Chapter 2

Pests of Stored Dates

2 Pests of Stored Dates

2.1. Order: Coleoptera

2.1.1. Saw-Toothed Grain Beetle

Oryzaephilus surinamensis **(Linnaeus)**
(Coleoptera: Silvanidae)

Distribution

The saw-toothed grain beetle, *Oryzaephilus surinamensis*, is cosmopolitan and is mostly found in warmer, temperate and tropical regions. It attacks dates in many countries such as Iran, Iraq, Egypt, Libya, Tunisia, Algeria, Morocco, Pakistan, Oman, Saudi Arabia, USA as well as many other countries. It infests dates, dried fruits, cereals and cereal products, flour and many other stored foodstuffs. This pest considered one of the most serious insects infesting dates.

Economic Importance

The saw-toothed grain beetle causes great economic damages to the international date trade. In El-Medina in Saudi Arabia, it is considered the gravest pest infesting the dates as it fiercely attacks them. It is regarded as one of the key problems affecting the date trade and packaging industries. It is important to point out that the longer the dates are stored, the more severe the rate of infestation. In the central area of Iraq Hussain (1985) found that the percentage of infestation started at 5% in December, and after three months of storage the percentage of infested dates in the warehouses went up to 22%. Moreover, after six months of storing, the percentage of infestation rose to a staggering 64% of all the stored dates. Upon inspection, it was found that the number of insects in a date fruit ranged from 1-21 insects with an average of five insects in each infested date fruit.

The adult beetles and larvae feed on the ripened date fruits with low moisture content. The larvae feed on the space between the skin of the fruit (pericarp) and its flesh (mesocarp) which provides a natural space accommodating to the growing size of the larva by time.

The frass of the larvae are clearly noticeable in these spaces. Adult beetles of *O. surinamensis* can be easily seen moving rapidly over the infested dates, while the immature stages are inconspicuous. They diffuse to all areas of the fruit and near the endocarp around the seeds. In the case of severe infestation, all what is left of the inner contents of the seed is powder consisting of the insect's frass and the skins of molten larvae. It was observed that saw-toothed grain beetles infest the dates whether they have their perianths or not. They can also attack pressed dates as the adult beetle can pass through the ruptures or cracks in the packaging bags. Although it usually assaults the stored dates, it was observed that saw-toothed grain beetles can infest fallen date fruits or dates kept aside only for a short time in the farms. In general saw-toothed grain beetle infestation renders the dates not suitable for human consumption.

General Description

The adult beetle of *O. surinamensis* is tiny in size, slender, parallel-sided, dark-brown beetle and measure from 2.5 to 3.5 mm long. It has dark brown colour inclined to be black. It is covered with light coloured fine hairs. The antennae are relatively short and weakly clubbed. The saw-toothed grain beetle is characterised by the presence of six distinctive tooth-like projections along each side on the prothorax, which has three longitudinal elevations on the upper surface. The male can be differentiated from the female by the presence of a visible tooth-like spine on the femur of its hind leg. The egg is elongated in shape, white in colour and 1 mm long.

The larva is dirty white in colour with a yellow head, which is flattened and protrudes forward (prognathous). It is from 4 to 5 mm long when fully grown; cylindrically shaped and almost straight and do not have urogomphi. The larvae have well developed thoracic legs and its antennae are as long as the head. The second segment of each antenna is the longest. There are three simple eyes near the bases of the antennae. The segments of the larval body have some long and some short hairs, Fig. 2.1. The pupa of *O. surinamensis* is free, white in colour and 3 mm long. It is covers with few knobbed shaped hairs. The pupa lives inside pupal cell, as cocoon, made by the last larval instar.

Fig. 2.1. Larva of *O. surinamensis.*

Life Cycle

Hussein (1974) and Mohaimeed (1978) extensively studied the life cycle of the saw-toothed grain beetle in Iraq. They found that, *O. surinamensis* has five overlapping generations per year on dates, Table. 2.1. The mature female deposited 150-200 eggs, which lay singly on the stored date fruits. However, Howe (1956) reported that the adult female of *O. surinamensis* laid up to 375 loosely arranged eggs on foodstuffs at a peak rate of 6-10 eggs per day. When the eggs hatched, the larvae came out to wander and feed on the stored dates. The incubation period of eggs was ranging from 7-17 days according the temperature and relative humidity in the warehouses.

The newly emerged larvae burrow tiny tunnels in the flesh of the dates and moults 2-4 times, depending on conditions. The duration of the larval stage of *O. surinamensis* varies from about 16 to 76 days. When the larva is fully-grown, it makes a wider hole at the end of the tunnel; i.e. pupal cell, and transforms into a pupa. The pupal stage ranges from 12-26 days, then the adult beetle emerges and repeats the life cycle. The adult longevity may range from 31 to 59 days. Hussain (1985) reported that some adult beetles of *O. surinamensis* could live up to three years.

