynchophorus phoenicis* Fabricius, known as the African Palm Weevil also attacks the date palm as it was recorded in both South Africa and Zimbabwe. This was the first time that this species was recorded to infest the date palms.

Table 1.11. The first record of *Rhynchophorus ferrugineus* in GCC countries and Egypt.

Country	First Recorded	Area/Location Infested	Reference
UAE	1985	Rass El Khaima	AOAD* (1995) FAO ** (1995)
Saudi Arabia	1986	Qateef	Al-Abdulmohsin (1987)
Qatar	1989	Doha	Abdallah (1997)
Egypt	1992	Ismaelyia and Sharkyia	Cox (1993)
Kuwait	1993	Throughout	FAO ** (1995)
Oman	1993	Buraimi and Mahdah	Al-Kaabi (1993)
	1994	Musandam	
Bahrain	1995	Bahrain	Hamdi (1998)

AOAD * Arab Organization for Agricultural Development

FAO ** Food and Agriculture Organization

It is important to note that there are other species of the genus *Rhynchophorus* having several hosts and they are distributed in many countries around the world, as shown in Table 1.12. Booth *et al*. (1990) mentioned that the genus *Rhynchophorus* contains ten species, of which seven, including *R. ferrugineus* and *R. vulneratus*, are known to attack palms.

Table 1.12. The distribution of some species of the Genus *Rhynchophorus* and their hosts.

Species	Distribution	Host	
		Common name	Scientific name
Rhynchophorus schach Olivier	Singapore-Indonesia Malawi-Thailand Papua New Guinea	Coconut palm	*Cocos nucifera*
Rhynchophorus papuanus Kirsch	Indonesia Papua New Guinea	Sago palm	*Metroxylon sagu*
Rhynchophorus palmarum Linnaeus**	Central and South America	Coconut palm Oil palm	*Cocos nucifera* *Elaeis guineensis*
Rhynchophorus phoenicis Fabricius	Tropical regions of Africa	Coconut palm	*Cocos nucifera*
Rhynchophorus cruentatus (Fabricius)	USA (Florida)	Cabbage palmetto Sugarcane Coconut palm	*Sabal palmetto* *Saccharum officinarum* *Cocos nucifera*
Rhynchophorus bilineatus (Montrouzier)	Indonesia Papua New Guinea Solomon Islands	Coconut palm	*Cocos nucifera*
Rhynchophorus vulneratus (Panzer)	Singapore-Indonesia Philippines-Malaysia Papua New Guinea Thailand	Betel nut palm Sugar palm Coconut palm African oil palm Sago palm	*Areca catechu* *Arenga pinnata* *Cocos nucifera* *Elaeis guineensis* *Metroxylon sagu*

** The importance of this species stems from being a carrier of nematode of the genus *Rhadinaphelenchus*, which is responsible for the red ring disease in Coconut palm.

Economic Importance

The RPW, *R. ferrugineus*, is considered one of the most dangerous and destructive pests attacking the date palms. The larvae cause the main damages whereas the adult weevils oviposit in the available places or dig a little to deposit their eggs, so that they do not cause harmful effects in comparison to the larvae. The larvae of this pest devour the inner living tissues of the palm trunk producing tunnels in all directions including all the inner parts of the trunk, as shown in Fig. 1.49. After infestation, the infested palms become brittle and breakable under a gush of wind or other external forces. In other words, this pest leads eventually to the death of the palm.

Fig. 1.49. The extent of damage caused by larvae of *R. ferrugineus*

It is important to mention the extreme difficulty in detecting early infestation, or in differentiating the infested palm especially in the early stages of infestation due to the absence of any external changes of the trunk of the infested palms especially in the beginning of the infestation.

Symptoms of Infestation

The RPW, *R. ferrugineus*, is a concealed tissue borer, hence symptoms of infestation at an early stage are difficult to detect. Generally, the most important symptoms of infestation by the RPW can be summarized as follows:

• Oozing of liquid on the trunk of the infested palm, Fig. 1.50, which is smelly, sticky, viscous and creamy in colour. This liquid turns into reddish brown from the outside.

• The presence of reddish brown rotten sawdust in the infested areas on the trunk, they represent the debris of burrowing done by the larvae. Such debris may be seen under the infested palms or on the bases of the fronds.

• Fronds bases are easily detached or they may fall off to the ground in the case of severe deterioration of the bases due to larvae feeding.

• Wilting and yellowing of the green fronds in the infested palms. The infested offshoots appear weak as if just transported.

• The infested offshoots are easily detached from the parent palm especially the aerial ones. When removed the different stages of the RPW can be observed inside the palm.

• When the infestation advances, the movement of the strong mandibles of the larvae can be heard while they feed and chew the tissues inside the infested trunks, either directly or by special audio-equipment.

• In advanced infestations, holes can be seen in the infested trunk caused by the burrowing and feeding of the larvae, as shown in Fig. 1.51. These holes are filled with the debris of burrowing and feeding which has a foul odour. The trunk itself may break at the site of infestation and fall down. Upon inspection, all the stages of the RPW can be easily observed inside the trunk.

Most Favourite Palm Ages to RPW Infestation

It was observed that RPW prefers to attack and infest the palms aged less than 20 years, both young offshoots or fruitful palms. The rate of infestation was found to be higher in the offshoots and decreased markedly in the older palms. Lever (1969) mentioned that around 5% of the young palms up to 10 years old die by the red palm weevil infestation, while Abraham and Kurian (1975) mentioned that the pest prefers to attack the palms younger than 20 years old.

Fig. 1.50. Oozing of liquid on a date palm trunk infested with *R. ferrugineus*.

Fig. 1.51. The big holes made by the larvae of the *R. ferrugineus*.

Blancaver *et al*., (1977) had shown that the RPW preferred to attack coconut palms aged between 5 and 15 years in the Philippines and India. It was also mentioned that the RPW is the main pest in the coconut palm plantations aged between 7 and 10 years. It can be stated that the RPW prefers to attack the young palms, i.e. those aged between 5 to 10 years. In addition, the Red Palm Weevil infestation can occur anywhere in the palm. Because it may start in the canopy, infestation is extremely difficult to detect before the fall of the crown to the ground. In such a case, the larvae migrate down even after the death of the growing top. The infestation can be in the trunk, wherever the pest finds a suitable entry. It was observed that the infestation increases in the area between the ground and the height of 2 metres of the trunk. Here the larvae move upwards and downwards. Hence, the infestation extends in the trunk even below the ground surface.

In addition to the above, the RPW may attack the cut palms lying on the ground if these parts have enough moisture to allow for the egg incubation and the growth of the larvae after hatching. In this case, the larvae move downwards. It was also found that the RPW infests all date palm varieties without discrimination even infesting the males of date palms.

Lever (1969) and Abdul Hag and Akmal (1972) stated that the RPW may lay its eggs in burrows made by the fruit stalk borers of the genus *Oryctes* to the extent that the researcher Lever noted that red palm weevil infestation is always related to the infestation by the fruit stalk borer. Some researchers have stated that it can be considered a wound parasite as the females lay their eggs in the wounds or the damaged areas on the surface of the palm trunks. Blancaver *et al*., (1977) mentioned that the RPW laid their eggs in the cracks found in the trunk or in any injured part of the palm.

Based on field observations and the review of several researchers and scientists, the favourite places for the RPW infestation to start are the following sites:

- Burrows made by the adult beetles of the fruit stalk borers (*Oryctes* sp.) in the trunk or the frond bases.
- Offshoot detachment sites and midrib base-removal wounds.
- Pruning and cutting wounds of the green fronds from the palm.
- Mechanical injuries and cracks present on the palm whatever the cause.
- The exposed aerial roots in the palm trunk bases.
- Tunnels made by rats in the palm trunks.

General Description

The adult weevils are rusty red in colour, between 35-40 mm in length and 12-14 mm in width. It has a long curved rostrum (snout), which carries on its end the chewing

mouthpieces with the antennae at its base. The head and rostrum comprise about one-third of the total length. The rostrum upper side is reddish brown in colour and dark brown under side. The adult male can be differentiated from the female by the presence of a patch of short brownish hairs on the dorsal apical part of the rostrum of the male, which are absent in the female. The rostrum of the female is also little longer, more slender and curved than that of the male, Fig. 1.52. On the dorsal thoracic area, there are black spots, which vary in number and shape from one adult weevil to another. The newly emerged adult weevils are light orange in colour and their colour turn to reddish brown as they advance in age. The forewings are deep red in colour and do not cover the whole abdomen. Generally, the adult weevil's body is hardened and fortified with a strong layer of chitin. The hind wings are translucent and longer than the body, folded under the forewings and are spread only before or during flying.

The egg is creamy white in colour, shiny with smooth texture and oval with a relatively wider base. Menon and Pandalai (1960) stated that the average size of an egg is 2.62 mm long and 1.12 mm wide. The brown mouthparts of the larvae can be seen through the shell before eclosion.

The larvae have yellowish white colour and are legless with deep red heads and mouthparts that are well developed and strongly chitinized with extremely powerful mandibles. They are cylindrical in shape with slightly curved bodies having many curvatures. They are fleshy from the centre with slightly elongated abdominal ends. The larva has 13 segments of which the two adjacent to the head, are light brown in colour. The average length of fully-grown larvae is between 50 to 65 mm and the mean width is 20 mm in the middle. The larval stage has five instars; however, Jaya *et al*. (2000) recorded seven larval instars when *R. ferrugineus* was reared on sugarcane. The fully-grown larva constructs a cylindrically shaped cocoon out of the palm fibres in which it pupates. The pupal case can range in length from 50-95 mm and in width from 25-40 mm. The average length of pupae is 35 mm and the average width is 15 mm, Fig. 1.53. The pupa is initially cream coloured but later turns brown. It has a shiny surface, which is strongly furrowed and reticulated.

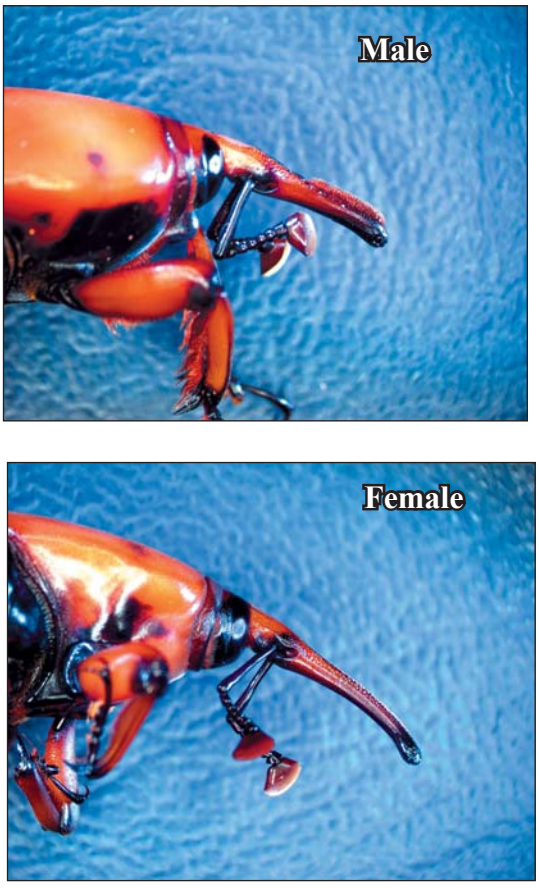


Fig. 1.52. The adult (male and female) of *R. ferrugineus*

Life Cycle

The different stages of the RPW, *R. ferrugineus*, (eggs-larvae-pupas-adults), can be occur simultaneously inside the infested palm trunk. Murphy and Biscoe (1999) mentioned that the female of the RPW deposits 127 to 350 eggs with an average of 250 eggs during its life span.

Eggs are lay singly in separate holes made by the snout of the female weevil in the tender palm tissues, in the mechanical injuries, in the pruning sites or wounds, in places from which the fronds were removed or in wounds caused by the rhinoceros beetle, *Oryctes rhinoceros*.

Fig. 1.53. The pupa of *Rhynchophorus ferrugineus*
Left: Inside the cocoon, which constructed by the larva from the palm fibres.
Right: Outside the cocoon, the size of the pupa may reach up to 95 mm long.

Menon and Pandalai (1960) mentioned that oviposition of RPW is generally confined to the softer portions of the palm and continues from there. The pre-oviposition period can range from 1-7 days. The oviposition period is approximately 45 days. During this period, the weevil lays an average 204 eggs; the maximum number of eggs laid by a single female under captivity is 355 in 42 days and the minimum is 76 in 26 days. There is a short post-oviposition period of 10 days before the weevil dies.

Under captivity, the maximum life span of the adult weevil was 76 days for the female and 113 days for the male. It has been suggested that a single pair of weevils can theoretically give rise to more than 53 million progeny in four generations in the absence of controlling factors (Menon and Pandalai, 1960; Leefmans, 1920). Usually eggs are deposited in the same palm tree if its tissues can support another generation. Generally, the adult of the RPW live for 6 to 8 weeks and mostly the males live longer than the females.

The female covers the eggs with a sticky substance produced from the auxiliary glands in its reproductive system. The incubation period is about 3-7 days, then eggs hatch into legless grubs, which bore into the interior of the palm and feed with their strong mandibles capable of penetrating wood and burrowing into the trunk.

The duration of the larval stage takes from 4 to 8 weeks. When the larva is fully-grown, it makes for itself an oval fibre cocoon out of the tissues of the trunk or the leaf bases already destroyed while feeding. Inside, it changes into a pupa. The prepupal stage lasts for about 3 to 6 days and the pupal stage lasts from 2 to 4 weeks till the adult weevils emerge and become sexually mature after 4 to 17 days, (Menon and Pandalai, 1960) and (Murphy and Biscoe, 1999). Mating takes place at any time of the day and males and females mate several times during their lifetime, i.e. the RPWs are polygamous.

It was found that the duration of each generation is between 2 to 3 months making the number of overlapping generation each year from 3 to 4. In Egypt, El Ezaby (1997) reported that the RPW has three generations per year, the shortest generation (first) of 100.5 days and the longest (third) of 127.8 days. The study also showed that the lethal (threshold) temperature for the egg was 40°C.

Behaviour of Red Palm Weevil

Behaviour of Larval Stage

The larvae are considered the most harmful and damaging stage of the RPW on the trunks of the date palms. As soon as the eggs hatching, the larvae feed voraciously on the inner tissues of the stem. They make tunnels in

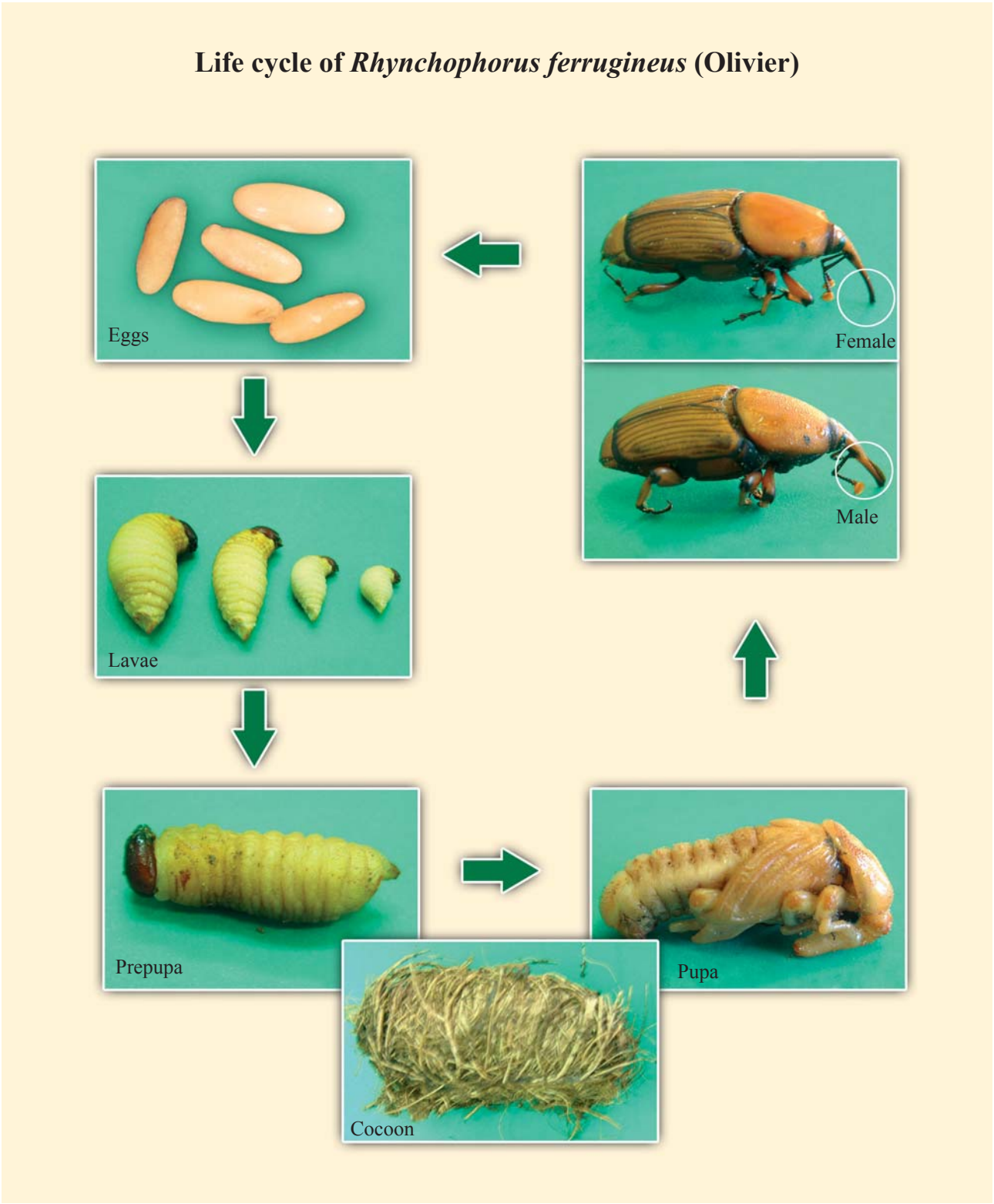


Fig. 1.54. Life cycle of the Red Palm Weevil, *Rhynchophorus ferrugineus* (Olivier).

all directions throughout their lifespan to include all the vegetative parts in the affected area of the trunk, which turns into a tube full of decayed tissues (chewed up plant fibre) which combines with the plant sap. In severely infested palms, the feeding larvae form cavities, thus the trunk becomes susceptible to cracking if exposed to strong winds. While feeding the larvae push these decayed plant matter and debris out of the tunnels, which can be seen by the material resembling sawdust that has accumulated on the ground around the affected palm.

It is important to note that crunching noise produced by the feeding larvae (grubs) and their extremely powerful mandibles can be heard in a quiet surrounding when the ear is placed against the trunk of the palm. When the larvae are fully-grown they move toward the outside of the trunk and make cocoons from the palm fibres in the axils of the leaves, inside which they change into the pupal stage and later into adult weevils, which emerge to repeat the life cycle. The phenomenon of cannibalism has been recorded in the larvae as they may devour each other especially in the advanced ages when they are present as groups of larvae on a limited space in the infested area inside palm trunk.

Behaviour of Adult Weevils

The adult weevil of the RPW, *R. ferrugineus*, tears the cocoon to emerge from the pupal stage. No emergence holes were detected on the trunk of the palm unlike in case of the tree borers. The emergence of the adult insects can be identified by the presence of surface cocoons on the trunk at the leaf axils, which are empty and have one hole at one of its ends as a result of the exit of the adult weevil with its fusiform body. Menon and Pandalai (1960) noticed that the adult weevil of the RPW remains inside the cocoon for 4-17 days (with an average of 8 days) after emergence from the pupal case and the weevil becomes sexually mature during this period of inactivity.