Although, the adult beetles of *Oryzaephilus* spp. are winged, they rarely fly. They tend to wander from the stored food into crevices, ducts and roofing spaces, from which they are difficult to eradicate; they often be found beneath the bark of trees near to warehouses. It have been reported that adult of *O. surinamensis* can survive sub-zero temperatures for up to 4 days. It was found that the different stages of *O. surinamensis* die when subjected to a temperature of - 6°C for one week while it dies after one day at - 17°C (Hussain, 1969).

Generally, it is obvious that the larvae, pupae and adults of *O. surinamensis* withstand low temperature conditions, while the eggs affected rapidly by cold. Accordingly, in temperate areas *O. surinamensis* can survive winters in unheated stores. It was also found that the different stages of *O. surinamensis* would die within few hours only, when exposed to high temperature degrees of about 42- 45°C.

Control measures

1. Cultural Control and Sanitary

Clean and good store hygiene plays an important role in limiting infestation by *Oryzaephilus* spp. The removal of infested residues from the previous season's harvest is essential, as is general hygiene in stores such as ensuring that all wastes from the previous crop are removed and all cracks and crevices filled. In case of grain stores, infestations may also be limited by storing good quality grains such as whole cereals with fewer broken grains and dockage and milled rice with a high milling degree (at least 95%) and few broken grains.

2. Chemical Control

Dates must be fumigated with phosphine or methyl bromide to eliminate an existing infestation but these treatments provide no protection against re-infestation.

3. Biological Control

Although, biological control has not been practised against *Oryzaephilus* spp., it was found that a wide range of organisms including the protozoans *Nosema oryzaephili*, *N. whitei*, *Mattesia oryzaephili* and *Helicosporidium parasihcum* attack them. Granulosis virus from the moth *Plodia interpunctella* has been shown to affect *Oryzaephilus* in the laboratory. Also, the hemipteran, *Xylocoris cursitans* and *Xylocoris flavipes* Reuter (Family: Anthocoridae - Minute Pirate Bugs), have been reported as predators of *Oryzaephilus* spp. (CABI, 2005).

On the other hand, it was recorded that the parasitic Hymenoptera of the family Bethylidae, parasitize the larval stage of *Oryzaephilus* spp., i.e. *Cephalonomia meridionalis*, *C. tarsalis* and *Holepyris sylvanidis*.

Table 2.1. Duration of the different stages of *O. Surinamensis* for the five overlapping generations.

Stages	Duration in days				
	1st Generation	2nd Generation	3rd Generation	4th Generation	5th Generation
Egg	8	17	12	8	7
Larva	16	76	55	32	31
Pupa	26	20	12	19	16
Adult	31	55	59	34	33
Total	81	168	138	93	87
Period of generation	Sep. - Dec.	Oct. - May	Mar. - Jul.	June - Sep.	Aug. - Oct.

2.1.2. Merchant Grain Beetle

Oryzaephilus mercator **(Fauvel)**
(Coleoptera: Silvanidae)

The merchant grain beetle, *Oryzaephilus mercator*, resembles the saw-toothed grain beetle in its habits and inflicts damages as it feeds on stored dates, dried fruits, stored cereal grains and other foodstuffs. The difference between the two species is that *O. mercator* has rounded pointed temples, behind its eyes, while in *O. surinamensis* the temple is flat and broader (equal to vertical eye diameter).

Distribution

O. mercator is distributed in Iraq, Egypt, Iran, Pakistan, Oman, Saudi Arabia, India, Singapore, Thailand, China, Somalia, Tanzania, Zimbabwe and USA. Both species *O. mercator* and *O. surinamensis* are reddish-brown and present in varied numbers on dates. The merchant grain beetles, *O. mercato*r, infest dates that are stored for a long time to dry, but rarely infest freshly collected dates. Generally, the merchant grain beetles are not considered economically important on the stored dates.

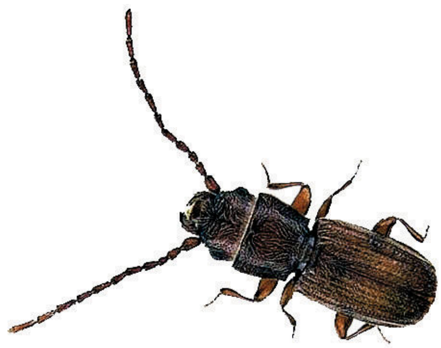
General Description

The larva of *O. mercator* moults 2-4 times. On a diet of wheat, the life cycle of *Oryzaephilus* spp. varies from about 20 days to more than 80 days at temperatures of 17.5-37.5°C and 10-90% RH, respectively. Optimum conditions for development are 30-35°C and 70-90% RH for *O. surinamensis*, and 30-33°C and 70% RH for *O. mercator*. It was found that; *O. surinamensis* is more tolerant of extremes in temperature and humidity than *O. mercator*. For example, *O. surinamensis* can survive at temperatures of 20-37°C at 0% RH, whereas *O. mercator* can only survive at 25-32.5°C at this humidity, Howe (1956).