The female can use its fusiform body to penetrate the leaf bases to make certain holes with its snout in the tender tissues of the leaf bases, the tender tissues on the palm stem in the part containing aerial roots, the parts not covered with leaf bases or the cracks present on the leaf bases.

The adult weevils are active during day and night although flight and crawling are generally restricted to the daytime. They are not attracted to light traps. On the contrary, it was observed that the adult weevils try always to escape from light to hide in dark places.

It was found that the behaviour of the weevils is an aggregate behaviour as they are attracted to dying or damaged parts of palms but it is possible that undamaged palms are also attacked. It has been observed that the smell of the damaged palms and the injuries caused by the pruning or offshoot removal as well as the tender new outgrowths attract the adult weevils. In addition, the males of the RPW, *R. ferrugineus*, produce a pheromone, which causes the weevils to aggregate on damaged palms. Gunawardena and Bandarage (1995) have demonstrated that the activity of the adult red palm weevil insects in Sri Lanka extended between six and eight in the morning and between six and eight in the evening.

In Oman, Al-Khatri and Abdallah (2003) studied the daily activity of the RPW, *R. ferrugineus*. The study revealed that the peak activities of the adult weevils during the day were at sunrise and sunset specifically between 6 and 9 am and 6 and 9 pm, as when the percentages of the adult weevils were 39.4% and 36.6%, respectively. They also mentioned that the activity of the weevils stopped completely between 9 am and 3 pm as well as between midnight and 3 am. In the periods between 3 am and 6 am and between 3 and 6 pm the population densities of the adult weevils were 9.1% and 15.2%, respectively.

From field observations, the flight of the adult weevils is along an uneven path as the weevil circles over the suitable site before landing. The preferable landing site of the weevil is the pruning site to mate and deposit the eggs. Generally, the RPW have a high capability to fly and

a flying range of up to 1.6 kilometres has been observed. Leefmans (1920) reported that weevils are capable of long flights and can find their host plants in widely separated areas. His studies suggested that weevils could detect breeding sites at distances of at least 900 m.

Rate and Levels of Infestation

It was found that the rate of infestation of red palm weevil on the date palm in the Middle East region ranges between 5 to 6%. It was also found that the annual rate of increase in infestation was 1.9% as shown in Table 1.13.

As mentioned earlier, the first record of RPW infestation in Oman was at the end of 1993, in Wilayats Al Buraimi and Mahdhah in Al Buraimi governorate (Abdallh and Al-Khatri, 2000b). Then the infestation spread to include the Wilayat Al Sinainah in Al Buraimi governorate, Yanqul in A'Dhahirah region, the Wilayats of Shinas, Sohar, Saham, Al Khabourah and Liwa in Al Batinah region and Wilayats Dibba and Bukha in Musandam governorate.

Data in Fig. 1.55 illustrate the levels of infestation by red palm weevil in different areas in the Sultanate of Oman during the years from 1998 to 2003 (Al-Khatri, 2004). The levels of infestation, i.e.: the numbers and rate of change of adult weevils in each area were estimated by using pheromone traps, in which the number of adult weevils was counted. These data show that the level of infestation by the red palm weevil in A'Dhahirah region decreased by 73% in five years. The average number of weevils was 89 weevils per trap in 1998, and then declined to 24 weevils per trap during the year 2003. In Al Batinah region, the infestation had almost disappeared, as the pheromone traps did not trap any weevils during the years 2001, 2002 and 2003. The infestation in Musandam governorate in 2003 decreased markedly by 74%, as the number of weevils trapped during that year was about six insects per trap. In 1999, the number of weevils trapped was about 23 weevils per each pheromone trap.

Table 1.13. The annual rate of increase in the RPW, *R. ferrugineus*, infestation in United Arab Emirates and Saudi Arabia.

Country	Year	Number of date palms infested by RPW	Annual increase rate in the level of infestation
United Arab Emirates	1990	1,300	2.02
	1995	44,000	
Saudi Arabia	1987	Less than 1,000	1.70
	1996	120,000	
Average annual infestation rate			**1.90**

(Source: FAO, 1999)

The rate of annual increase in the infestation level was calculated using the following equation:

$$X = (y^2 / y^1)^{1/n}$$

Where,

y^2 = the number of the infested palms at the end of the period.

y^1= the number of infested palms at the beginning of the period.

n= the period in years.

Seasonal Activity of RPW

Al-Khatri and Abdallah (2003) studied the seasonal fluctuation in the population of the RPW in Oman. The study showed that the adult weevils emerged all over the year without disappearance periods. It was also found that there were four peaks of the weevil's emergence during the year. These peaks were detected during March, May, July and October. They were also mentioned that the highest emergence of the RPWs was recorded during May each year, and the lowest population of the RPWs was recorded during December and January annually.

From the previous findings, it was possible to recommend carrying out pruning of the date palms during the months

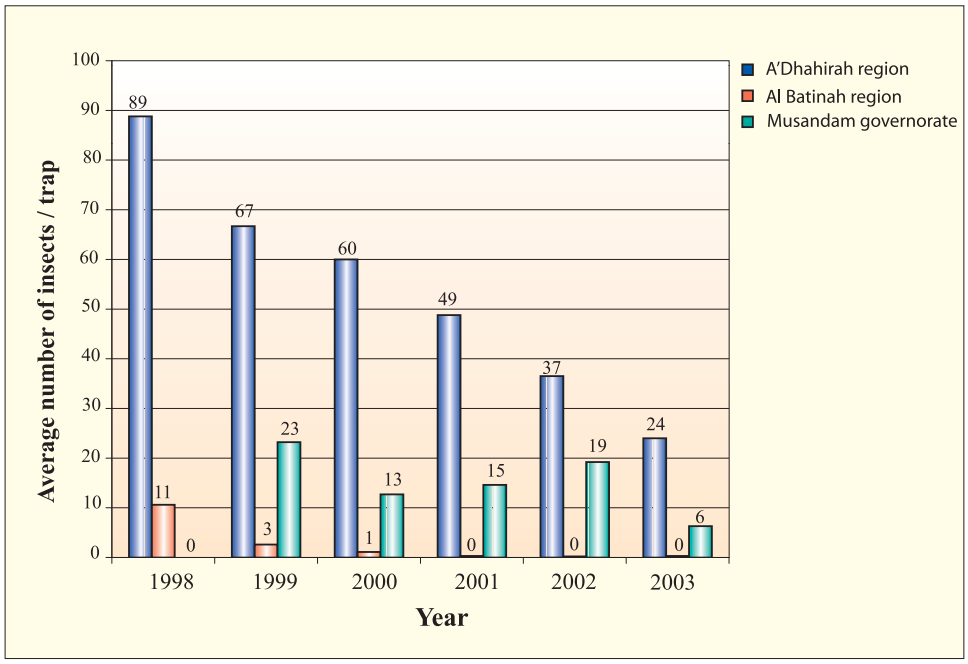


Fig. 1.55. The levels of infestation by RPW, *R. ferrugineus*, from year 1998 to 2003 in various regions in Oman.

of December and January to protect the palms from RPW infestation. This period is also considered the best period to examine the palm groves as the exudates can be easily spotted oozing from the infested palms due to the increased activity of the larvae, which are preparing to develop into pupal stage during the months of February and March. Therefore, the infested palms can be easily identified for treatment.

Control Measures

It is worth mentioning that the Ministry of Agriculture and Fisheries (MOAF) in Oman has implemented immediate and effective measures to combat the RPW, *R. ferrugineus*, once discovered in their sites. If these measures are not taken, then this dangerous pest could spread all-over the date palms groves in Oman.

Table 1.14. demonstrates the control measures undertaken by the MOAF against the red palm weevil in Oman in the period from 1994 to 2003, AL-Khatri (2004).

One of the most important and effective control measures during the first three years after discovery of the RPW infestation in Oman was the removal of several infested date palms in these regions. The total number of eradicated infested date palms was approximately 2782 date palms from 1994 to 2003, of which the greatest number was in the first three years after infestation (from 1994 to 1997). A total of 1604 date palms had been removed with 78% of them (1249 palm trees) eradicated from A'Dhahirah region in Wilayats Al Buraimi and Mahdhah, which were the regions where RPW was discovered first, i.e., in September and October of the year 1993, respectively. These Wilayats are adjacent to the United Arab Emirates, which had recorded infestation as early as 1985. On the other hand, large numbers of RPW infested date palms have been treated in different regions of Oman using chemical control measure by chemical injection. During 10 years, from 1994 to 2003, a total number of 12409 date palms were treated with chemical pesticides against infestation of RPW.

Table 1.14. Control measures undertaken against the RPW, *R. ferrugineus*, in different regions of Oman during the Period between 1994 and 2003.

Control Measures Against Red Palm Weevil								
Year	No. of date palms removed				No. of date palms, which treated with chemical pesticides			
	A'Dhahirah	Al Batinah	Musandam	Total	A'Dhahirah	Al Batinah	Musandam	Total
94 - 97	1249	116	239	1604	1076	0	414	**1490**
1998	192	193	74	459	837	55	124	**1016**
1999	169	45	86	300	2369	168	236	**2873**
2000	105	14	32	151	1949	55	221	**2225**
2001	95	3	23	121	1472	1	174	**1647**
2002	52	13	50	115	1822	18	256	**2096**
2003	17	1	14	32	908	3	151	**1062**
Total	**1879**	**385**	**518**	**2782**	**10433**	**300**	**1676**	**12409**

Integrated Pest Management (IPM)

The RPW is considered one of the most dangerous pests because it causes massive economic damages to the date palms wherever it exists, leading eventually to the total destruction of the infested palms.

Due to the RPW behaviour, i.e. its high capacity to fly and spread from one region to another and to survive in unfavourable environmental conditions, in addition to the existence of its different stages hidden inside the palm trunks as well as the difficulty to detect the infestation early, it is difficult to rely on traditional measures of control. Different studies have demonstrated that relying on the chemical control as a sole measure, did not control the danger and the spread of the pest. In addition, the dramatic extension of the RPW in the last 20 years demonstrates that the control measures used were insufficient. The control of the red palm weevil needs the adoption of an integrated control management strategy. Accordingly, any recommendation must include in a complementary and inseparable way the following elements: detection, mass and monitoring trapping, preventive and curative treatments and quarantine. Thus, it is important to design an IPM program against this pest, which must has chemical control as an essential and important part of the program.

In India, IPM program for the RPW, *R. ferrugineus*, has been developed and tested in coconut palms (Kurian *et al*. 1976; Sathiamma *et al*. 1982; Abraham *et al*. 1989). Included in the IPM program were cultural measures such as plant and field sanitation, physical methods to prevent entry of weevils through cut ends of petioles and wounds, and the use of attractants and other chemicals (including filling of leaf axils with gamma BHC and sand as a preventive measure).

Vidyasagar *et al*. (2000) successfully developed an IPM program in Saudi Arabia, which depended on mass pheromone trapping of RPWs and also included a survey of all groves cultivated with date palms, systematic checking of all palms for infestation, periodic soaking of palms and mass removal of neglected farms.

Accordingly, it is clear that the IPM program RPW should include legislative, cultural, chemical, behavioural, biological and other possible control measures in order to limit the numbers of this insect and eventually eradicating it from its sites. This is the aim of IPM. It is important to study the economic feasibility when applying the different measures mentioned earlier to control this pest keeping in mind to utilise safe, specialized chemical insecticides in the chemical control measures.

The following are the different control measures, which should be implemented in the IPM program. They should not be only confined to limiting the numbers of the RPW and eventual eradication in the affected areas but should also be enable to prevent the spread of the pest from these areas to new areas.

I. Legislative Control

In this scope appears the importance of legislations and laws in limiting the spread of the pest to new areas in the country through transport or import of infested offshoots. The MOAF in Oman pioneered in issuing legislations and laws since the early detection of this pest in some border provinces. The MOAF in Oman issued a ministerial decree numbered (23/93) dated September 11th, 1993 prohibiting the entry of date palms, coconut palms, ornamental palms and their parts into the Sultanate of Oman from other countries. The Ministry also published some instructional pamphlets to educate the farmers and engineers informing them of the dangers of transporting offshoots from affected areas to infestation- free areas and its contribution in helping the implementation of the internal agricultural quarantine to prevent the spread of the pest in Oman.

It is important to highlight that it is extremely difficult to discover the infestation in the beginning, and it could be only determine at the late stages. Hence, the importance of the role of the concerned ministries and agencies in following the infestation by periodic examination in both the free and infested areas to make the right decisions at the right time when the infestation appears in a certain area. There are some important steps must be considered to prevent the spread of the RPW and to detect the infestation in early stage;

- Not buying or transporting palm offshoots from infested areas and strictly implementing the internal agricultural quarantine.

- Periodic inspection of the date palms and identifying the affected areas as well as determining the degree and severity of infestation with RPW. Thus, the rapid and necessary control measures can be taken at the right time to limit the spread of the infestation.

- Issuing laws to force the farmers to remove the debris of date palms like those after pruning and old fronds, and to destroy them by burning in suitable locations away from the palm groves.

II. Mechanical Control

1. Removing and burning the heavily infested palms

All heavily infested date palms should be exterminated to prevent becoming the centre of spread and transfer of the infestation to intact date palms. This is achieved by taking the heavily infested date palms out and cutting them with saws into small chunks to be placed in a hole and burned with the aid of fuels like kerosene. After burning, the remains should be buried in a one-metre deep hole adding lime on them to ensure the destruction of the different stages of the RPW and the prevention of the emergence of any living insects from the remains of the cut palms. The burning of the cut date palms should be performed within the infested plantation or farm in order to prevent the spread of the infestation to unaffected areas during transport. Complete burning of the affected date palms, as detailed above, should result in the killing of all the stages of the RPW living inside the palm. It is observed that partial burning of the infested palm trunk cutting would not kill the RPW stages inside them, as shown in Fig. 1.56.

2. Collecting and eradicating the adults of RPW

Intensive mass trapping systems can be used to collect large numbers of the adult weevils of RPW and to kill them. These traps and the used pheromone and baits will be discussed later under the behavioural control measures. Parts of the trunk of the sago palm in the form of discs can also be used as traps to attract the adult weevils during their active period to collect and kill them.

3. Using of Plant Traps

Sago palms can be planted in the non-infested groves as plant traps for the RPW; as they are one of its preferred hosts. The RPW opts for these hosts for feeding, and then they can be collected later and burned with the insects they contain.

4. Collecting the adults of the fruit stalk borers, *Oryctes* spp.

Because of the finding and observations of many authors that the fruit stalk borers, *Oryctes* spp., prepare the entry for the, *Rhynchophorus ferrugineus* (RPW) infestation, killing them can be an indirect measure to decrease the infestation. In this respect, light traps can be used to attract and collect the adult beetles of the fruit stalk borers and then burning them.

III. Cultural and Sanitary Control

1. Pruning

Performing pruning properly and periodically to remove the dried fronds and stalks are essential parts of any control program. These include also the prompt destruction of infested plant material and prophylactic treatment of cut wounds. Abraham (1971) suggested that fronds be cut at or beyond the region where leaflets emerge at the base to prevent entry by the weevil into the stem. Azam and Razvi (2001) found that deep cutting to completely remove the growing point of unwanted offshoots (shoots from the trunk), then treating the cut surface with an insecticide such as Formothion or Dimethoate and covering it with mud reduced the level of infestation to less than 4% compared to 20% for an untreated control (cut at the trunk surface).

2. Spacing between date palms

Adhering to the planting spaces between the date palms, which should be not less than 8 metres as the dense plantation and the palms being adjacent to each other increase the possibility of RPW infestation and other palm pests. In addition, the dense palm plantations make early detection of RPW infestation difficult.

Fig. 1.56. Faulty partial burning of infested date palms,which was intended to kill the different stages of the RPW.

3. Painting the injured places with insecticides

All injury sites due to pruning or offshoot removal should be painted with one of the following insecticides: Phenthoate (Cidial® 50%) or Methidathion (Superacid® 40%) in the concentration of 30 ml per 10 litres of water.

4. Cultural practices

Most important in the agronomic management are moderation in irrigation and proper drainage with balanced fertilization. The fertilisers used should come from known sources to prevent the transfer of one of the forms of the fruit stalk borer, which lives primarily in manure as well as covering the young palm roots and getting rid of the neglected or dead palms by scorching after cutting them into pieces.

In a recent study on the effect of the method of irrigation (flood or drip irrigation) on the behaviour of RPW and spread of its infestation, it was found that flood irrigation increased RPW infestation. The percentage of the infested date palms was 89% of the total palms irrigated by flooding, whereas it was only 10% in those irrigated by drip emitters. These results indicate that the method of irrigation and therefore the level of soil moisture is one of the major factors influencing the spread of the RPW infestation (Yousif and Al-Bukiri, 2003).

IV. Chemical Control

a. Preventive Programs

1. Spraying the date palms

All date palms in the affected places whether infested with RPW or not should be sprayed after determining the seasons of RPW activity period in each area. The spraying is a thorough rinse of the date palms trunks in order to penetrate the leaf bases and twigs as much as possible. The spraying program should be in the affected area and within an area of one kilometre from the outermost infested palms, which is the distance expected to be travelled by the adult weevils.

The following are some of the chemical insecticides, which can be used in these preventive programs, taking into consideration the processes of spraying or dusting: Fenitrothion (Sumithion® 50%) or Isoxathion (Karphos® 50%). The spraying program should be suspended during the pollination of the palms and in case of productive palms for a period of not less than two months before harvesting the dates.

2. Treatment of offshoots

The date palm offshoots are immersed in one of the previously mentioned insecticides, which used in spraying the date palms, for 5-10 minutes until the offshoots fibres are saturated with the insecticide in order to kill all the stages of the RPW in the offshoots. The entire offshoot can be dusted after planting with the insecticides mentioned earlier under dusting palms.

b. Remedial Programs

1. Injection of the infested date palms

This program is used to treat recent and moderate (superficial) infestation. When an infestation is detected on the date palm trunk in one or more points, three vertical holes are drilled in the trunk; one in the exudate pore, one above it and the third below it, each at a distance of 20 centimetres from the central hole. A drilling machine using a drill bit of 40 cm length and 1.9 cm diameter is used to make the holes. Each hole should be from 30 to 35 cm deep and at a 30 degrees angle from the horizontal. A plastic tube of a length of 45 cm and a diameter of 1.3 cm is inserted in the hole to pour or to inject the insecticide into the palm at a rate of 50 cm3 for each hole. When the insecticide solution has penetrated into the trunk, the tubes are removed and the holes are sealed with mud.

The following insecticides have been used with success: Formothion (Anthio® 33%) or Demeton-S-methyl (Metasystox®), both giving excellent results when injected into date palms infested with RPW. These insecticides were diluted to a 1:1 ratio. The percentages of larval mortality in

the treated palms were 100% and 93.3% for the previous two insecticides, respectively, (Abdallah and Al-Khatri, 2000a).

2. Fumigation

This method is used to treat severe (deep) infestations, which result in pockets in the date palm trunk. Phostoxin® tablets (aluminium phosphide) can be used as fumigants tablets by placing 2 to 5 tablets in the hole in the trunk after cleaning and drying it. Then the hole is sealed tightly with fibres or hay, then covered with cement, gypsum or heavy muddy soil, so as to prevent the leaking of the gases produced by the Phostoxin tablets to the outside. A piece of cotton soaked in carbon disulphide can also be placed in the holes on the trunk or the cutting sites, and sealed tightly to leave the gas to fumigate. Para-dichlorobenzene granules may be used as well. In general, the different stages of the RPW present inside the palm die by the toxic fumigant gases used, provided the holes are properly sealed to prevent the gases from escaping. This method has some drawbacks, as it is only effective for a short time, lasting only as long as the toxic gas remains. In addition, it only affects the larvae present near the tablets while the other larvae are not affected and it will not prevent the recurrence of infestation in the treated palms.

3. Soil application

In this method, systemic soil insecticides in granular form are applied into 25 cm deep groove made approximately 80 cm from the palm trunk. About 30 to 60 grams of the insecticide are applied in each groove, the quantity depending on the size of the palm and the number of offshoots around it. The groove is covered and irrigated to aid in the dispersion of the insecticides. This treatment can be repeated every three months as needed. It should be noted that the period between last treatment and harvesting dates should not be less than two months. It is important to note that this method has not been proven effective in field trials in controlling the RPW, Rhynchophorus ferrugineus.

4. Root application

This method is used in the beginning of the infestation with RPW. This method is implemented by digging around the infested date palm to find a major and active root, which is then cut with a sharp knife in a horizontal and circular manner. The exposed end is placed in a polyethylene bag filled with a mixture of one of the systemic insecticides in the concentration of 3.5-4 grams of the active ingredient with 100-150 ml water for each root. The root end should be checked for complete immersion in the insecticide solution in order to properly absorb the insecticide. It was found that the root could absorb the insecticide in a period of 24-48 hours.

This method can be used after collecting the fruits to avoid any residual insecticides in them. Some of the drawbacks of this method are that it requires great skills to perform and that it is impractical to apply on a large scale.

V. Behaviour Control

The behaviour control is considered one of the most important elements in the integrated management (IPM) program of the RPW. This method depends on trapping large numbers of the adult weevils in what is called “the mass trapping system” which would lead to actually lower pest populations. This is done by using special traps with the RPW aggregation pheromone in addition to Kairomones, which are RPW-attractive food substances.

Aggregation Pheromone

Hallett *et. al*., (1993) reported that the source of this pheromone is from the males of the red palm weevil, *R. ferrugineus*. They found that the male weevils secret certain volatile substances specific to this species, which act to attract the adults of RPWs both males and females. The chemical composition of this pheromone is:

CH3 (CH2) 2 CH (CH3) CH (OH) (CH2)3 CH3

+

CH3 (CH2) 2 CH (CH3) C (O) (CH2)3 CH3

This pheromone has been commercially produced by Chem Tica company under the trade name Ferrolure®

and the chemical name is (4-methyl-5-nonanol, 4-methyl-5-nonanone). In addition, another company, SEDQ, also produces it commercially under the trade name of Red Palm Weevil Attract and Kill Dispersers. It was found that using traps containing the aggregation pheromone and chunks of date palms, date fruits or fermented sugar cane pieces among other items, enhanced the attraction of the adult male and female weevils to the trap, where they can be collected and eradicated.

Kairomones

Kairomones are volatile plant substances that help the herbivores to find their food easily. Some of them are phagostimulants, which help predators to find their prey. Kairomones have been used successfully in pheromone traps to attract the RPW.

Gries *et al*. (1994) found that palm esters produced by the fermentation of palm tissues, or sugar cane contain ethyl acetate, ethyl propionate, ethyl butyrate and ethyl isobutyrate and have an attracting effect on the following insect species; *Rhynchophorus ferrugineus*, *R. phoenicis*, *R. cruentatus*, *R. palmarum*, *R. bilineatus* and *R. ulneratus*.

Pheromone Traps

Fig. 1.57 shows the structure of the classical pheromone trap used to attract the RPW. It is a plastic bucket with a lid having a capacity of 7 litres. There are four holes in the sidewall. The bucket is covered with fibres or burlap to help the insect to settle when it has descended on the trap.

A polyethylene bag is fitted on the plastic lid inside the bucket to ensure that the pheromone is not immersed in water. Pieces of tender palm trunk pre-treated with insecticide are also placed in the trap (2-4 pieces on average). It is best to use an insecticide without a strong odour. The trap is filled with water to the middle. It is also possible to use pieces of fresh sugar cane instead of the palm trunk, which cut in pieces of 2-3 inches and battered with a hammer while preserving their juice inside.

The fermented date fruits can be used as Kairomones attracting RPW. The traps are placed on the height of one metre on the shaded side of a noninfected palm. The trapped weevils are collected weekly and are buried after ensuring that they are dead.

Fig. 1.57. Classical pheromone trap.

Fig. 1.58. Terrestrial pheromone trap.

Terrestrial pheromone traps as reported by Hanounik *et al*. (2000) can also be used, Fig. 1.58. This trap consists of a 10 litres plastic bucket with four holes of 3 cm diameter in the bucket's lid and six such holes on the sidewalls just below the lid. A pack of 400 mg of aggregation pheromone mixture: 4-methyl-5-nonanol + 4-methyl-5-nonanone (9:1), Chem Tica International. S. A. Costa Rica, and a 20 ml dark-brown bottle, with 1 mm hole in its lid, filled with kairomone extracted from dates are attached to the inner surface of the trap's lid. The trap is provided with food substrate consists of 500 g of dates, a teaspoonful of yeast and 5 litres of water. The trap is buried in soil to the level of the lateral holes.

In Oman, Abdallah and Al-Khatri (2000b and 2005) investigated the effect of the attracting substance and the shape of the trap on attracting the RPW. They found that the open trap, which is not covered with burlap, i.e. just a 7 litres plastic container containing the following: attracting material (1 kilogram dates+5 litres of water+5 grams yeast) + aggregation pheromone of the RPW, was the best of the tested traps. It attracted the highest number of red palm weevils (males and females) and was less costly than the traps covered with burlap and side openings. The distance between one tap and the next was 25 metres. They also mentioned that the bait should be prepared one day before hanging the pheromone trap to allow sufficient time for fermentation to start. Water should be replenished every 3-4 weeks or less, especially on very hot days (before dried), to compensate water evaporation.

Fig. 1.59 shows the modified pheromone traps currently used in Oman. The trap contains the attracting material and the RPW aggregation pheromone, as well as the attracting Kairomones lure. The Kairomone is ethyl acetate, which is to efficiently attract the adults of RPW exactly like the Kairomones prepared by fermenting the plant tissues, as the dates, sugar can, or grated coconut.

This type of pheromone traps have been used successfully in Oman since 1994. Table 1.15. demonstrates the number of the pheromone traps used to collect the RPW in different regions, as well as the number of the adult weevils collected and eradicated in the years from 1994 to 2003, (Al-Khatri, 2004). Undoubtedly, this method has helped in decreasing the number of the pest and thus the rate of infestation by the RPW.

Fig. 1.59. The modified pheromone trap, which are used in Oman to attract *R. ferrugineus*

Data in Table 1.15 show that the total number of RPW trapped by the pheromone traps in the 10 years period (from 1994 to 2003) exceeded 265 thousand weevils in A'Dhahirah region, which is considered one of the most important regions with high rates of RPW infestation.

On the other hand, the total number of weevils trapped by the pheromone traps in the same period was not more than 1045 weevils in Al Batinah region and approximately 6908 weevils in Musandam governorate.

In this field, the use of pheromone traps deployed to limit the number of an insect pest, should be accompanied by the use of other measures to control such a dangerous pest. The most important of these measures are the use of the chemical insecticides to kill the different stages of the pest (the adult weevils and the larvae), which attack and infest the date palms. In other words, the IPM program of RPW should be applied by employing all measures available and possible to decrease the number of the pest and to control or eradicate it.

Table 1.15. The number of RPW, *R. ferrugineus*, caught by the pheromone traps in different regions in Oman during the years from 1994 to 2003.

Year	A'Dhahira		Al Batinah		Musandam	
	Number of Traps	Number of weevils	Number of Traps	Number of weevils	Number of Traps	Number of weevils
94 - 97	324	45778	49	257	45	-
1998	375	33318	29	307	31	-
1999	730	48709	71	184	79	1831
2000	775	46506	169	190	74	942
2001	863	42104	173	58	103	1504
2002	860	31361	123	21	110	2116
2003	752	18082	108	28	82	515
Total	**4679**	**265858**	**722**	**1045**	**524**	**6908**

VI. Biological Control

Many researches have been conducted to utilise the biological control of RPW as a strategy to eradicate this pest or at least limit its population, thus decreasing the damages to the date palms. The following are the major studies conducted in the field of biological control of the RPW, *R. ferrugineus*, in various countries.

1. Parasitoids and predators

Lepesme (1947) and Lever (1969) recorded some parasitoids on the larvae of the RPW, *R. ferrugineus*, which are the large wasp, *Scolia erratica* Smith (Hymenoptera: Scoliidae), and the Calliphorid fly, *Sarcophaga fuscicauda* Böttcher (Diptera: Calliphoridae). Kurian (1963) recorded *Tetrapolypus rhynchophori* Ewing (Acari: Pyemotidae) as a predatory mite on the RPW, *R. ferrugineus*.

In addition, Abraham *et al*. (1973) mentioned that the earwigs insect, *Chelisoches morio* (Fabricius) (Dermaptera: Chelisochidae), is a predator of eggs and newly hatched larvae of RPW. They reported that *C. morio* nymphs consumed 5.3 weevil eggs and 4.2 weevil larvae per day, whereas *C. morio* adults consumed 8.5 weevil eggs and 6.7 weevil larvae per day. It was also found that the earwig insect can prey during its lifetime under laboratory conditions, approximately 662 eggs, or 633 newly hatched larvae of the RPW. However, Reginald (1973) reported a fortuitous occurrence when *Platymeris laevicollis* Distant (Hemiptera: Reduviidae) was imported into Sri Lanka from Western Samoa as a possible predatory bug on *Oryctes rhinoceros*, and it was established that this predator has the capacity to devour the larvae and the adult weevils of the RPW, *R. ferrugineus*.

Because the above-mentioned natural enemies do not play a significant role in suppressing RPW populations, it is necessary to look for other biological control agents to use one on them in the IPM program against RPW, *R. ferrugineus*.

2. Entomopathogenic Fungi

Several research projects have been conducted in the Arabian Gulf countries to control the red palm weevil biologically. The Arab Organization for Agricultural Development adopted one project titled as "The Biological Control of Red Palm Weevil and Stem and Roots Borers in the GCC Countries". In this project, the effectiveness of two strains of the entomopathogenic fungus, *Beauveria bassiana* (Bolis.), were studied, i.e., the Columbian and Brazilian strains, for controlling the adult insects of the red palm weevil compared to the chemical insecticide Regent 50 SC. The obtained results showed that the method of spraying the trees with an oil-based preparation of the Columbian strain of the fungus was superior to all the other treatment methods in the study. This treatment led to the mortality of 90% of the weevils released on the palms inside metal cages covered with plastic net.

In addition, El-Sufty *et al*. (2007) studied the biological control of the RPW, *Rhynchophorus ferrugineus* by using the local strain of the entomopathogenic fungus *Beauveria bassiana*, i.e. UAE-B2, in United Arab Emirates. For mass production of dry conidia, a new and cheap simple medium containing granulated rice was evaluated and used. The culture medium yielded 5.2 mg conidia/cm^2 with a potentiality of 91.7% on adult weevils. The conidia were stored at –10°C for 13 months without decrease in their virulence. Preliminary field investigations were carried out in date palm plantations at Ras Al Khaimah to evaluate the efficacy of the fungus. Spraying date palm trees with an oil formulation containing 5 x 107 con. / ml at a rate of 5 L / tree caused a mortality of 13.7-19.2% in the adult population during the three weeks after application with a monthly delayed mortality of 2.3-12.5% in the following four months. Dusting a date palm tree with 40 g of a powder formulation containing 5% conidia killed 8.9% of adult population during the three weeks after application and caused monthly delayed mortality of 4-5.9% in the following three months.

3. Entomopathogenic Nematodes

Shamseldean and Abd-Gawad (1994), Hanounik (1998) and Abbas and Hanounik (1999) studied the effect of Steinernematids and Heterorhabditids as biological control agents for the RPW, *R. ferrugineus*. These entomopathogenic nematodes are soil-resident. They are market in the form of the third instar larvae, what can be calling the infective juveniles. This is because the third instar larvae are the infectious stage and only these can survive outside the host insect, because they do not require food. The third instar larvae, the infective juvenile stage, can invade and enter the insect host through one of its natural opening, i.e. via the mouth and anus or through the spiracles.

RPW infected with
Beauveria bassiana

The 4th instar larvae inside
the deceased larva of *Oryctes* sp.

Mode of Action of Entomopathogenic Nematode

As soon as the infective juvenile nematodes ((IJs, third instar larvae) enter the body of the insects, they start releasing a bacteria inside the insect's body (*Xenorhabdus* spp.). The bacteria in its turn, proliferate and produce a wide range of toxins and hydrolytic enzymes that are responsible for the death and bioconversion of the insect into a nutrient soup that is ideal for nematode growth and reproduction. The releasing toxins in the insect's body killing the affected insect within 24-72 hours after the entry of the nematodes. The nematode-bacterium relationship is mutualistic. The bacteria benefit from this interaction by being protected from the competitive environment of the soil and the bacteria being transported to the nutrient-rich haemolymph of an insect. The nematodes benefit from this interaction as bacteria help the nematodes to kill the insect host, supply the nutrient base for growth and development of the nematode and suppress contamination of the insect cadaver by soil microorganism (Forst and Clarke, 2002). Steinernematidae and Heterorhabditidae are symbiotically associated with bacteria of the family Enterobacteriaceae. Forst *et al*. (1997) mentioned that *Xenorhabdus* and *Photorhabdus* are motile Gram-negative bacteria associated with the families Steinernematidae and Heterorhabditidae, respectively.

Consequently, the nematodes develop into the fourth instar larvae inside the deceased insect. The fourth nematode stage develops within the dead insect. These fourth stage larvae develop into sexually mature males and females, which mate inside the host insect. After mating, the males die and the females start depositing the eggs inside the deceased insect if there is enough food for the first and second instar larvae, otherwise, the females keep the eggs inside their bodies to hatch and the first and second instars develop inside the female nematode's body. Later, when larvae reach the third stage (infective juvenile), they are able to leave the dead insect or the female nematode's body and seek out a new host to repeat the life cycle. However, there may be two or more generations within the host depending upon the availability of food.

It is worth mentioning that the infectious nematodes can move in the soil for few centimetres and wait for a new source of food, i.e. an insect to enter through its natural openings. The nematode life cycle depends on the condition and the temperature of the soil as well as the availability of food (host insects) in the surrounding environment. The pathogenic nematode used in the experiments to control the red palm weevil has a life cycle of 14-20 days. Abbas and Hanounik (1999) tested three species of pathogenic nematodes for their pathogenicity to the RPW: *Steinernema riobravae*, *Steinernema carpocapsae* (weiser) and *Heterorhabditis* sp. They found that these three species had a toxic effect on the larvae and adult insects of the red palm weevil. They also added that the larvae of the RPW, *R. ferrugineus*, were more sensitive to the toxic effect of the three nematode species than the adult weevils. The calculated LC50s for the tested nematodes to adult weevil of the RPW, *R. ferrugineus*, were 900, 1100 and 1416 IJs/weevil by *S. riobravae*, *S. carpocapsae* and *Heterorhabditis* sp., respectively, whereas LC50s to the larvae of *R. ferrugineus*, which were more susceptible to the previous three nematode species, were 61, 61 and 56.7 IJs/larva, respectively.

In addition, cited authors added that 100% mortality of the larvae was reached at a concentration of 240 IJs/larva; while the highest mortality for the weevils was 93.3% with the species *Steinernema riobravae* at a concentration of 4000 IJs/weevil. The multiplication of the nematodes inside the dead body of the adult weevils was easily observed as the population of the infective juveniles produced from an adult weevil was 242 thousand infective juveniles, whereas the multiplication of the nematodes inside the dead body of the larvae was minimal.

Abbas *et al*.(2000) conducted field studies on the effect of the pathogenic nematodes of the species *Steinernema riobravae* on the adult weevils and larvae of the RPW, *R. ferrugineus*, and mentioned that through field observations and laboratory studies, 20- 100% of weevils

collected from the fields had different species of nematode parasitizing on them. Two pathogenic nematode species were isolated: *Steinernema abbasi* and *Heterorhabditis indica*. In the field tests, Abbas released the nematode species *Steinernema riobravae* by three methods:

- Injecting the tunnels in the date palm trunk with nematodes at a concentration of 50-200 ml (500 IJs per ml) for each tunnel. This treatment produced 25% mortality of the larvae.
- Spraying the date palm trunk with nematode solution with a dehydrating agent in the concentration of 8 X 106 IJs per tree. This treatment gave 8.3- 86.7% mortality of the weevil's population.
- Soil treatment with nematode solution around the date palm trunk in the concentration of 8 X 106 IJs per tree. This treatment gave 33.3- 86.7% mortality of the weevil's population.

From the above it is evident that the adult weevil of the RPW in the regions, where the studies were conducted, may remain in the soil for some period of time or may just be passing. Thus, many soil nematodes could be isolated from the adult insects. The treatment of soil by the pathogenic nematodes around the date palm trunks gave a satisfactory mortality of the adult weevils ranging between 33.3-86.7%.

It is worth mentioning that, most of the successful bio-control program with nematodes was achieved against soil inhabiting insects, or those visiting the soil from time to time, Figueroa (1990), Smith *et al.* (1993) and Sen Selvan *et al.* (1994).

The fruit stalk borer, *Oryctes agamemnon* Burmeister, possibly could be controlled by nematodes because it lays its eggs on decomposing matter in the soil and its larval and pupal stages are present in the soil.

In this respect, the soil application with the entomopathogenic nematodes to control the RPW, *R. ferrugineus*, could not be as an effective control method against it. There is no evidence that the *R. ferrugineus* inhabit the soil at any stage of their life cycle or visit the soil regularly.

It is known that nematodes cannot withstand drought and the soil where they are applied must be kept moist. Accordingly, in the areas where the date palms are irrigated regularly the use of entomopathogenic nematodes in such case could survive for some time. But on the other hand, the number of RPW adults that accidentally visit the soil are few which extremely limiting the rationality of this method.

1.3.2. Date Palm Stem Borer

***Jebusea hammerschmidti* Reiche**
syn. *Pseudophilus testaceus* (Gah.)
(Coleoptera: Cerambycidae)

Distribution

The date palm stem-borer, *Jebusea hammerschmidti*, is an important borer pest in date palm groves in the Middle East and India. It spread in Iraq, Saudi Arabia, Bahrain, UAE, Egypt, Algeria, Iran and India. In Oman, this pest is considered of limited distribution and can only be found in places with neglected palms or weak palms, which are not been adequately cared for such as regular irrigation, suitable fertilization, trimming and continuous cleaning of the palms among other processes. However, the date palm stem borer seems to come in second to RPW as regards its economic importance for date palms in Oman.

The date palm stem-borer, *Jebusea hammerschmidti*, belongs to family Cerambycidae, (Longhorn beetles). In Oman, this beetle is called the red beetle because of its reddish colour. Like many of the borers in this family, it attacks weak and neglected date palms. The larvae of this beetle are called the round-headed borer. Like the other wood borers of this family, the larval stage of this pest is the only damaging stage. The functions of the adult insects of *J. hammerschmidti* are to reproduce and deposit eggs.