Fig. 2.2. Larvae and pupae of *Oryzaephilus mercator.*

2.1.3. Flat Grain Beetle

***Cryptolestes pusillus* Schönherr**
(Coleoptera: Cucujidae)



Distribution

The flat grain beetle, *Cryptolestes pusillus* Schönherr, attacks dates and is distributed in Egypt, Iraq, Iran, Libya, Morocco, Tunisia, Pakistan as well as other countries infesting stored dates and cereal grains.

General Description

The adult beetle of *Cryptolestes pusillus* is reddish-brown with an elongated flat body and 1.5 mm in length. The antenna is consists of 11 segments, the last three of which are somewhat larger. The female antennae are about half the length of the body, while in the male they are about two thirds of the length of the body. In the male, the last segment of the antenna is a little elongated. The thorax is flat with no pits or grooves and hence, the insect is called the flat grain beetle. The front thorax angles are rounded while the hind angles are sharp. The elytra are round ended and cover the abdomen. The femur is big while the leg is weak and has two spikes. At the end of the legs, all tarsi are five-segmented, except for the male hind tarsi, which are four-segmented. However, as the basal segment is rather small, it may be only possible to count four segments on each tarsus, or three on the male hind tarsus. The abdomen is consists of five segments which are unequal in length.

The eggs are translucent white, elongate and ovoid, without obvious surface sculpturing or specialized structures. Small particles of food may adhere to the surface of the egg. The egg is about 0.25 mm in diameter and 0.75 mm in length.

Newly hatched larvae are translucent white, becoming less translucent with age. The body is elongate and depressed vertically. The head capsule and anal hooks are sclerotized. The short antennae are three-segmented, and lateral ocelli are present on each side of the head. Each of the three thoracic segments bears a three-segmented leg, which terminates in a sharply pointed claw, which curves ventrally. There are seven abdominal segments, which are uniform in size, a longer eighth segment, and the ninth segment, which bears the anal hooks (urogomphi). There is one pair of metathoracic spiracles, and a pair on each of the first eight abdominal segments. The first-instar larva is about 1 mm in length. There are four larval instars and a quiescent prepupal stage. All larval instars are similar to the first ones, but the body becomes more elongate in shape, Fig. 2.3. The head is wider than the rest of the body in the first instar, but then becomes narrower than the rest of the body in later instars. After the first instar, there is a pair of lateral setae on abdominal segments 1-7. The mature fourth stage larva is about 2 mm in length, (Bishop, 1960; Yablokov-Khnzoryan, 1978).

The mature fourth stage larva enters a prepupal stage, where the body becomes broader, the behaviour sluggish, and silk glands form on the prothorax. These glands are used to spin the silk cocoon in which pupation occurs. The pupa is of the exarate form. The newly formed pupa is white, but becomes darker with age and the pupal cocoon is slightly longer than the mature larva.

Fig. 2.3. Larva of *C. pusillus.*

Life Cycle

The female beetle of the flat grain beetles, *Cryptolestes pusillus*, digs tiny cavities in the flesh of the date fruit (mesocarp) and deposits one egg in each hole. The egg needs 3-5 days to hatch. The larva of *C. pusillus* has five instars as it moults four times. The larval duration lasts from 30 to 180 days, according to the environmental conditions. The flat grain beetles, *C. pusillus*, overwinter in a state of hibernation in the form of larva inside the stored dates.

When the larva is fully grown, it makes a small hole inside the flesh of the date fruit and spins a silken cocoon in which it pupates. The pupal stage lasts 12 days at 17°C, and 3 days at 37°C. Then the adult beetle emerges, it can live for a long period, about one year at 17°C, and about 6 months at 37°C.

A female starts laying eggs within a few days after emergence, and will lay about 200-300 eggs during her lifespan. The flat grain beetles, *C. Pusillus*, have two or three generations per year on stored dates. The parasitic wasp, *Cephalonomia waterstoni* Gahan, has potential to control this pest when used as part of an integrated pest management programme (Flinn and Hagstrum, 1995).

2.1.4. Rusty Grain Beetle

***Cryptolestes ferrugineus* (Stephens)**
(Coleoptera: Cucujidae)

Distribution

The rusty grain beetle, *Cryptolestes ferrugineus*, is cosmopolitan, with a wide range extending from the tropics to temperate areas, Haines (1991). Sauer (1992) mentioned that *C. ferrugineus* is more cold tolerant than other species of Cryptolestes, it can survive winter in temperate climates and is an important pest in Canada and the USA. The major hosts of *C. ferrugineus* are rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), dried stored products, wheat (Triticum), maize (*Zea mays*).

Economic Importance

The rusty grain beetles, *C. ferrugineus*, infest dates and are distributed in Egypt, Iraq, Pakistan, Tunisia, the USA and other countries as well. It feeds on the stored dates and grains. It resembles the flat grain beetle in its habits and life cycle. However, the rusty grain beetles, *C. ferrugineus*, can tolerant low temperature conditions.