Economic Importance

The date palm stem-borer, *J. hammerschmidti*, prefers to infest neglected date palms, which had not undergone pruning, in addition to weak or aged palms. It was found that the lower third of the date palm trunk is more susceptible to infestation than the middle or upper thirds. As mentioned earlier, the larvae of this pest are the damaging stage. They burrow their tunnels in the frond base and go down toward the palm base. Generally, the repeated infestations with the stem borer, *J. hammerschmidti*, season after season lead to weakening of the trees due to the larval tunnels inside the stem. The affected trees become breakable, decreasing their productivity, in addition to lowering the quality of the wood of the infested palms when used in manufacturing. Hussain (1963b) mentioned that the level of infestation with the date palm stem borer, *J. hammerschmidti*, reached up to 79% of date palm trunks in Iraq. In addition, the infestation with the date palm stem borer facilitates and eases the infestation with the fruit stalk borers of genus *Oryctes*, as they live on the excreta of the larvae of the date palm stem borers. The most prominent sign of infestation by the date palm stem borer is the

presence of the beetles' exit holes on stem, as well as gummy excretions on the infested palm stem oozing from the bases of the tunnels of the larvae because of their feeding and pushing backward the digging substances with their faeces. These excreta are dark and shiny and in the form of spots on the date palm stem.

General Description

The adult beetles of the date palm stem-borer, *J. hammerschmidti*, are large with reddish brown colour and extremely long antennae. The male can be differentiated from the female by the length of the antennae. In the female, the antenna is as long as the body length while in the male it is generally longer. The female is 30 to 45 mm long while the male is usually smaller, being 26 to 30 mm long. The egg is elongated in shape and white in colour. It is from 3 to 5 mm long and 2 mm wide. The female lays the eggs individually in any cracks in the date palm trunk or on the frond bases.

The newly hatched larva of the date palm stem-borer, *J. hammerschmidti*, is whitish in colour and then turns into off-white over time. The larva is apodous (legless). It is cylindrical in shape like the other larva of family Cerambycidae, which is known as the round-headed borer due to the rounded or cylindrical shape of their body. It is wide at the anterior, pointed at the posterior end of the body, and has a small brown coloured head. The newly hatched larva is 6 mm long and the fully-grown larva reaches up to 45- 50 mm, as in Fig. 1.60. The larva pupates and overwinters in a cell in the date palm stem. The Pupa is present at the end of the tunnel nearer to the surface of the stem. Before the larvae enter the pupal stage, each larva prepares the pupal chamber for itself as well as the exit hole for the adult beetle; however, the larva does not open

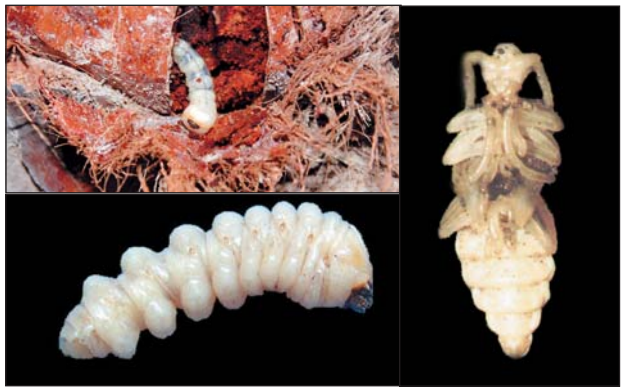


Fig. 1.60. The larva and pupa of *J. hammerschmidti*

it to outside but the beetle open its exit hole to emerge from the pupal stage. The exit hole of the adult beetle has circular or semi-circular shape, Fig. 1.61.

Fig. 1.61. The exit hole of the adult beetle of *J. hammerschmidti*

Life Cycle

The date palm stem-borer, *J. hammerschmidti*, is univoltine, i.e., has one generation each year, like many of Cerambycidae species. The larval stage lasts from 10 to 11 months, which is the only harmful stage of this pest.

The female cuts a small slit in the bark, where she lays an egg. In addition, the female can lays its eggs on the date palm stem inside any crevices or cracks. The eggs hatch after about 15 days and the legless larva (grubs) directly commences digging inside, feeding as it digs in the frond bases until reaching the stem. The larvae burrow long tunnels inside the stem, which sometimes reach the

middle of it. The larval stage duration is from 10 to 11 months and has from 3 to 4 larval instars till fully grown. Thereafter, the larva reaches the outside near the surface of the trunk, where it makes the pupal cell or chamber, which is elongated and lined with the remnants of sawdust and faeces, and pupates inside the cell. In addition, the larva prepares the exit hole for the beetle but does not open it to the outside, leaving this task for the beetle. The adult beetle bores its way out through an oblique gallery, creating a symptomatic one-centimetre diameter emergence hole.

The adult beetles start to emerge from early May and their activity extends until August. However, the peak activity is during August when most of the beetles emerge. Thus, the various control operations should be directed to kill the adult beetles of this pest preventing them from repeating the life cycle. The adult beetle stage is the only stage that can be detected and controlled easily, in contrast to the other stages, which live sheltered in their tunnels inside the date palm trunk and are very difficult to reach and to control chemically or mechanically. The adult beetles of the date palm stem-borer, *J. hammerschmidti*, are attracted strongly to light. So, light traps can be used as a measure to decrease the pest population during their activity period, which extended from May to August.

The beetles exit holes are considered as clear indication of infestation with this pest. The adult beetle emerges leaving circular or semi-circular exit hole on the stem. The exit holes of the adult beetles are used in the ecological studies to determine the seasonal activity of the adult beetles, the level and severity of infestation as well as its distribution on the date palms in different regions. The number of exit holes on each palm reflects the number of beetles that emerged from this palm tree. The beetle exit hole is circular of about 12 mm diameter or semi-circular, in average 14 mm long and 10 mm wide.

Control Measures

1. Mechanical and Cultural Control

Because the date palm stem borer, *J. hammerschmidti*, attacks only the weak or neglected palms, the cultural control is considered from the most important measure to depend on in controlling this pest by applying the following:

- Removal of weak and dead palms as well as the remaining palm trunks and incinerating to kill any larvae they may contain.
- In areas with severe infestation with the date palm stem-borer frond base pruning should be done from time to time as it helps in eradicating the larvae and eggs depositing sites of this pest.
- When planting date palms in new groves, we should leave appropriate distances between the date palms.
- Using light traps as a mass trapping system, to collect large number of the adult beetles during their activity period, which extends from May until August.

2. Chemical Control

There is no specific chemical control program to control this pest. However, when necessary, one of the recommended organophosphorus insecticides can be used in spraying the date palms concentrating on the trunks and crown during the period of beetles activity, which extended for four months from May until August of each year. The insecticide application is directed against the adult beetles only, but not the larvae residing inside the date palm trunks, thus preventing the adult females from depositing their eggs in the cracks on the palm trunks.

3. Biological Control

Al- Hafeez *et al*. (1975) conducted some research on the fungus *Beauveria bassiana* (Bolis.), which attacks the date palm stem borer larvae causing their death. The diseased larvae exhibit black spots and die within 3-14 days of infection with the fungus. After the death of the larvae, white mycelia of the fungus appear. Hammad *et al*. (1983 b) recorded the fungus *Cordyceps* sp. and two species of Mesostigmatid mites; *Ameroseius* sp. (Mesostigmata: Ameroseiidae) and *Hypoaspis* sp. (Mesostigmata: Laelapidae) on the larvae of the date palm stem borer, *J. hammerschmidti*.

1.3.3. Fruit Stalk Borer

***Oryctes* spp.**
(Coleoptera: Scarabaeidae)

Dechambre (1983) mentioned that there are forty known species of *Oryctes*. Eighteen occur in the Madagascan region (Madagascar, Comoros, and Mascarene Islands). From the genus *Oryctes* there are several species known to attack the date palm fruit stalks in the Arab countries. These beetles are called Fruit Stalk Borers. The rhinoceros beetle also belong to the genus *Oryctes*, although it differs in the way it infests the date palms from the fruit stalk borer as will be seen later. The following are the main species of the fruit stalk borers:

1. *Oryctes agamemnon* Burmeister

This beetle, *Oryctes agamemnon*, infests the date palms in India, Pakistan, Iran, Yemen, Iraq, Saudi Arabia, Qatar, UAE and the Sultanate of Oman (El-Haidari and Al-Hafidh, 1986). The adult beetles of, *O. agamemnon*, attack the fruit stalks and feed by digging surface tunnels along the stalk vein to suck the sap from the tissues, leaving them as dry fibres. This leads to the weakness of the stalk, becoming breakable by the winds and unable to carry the fruits, which wither, shrivel and stay green. The fruits fall heavily if the stalk is shaken.

In addition, the adult beetles of the fruit stalk borers, *O. agamemnon*, attack the frond leaves making deep tunnels leading to the breaking and suspending of the frond, which leads to its dryness, as seen clearly in the infested date palms. They also attack and feed on the date inflorescence. It was also observed that the beetles can feed on the living and non-rotten parts inside the trunk, as in the Figs. 1.62 - 1.65.

The infestation with this pest is different from the infestation with the lesser date moth, which leads to turning the fruits in their early stages into red colour in addition to their dryness and being left on the stalks for some time before falling.

The adult beetles of all the species of the genus *Oryctes* are attracted strongly to light as they are nocturnal insects. During their active time, they are seen flying after the sunset and during the night toward any artificial light source in the farms. As for the larvae, they do not cause any significant damages as they live inside the stems of the weak or dying palms or may live under the surface of

Fig. 1.62. Beetle of the fruit stalk borer feeding on frond.

Fig. 1.63. The feeding leftovers of fruit stalk borer.

the soil rich in decaying organic matter. However, it was observed that occasionally the larvae present in the soil make deep holes in the frond bases covered by soil and feed on them.

General Description

The adult insect is characterized by the presence of a dark coloured horn in the anterior of its head. This horn is usually long in the male and shorter in the female. The body of the adult beetle of the fruit stalk borer, *O. agamemnon*, is wider and more convex in shape and less shiny than the species *O. elegans*, which will be mentioned later. The upper surface of the body is not smooth because of the presence of a number of tiny pits on its elytra. The egg is oval in shape and ivory white in colour. It is 4 mm long and 3 mm wide.

The larva is white in colour and with enlarged abdominal end segments. The larvae are strongly curved, C-shaped and covered with dark coloured short bristles. When fully grown, the larva is 60 mm long. The larva has strong thoracic legs and powerful mandibular parts pointed down to enable them to dig inside the soil to which they are often added together with organic fertilizers. The pupa of *O. agamemnon* is of the free type but it lives inside a cocoon or cell made by the last instar larva inside the soil.

Fig. 1.64. The damages in inflorescence caused by the fruit stalk borer.

Fig. 1.65. The damages caused by the fruit stalk borer.

From the above, it is obvious that the infestation with date palm fruit stalk borer insect leads to weakening the affected palm trees and the stalks may break due to the infestation and hence, lose their fruits. This leads to the deterioration of the product, quantitatively and qualitatively. It is important to note that infestation with the date palm fruit stalk borer enhances the infestation with the red palm weevil.

In Iraq, Hussain (1985) studied the seasonal population dynamics of *O. agamemnon* and found that it has two peaks, one during April-May and the second during August. In Oman, Mokhtar *et al*. (2000b) studied the seasonal abundance of the fruit stalk borer, *O. agamemnon* in date palm plantation in the interior region by using the light traps as in Fig. 1.66. They found that the activity of the insects was confined during the period from end of April until the end of September, each year. They also observed that the peak of the activity of the adult beetles is in the third week of June. The study also revealed that the activity of the adult beetles of *O. agamemnon* lasted for six months, and this was coinciding with the presence of the fruits of the date palm crop under the conditions of the interior region of Oman. They mentioned that the number of the female beetles attracted to light traps exceeded the number of the male beetles.

On the other hand, Abdallah and AL-Khatri (2003) found that the activity of the adult beetles of the fruit stalk borer, *O. agamemnon*, extended from April to the end of July. The emergence of the largest number of the adult beetles was recorded during the period from the end of May to the beginnings of June. The study also showed that the adult beetles of *O. agamemnon* disappeared in the second half of July. Thus, the activity of the adult beetles of the fruit stalk borer, *O. agamemnon*, in Al Batinah region in Oman extends only for a period of four months.

2. *Oryctes elegans* Prell.

This insect pest spread in several countries and has been recorded in Iraq, Bahrain, Saudi Arabia, UAE, Iran, Pakistan and Oman (Hussain, 1985). Walker and Pittaway, 1987 stated that this species is present in Eastern Saudi Arabia, Kuwait, UAE, Qatar and the Sultanate of Oman. *Oryctes elegans* is also called the Elegant Rhinoceros Beetle.

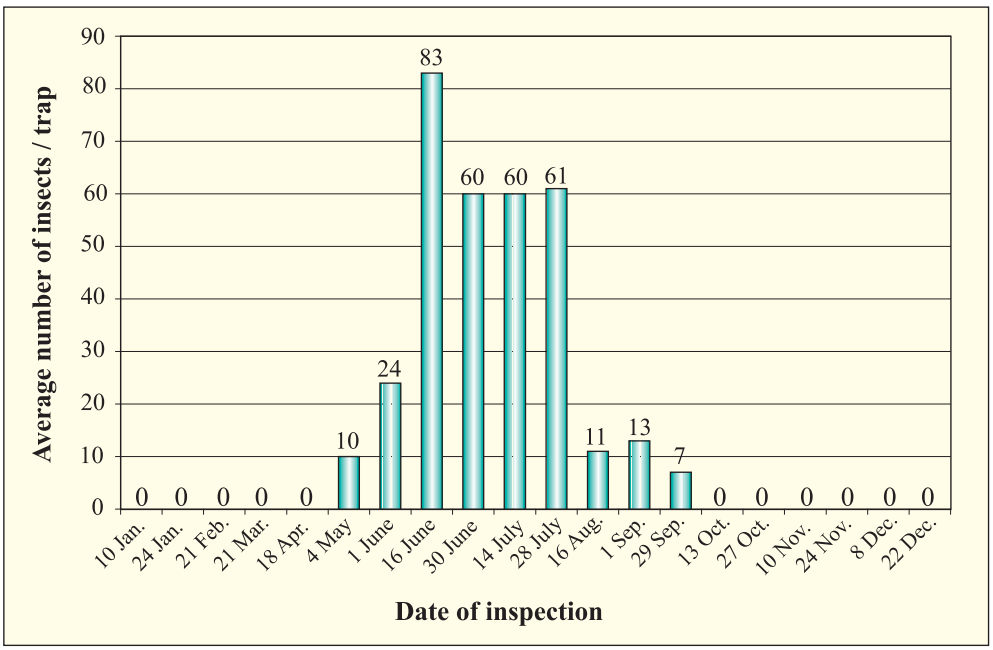


Fig. 1.66. The seasonal activity of the fruit stalk borer, *O. agamemnon.*

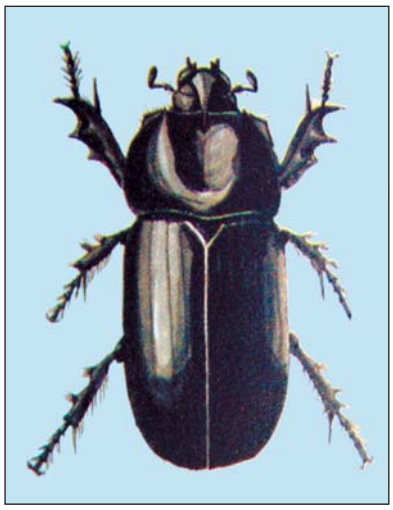


Fig. 1.67. *Oryctes elegans* Prell.

General Description

The adult beetle of *Oryctes elegans* is glossy brownish black in colour. The body is convex and has a small head buried in front of the first thoracic segment (pronotum). The forewings or the elytra are covered with dense and short hairs, which are light in colour. The upper surface of the head has a dark brown horn, which is long and curved toward the posterior of the body in the male and short and non-curved in the female, Fig. 1.67. The female is about 35 mm long, while the male is about 30 mm long. The first thoracic segment in the female has a rather deep and large depression. On the posterior edge of the depression, there are two elevations each resembling a very short horn. This depression is small in the male and its two elevations are indistinct. In the female of *O. elegans*, the lower surface of the last abdominal ring is relatively coarse due to the presence of tiny pits on the posterior edge of the last ring, which is curved with a straight anterior edge. In the male, the lower surface of the last abdominal ring is somewhat smooth with scattered tiny pits. Clearly, this pest has one generation per year as the adult beetles start to appear during April and their activities continue until September.

Life Cycle

The females of *Oryctes elegans* lay their eggs in the decaying moist organic matter near the living wood inside the holes on date palm trunk, which have been made by the date palm stem borer, Jebusea hammerschmidti Reich, as well as on the date palm trunks, which are collapsing and decomposing, i.e. the weak or dying palms. The females also lay their eggs between the fibres at the frond bases and fruit stalks. However, it is observed that the females prefer to deposit their eggs in the piles of organic matters and the decaying organic and plant leftovers in the farms. These are from the favourable places to raise their broods. Each female of *O. elegans* lays approximately 108 eggs in average throughout its lifespan, which lasts for around 6 months.

The incubation period of the eggs of *O. elegans* is 6-8 days, producing sturdy larvae, which are white or creamy in colour with heavy and coarse body curved from behind at the abdominal end. The terminal abdominal rings are larger than the rest of the rings.

The duration of the larval stage is between 9 to 10 months during which the larva moults three times. Generally, the larvae live and exist in places with plenty of decomposed organic matter like the decaying trunks and organic manure with its decomposed plant debris. Later the larvae transform into pupae. The pupal stage lasts approximately three weeks after which the adult insects emerge to repeat the life cycle.

3. *Oryctes boas* Fabricius

This species attacks date palm (*Phoenix dactylifera*), coconut palm (*Cocos nucifera*), African oil palm (*Elaeis guineensis*) and Washingtonia palm (*Washingtonia* spp.) in Somalia and some African countries. It is known as "rhinoceros beetle" or "scarabeid oryctes boas". However, *O. boas* is confined to African countries, it was recorded in Yemen and Saudi Arabia by Hill and Waller (1982) and EPPO (2006). The adult beetles of *O. boas* are shiny, reddish-brown to black in colour, 3.5-4.5 cm long and have a rhinoceros-type frontal horn, which is well developed in the male but short in the female. The beetles of *O. boas* are strong fliers, but only at night.

4. *Oryctes sahariensis* De Mire

This species attacks date palms in Egypt and coconut palms in Somalia and Central African countries.

5. *Oryctes monoceros* (Olivier)

O. monoceros is also called "coconut beetle", it is recorded in Yemen and eastern African, Zanzibar, Madagascar and the Seychelles. The adult beetle of *O. monoceros* is black or dark brown, head with frontal horn moderately long; frons of female with a strong tubercle or a short horn; clypeus broad and deeply excised, anterior angles sharp. This species attacks date and coconut palms. Lever (1969) mentioned that the incubation period of *O. monoceros* eggs is 7-9 days, the larval stage lasts 100-200 days and the pupal stage 14-21 days; the complete life cycle from egg to adult occupies about 6 months. In addition to coconut and date palms, it attacks Hyphaene and Borassus palms.

Control Measures

1. Mechanical and Cultural Control

- Getting rid of the weak and dying date palms as they are considered the favourable places for the pest to raise its offspring.
- Getting rid of the decomposing plant debris in the farm and treating their locations with insecticides to kill the larvae of *Oryctes* spp., if present.
- Turning any piles of organic manure periodically to expose the present larvae to the sun and / or predators.
- Strengthening the palm trees with organic and chemical fertilization.
- Using light traps to attract and trap huge number of adult beetles of Oryctes spp. during their active period, which extends between April and September annually, i.e. "mass trapping system".

2. Chemical Control

Because the breeding sites of *Oryctes* spp. are distinct and many, the use of insecticides is useless and costly. In addition, using of chemical insecticides to reduce the population of these pests and to control them should not be solely relied upon. Generally, the following insecticides can be used in the IPM programs of this pest to treat the breeding sites of the insects such as, Carbofuran (Furadan®10% granulated) or Oxamyl (Vydate®10% granulated).

3. Biological Control

A fly species has been recorded as a parasitoid on the larvae of the fruit stalk borer, namely *Microphthalma disjuncta* (Wiedemann), (Diptera: Tachinidae). It was found that the female of this parasitoid lays its eggs on the surface of the bodies of the larvae. After hatching, the larva of the parasitoid enters the body of the fruit stalk larva (the host, *Oryctes* spp.) to nourish upon its internal parts. It was observed that a single larva of the *Oryctes* spp. could be attacked by several parasitoid larvae. After the death of *Oryctes* larva, the fully-grown parasitoid larvae emerge to enter to pupal stage, which takes about five days, after which the flies of the parasitoid emerge to repeat its life cycle.

1.3.4. Rhinoceros Beetle

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

The rhinoceros beetle, *Oryctes rhinoceros*, is the notorious rhinoceros beetle, certainly one of the most serious pests attacking coconut palms. This pest belongs to the family of scarab beetles, Scarabaeidae, as the rest of genus *Oryctes* mentioned earlier. The larvae of this family are known as white grubs. It has been spread into all the areas famous for coconut palm cultivation. For this reason, it is also known as the "Black Coconut Beetle".

Distribution

The rhinoceros beetle, *O. rhinoceros*, is endemic to the coconut-growing regions of South and South-East Asia from Pakistan to the Philippines (CIE, 1967). It is spread into the South of China, Pakistan and the South of the Pacific Ocean. It is also present in Oman, being one of the most important pests in the southern region, attacking coconut palms. It also attacks the date palms in the northern wilayats of Oman.

Economic Importance

Coconut palm (*Cocos nucifera*) and African oil palm (*Elaeis guineensis*) are among the most favourite hosts of the rhinoceros beetle, *O. rhinoceros*. Besides, it is also known to attack the date palm (*Phoenix dactylifera*). Moreover, it also attacks and feeds on some other fruit trees as banana, papaya and pineapple, as well as sugar cane plantations. In Mauritius, Bedford (1980) recorded *O. rhinoceros* attacks on some ornamental palms such as the royal palm (*Roystonea regia*), the latanier palm (*Livistona chinensis*), the talipot palm (*Corypha umbraculifera*), and the raphia palm (*Raphia ruffia*).

The adult beetles feed on the young leaves, spathe sheath, green frond bases and the tender tissues present on the growing apex. The beetles also bore into the young fronds with unopened leaflets in the central bud, as they bore in the green and tender frond base near the centre. Therefore, the fronds open showing triangular gashes in them, as if the leaflets had been cut with scissors. Accordingly, the damaged fronds appear like a fan or like the letter V after opening, as shown in Fig. 1.68.

When the adult beetles reach the palm crown, they cause its death due to their feeding and damaging the heart. In addition, the resulting holes become suitable places for the red palm weevil to lay its eggs and for the accumulation

Fig. 1.68. Infestation signs of *O. rhinoceros* (V- or fan shaped leaflets).

Fig. 1.69. Dead date palms, which consider suitable breeding site of *O. rhinoceros.*

of rainwater in them. The fungi are encouraged to grow causing rotting of the palm and eventually death. Like the other species of genus *Oryctes*, the adult beetles become active at night and are strongly attracted to light. The larvae are relatively harmless as they live in the decomposing organic matter like garbage piles and inside the trunks of dead palms, which left in the farm. The female beetles deposit their eggs and breeding their offspring inside such dead palms, Fig. 1.69. Any decomposing plant materials in the farm are considered suitable breeding sites.

General Description

The adult of the rhinoceros beetle, *O. rhinoceros*, is a large beetle with its length reaching from 35 to 50 mm and 20-23 mm wide. It is sturdy and stocky. The dorsal surface is shiny black in colour while the abdominal side is brownish red. The adult beetle has an observable horn on the front of the head, which in general is longer in the male than in the female, although in this respect there may be interchange in the two sexes. The males can be differentiated more accurately by having a rounded shiny terminal abdominal segment while the female has a relatively more hairy tail than the male. *O. rhinoceros* has two tubercles on the thoracic ridge.

O. rhinoceros eggs are yellowish-white in colour, measuring 3.5 mm long and 2.5 mm wide and laid inside rotting vegetative matter. The incubation period of the eggs is 7 to 18 days, with an average of 12 days, after which they hatch into larvae.

The larvae (grubs) are usually creamy white in colour like the rest of the larvae belonging to the scarab family and strongly curved in shape. Its head is brown and the body is stocky with a thick terminal end. Dark-coloured bristles are present on the larva and are plenty on the last three abdominal segments, Fig. 1.70. The newly hatched larva is approximately 7.5 mm in length, while the fully-grown larva is as long as 60 to 105 mm. The larval stage has three larval instars.

The pre-pupa is somewhat similar in appearance to the larval stage except that it is smaller than the final larval instar. Shrivelled in appearance, it shakes its body actively when disturbed. The *O. rhinoceros* pupa is yellowish-brown in colour and measures up to 50 mm in length. The pupa is of the free type but exists inside a cocoon it makes in the last instar, which made from the boring remains, plant debris and dust, Fig. 1.71. Generally, pupation occurs in the soil in decomposed organic matter but it occasionally occurs also in the apex of the dead palm left in the farm. It was observed that after transformation of the pupa to the adult insect, it does not leave the pupal cocoon for 11 to 20 days until its body hardens.

Fig. 1.70. Larvae of rhinoceros beetle, *O. rhinoceros.*

Fig. 1.71. The pupa of *O. rhinoceros.*

Life Cycle

Khawaja and Akmal (1971) studied the life cycle of the rhinoceros beetle, *O. rhinoceros*, and found that it had one generation per year. They mentioned that the adult beetles appear in May and start to lay their eggs after a week of leaving the garbage piles, decomposed organic matter, rotten palm tissue or other decaying insects. After 11-13 days, the eggs hatch into small larvae, which are pale yellow and curved to feed on the remains of decomposing organic matter. The larvae moult three times and larval duration lasts 4 to 5 months to reach full growth. Then, the larvae undergo a quiescence period for up to 6-7 months prior to transforming into the pupal stage. Hence, the larval stage takes from 10 to 12 months. Before the fully-grown larva transforms into a pupa, it builds a special chamber from dust and plant debris to pupate inside. The pupal stage lasts 3 to 4 weeks before the adult insects emerge to repeat the life cycle.

Kinawy (1986) studied the life cycle of the rhinoceros beetle, *O. rhinoceros*, under the conditions of the southern region of Oman. He mentions that the incubation period of the eggs are 11 to 13 days, while the duration of the larval stage is 80 to 130 days and the pupal stage takes 16 to 28 days under optimal conditions. He also mentioned that the adult female lays 90 to 100 eggs throughout its life span of six months. Kinawy states that under the prevailing weather conditions in the southern region of Oman the adult insects of this pest become active during March and April. In addition, under optimal conditions for growth a single generation of the rhinoceros beetle, *O. rhinoceros*, takes 4 to 5 months.

Control Measures

1. Mechanical and Cultural Control

The farmers should follow some hygiene procedures, which are considered indispensible and fundamental in controlling this pest. These practices include the following measures:

- Getting rid of the possible breeding sites for the larvae of the rhinoceros beetle, *O. rhinoceros*, from palm grooves, which includes manure piles, animal faeces piles, garbage piles and the trunks of dead palm trees left in the farm.
- Turning the piles of organic manure from time to time is important to kill the existing larvae by exposing them to the sunshine or predators.
- Examining the above mentioned breeding sites periodically to get rid of the existing larvae by collecting and eradicating them.
- Cultivating some plants under the date palms to make the larvae breeding sites less attractive to the beetles to lay their eggs, e.g. cultivating legume crops under the date palms.

- Collecting the adult beetles from the crowns of the infested palms by using a slender iron rod, 5 mm thick and 80 cm long with a spear-like pointed end, Fig. 1.72. The rod is inserted in the tunnel of the adult beetles to pull the beetles and kill them.
- Using light traps to attract the adult beetles during their active season and collect a large number, then eradicate them, i.e. "mass trapping system".
- Using plant traps made by cutting trunk of a recently dead palm into two halves and putting them on the ground turned upside down, after putting manure under the trunk pieces to attract the adult beetles to deposit their eggs. The area under these cuttings is examined every few days to collect and kill any larvae or adult beetles.

2. Chemical Control

Because of the distinct behaviour of the rhinoceros beetle and the diversity of breeding sites in the farms, the use of chemical insecticides is considered as expensive and inefficient. In addition, one cannot rely solely on the chemical insecticides to control and limit the number of this pest. Generally, the following insecticides can be used in the IPM programs of this pest:

• Treatment of the infested palm crowns

Diazinon 10% granulated, Carbofuran (Furadan®10% granulated) and saw dust (1:9 ratio) by placing the insecticide on the infested palm crown heads inside the tunnels of the adult beetles after forcing them out in order to prevent repeated attacks.

• Treatment of the larvae breeding sites

The above-mentioned breeding sites can be treated with Diazinon 10% granules to kill the larvae. Care must be taken to guard against inadvertent poisoning of farm animals.

3. Biological Control

• The use of *Baculovirus oryctes* virus

Successful biological control of *O. rhinoceros* is attributed largely to the dissemination of the *Rhabdionvirus oryctes* Hüger (Baculovirus). The simplest, most economical

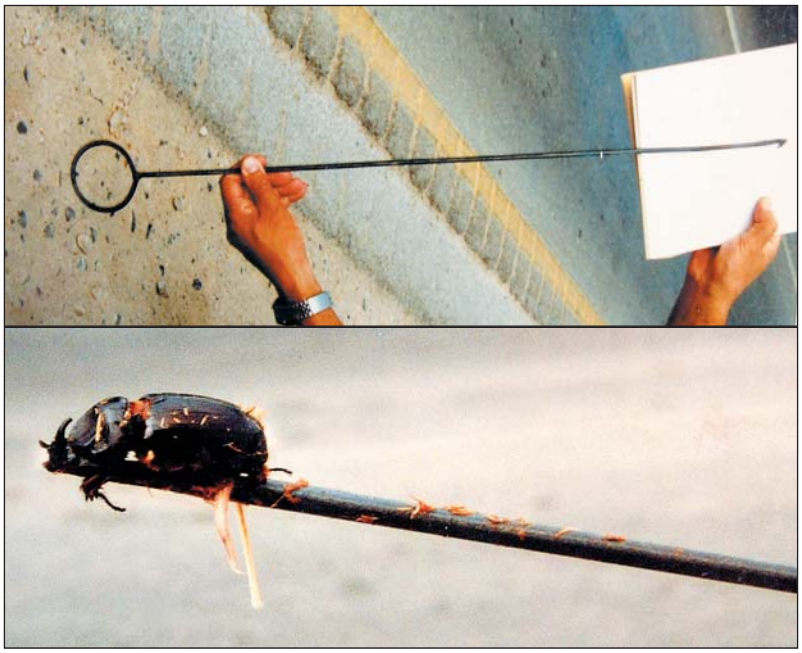


Fig. 1.72. The iron rod used to collect and kill the rhinoceros beetles, from their tunnels situated in the palm crown.

and direct method of virus dissemination was to release virus-infected beetles. This virus was used successfully as a microbial control agent against *Oryctes rhinoceros* in many countries. It was released in Western Samoa (Marshal, 1970 and Hüger, 1973), Wallis Island (Hammes, 1971), Tonga (Young, 1974), Fiji Island (Bedford, 1976), Philippines (Zelazny, 1977), Mauritius (Monty, 1974) and Papua New Guinea (Gorick, 1980). The safety of using this virus was tested in France in 1975 using purified virus as reported by FAO (1978).

Kinawy (2004) mentioned that 900 adult-inoculated beetles were released during 1989 at six sites all-over Dhofar plain in the southern region of Oman. Two months after release the incidence and spread of the virus to local population of *O. rhinoceros* using the rapid smear technique was confirmed, Fig. 1.73. He also added that two years after virus introduction a marked reduction in rhinoceros beetle damage to coconut palms was recorded. Initially the per cent of fronds damage ranged from 24 % to 37 %, and palm damage ranged from 19 % to 43%, but three years after virus introduction, the *O. rhinoceros* beetle's damage was dramatically reduced to about half. Then, in the fourth, fifth and sixth years after virus introduction, the percentage of beetle's damage continued to decrease. The lowest per cent levels of *O. rhinoceros* beetle's damage were recorded in the fifth and the sixth years after virus introduction.

Fig. 1.73. Artificial infection of the *Oryctes rhinoceros* beetles by the virus using Oral Inoculum Technique, performed by Dr. Magdy Kinawy in October, 1989.

• The Parasitoids

Some parasitoids were efficiently used against the rhinoceros beetles, *Oryctes rhinoceros*. These are wasps of the family Scoliidae (Hymenoptera), indigenous to Eastern Africa and the island of Madagascar. These wasps are strong fliers, and they feed on the nectar of many wild flowers and those of other trees like citrus trees. The female wasp burrows deep into rotting vegetation and other breeding sites of *O. rhinoceros* to find *Oryctes* larvae and to lay eggs on them. When the eggs hatch, the wasp larvae feed on the *Oryctes* larvae and eliminate them (Simmonds, 1941 and 1949).

The following are the most important species of the Scoliid wasps, all of which are parasitoids on the *Oryctes* larvae in some places:

1**. *Scolia oryctophaga* Coquerel**

This parasitoid wasp was introduced to several regions as a biological control agent of *Oryctes rhinoceros*. It was imported from Madagascar Island to Mauritius in 1917, to Western Samoa Islands in 1939 and to Fiji and New Britain Islands in 1954. In addition, it was imported from Mauritius to the Indonesian Islands between 1934 and 1936. The adult wasp of *S. oryctophaga* is 40 mm long, reddish brown in colour with yellow coloured antennae.

2**. *Scolia ruficornis* Fabricius**

This parasitoid wasp was imported from Madagascar and Zanzibar to Mauritius and Western Samoa in 1945, to the Islands of New Britain and Palau, Chagos Islands in 1949 and to Fiji Islands in 1958. The adult wasp of *S. ruficornis* is blue to black in colour and smaller than the previous species, *S. oryctophaga*.

3**. *Elis romandi* Saussure**

This parasitoid was introduced from Madagascar to Western Samoa Islands in 1939. It is important to note that these parasitoids are extremely sensitive to chemical insecticides, which explains the failure of some of them to establish themselves in new locations to which they were

released. It was imperative to stop any chemical control programs in the areas into which they were released and to carry out preliminary research to evaluate the effects of insecticides on these parasitoid wasps.

• The Predatory Bug, *Platymeris laevicollis* Distant (Hemiptera: Reduviidae)

This species of Assassin bugs was used in some areas to prey upon *Oryctes rhinoceros* beetles, where it can be imported and released into the places of the beetles. This large predatory bug is black in colour with prominent orange-red patches. It can insert its proboscis between the head and the thorax of *Oryctes* beetles and kill them. It was found that one predator of the *Platymeris* species can devour one beetle of the *Oryctes* species daily. The duration of the adult life of this predatory bug, *Platymeris laevicollis*, is up to four months. Because the incubation period of its eggs is about one month, it is easy to import this predator and release it to control *Oryctes rhinoceros* (Vanderplank, 1958).

• Entomopathogenic fungus, *Metarhizium anisopliae* (Metchnikoff)

The Entomopathogenic fungus *Metarhizium anisopliae* (Metsch.) Sorokin (Deuteromycotina: Hyphomycetes) occurs widely in nature and is not expected to have any adverse effects on non-target organisms or on the environment. This fungus can be used against *O. rhinoceros* larvae in their breeding sites. The first attempt to control *Oryctes rhinoceros* biologically was by using the entomopathogenic fungus, *Metarhizium anisopliae* in the Samoa Island in 1913 (Friedrichs, 1913). The common name of this fungus is "Green Muscardine Fungus". The genus *Metarhizium* is recorded on more than two hundred species of insects. *M. anisopliae* is a very effective entomopathogen. It attacks the target insect by penetrating its cuticle and invading the haemolymph. Conditions favourable for the development of the fungus include high relative humidity (over 70%), a temperature of about 27°C and overcast skies. Fig. 1.74. shows larvae of rhinoceros beetles infected by the fungus, *Metarhizium anisopliae*.

Fig. 1.74. The larvae of *Oryctes rhinoceros*, infected by *Metarhizium anisopliae*

1.3.5. Young Date Palm Borer

***Strategus julianus* Burmeister**
(Coleoptera: Scarabaeidae)

Distribution

Nixon (1951) and Carpenter and Elmer (1978) stated that the young date palm borer, *Strategus julianus*, attacks young date palms and offshoots in the nursery causing their death in Texas (in Rio Grande Valley) and Arizona states in USA. The hosts of this species include date palms and coconut palms. In addition, pineapple (*Ananas comosus*) is considered one of the hosts of this pest. In Oman, the young date palm borer, *S. julianus*, is present in many of the northern Wilayats and attacks the young date palms, but without causing serious damage.

Economic Importance

The beetles of the young date palm borer, *S. julianus*, burrow into the ground close to young date palms and penetrate into the trunks below ground level, usually killing the palms especially those about two years old and offshoots. In some cases, the beetle burrows near the growing apex of the offshoot leading to its gradual death, as the fronds of the young dates and offshoots become yellow, wilt and then die. Currently this pest does not constitute an economic importance in Oman. However, it was observed that it might cause some problems whenever it is present in large numbers attacking newly planted offshoots.

General Description

The adult beetles of *S. julianus* are different from the Scarabaeidae species mentioned above in having no horn on the head. It is a big beetle, 40-60 mm long and black or dark brownish in colour. It is easy to recognize this beetle by the presence of three elevations on the upper surface of the first thoracic segment. The female has several deep pits on the upper surface of the first thoracic segment. Dense hair can also observe on the lower surface of the abdomen in both sexes, Fig. 1.75. The larva, like other larvae of the scarab family, is curved, legless and creamy in colour.

Life Cycle

In Oman, the adult beetles start to emerge during the summer season in the warm months of May, June and July. The female lays its eggs on decaying materials in soil, old palm trunks and other dead plant matter. After hatching the larvae feed on these rotting vegetation. To date the life cycle of the young date palm borer has not been extensively studied.

Fig. 1.75. The adult beetle of *Strategus julianus*
Right: side view of the male, note the three elevations on the tergum of the first thoracic segment.
Left: abdominal view, note the dense hair in the abdominal area.

Control Measures

In case of the presence of large numbers of the young date palm borer, *Strategus julianus*, some measures can be applied to control it as follows:

• Immersing the heavily infested offshoots during the summer season in water will force the adult insects to surface. Then, they can be collected and eliminated.

• Because these nocturnal insects are strongly attracted to light, light traps can be used to collect large numbers of these adult beetles, i.e. "mass trapping" and to eliminate them. The light traps can be used during the active period of the adult beetles, which was found to extend from April to late August or early September in Oman.