General Description

The adult beetle of *C. ferrugineus* is characterised by the presence of few pits on the head and thorax. It is reddish brown, flat, oblong and quite shiny, with long slender antennae. In both sexes, antennal length is about half the length of the body, which measures about 1.5 mm. The head and prothorax are comparatively large. They account for nearly half the body length and are almost as broad as the elytra. The prothorax narrows posteriorly. Near the base of the upper mandible in the male, there is a blunt tooth. The adult beetle of *C. ferrugineus* is a strong flyer according to Sauer (1992), but Haines (1991) reports that adults rarely fly.

Larvae of *C. ferrugineus* are white, somewhat flattened, with the posterior part of the body slightly larger than the anterior half. Newly hatched larvae are very small, and reach about 3 mm in length when fully grown. The head and a distinctive forked process at the tip of the abdomen are slightly darkened (Haines, 1991 and Sauer, 1992).

The eggs are laid singly on or amongst the commodity, are moist, and particles of food material adhere to them. They are white, 0.5-0.8 mm in length and about 3.5 times as long as they are wide. Under favourable conditions (25-35°C, 70% RH), 100-400 eggs may be laid per female, according to Sauer (1992).

Control measures

Phosphine is commonly used to control *C. ferrugineus* (Price and Mills, 1988) but resistance has often occurred. Barker (1978) mentioned that the fumigation with carbon disulphide is also effective. The Bethylid wasp *Cephalonomia waterstoni* parasitizes the rusty grain beetles, *Cryptolestes* spp. The schizogregarine protozoan, *Mattesia dispora*, also attacks the rusty grain beetles. The cysts of this protozoan are spread by *Cephalonomia waterstoni*, (Flinn and Hagstrum, 1995).

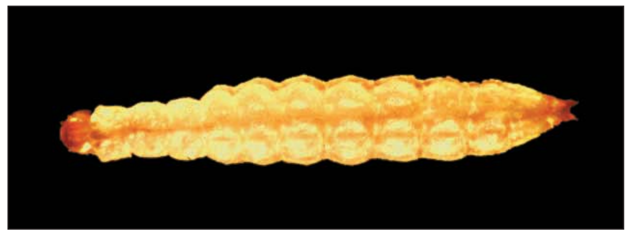
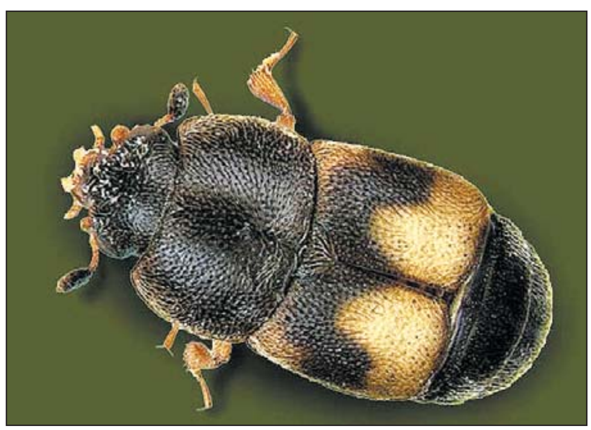


Fig. 2.4. Larva of *C. ferrugineus.*

2.1.5. Two-Dots Dried Fruit Beetle

***Carpophilus hemipterus* (Linnaeus)**
(Coleoptera: Nitidulidae)



Distribution

Nitidulid beetles are considered serious pests of date palms throughout the world. They attack ripe fruit, causing it to rot, and damage is reflected in both reduced yield and lower fruit quality. The two-dots dried fruit beetle or dried fruit beetle, *Carpophilus hemipterus*, spread widely in a large number of countries like Egypt, Tunisia, Libya, Palestine, Lebanon, Iraq, Iran, Pakistan, Somalia, Yemen, Saudi Arabia, Kuwait, Bahrain, United Arab Emirates, USA and Oman among many other countries.

The two-dot dry fruit beetle, *C. hemipterus*, infests stored date, figs and other fruits as well as the spices and rice. It is among the most important pests of stored grains and dried stored fruits. It also infests pomegranate fruits, which have first been infested by pomegranate fruit worms. It is attacks pineapple fields in Hawaii in USA, (Lai and Funasaki, 1986).

Economic Importance

The dried fruit beetle, *C. hemipterus*, causes great economic damages to the date fruits in orchards and to those in warehouses or packing factories. The infestation of this insect is more in dates with high moisture content. In California State in the USA, the economic losses in the date fruits due to infestation by the dried fruit beetles are estimated to be from 50 to 75%. Also in Aswan governorate in Egypt, the damages to the ripe date fruits reached up to 89% of the crop. It is worth mentioning here, that the adult stage of this pest feeds on the fallen date fruits in the farms and the date fruits stored for long periods in damp warehouses. The dried fruit beetle prefers ripe fruits with high moisture content. It enters through cracks and fissures in the fruits and feeds on the flesh inside. It was observed that moulds, bacteria and yeasts grew on the infested date fruits, which rendered them sour or rotten.

The dried fruit beetle, *C. hemipterus*, may even feed on the date fruits still on the date palm trees in some countries, as is the case in California during June. The infestation is most severe when rain falls during the fruit ripening. In Oman, these beetles attack the date fruits when they are still in the Kimri stage (when the fruits start to ripen) during the month of March. Their presence results in downgrading or rejection of the fruit. They are also attack stored dates.

General Description

The adult of *C. hemipterus* is slightly flattened ovate to oblong beetle, light or dark brown in colour and rarely black. Its length is 2-4 mm. The elytra are short, 1 mm in length, and truncate at the posterior edges. There are two conspicuous, yellow patches at the posterior tips of the elytra and two smaller, more obscure near the bases of the lateral margins of the elytra separated by a brown coloured area in the shape of the letter (M). Their antennae consist of 11 segments; the distal three segments forming a compact oval or round club. The surface of the body is finely punctate; each pit is round and gives rise to a hair. The egg of *C. hemipterus* is white in colour and somewhat elongated.

The Larva of *C. hemipterus* is yellowish white in colour and almost cylindrical in shape (cigar-shaped). The antenna in the larva is made of three segments. It is observable that most of the body segments are nearly equal in diameter and length. The terminal abdominal segment carries two anal horns, the urogomphi, one of which is bigger than the other. The fully-grown larva is about 7-9 mm in length. Pupae are white in colour, turning cream and later tan before adult emergence. The pupa is typical exarate and averaging 3 mm in length, Fig. 2.5.

Life Cycle

Each female of *C. hemipterus* lays between 500-1000 eggs during its lifespan which is around two months. The adult female begins to lay eggs after three days of its emergence. The eggs are deposited singly on the surface of date fruits in the warehouse or on fermented or fallen date fruits in the fields under the date palms. The incubation period of eggs is about 2-3 days. After hatching, the larvae feed on the date fruits and the total larval duration is between 6-14 days. When fully grown, the larvae abandon the date fruits and migrate to the soil to develop into the pupal stage. The full-grown larva burrows into the soil normally to 20-30 cm depth but when the moisture is high, it digs only 10 cm deep. The duration of the pupal stage is average about 7 days.

The adults of *C. hemipterus* can live for up to a year or more but the normal average lifespan of the adult is two months. On dried dates, the development period of *C. hemipterus*

Fig. 2.5. Larvae and pupae of *Carpophilus hemipterus.*

varied from 42 days at 18.5°C to 12 days at 32°C when the relative humidity was above 70%. *C. hemipterus* feeds on the flesh of dried fruits and on yeast and moulds present, but these beetles cannot normally get into the fruit unless the surface is damaged. The dried fruit beetle, *C. hemipterus* has several overlapping generations each year in the date palm groves. Under field conditions, each generation lasts about 15 days. Generally, the generation duration of *C. hemipterus* in warehouses ranges from 12 to 42 days depending on the temperature. In warehouses, the male beetles can live from 30 to 143 days with an average of 114 days, while the female beetles can live from 59 to 159 days with an average of 129 days.

The dried fruit beetle, *C. hemipterus*, can fly to a distance of one kilometre per day. The adults begin to fly during the day when the temperature rises to around 35°C, thus they can reach the date palm crowns and infest ripe fruits on the bunches.

The duration of different stages and subsequently the durations of each generation depend upon the prevailing temperatures inside the dates warehouses. Data represented in Table 2.2 illustrated the effect of different temperature in the warehouse on the duration of the different stages of the dried fruit beetle, *C. hemipterus*.

Table 2.2. The effect of temperatures inside the date's warehouses on the duration of different stages of the dried fruit beetle, *C. hemipterus* (Linnaeus).

Stages	Duration at different temperature degrees (in days)		
	18°C	21°C	32°C
Egg	3	3	1
Larva	22	15	7
Pupa	16	9	4

Control Measures

1. Cultural Control and Sanitary

Collecting fallen and rotten fruits and discarding them helps to reduce the infestation of the dried fruit beetle, *C. hemipterus*. Most Carpophilus species will enter stores on suitable commodities, especially if these are moist. In warehouses, dates should be stored at moisture contents recommended for good storage to minimise the infestation and damage.

2. Chemical Control

Carpophilus spp. can be effectively controlled in stores by fumigation with phosphine or methyl bromide. However, fumigations are very unlikely to be undertaken purely on account of this species but for a larger pest complex which includes them. Dusting date fruit bunches with Malathion about a month and a half before collecting the fruits gave good resulting in control and reduction of the infestation level of the dried fruit beetle, *C. hemipterus*.