1.3.6. Date Stone Beetle

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

Distribution

The date stone beetle, *Coccotrypes dactyliperda*, has been recorded in many countries around the world, such as Palestine (Bodenheimer, 1937), Egypt (Alfieri, 1976), Greece (Alexopoulou *et al*. 1986), Iraq, Libya, Algeria and India (El-Haidari and Al-Hafidh, 1986), Nigeria (Aisagbonhi, 1988) and USA (Bright, 1981). This pest was recorded in Egypt for the first time in 1914 by Willcocks (1914), who mentioned that the date stone beetle is one of the important pests on date palms in some regions. In USA, Linsley (1944) stated that *C. dactyliperda* had spread into the State of California. Martin (1958) showed that in the northern coastal provinces in Libya, this pest attacked and infested date palms. It was also found that the date stone beetle, *C. dactyliperda*, has spread into most of the date palm plantations in Oman. In addition to date palm, this pest also attacks the Paradise palm (*Howea forsteriana*).

Economic Importance

The date stone beetle, *C. dactyliperda*, causes fruit drop in dates when they attack them before ripening, because they move toward the stone to penetrate into and to feed on its content. *C. dactyliperda* causes economic damages in some countries as the rate of infestation among the fruits may reach from 7 to 45%, according to the country, region and date palm variety. It was found that this pest heavily attacks the fruits during the months of June and July in India. In California State in USA, the damage is restricted to fruit drop. It was observed that this pest causes some economic losses in the regions and countries where the dates are spread on the ground to dry.

The most important symptoms of infestation by this pest is the dropping of date fruits before ripening with the presence of the entry pores of the adult beetles in the fruits. The adult beetle bores a small round hole (1 mm diameter) in the fruit. These holes can be observed on the surface of the stone, which becomes brittle and breakable. The larvae and adult beetles feeding sites can be observed in the stone as well, Fig. 1.76. When breaking the infested stone, all the stages of development of the insects can be observed; eggs, larva, pupae and adult beetles. The stone may be seen completely hollow inside. In addition, because of the pest infestation and piercing the fruit, it is easier for moulds to grow and spread inside the infested fruits.

In Egypt, Hussein (1990) mentioned that the infestation of the date varieties Kakea, Soltani and Saidi with *Coccotrypes dactyliperda* in the Baharia Oases Province in 1988 averaged 24.9, 21.4 and 3.24%, respectively. On Kakea, short palms were more heavily infested than tall ones, but in the other two varieties tall palms (5-7 m) were more heavily infested than short ones (2-3 m). Temperature had a pronounced positive effect on infestation, while the influence of relative humidity was weak.

Fig. 1.76. The entry pores of the adult beetles of the date stone beetle. Note the destruction of the stone by feeding on the content.

General Description

The adult beetle of *C. dactyliperda* is a typical Scolytid beetle. It is a small beetle with dark brownish or reddish brown colour. The body is elongated and concave in shape and covered with brown short dense hairs. The female is about 2 mm long while the male is about 1.5 mm. The adult beetles do not fly much but are active and fast moving.

The larva is creamy white in colour with miniscule hair used in movement. The fully-grown larva is about 3-4 mm long. Unlike most Scolytids, the larva has dense hairs on the body segments to help free movement in the larval tunnels. No cannibalism was noticed in this species; hence, the larvae live and feed together in the same tunnel. The larvae usually prefer feeding just under the outer layer of the stone. The pupa of *C. dactyliperda* is exarate, white in colour when newly formed but gradually turns into brown. At the end of the larval tunnel, the larva pupates in a pupal chamber under the outer layer of the stone.

Life Cycle

Hussain (1985) stated that the adults of the date stone beetle, *C. dactyliperda*, appear during the months of June, July and August, in India. After mating, the female burrows the fruit and the stone to make a tunnel to deposit its eggs. It is interesting to know that their male's counterparts cannot pierce the stone. Abdallah and Tadros (1994) studied the life cycle of the date stone beetle and found that the females bore into the fruits and lay their eggs inside the stones of the dates. The eggs are laid singly and randomly in the gallery. The incubation period ranged from 6 to 14 days, according to seasonal variations. After hatching, the larvae emerge to feed inside the stone. The larval duration varied from 31 to 74 days according to the temperature. The date stone beetle, *C. dactyliperda*, has four generations per year. They added that the minimum larval duration was recorded during the 3rd generation (with an average of 34.9 days), while the maximum larval duration occurred during the 1st generation (with an average of 69.4 days). During the 2nd and 4th generations, the larval durations were 45.8 and 40.1 days, respectively. When the larvae were fully-grown, they transformed into pupae in the date stone for a period from 6 to 16 days. The total life cycle of *C. dactyliperda* lasted between 49 to 183 days with approximately four overlapping generations each year.

The female of the date stone beetle, *C. dactyliperda*, lays eggs within one day after penetrating the stone, and the resultant progeny remains in the stone until they become adult. Blumberg and Kehat (1982) mentioned that the mated female lays eggs, which produce male and female adults, but about 85% of the progeny of the fertilized females are females. On the other hand, the unmated females deposit eggs, which produce only males. Overwintering probably occurs in the adult stage within date stones of fruits which had dropped and were left on the ground.

Sensitivity of Date Palm Varieties to Infestation with Date Stone Beetle

Hussain (1985) stated that early ripening varieties in Iraq were sensitive to being infested with the date stone beetle, *C. dactyliperda*. The infestation percentages in fruits were: 12% in Aklani, 17% in Khadrawi, 22% in Halawi and 45% in Bakria. In India, it was found that the infestation with the date stone beetle did not generally show on the date palm of the varieties Medjool and Thouri because of the late ripening of their fruits.

Control Measures

1. Mechanical and Cultural Control

The farmers should follow some hygiene procedures, which are indispensible and fundamental in controlling the date stone beetle, *C. dactyliperda*. These procedures include the following measures:

- Get rid of infested fruits and stones and burning them to prevent any source of infestation. The dropped fruits and stones under the palm trees must be collected and eliminated, especially in the winter season.
- Cover the stalks with burlap cloth to prevent the adult beetles from reaching and attacking dates.
- In heavily infested areas, it is preferable to plant the resistant palm varieties.

2. Biological Control

Hussain (1985) mentioned that *Cyrtosus cyanipennis* (Erichson) (Coleoptera: Melyridae), is found to be a predator of the date stone beetle, *C. dactyliperda*.

1.3.7. Date Palm Frond Borer

***Phonopate frontalis* Fåhraeus**
(Coleoptera: Bostrychidae)

Distribution

The date palm frond borer, *Phonopate frontalis*, is a Bostrychid beetle and considered a pest of date palm in North Africa and Middle East, Carpenter and Elmer (1978). *P. frontalis* is a common pest on date palm in Iraq, Saudi Arabia, Libya, Tunisia, Algeria, Bahrain, Yemen, Egypt and Oman. Beside the date palm, pomegranate and grapes are among the hosts of this pest.

Economic Importance

The adult beetles and larvae of *P. frontalis* are the harmful stages of this pest. The adult beetles and larvae attack the green fronds and damage the rachis by burrowing slant tunnels. The injury causes the release of a resinous substance at the entry pore, the break of the attacked fronds and their gradual wilting.

In addition, this pest attacks the dried fronds used in the building of roofs or others. The severe infestation damage the fronds and they become powder-like; the burrowed by-products of both beetles and larvae accumulated inside the tunnels. This pest also burrows in the date palm fruit stalks causing their gradual dryness leading to the dryness and shrivel of the dates and thus decreasing their market value.

The most important symptoms of infestation of the date palm frond borer, *Phonopate frontalis*, can be summarized as follows:

- The presence of a sticky dot at the entry and feeding points of the adult beetles, on the fronds and stalks.
- The presence of circular holes of 4-5 mm in diameter as exit holes of the adult beetles from the infested fronds.
- Fall of dusty powder from the frond midribs used in making roofs and other items.

General Description

The adult beetle of the frond borer, *P. frontalis*, is a medium-sized beetle, 1.5 mm long with deep brown or black colour. The body is cylindrical and elongated in shape and the head covered with the first thoracic segment. The upper anterior part of the first thoracic tergum is indented and the posterior part is shiny and smooth. The lower surface of the abdomen is lighter in colour and villous.

The egg is small and yellowish white in colour. The female beetle deposits the eggs in pits, which it makes along the tunnels it lives in. The larva is creamy white in colour with a tiny brown head. It is legless and semi-curved. It lives in tunnels inside the infested palm fronds. The pupa is of the free type and exists in the pupation chamber at the end of the larval tunnel.

Life Cycle

The adult beetles attacks the palm fronds when they have lost some of their moisture. The female beetles make tunnels to feed and deposit their eggs. The eggs hatch and larvae emerge to feed on the inner contents of the rachis. The tunnels of the larvae are parallel to the axis of the frond. When the larvae are fully grown, they transform into free pupae at the end of the larval tunnels. Later, the pupae transform into adult beetles, which exit through rounded holes. The diameter of each of these exit holes may reach up to 4-5 mm.

Sensitivity of Date Palm Varieties to Infestation with Date Palm Frond Borer

Differences have been observed in the sensitivity of various date palm varieties to infestation with the date palm frond borer, *P. frontalis*. El-Haidari (1980) mentioned that the Saieedi variety in both Egypt and Libya was heavily infested with the date palm frond borer in comparison to other varieties.

1.3.8. Metallic Beetle

(Sulphurous Jewel Beetle)

***Julodis* spp.**
(Coleoptera: Buprestidae)

Distribution

The jewel or metallic beetle, *Julodis* spp., belongs to the family Buprestidae and is characterised by its shiny metallic colour. The larvae of this family are called the flat-headed borers because of their flattened heads and being wood borers. Several species from genus *Julodis* have been recorded on the date palms in different countries. The species *Julodis euphratica* Castelnau and Gory was recorded in Saudi Arabia, whereas the species *Julodis distincta* Gory was found in northeast Saudi Arabia and Kuwait. The species *Julodis fimbriata* Klug was recorded in United Arab Emirates South of Arabian peninsula, Somalia, Niger and Chad. The species *Julodis caillaudi* Latreilli was recorded in Algeria, Libya, Ethiopia, Eritrea, Djibouti, Senegal, Sudan and Egypt, (Walker and Pittaway, 1987).

Economic Importance

Dowson and Pansiot (1965) mentioned that the beetles of the species *J. caillaudi* feed on date palm fronds in Sudan, where they were called Abu Zanan or Abu Danan (In Arabic). They added that the damages caused by these beetles on date palms might be extensive in individual cases, that however the overall damage on date palms was insignificant.

In Oman, two species of Genus *Julodis* were recorded on the date palms during March, April and May. These two species are *Julodis euphratica* Castelnau and Gory and *Julodis fimbriata* Klug, Fig. 1.77. The adult beetles voraciously chew the leaflets leaving the rachis naked. They are usually found in a large numbers on each palm. There are no studies clarify where the larvae are live and their damages. It is probable that the larvae of this pest live as borers on wild trees, such as *Acacia* spp. The metallic beetle, *Julodis euphratica* is found in Batinah and Sharqiyah regions in Oman, where it is called Fanzouz (In Arabic).

The jewel or metallic beetle, *J. euphratica*, is characterised by the metallic green colour and the sulfur yellow coloured spots on the elytra, hence, the name Sulphurous Jewel Beetle. It is a big beetle; its length is about 2-4 cm. The eggs of *J. euphratica* are creamy in colour. The beetles of *J. euphratica* were seen in large numbers flying noisily around the wild acacia trees in Oman. They feed on the white coloured flowers of *Acacia tortillis* and the yellow coloured flowers of *Acacia ehrenbergiana*.

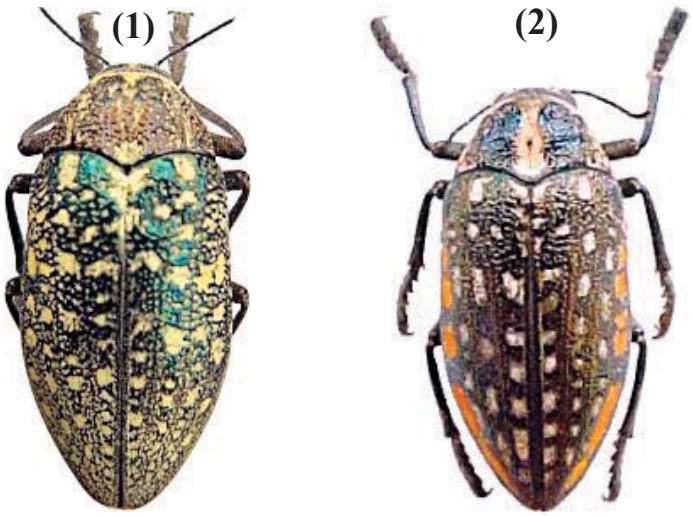


Fig. 1.77. The adult beetles of the Sulphurous Jewel Beetle.
1. *Julodis euphratica* Castelnau and Gory
2. *Julodis fimbriata* Klug

1.3.9. Inflorescence Beetle

***Macrocoma* sp.**
(Coleoptera: Chrysomelidae)

Distribution

The inflorescence beetle, *Macrocoma* sp. was recorded in Oman and United Arab Emirates. Its distribution is limited in the Sultanate of Oman, but it could be seen each year in large numbers on the date inflorescences in Wilayat Baraka, in Batinah region, during March. Locally, this beetle is called "Kao Kao" (in Arabic). To date, there are no detailed studies on this pest.

General Description

The adult beetle of the inflorescence beetle, *Macrocoma* sp., is a small beetle, about 5 mm long and brown in colour. It belongs to family Chrysomelidae. The adult insect is the harmful stage of this pest as it feeds on the female flowers leading to their destruction and failure to be fertilized and set fruit.

Fig. 1.78. shows the extent of damage caused by the inflorescence beetle, *Macrocoma* sp., to the date inflorescence as a result of feeding and destroying the female flowers.

The larval and pupal stages live in the soil around the infested date palm roots, at a depth of approximately 8 mm. The full-grown larva pupates in the soil. The pupa surrounds itself with a mass of soil and becomes a spherical shape. The duration of the pupal stage ranged from 4 to 5 weeks.

It is observed that the adult of the date inflorescence beetles, *Macrocoma* sp., begin to emerge from mid-February each year, which coincides with the start of the opening of the date palm inflorescences. The beetles attack the inflorescences to feed on the young female flowers leading to complete losses of production from the infested palms.

From field observations, it is evident that the adult beetles of the date palm inflorescence beetle, *Macrocoma* sp., cannot be detected during daytime. They are seen in large numbers immediately before sunset hovering around palm inflorescences to hide inside the sac.

It is important to note that this pest does not require a specific control program because of its limited distribution. If at all necessary and if the infestation intensifies, the affected palms can be sprayed during the activity of the adult beetles with Pirimiphos-methyl (Actellic® 50%). In addition, it is easy to collect and destroy the larvae of *Macrocoma* sp. found around the roots of the infested date palms.

Fig. 1.78. The damages incurred by the inflorescence beetle, *Macrocoma* sp.

1.4. Order: Hymenoptera

1.4.1. Oriental Hornet or Red Wasp

***Vespa orientalis* L.**
(Hymenoptera: Vespidae)

Distribution

The world distribution of the oriental hornet wasp, *Vespa orientalis* F. (Hymenoptera: Vespidae), comprises northern part of Africa, south eastern Europe, southwest Asia across Turkey and Arabian Peninsula to India, and Nepal, Carpenter and Kojima (1997) and Archer (1998). The oriental hornet, *V. orientalis*, is also called the red wasp and it is common pest in many countries such as Iraq, Palestine, Sudan, Egypt, Yemen, Iran, Pakistan, Afghanistan, Saudi Arabia, Oman, Kuwait, Bahrain, Qatar and United Arab Emirates among other countries.

Economic Importance

The oriental hornet wasp, *V. orientalis*, is a major pest of apiculture, indirectly disrupts pollination of fruit and vegetable crops, and constitutes a public health menace. They are such severe stingers, especially when a nest full of individuals cooperate, that their general appearance has come to suggest to us the danger of being stung.

The oriental hornet wasp, *V. orientalis*, is a social wasp living in colonies with a sterile worker caste in addition to both males and females, the workers taking most care of the females' young. Each colony is comprised of a queen (the female), workers and males. They build their nests inside the hollow trees or wall corners. They may also build them connected by a small tunnel in roofs or trees. The female of *V. orientalis* lays eggs in cell of nests composed of paper, which the adults make from wood. The males are reproduced from non-fertilized eggs. The larvae of *V. orientalis* are fed from day to day on the juices of insects or sweets. The adults of the oriental hornet wasp, *V. orientalis*, are pest of date palms; they feed on the ripe dates on the palms by eating pieces out of them. They either gnaw bits of the dates on the palm or on the ground. The infestation is relatively severe in the soft date, late ripening varieties or those dates collected late, as in Fig. 1.79.

They are also feed on flower nectar and sugary substances. They attack the ripe fruits of many fruit trees; like grapes, pears, peach, apricot, plum, guava, mango and others as well as eating the tree phloem sap.

In addition to the previous damages, the adults of the oriental hornet wasp, *V. orientalis*, are considered carriers of plant pathogens by feeding and moving from infested to healthy plants. Furthermore, their feeding habit on the fruits causes injuries facilitating the entry and growth of the fungi and moulds. Hence, fruits deteriorate and their market value decreases.

Fig. 1.79. Damages caused by *V. orientalis* on dates.

General Description

The adult of the oriental hornet wasp, *V. orientalis*, is a large wasp, 25-30 mm long and is generally reddish brown in colour with yellowish brown wings. The yellow colour is present on the forehead, first abdominal segment, the sides of the second abdominal segment and all the parts of the third and fourth abdominal segments.

The abdomen consists of seven segments in the male, whereas they are only six in the female. The antenna in the male consists of 13 segments, while it is 12 segments in the female (the queen). In general, the male looks the same size as the worker albeit paler in colour. The female (the queen) is the longest as it may be measure up to 30 mm long.

Data in Table 1.16 show a comparison of different members of the oriental hornet wasp, *V. orientalis*. The eggs are brown or white in colour and about 3 mm long. The larvae are white in colour and about 20 mm long, when fully grown. The pupa is creamy in colour and of the free type.

Life Cycle

The adults of the oriental hornet, *V. orientalis*, male and female (the queen) appear in early autumn, in September, in order to mate. After mating, the males die and the fertilized queens remain in hiding in safe places during the winter season. Later they reappear in the spring to build a new colony at the end of April and May. Each queen builds a separate nest to deposit its eggs in large numbers during the summer and autumn seasons. Each nest and colony has one queen, a small number of males (also called drones) and a large number of workers. In some cases a nest may contain more than one queen.

The nest has several passages leading to chambers containing hexagonal cells made of mud mixed with straw, paper or other matter. The queen starts to deposit the eggs in the hexagonal cells to hatch larvae. Adult food is nectar or other sugary solutions such as honeydew and the juices of ripe fruits. They feed the young larvae on bits of caterpillars or flies, which they catch and partially chew before presenting to their young. These workers collect food, further expand the nest and take care of the queen to concentrate on depositing eggs. The number of the workers in the colony multiplies gradually to very large numbers during the period from July to September. Starting from mid-September, the queens begin to produce males and fertile females to mate again. The males are produced from unfertilized eggs, while the females or future queens from fertilized eggs. At the end of the season all the workers and male insects die leaving only the queens by the end of December. The queens hide all the winter in the cracks appearing only for short periods to feed.

Control Measures

1. Mechanical and Cultural Control

It depends upon the following measures:

- Collecting the dates at the proper time and not leaving them on the palms for over- ripening when they would be more susceptible to attacks by wasp, which prefer ripe dates.
- Covering the fruit stalks with bags made of paper, wired mesh, nylon or with pieces of burlap, or woven palm leaves to prevent the wasps from reaching the dates, as in Fig. 1.80.