3. Biological Control

The encyrtid wasp *Cerchysiella* (*Zeteticontus*) *utilis* (Noyes) is known as a parasite of the larvae of the dried fruit beetle *Carpophilus hemipterus* and the flower beetle *Carpophilus mutilatus* Erichson, (Greathead & Greathead, 1992). In addition, this parasite had been introduced for biological control of the pineapple sap beetle, *Carpophilus humeralis* (Fabricius) which infesting pineapple in Hawaii (Lai and Funasaki, 1986; Funasaki *et al.* 1988).

In addition, a study was carried out to evaluate the susceptibility of different Nitidulid beetles to entomopathogenic nematodes. Experiments using entomopathogenic nematodes with a view to controlling the pineapple sap beetle, *Carpophilus humeralis*, and the dried fruit beetle, *C. hemipterus*, in date orchards, have been successful (Glazer *et al*. 1999).

2.1.6. Dry Fruit Beetle

***Carpophilus dimidiatus* Fabricius**

(Coleoptera: Nitidulidae)

Distribution

The Nitidulid dry fruit beetle, *Carpophilus dimidiatus*, is also called the Corn-sap Beetle. It causes limited economic damages to the stored dates in some countries. It also infests the ripe fruits in many orchards as it attacks the ripe fruits on the palms. It is widespread in the tropical and subtropical regions of the world and has been recorded in USA, Egypt, Palestine, Iraq, Iran, Turkey, Sri Lanka, Hong Kong, India, Malaysia, Myanmar, China, Indonesia, Philippines, Thailand, Solomon Islands and Australia Libya and many other countries (Aitken, 1975 and Haines, 1981).

Economic Importance

As mentioned above, this insect causes limited or moderate economic damages to the dates after collection and during storage. However, it may infests the ripe date fruits on the palm trees, where it would cause serious damages as high as 74-96% depending on the differences between the geographical regions and date palm varieties (Hussain, 1985). The damages caused by the Nitidulid dry fruit beetle are due to the feeding of both larva and adult stages inside the stored dates, which turn sour or rotten. It was found that the adult beetle pierces the fruit near the perianth and feeds on the date flesh. The dry fruit beetle prefers the stored dates with high moisture content or those stored in humid warehouses for long periods. The field infestation is high in damp humid areas or those in which rain falls when the date fruits are ripening on the trees.

General Description

The adult beetle of *C. dimidiatus* is slightly flattened, ovate to oblong and measures 2-3 mm in length. It is reddish black or yellowish black in colour and a little shiny. The elytra are shortened leaving two large segments of the abdomen exposed, lighter in colour and have no spots. The antennae are 11-segmented, the distal three segments forming a compact oval or round club. The second segment of the antenna is shorter than the third one. The Larva is white or inclined to yellow colour. It is characterised by the inner rim between the urogomphi being circular and narrow and is cigar-shaped and slightly flattened. The fully-grown larva is 5-6 mm. long. When it is fully-grown, it turns to the soil to develop into the pupal stage.

Life Cycle

The adult female starts laying eggs one or two days after emerging from the pupal stage. The female deposits 500-1000 eggs during its lifespan. The adult longevity ranged between 3-7 months. The incubation period lasted four days, the larval duration lasted 27 days and the pupal duration lasted 18 days; at the temperature of 18°C. Data in Table 2.3 clarify that the life spans of the different stages of *C. dimidiatus* are greatly decrease by the rise in temperature, (Hussain, 1985).

The total development period of egg, larval and pupal stages of *C. dimidiatus* bred on dates varied from 49 days at 18°C to 15 days at 32°C. Thus, the duration of each generation ranges approximately from 15 to 49 days depending on the temperature. In addition, there are several overlapping generations of the corn-sap beetle each year.

It was also observed that the corn-sap beetles, *C. dimidiatus*, infest the date fruits fallen in the ground and would multiply in the field when the temperature ranged from 26 to 32°C with high humidity. Lindgren and Vincent (1953), in California State in USA, mentioned that the corn-sap beetle's *C. dimidiatus* multiplies in the fields during the months from June to September due to suitable conditions of temperature and humidity. Starting from June date fruits start to fall and the corn-sap beetles multiply inside them. When the adult beetles emerge from the infested fruits, they fly to the crowns of the date palms and attack ripe fruits. The adult beetles hibernate as pupal stage inside the soil.

The adult beetle of *C. dimidiatus* can fly for short distances. It should be noted that there are many species of dry fruit beetle belong to genus *Carpophilus* such as: *Carpophilus obsoletus* Erichson, *Carpophilus lugubris* Murray, *Carpophilus ligneus* Murray, *Carpophilus freemani* Dobson and *Carpophilus mutilatus* Erichson

Table 2.3. The effect of temperatures inside date warehouses on the duration of different stages of the corn-sap beetles, *C. dimidiatus* (Fabricius).

Insect Stages	Duration at different temperature degrees (in days)		
	18°C	26°C	32°C
Egg	4	2	2
Larva	27	11	8
Pupa	18	7	5

Control Measures

Control measures are the same as in case of the dried fruit beetle, *Carpophilus hemipterus*, mentioned earlier.

2.1.7. Yellowish Nitidulid Beetle

***Haptoncus (Epuraea) luteolus* (Erichson)**
(Coleoptera: Nitidulidae)

Distribution

The yellowish Nitidulid beetle or the yellow brown sap beetle, *Haptoncus luteolus* (Erichson) is distributed in date warehouses and date palm groves in both India and USA where it feeds on the dates and other stored fruits e.g. figs, peach and apple. Generally, this insect causes moderate damages to the stored dates.

Economic Importance

The adult beetles and larvae of the yellowish Nitidulid beetle, *H. luteolus*, feed on the stored dates with high moisture content. The beetle enters the date fruit through the crevices or cracks. It can also feed on the ripe date fruits on the date palm. As a result, the infested dates are also attacked by fungi and turn sour and rotten. This would render them unsuitable for human consumption. In general, the yellowish Nitidulid beetle inflicts moderate economic damages on the stored dates.

General Description

The adult beetle is oval or elongated in shape and yellowish in colour with a mild shine. The adult is 2-2.5 mm long and 1.2 mm wide.

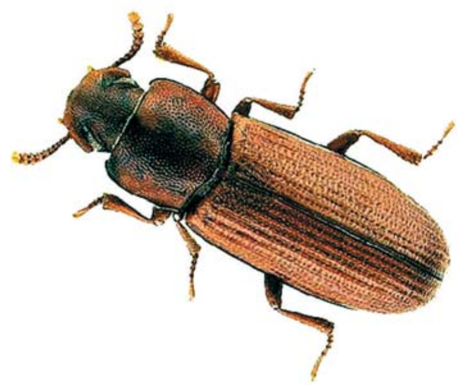
Life Cycle

The female beetle of *H. luteolus* deposits its eggs on the stored dates where they hatch into larvae, which burrow into the flesh of the date fruits and feed on them. When the larvae are fully-grown, they migrate to the soil where they dig inside and develop into the pupal stage. The single generation of the yellowish Nitidulid beetle, *H. luteolus*, takes from 4 to 6 weeks, with the exception of the winter generation that may need up to several months inside the warehouses.

This insect has several overlapping generations in the year. It is also infests the fruits fallen under the date palms and after emergence of the adult beetles, they fly and invade the ripe date fruits on the date palms. In India, infestations by the yellowish Nitidulid beetle were recorded on date fruit bunches during the months of July and August, Batra (1972). The beetles continue to multiply on the fallen fruits, as the adult females prefer the fallen fruits with high moisture content to deposit their eggs. It was found that the yellowish Nitidulid beetle hibernate in their pupal stage in the soil.

2.1.8. Confused Flour Beetle

***Tribolium confusum* Jacquelin du Val**
(Coleoptera: Tenebrionidae)



Distribution

The confused flour beetle, *Tribolium confusum*, is widely spread all over the world. *T. confusum* is believed to have originated in Ethiopia. It is cosmopolitan, but particularly common in temperate climates, and much less common than *T. castaneum* in most parts of the tropics. It feeds on many kinds of stored foodstuffs like wheat flour, wheat, corn as well as the pressed dates in the warehouses.

Economic Importance

The confused flour beetle, *T. confusum*, is an important pest of many commodities, especially cereals and cereal products. In addition, it also attacks dried fruits, nuts and spices (Sauer, 1992). It also has cannibalistic and predatory tendencies. *T. confusum* does not cause serious economic damages to the stored dates that warrant controlling.

General Description

The confused flour beetle, *T. confusum*, was named because of the confusion over its identity. It resembles the rust-red flour beetle; *Tribolium castaneum* Herbst, except for the antennae, the club of the confused flour beetle antennae is four segmented, which is clavate in shape and is gradually thickens towards the tip. Another slight difference is in the shape of the thorax. The sides of the rust-red flour beetle are curved, whereas the thorax of the confused flour beetle is straighter. When agitated or crowded, they may secrete chemicals called quinones. These chemicals can cause the infested feed to turn pink and have a pungent odour.

The adult of the confused flour beetle, *T. confusum*, is oval and somewhat flattened. It is reddish brown in colour, rather shiny in appearance and about 3-4 mm long and 1-1.2 mm wide. The antennae have a 4-segmented club. The first thoracic segment, the prothorax has tiny pits, which spread onto the elytra where they are arranged in longitudinal lines. The distance between the two eyes equals three times the diameter of one of the compound eyes. The adult beetles are very active, moving rapidly when disturbed. It has well-developed wings but seldom flies.

The Larva is yellowish white in colour and the upper side of the body segments is dark in colour and covered with yellow hairs. It has three pairs of legs located on the segments immediately behind the head. The antenna is three segmented which differ in length. The head is prognathous. The ninth abdominal segment ends with a pair of short and sharp pointed anal horns, the urogomphi. The fully-grown larva is 6-7 mm long. The Pupa is free type (no cocoon), is either white or yellow in colour, and measures up to 4 mm in length, (Sauer, 1992).