Fig. 1.80. Covering the fruit stalks with nylon bags for protection from wasps attack.

Table 1.16. A comparison between queen, workers and males of the oriental hornet wasp, *V. orientalis*.

Element	Queens	Workers	Males
Size and Behaviour	The biggest colony members, they are fully formed females. Each nest may have one or more queens working together. The functions of the queen are to lay eggs, nurse the larvae and feed them with honeydew and pollen.	The smallest in size, and thousands of them are present in each nest or colony. They perform all the jobs.	Smaller than the queen's, size. They appear at the end of the activity season to inoculate the virgin queens and are abundant in October and November.
Colour	Low percentage of the yellow colour on the thoracic terga. There are brown stripes connecting the two spots present on the tergum of the fifth abdominal ring.	High percentage of the yellow colour on the terga of the fourth and fifth abdominal rings. There are no connecting lines between the two spots present on the tergum of the fifth ring.	The same as the colour of the workers.
Antenna	12 segments	12 segments	13 segments
Upper Mandible	Large	Medium	Rudimentary
Lower Mandible	Large	Medium	Small
Number of abdominal segments	6 visible (2-7)	6 visible (2-7)	7 visible (2-7)
Stinger	Long	Shorter than the queen	Absent

2. Mechanical control

It depends upon the following measures:

Eradicating the queens

The queens appear in the spring season (April and May) to establish a new nest. It is advised to collect the queens and eradicate them, as each queen killed in this period equals eradicating hundreds of its offspring during the summer. The queens can found in the old nest and near the apiaries. The queens can be collected by placing moistened lumps of sugar wetted in special places and when they come to feed, they are eradicated by hitting them with date stalks.

Destroying the wasp nests

Finding and destroying the wasp nests with the adults inside them, by using one of the following methods:

- Igniting a piece of burlap, tying it at the end of a long stick, then burning the wasp nest with its members inside during the night or early in the morning.
- Placing a piece of burlap soaked in honey and arsenic near the nests for the adult wasps to eat and die.
- Putting a piece of ignited sulphur in the nest opening, half an hour after the sunset, to ensure the return of all the workers to the nest, then rapidly closing the opening with mud. The wasps suffocate or burn inside the nest.

Using the wasp traps

Several types of traps can be used to collect and kill the wasps. The simple wired trap used in collecting the wasp is an example. It is a small box made of wire with dimensions of 80X60X90 cm. It has legs of 20 cm height having a lower opening in the shape of a cone, which also is made of wires and is 25 cm long. On the upper side there is a free moving barrier. The trap is used as follows: a sugary substance or bee wax containing residual honey are placed in a plate and left for at least two hours to attract the wasps. The trap is then placed on the plate containing the food with the cone facing the plate. When the wasps come to feed, they climb vertically inside the cone through its opening. The wasps are then collected and killed. The presence of a free queen barrier at the upper end of the trap is noticeable. This is to allow the escape of any bees trapped inside by chance. Fig. 1.81 illustrates the modified wire trap used in Oman to collect and destroy oriental wasps, *V. orientalis*.

3. Chemical Control

This method depends on careful search for wasp nests, then using poisonous baits to exterminate them inside their nests. The poison bait is made of a mixture of an insecticide and an attracting substance. For example, the insecticide Malathion WP or Methomyl (Lannate) may be mixed with molasses as an attracting vehicle to penetrate the cracks and holes in the nest. After placing the bait at the opening of the nest, the main entrance is closed. Some of the baits are placed outside for the wandering and returning wasps to consume and die. It is better to do this poisoning process in the evening after the return of most wandering wasps.

In Oman, Mekki and Osman (1991) stated that the wasp nests can be sprayed with some insecticides like: Permethrin 10%. Because the wasps attack the dates in the last ripening stage (rutab stage), it is difficult to advise the use of chemical insecticide to be sprayed at the wasp nests on the date palms or the wasps around the fruit stalks during that period. Thus, the best measure is to destroy the wasp nests by using the other measures, which mentioned above.

Fig. 1.81. The modified wire trap used to catch and collect the adults of the oriental hornet wasp, *V. orientalis.*

1.4.2. Spotted Yellow wasp

***Polistes gallicus* (Linnaeus)**
(Hymenoptera: Vespidae)

Distribution

The spotted yellow wasp, *Polistes gallicus*, attacks the dates on the palms and other species of fruits on their trees, as well as many of the pest larvae. It is present in Iraq, Pakistan, Oman and many other countries. In addition, it is present in Austria, France, Italy, Netherlands, Romania, Turkey and Chile, CAB Abstracts (1973-1998). It is also known as the European paper wasp.

Economic Importance

As mentioned earlier the adults of the spotted yellow wasp, Polistes gallicus, feed on the early-ripened dates. They drink nectar and juices from crushed and rotting fruits. They bite small pieces of the fruit and the kernel may show in severe infestation. This wasp usually appears before the oriental wasp, *V. orientalis*, and feed on several species of fruits, which are ripened on the trees.

The spotted yellow wasp, *P. gallicus*, like species of family Vespidae, is considered a predator because the adult wasps prey on the larvae of cotton worm and other larvae of order Lepidoptera. The adult wasps chew their prey mixing them with their saliva to form small balls to be offered to their young larvae in the nest holes to feed on.

General Description

The adult wasp is slender, hornet like and about 18 mm long with a short single segmented "waist" (pedicel) between thorax and abdomen. The upper portion of the head is pointed and never notched. Head and body are dark brown to black in colour with yellow rings and reddish areas on abdomen, while the wings are yellowish brown. The male's face is pale with antennal tips hooked, while the female has a brown face.

Life Cycle

The female builds its nest from paper chewed into a paste to make a nest in the roofs of houses, or on the branches of trees. Unlike those of the red wasp, the nests of the spotted yellow wasps are built in open places and are unprotected. The fertilised queen deposits its eggs in the bottom of the nest. The egg is about 1.5 mm long. The incubation period is around 7 days, and then they hatch into larvae that feed on prey brought to the nest by the adult wasps. The larva has five instars to complete its life and then it surrounds itself with a silk cocoon to pupate. The duration of the pupal stage is about 2 weeks, and then it develops into an adult wasp, which repeats its life cycle.

Many species belonging to the genus *Polistes* that attack the dates are recorded in several countries around the world. In addition to the yellow spotted wasp, *Polistes gallicus*, there are three species of *Polistes* recorded in Oman. These are *Polistes hebraeus* F., *P. olivaceus* (De Geer) and *P. wattii* Cameron.

Fig. 1.82 shows the species *P. hebraeus*, which are known as the yellow wasp. This adult wasp is yellow in colour and about 20 mm long. It is noticed that the yellow wasp helps in spreading the dust mites from infested palms to healthy ones. This wasp species builds paper nests with hexagonal cells anywhere even on the palm fronds. It is the most abundant species in Oman, and considered one of the most important predators of the Lepidopterous larvae.

The species *Polistes wattii* is known as the Arabian Paper Wasp. It builds small nests, each containing less than 50 cells. It spreads in all regions of Oman from April to November (Walker and Pittaway, 1987). All the species of the genus Polistes are characterized by their gathering around the water in irrigation canals, or the water basins in the groves during the hot summer months, where they quench their thirst and carry back some water to the larvae in the nests, Fig. 1.83.

In Iraq, the following three species of the genus *Polistes* were recorded: *Polistes hebraeus* F., *Polistes foederatus* Kol. and *Polistes nympha* Chr.

In addition, in Texas State in USA, there are another three species of the genus *Polistes* are recorded, these species namely, *Polistes exclamans* Vier., *Polistes annularis* L. and *Polistes fuscatus* Cr. The three aforementioned species were found to attack dates in Texas as well as several other fruit species with fruits ripening on the plant.

Fig. 1.82. The yellow wasp, *P. hebraeus* F., the most abundant species in Oman

Fig. 1.83. The yellow wasp, *P. hebraeus* F., gathered around in the irrigation canals to drink

1.5. Order: Orthoptera

1.5.1. Desert Locust

***Schistocerca gregaria* Forskål**
(Orthoptera: Acrididae)

Locusts belong to a large group of insects usually known as the grasshoppers, which are characterized by their big hind legs used in hopping. According to insect taxonomy, locusts belong to the family Acrididae, short-horned grasshoppers.

Actually, locusts are mere grasshoppers with larger size and the ability to alter their behaviour and habits when present in large numbers and in dense groups. Generally, the major difference between locusts and ordinary grasshoppers is their capacity to become gregarious at high population densities (Ellis and Ashall (1957) and Gillett (1973), to form large swarms and migrate over large distances. These are called: Swarms, when they are consists of winged adult insects, or Hopper Bands, when they are include the wingless early stages (the nymphs).

As mentioned above, the swarms of several species of locusts can migrate for long distances. Such a phenomenon and aggregation behaviour is the prime characteristics of typical locusts over the other species of hoppers. It is interesting to note that small numbers of locusts behave and live like ordinary hoppers.

Phase Theory

The Russian scientist Uvarov (1921; 1966) pioneered this theory, when he postulated that each species of locusts can exist in two main forms, "phases", which differ structurally and biologically. These are the gregarious phase or migratory phase and the solitary phase. Date in Table 1.17 shows the main differences between the gregarious and solitary phases in locusts. Biologically, the most important difference between the two phases is the hyperactivity and gregarious tendencies of the gregarious phase. Generally, among the factors controlling the emergence of the gregarious or the migratory phase in locusts is their multiplication in huge numbers in limited areas. When the nymphs aggregate, their movement and activity increase and move in one direction with all the distinctive signs of the migratory phase emerging. After the maturation of the nymphs to the adult stage, they remain influenced by what they gained during the nymphal stage of hyperactivity and the tendency to collective movement, which resulted from imitating each other's movements. These adult insects (locust) start migration once, one or a group begin to fly following one another. These adults move in circular paths, which gradually widen during ascending, then move in straight path.

Table 1.17. The main differences between the Gregarious and Solitary phases in locusts

Characteristic	Gregarious phase	Solitary phase
Number of ovisacs Average number of ova/sac	2-3 60-80	3-4 100-160
Nymphs Movement	The nymphs in their early instars move in pattern for long distances for more than 1 kilometer/day.	The nymphs don't move in regular pattern and only for few meters each day.
Duration of the nymphal stage	Shorter than the solitary phase.	Longer than the Gregarious phase (migratory phase).
Life span of the adult insect	Shorter than the solitary phase.	Longer than the Gregarious phase (migratory phase).
Colour of the nymphs	Yellow or orange with dark marks.	Green with the presence of some black marks.
Colour of the adult insects	Reddish before maturity and turn yellow after maturity, which is more obvious in the males.	Greenish grey and remain so till sexually mature.
Behaviour of the adult insects	The adult insects aggregate in dense swarms, which are characterized by hyperactivity during the day.	The adult insects may form temporary small groups and do not fly during the day unless disturbed.

Distribution

The desert locust, *Schistocerca gregaria* Forskål, occurs in all date palm growing areas of the North Africa, Middle East and Asia, where they attack palms, different fruit trees, ornamental trees, field crops, vegetables as well as wild plants and trees.

The desert locust attacks the date palms in the Northern African countries: Egypt, Libya, Tunisia, Algeria and Morocco as well as Palestine, Jordan, Iraq, Iran, Pakistan and India. They also raid the date palms in the Arabian Gulf countries, Saudi Arabia, Qatar, UAE and Oman. Very few plant species are reported to be repellent to the desert locust, *S. gregaria*. Secondary compounds of the Neem tree (*Azadirachta indica*) are highly repellent to *S. gregaria* at very low densities (Bernays and Chapman, 1978).

Economic Importance

In Oman, the desert locust usually attacks the wild trees present in abundance in the valleys (wadis). The following are some of its most important hosts; *Acacia raddiana* and *Prosopis spicigera*. The desert locust had attacked the date palms in Oman in some years and had caused severe damages to the palms.

The desert locust (the migratory phase) causes severe damages in date palms and other agricultural crops in some years. The locusts feed voraciously while attacking the palms depriving them of their leaves and leaving the palm naked. The locust feeds on leaves and fruits of the date palm. The result is the decline in the yield for several years, as the fronds cannot produce new leaves and rather die. Most of the green fronds in the raided area die and the

palms need more than three years to produce new fronds and to recover their natural production of dates. In short, locust plaques deprive the date palms of most of their fronds leading to the death of the green leaves and the inability to produce for several years.

General Description

The adult insect of the desert locust is big in size, 45-55 mm long. The wings are longer than the abdomen. The overall colour of the insect is light rose or red in the sexually immature insects. In the sexually mature insects, the male colour is shiny yellow and the female is light yellow, Fig. 1.84. Nevertheless, the insect colour varies according to the surrounding ecological and climate conditions, and the degree of density of the insects in the breeding sites. The wings are dusty yellow with clusters of small square, dark brown cells on the forewings. The hind wings are transparent or light yellow and have no marks. There is a papule or a spine on the sternum of the front thoracic segment, between the bases of the pair of forelegs called the Prosternal spine. The egg is spindle in shape with yellow in colour when laid and turns brown in the soil.

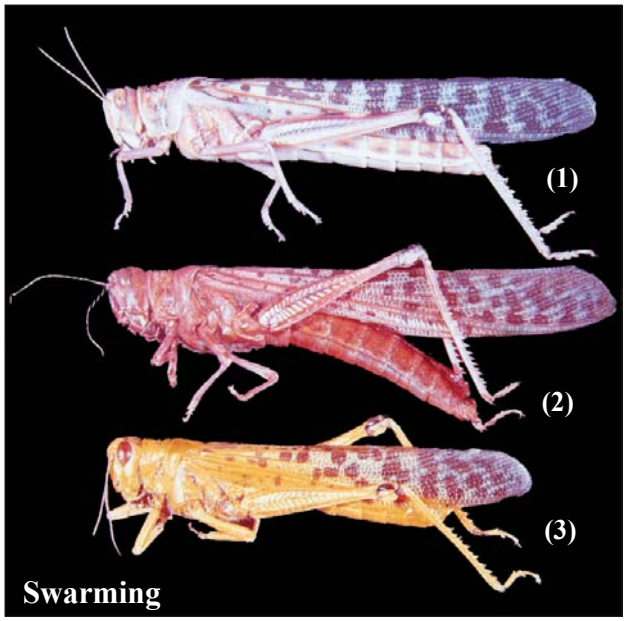


Fig. 1.84. Adult locusts from one swarm of desert locust, *S. gregaria.*
(1) Small and Immature Adult Insect.
(2) Immature Adult Insect but Bigger in Size.
(3) Sexually Mature Male Insect.

Gregarious nymphs are typically yellow, with a black head and pronotum, with black lateral stripes on the abdomen and pass through five instars. Solitary nymphs are green or pale in colour and can pass through six instars. The fully-grown nymph is around 50 mm long.

Life Cycle

As mentioned earlier desert locusts have two phases, the solitary and the migratory phases. The desert locusts of the solitary phase are found in the breeding sites in Sudan, Eretria, Ethiopia, Yemen and Saudi Arabia. When the weather and environmental conditions permit, the solitary phase locusts turn into the migratory phase locusts to form swarms and migrate to several other areas where they attack different crops in a large number in many countries around the world.

When the adult insects mature, they start to mate. It was observed that the male can inoculate more than one female and the copulation can last several hours. It may continue in some cases for up to 24 hours with the male mounting the female. It was observed that the male keep the females company during the oviposition period to re-inoculate them from time to time during oviposition.

The female deposits the eggs in the loose moist soil in the valleys, sandy lands around the groves and bridges or on the edges of canals. The females have the capacity to store sperms inside sperm sacs in their abdomen to use them to fertilize as much eggs as possible when needed. The female lays the eggs in groups or masses called the egg pods inside deep burrows in the sand. In average, the depth of the burrow reaches around 7 cm. The oviposition process takes from 1.5 to 2.0 hours. The female secrets a frothy fluid in the bottom of the burrow from its auxiliary glands that helps in protecting the eggs, Fig. 1.85. The female covers the burrow opening, as well, with the same frothy fluid, which hardens into spongy matter to act as

a plug to the burrow. This keeps the moisture around the egg pods and can be easily penetrated later by the nymphs after egg hatching to reach to the surface of the soil. The total number of eggs laid by each female is around 240 eggs. Eggs arranged in two rows. For the next 5 days after laid the egg pod, it absorbs as much water from the soil as its weight daily, if the soil moisture permits. This amount of water absorbed is enough to complete the egg growth successfully. The incubation period of the eggs is 15 to 21 days. The eggs hatch and nymphs emerge. In the beginning, they are green in colour. The nymphs can be seen spread in what is called egg fields. In one or two days, the nymphs connect while hopping to form dense bands.

Fig. 1.85. Egg pod of *S. gregaria*.

Later, when the nymphs feed they turn black in colour with several light green spots. The nymphal stage lasts around a month with five instars. It was observed that the nymphs increase their activity after each moulting while their appetite increases as they feed in the morning and rest at night. When the nymphs of the fifth instar change into adult insects, they work on forming flying swarms, which attack different trees and plants. After mating, the life cycle is repeated for three generation each year.

Formation of the migratory swarms in locust

With suitable environmental conditions, the nymphs actively move because the dark coloured spots on the aggregated nymphs absorb the heat leading to increased activity. As mentioned earlier, large groups of nymphs move out of sheer imitation to each other with no particular purpose. When the conditions permit the change of the adult insects, the locust, from the solitary phase to the migratory phase, the crowded members in the area increasingly become active and restless. Their body temperature rises leading to burning of fat bodies and other stored materials and the development of their genital organs. Some members start to fly in a circular motion above the other members on the ground, which start to join gradually in the flight and hence, the number of the flying locusts increases. Some members of the group take a certain direction and are soon followed by the rest forming a swarm, which migrate from the breeding places to distant lands as far as several hundred kilometres without stop. Moreover, the migratory swarms are formed in three stages:

1. The increase in the population of locusts in a certain area.
2. The aggregation of nymphs in the breeding places on land or plants.
3. The increase of the adult insects as swarm and the increase of their activity and their voraciously feeding. They move fast and fly as a group in one direction and are tightly connected together in the movement, flying and stopping.

It was found that locust swarms generally fly with the direction of the winds. Dense locust swarms fly higher than the less dense swarms. Hence they fly too high to be spotted with the naked eye. It is known that each locust swarm may contain 40 to 50 million locusts per square kilometre. Generally, different weather conditions, like the winds, rains, sunlight, temperature and atmospheric pressure control the direction of the swarms and their flying speed. Fig. 1.86 shows the adult insects in the solitary phase while Fig. 1.87 shows a locust swarm as photographed at high altitude from an aeroplane.

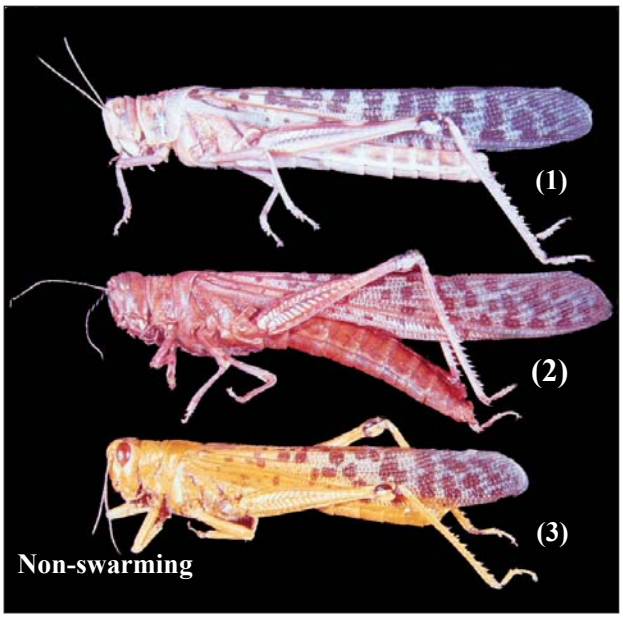


Fig. 1.86. The solitary phase of the desert locust, *S. gregaria*

(1) An adult male.

(2) An adult female with pale buff colour.

(3) An adult female with brown colour.

Fig. 1.87. Swarm of the desert locust.

Control Measures

1. Chemical Control

Several chemical pesticides are used to control the desert locusts in their breeding places. The chemical pesticides are used through spraying, dusting or making toxic baits placed in the breeding sites. Aerial spraying may help in rapidly combating the raids of the crawling nymphs or adult locust swarms.

In desert locust control, ultra-low volume (ULV) spinning disc spray equipment is mainly used. This equipment is available for hand application and for application by vehicle or aircraft (Matthews, 1992).

It is worth mentioning that the chemical control by insecticides is extremely important to thwart the formation of locust swarms and eradicating them in their breeding places. Hence, the international bodies like the FAO and the different affected countries should exert extensive and collaborative efforts.The locust control strategy, adopted by the locust control agencies and plants protection departments, depends upon preventing the formation of the locust swarms. Therefore, continuous field surveys should be conducted on the known seasonal breeding sites of locusts and eradicating aggregates before they can change into migratory swarms.

2. Biological Control

There are many natural enemies to the desert locust as the larvae of some fly species, which parasitize on their egg masses. Some species of acari, the larvae of some meat fly species and Takina fly parasitize on the locust nymphs. In addition, there are many predators of locusts like the mantis and mud wasps. Birds, lizards and snakes as well as some wild animals prey on the locust swarms.

The entomopathogenic fungus *Metarhizium anisopliae* var. *acridium* has been tested against desert locust (Lomer *et al*. 1999). This fungus can be applied using common ULV equipment and has been studied extensively in the field against many orthopterans and desert locust in particular (Langewald *et al*. 1997, 1999; Price *et al*. 1997). Also, the closely related fungus *Beauveria bassiana* (Bolis.) has also been tested against desert locust, Fig. 1.88.

Botanical products based on extracts of the Neem tree (*Azadirachta indica*) and Melia volkensii are repellent, have growth disruptive effects on many orthopteran species, and generally reduce fitness (Schmutterer *et al*. 1993; Wilps *et al*. 1993). In addition, Neem products seem to have an impact on the phase status of the desert locust (Langewald and Schmutterer, 1995).

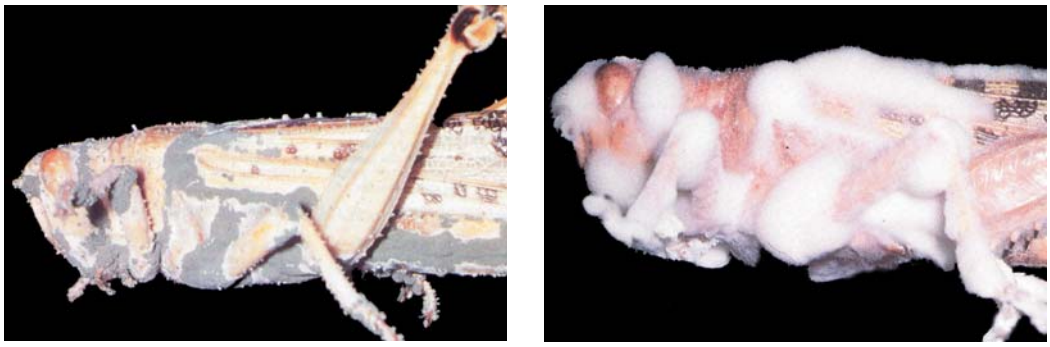


Fig. 1.88. Desert locust killed by the fungus,
Left: *Metarhizium anisopliae* var. *acridium* Right: *Beauveria bassiana*

1.5.2. Tree Locust

Anacridium melanorhodon arabafrum
(Orthoptera: Acrididae)

Distribution

The tree locusts, *Anacridium melanorhodon arabafrum*, live in the solitary phase and feed on many agricultural crops including the date palms. This locust is called "tree locust" because the nymphs and adult insects do not land on the ground except for short period and are always found on the trees. In Oman, the tree locust, *Anacridium melanorhodon arabafrum*, causes no economic damage to date palms or any other trees. However, its damages have intensified in recent years due to the suitability of environmental condi tions for its multiplication, and may they become a major pest.

The tree locust, *A. melanorhodon arabafrum*, is present in areas of Eastern Africa and the Arabian Peninsula. The nymphs of this species were present during a period from October to May. It is most probable that this species has one generation per year but from time to time, there can be two generations in one year.

Economic Importance

The tree locusts are present in few numbers in single farms. However, if the population of locusts rises in an epidemic manner, they may damage the crop, and the date palms fail to produce, which is similar to the damages caused by the desert locusts. Mating and egg depositing occurs after maturation (usually at the start of the rain season) in the same manner of the desert locust. However, mating couples usually stay on the trees until the females start to lay their eggs. The females lay eggs in masses in the soil like the desert locust but the average number of eggs in per sac is higher than the desert locust, as the average number of eggs is about 150 eggs per sac. It has been observed that tree locusts aggregated in swarms deposit fewer numbers of eggs, than the desert locust, and each female lays up to three ovisacs.

General Description

The adult insects are large in size and the female may reach up to 50 to 65 mm whereas the male is smaller than the female and is from 35 to 50 mm in length. The colour of the adult insect is light brown and the tergum of the front thoracic pronotum is big. The dorsal middle line is elevated in the shape of a visible edge, higher than the tip of the head. This line cuts three distinct grooves, which extend on the sides. The front thorax sternum has a papilla with dense hair between the bases of the front legs. On the hind wings, there is a crescent like space with dark brown colour, while the forewings are transparent.

The immature locusts are grey in colour of tan to black colour. The colour is relatively vivid in the young locusts and dark in the advanced age. A light rose tint shows on the base of the hind wings. In locusts' swarms, this light rose colour appears on the early stage of life, approximately one month after wing formation. The non-aggregated locusts are more brownish in colour in comparison to locust swarms and the rose colouration may not show on the wings before maturation.

Life Cycle

There are no differences between the life cycle of the tree locusts and the desert locusts, except in the number of the nymphal instars. The adult males of tree locusts pass through six nymphal instars, while the females pass through seven, eight or even nine nymphal instars. The extra instar is relatively common among the tree locusts whether aggregated in swarms, or not.

The incubation period of eggs in the tree locusts ranges from 18 to 27 days and the duration of nymphal stage last 62 to 141 days. The multiplication of this species of locusts occurs usually in the rain season. Generally, the tree locust has a single generation per year. However, as the case is in the other locust species, the development of the tree locust is influenced by the prevailing climate and the availability of food in the multiplication environment.

Generally, the nymphs of the tree locusts climb the bushes or trees nearby and may form large groups covering several acres. It was observed that the tree locust nymphs feed at night. When the growth and development of the tree locusts are completed, they form swarms, which are usually smaller than the desert locust swarms and with shorter migration distances. During the day, the fully-grown tree locusts usually settle on the trees and the swarm starts to fly typically at night just after the sunset, hence it is called the night farers.

To date, there is not enough information about the distance, which can be travelled by the tree locust swarms. Incidences of tree locust swarms had been recorded in places away from their multiplication origins as far as 50 kilometres, as they settle to feed in the presence of a suitable vegetation cover. If the bushes or trees are available, the locusts would settle down on them and hence, the name tree locusts given. Control measures of tree locusts is as mentioned before in desert locusts.

1.6. Order: Isoptera

1.6.1. Subterranean Termites

Microcerotermes diversus Silvestri (Isoptera: Termitidae)

Termites belong to the order Isoptera, an order with all its members living in societies each of which is called a colony. They feed on cellulose in its different forms. The termites are called mistakenly the "white ants", but they are not true ants. The term "ant" refers to the true ants of the order Hymenoptera especially the family Formicidae.

The word "white" also is erroneous as only one caste of the colony, the workers, is white in colour; the colour is actually pale colouration, which may be pale yellow, pale brown or pale grey. The remaining castes in the colony like the soldiers have anterior parts, which are brown in colour while the rest of the body is yellow or greyish brown. The winged caste has dark brown colour. Thus, the word termite is more accurate than "white ants". In Oman and some other Arab countries, the termite is called "Al-Ardha" possibly derived from the Arabic word for the ground.

Distribution

It is worth mentioning that the termite is one of the most ancient and historic insects as it was found in fossils dating to 55 million years. The Romans called these insects the termites from the Latin meaning "wood- worm".Termiyes are distributed in many regions around the world and infest several hosts like date palms, fruit trees, forests and ornamental trees. They also feed on the woods used in making furniture, houses and different other types of buildings.

Economic Importance

The termite workers attack all parts of the date palm especially the weak and neglected ones. Usually, the infestation starts in the date palms in the area of the roots as the workers bore several tunnels inside them or build mud tubes on them. Then, they start to attack the stem. The workers bore several tunnels inside the trunk leading to deterioration of a part. The affected trunk may show holes as long as 90 cm, as wide as 23 cm and as deep as 19 cm. The termites build many mud tubes or tunnels on the surface of the trunk and attack the frond bases resulting in deep, dark- coloured grooves, Figs. 1.89. and 1.90.

Generally, the infestation with the termites leads to a marked decline in the date palm's productivity as well as economic damages to the palm offshoots nurseries. They heavily attack the offshoots causing weakening in their growth or eventual death. They also infest the date offshoots while on the parent palm or when planted in the orchard. Usually the infestation is relatively high in the offshoots planted in new field dry areas, where they cause the death of the offshoots months after their implantation. It is worth mentioning that the termite rarely attacks the stalks or fruits but they feed on the "kimri stage" fruits fallen on the ground under the date palms.

General Description

As mentioned earlier, the termite is considered one of the social insects in the sense that there is functional specialization among the members of the colony. A termite colony consists of four main castes or types of individuals, two of which are reproductive forms and two sterile. A termite colony usually contains a royal pair, the king and queen, which are commonly primary reproductive that have lost their wings after founding the colony originally, while the sterile castes consist of soldiers and workers,

Fig. 1.89. The mud tubes made by termite workers on the date palm trunk.

Fig. 1.90. The damage of termites on date palm trunk after removing the mud tubes.

both of them, which may be apterous males and females, adapted to perform special non-reproductive functions. In addition, every colony also contains numerous immature individuals of various ages, which will develop later to one of the above castes. Generally, as mentioned, each caste performs a certain and specific job and thus there have been some modifications in the morphological characteristic of each caste that facilitate performing its function. Here is a description of each of the different castes in the termite colony:

1. Workers

They are responsible for all the damages incurred by termite infestations. They feed and provide food to all the castes of the colony and represent about 97% of the colony population. The most important functions of the workers are taking care of the eggs, nursing, and raising the offspring. They also groom and feed the king and queen, feed the soldiers, make tunnels and tubes as well as excavating the colonies especially from the skin moults of the other members. The workers are sterile, blind and have no wings. They are pale yellow in colour. The upper mandible is dark brown and ends with four teeth or protrusions. The worker is about 4 mm long.

2. Soldiers

They are the members responsible of guarding and protecting the colony. The population of the soldiers is a minority in the colony as they are between 1.5 to 3% of the colony population. The soldiers are blind and infertile members with big size and have large head-capsules, which may constitute up to one third of the body. They have strong, serrated mandibles, which are dark yellow coloured while the upper mandibles are dark brown, elongated in shape and curved. The end of the mandible is pointed making it look like generally a dagger. The soldier is about 5 mm long.

3. Winged Reproductive

The members of this caste appear in the spring and autumn. They have eyes and can see. They are pale brownish yellow in colour with a dark brown upper mandible, which ends

with four teeth or protrusions. They have long transparent wings that are twice as long as the body. The fully-grown winged reproductive insect is about 5 mm long, excluding the wings. They are attracted at night to the light and use their wings to fly and spread. These fertile members change into kings and queens then each king and queen pair start making a new colony.

4. The Queen

There is only one queen in each colony. The queens originate from the reproductive individuals and bind the colony members together. It is also highly effective in laying eggs as it deposits around six eggs every minute. The queen lives for several years and is big in size because of its enlarged ovaries. In the colony, only one king lives with the queen.

Life Cycle

Usually, the winged members emerge from their colonies during the months of April, May and September and are attracted to light at night. These members are the kings and queens and use their wings to fly and spread. Later they shed their wings and each king and queen begins to establish a new colony underground. There the queen transforms into egg laying machine while the workers tend to the queen, the eggs and the colony completely. The colony is consisting of queen, workers and soldiers. The termites stay under ground inside the affected date palms all year long. The queen lives for several years and it is big in size due to their enlarged ovaries as mentioned earlier. As mentioned earlier, the termites are social insects with the main duties distributed among the members of each caste in the colony. El-Naggar *et al*. (1985) recorded another species of termites, which attacks the date palms in Aswan governorate in Egypt that is *Amitermes desertorum* (Deseneux). In Oman, nine species of termites belonging to family Termitidae were recorded; *Amitermes gallagheri* Chhotani & Bose, *Amitermes stephensoni* Harris, *Amitermes vilis* Hagen, *Microcerotermes buettikeri* Chhotani & Bose, *Microcerotermes diversus* Silvestri, *Eutermes parvulus* Sjostedt, *Angulitermes arabiae* Chhotani & Bose, *Macrotermes sobhyalinus* Rambur and *Mycterotermes meringocephalus* Sands.

Control Measures

When symptoms of infestation with Termites are detected in a date palm farm, control begins first by removing the heavily infested palms, destroying them and treating the soil with a soil pesticide like Hexaflumuron (Sentricon®) or Carbofuran (Furadan® 5%).

The remaining date palms, which are moderately affected, must be treated by digging a tunnel around the tree at 50 cm distance from the trunk, 30 cm deep and 30 cm wide. Then they are drenched with the pesticide solution in the rate of 5 litres per square meter, in addition to destroying the tubes and cleaning the ground around the infested trees. One of the following insecticides can be used, Hexaflumuron (Sentricon®) or Imidacloprid (Confidor®). We should also consider treating the fallow orchards with one of the previous insecticides before implanting the offshoots in dry regions where termite colonies are widespread.

1.7. Order: Thysanoptera

Thrips

Thrips belong to the order: Thysanoptera. They are minute, slender-bodied insects, length less than one millimetre. They are hard to spot by the naked eye. Wings may be present or absent. The adult thrips are characterized by the presence of two pair of the elongated narrow wings with few or no veins, and fringes with long hairs on the edges of the wings. Thus, the thrips received the scientific name, from the Greek, "thysanos = fringe" + "pteron = wing".

Thrips are also characterized by having rasping and sucking mouthparts and having one short antenna consist of 4-9 segments, according to the species. The tarsi are one- or two-segmented, with one or two claws, and are bladder-like at the tip. The two sexes of thrips are similar in appearance, but the male are usually smaller. An ovipositor is present in some thrips. In others, the tip of the abdomen is tubular and an ovipositor is lacking. Parthenogenesis occurs in many species.

Family Thripidae contains most of the species that are of economic importance. Most of species in this family are plant feeders, attacking flowers, leaves, fruits, twigs, or buds. They aggregate in groups over the surface of the leaves around the axis to feed by rasping the cells and sucking the produced plant sap.

Infestation with thrips is characterized by the presence of silver coloured spots on the surface of the infested leaves. The reason behind the appearance of these silvery spots is that when the thrips feed, it sucks the content of the cells present under the epidermis of the leaves. The spaces are filled with air bubbles, which reflect the light and give the silvery appearance.

In addition, the green coloured thrips faeces are present on the affected parts. Some thrips species secretes red or crimson coloured liquid on the affected surfaces. After some time, these red droplets turn black. It is worth mentioning that some species of thrips can reproduce through parthenogenesis, as the males are extremely rare. Thus, the females deposit unfertilized eggs, which hatch into nymphs and the insect complete its life cycle in the absence of males and without mating. Some thrips species found on different varieties of date palms. In general, the species found on the old fronds are feeding upon the fungi present on the fronds. In addition, it is clear that some thrips species feed on the pollen grains of the date palms. Generally, the thrips insects cause little economic damages on the date palms. However, it is likely to cause greater damages on the date palms in the nurseries, if the infestation is severe.

1.7.1. Flower Thrips

Frankliniella schultzei (Trybom) (Thysanoptera: Thripidae)

Frankliniella schultzei is a polyphagous species, mainly living in the flowering parts of plants. It is present on many flowers of different vegetables and crops. It was recorded on the date palm inflorescence in the interior regions of Oman. Thrips are not considered an economically serious pest meriting control, because its damages are very limited due to their presence in few numbers on the inflorescence. The adult antenna consists of eight segments. This species of thrips is present in two forms or colours; the pale or dull form in which the females are yellow in colour with brownish spots and the other form is the dark form in which the adult insects are dark brown in colour. The latter form is distributed around the world and is responsible for the transmission of the virus causing the wilt disease known as tomato spotted wilt virus.

1.7.2. Inflorescence Thrips

Adiheteothrips jambudvipae Ramok
(Thysanoptera: Thripidae)

The Inflorescence thrips, *Adiheteothrips jambudvipae,* is called the palm inflorescence thrips in some references. The nymphs and adult insects of this species feed on the flowering inflorescence of the date palms. The inflorescence thrips, *Adiheteothrips jambudvipae*, is distributed in Iraq and India, and it is likely to be found in Oman. The adult insects of this species are black in colour and their wings have dark, long and dense hairs. The antenna has eight segments. In Iraq, Al Haidari and Al-Hafidh (1986) mentioned that the infestation with the inflorescence thrips, *A. jambudvipae*, is severe on the male inflorescence during the months of February, March and April and the nymphs and adults of thrips feed by sucking the sap. In addition, the fertilized females insert their eggs inside the tissues of the inflorescence. They also mentioned that it is likely that this thrips species hibernates in its adult stage in the palm crown, and it has one generation per year on the palm inflorescence.

1.7.3. Greenhouse Thrips

Heliothrips haemorrhoidalis Bouché
(Thysanoptera: Thripidae)

The greenhouse thrips or the black tea thrips, *Heliothrips haemorrhoidalis*, is the common species attacking fronds of date palms. The nymphs and adults of the greenhouse thrips feed on palm leaves. This species secretes a red liquid substance on the surface of the infected leaf. After some time, these drops turn black. Usually, the males of this thrips species are very rare and they reproduce through parthenogenesis. This species may cause some economic damages on the date palms. It is present in South America, USA, many European countries, Egypt, Morocco, Turkey, Philippines, Sri Lanka, India, Indonesia and Malaysia. To date, this species of thrips has not been recorded in Oman. The greenhouse thrips is characterized by being weak fliers and they remain most of the time in hiding in areas shaded with plants. The full-grown second-instar larvae are about 1.1 mm long. The body is yellow with the ninth and tenth abdominal segments brown. The antennae, except the first segment, are pale grey; the terminal segment is long, slender and needle-like. After that, the larva descends into the soil to transform into the pre-nymphal stage. Then it moults inside the soil after two days into the nymphal stage, which in turn moults after two days and the adult insect emerges. The adult insect is generally black in colour except for the legs, which are entirely white or yellow.