Fig. 2.6. Larvae and pupa of *Tribolium confusum.*

Life Cycle

The adult female beetle lays 350-450 eggs in its lifespan. The eggs take 5-25 days to hatch depending on the temperature. The Larva moults 5-11 times, depending on the food source and environment. The duration of the larval stage is about 32 days while the pupal stage ranges from 6 to 19 days. The confused flour beetle, *T. confusum*, lives 170-200 days and has from four to five generations per year. Sauer (1992) mentioned that the development from egg to adult can be completed in 26 days under optimum conditions and adult beetle of *T. confusum* normally live for about 1 year, but have been known to live for up to 5 years.

Rangaswamy and Sasikala (1991) found that the adults of *T. castaneum* produce sex and aggregation pheromones. The adult female produces the sex pheromone, Z-2, nonenyl propionate. The adult male produces the aggregation pheromone (4R,8R)-4,8-dimethyldecanal. Mondal (1985) mentioned that this pheromone attracts conspecific females and larvae. Adults of both sexes also produce quinones, which repel the larvae.

Control Measures

1. Chemical Control

LaHue (1966) observed that synergised pyrethroid have a repellent effect on the confused flour beetle, *T. confusum*. Sauer (1992) mentioned that Chlorpyrifos-methyl and Pirimiphos-methyl are effective control agents, and in some experiments they have been shown to be more effective against the confused flour beetle, *T. confusum*, than Malathion. Korunic and Hamel-Koren (1985) demonstrated that the confused flour beetle, *T. confusum*, has resistance to deltamethrin. Fumigation with methyl bromide or phosphine is effective against the confused flour beetle, *T. confusum* (Sauer, 1992).

2. Biological Control

The parasitoid *Holepyris sylvanidis* (Brèthes) has been reported to attack the larvae of *T. confusum* (Ahmed and Islam, 1988; Prozell and Scholler, 1997). The predacious species of mites including *Acaropsellina docta* Berlese and *Cheyletus malaccensis* Oudemans have been found to be effective control agents in laboratory experiments (Rizk *et al*. 1979).

In addition, many studies have investigated other predators as biological control agents against *T. confusum*. These predators are *Amphibolus venator* (Ashmead) (Hussain and Aslam, 1970), *Dufouriellus ater* (Dufour) (Awadallah *et al*. 1980), *Haemogamasus pontiger* on wounded larvae (Barker, 1968), *Orius albidipennis* Reuter and *Orius laevigatus* (Fieber) (Zaki, 1989), *Peregrinator biannulipes* Montrouzier & Signoret (Tawfik *et al*. 1982), *Termatophyllum insigne* Reuter (Tawfik *et al*. 1986a), *Xylocoris flavipes* Reuter (Awadallah *et al*. 1986a) and *Xylocoris sordidus* (Reuter) (Awadallah *et al*. 1986b; Tawfik *et al*. 1986b). Also, the pathogens *Nosema whitei* (Microsporidia: Nosematidae) and *Adelina tribolii* (Eucoccidiorida: Adeleidae) were found to infect *T. confusum* in Bulgaria (Golemanski and Dukhlinska, 1982).

2.1.9. Rust-Red Flour Beetle

***Tribolium castaneum* Herbst**
(Coleoptera: Tenebrionidae)

Distribution

The rust-red flour beetle, *T. castaneum*, is cosmopolitan in warmer countries (Hill, 1975). It is widespread in Algeria, Egypt, Iran, Iraq, Oman, Libya, Pakistan, Tunisia, Somalia, Sudan and other countries especially in hot regions. It infests stored dates, which have been previously attacked by other insects, as well as the flour, grains, dried fruits, nuts and other stored foodstuffs.

The rust-red flour beetle, *Tribolium castaneum*, and the confused flour beetle, *Tribolium confusum*, are very similar in appearance and can easily distinguished by examining the antennae: the antennae of the rust-red flour beetle end abruptly in a three-segmented club, while the confused flour beetle's antennae gradually enlarge towards the tip, ending in a four-segmented club.

Economic Importance

This insect does not cause serious economic damages in stored dates to warrant any control measures.

General Description

The red flour beetle, *Tribolium castaneum*, is very similar to the confused flour beetle, *Tribolium confusum*. The two species can be distinguished in the adult stage by the following differences:

• As seen from the underside of the head, the eyes of the confused flour beetle, *T. confusum*, are separated by about three times the width of either eye, whereas the width of each eye seen from below in the rust-red flour beetle, *T. castaneum*, is about equal to the distance between them.

• The antenna of the rust-red flour beetle is distinctly club-like, with a three-segmented club. The club of the confused flour beetle antennae is four segmented and forms the club gradually, Fig. 2.7.

• Another slight difference is in the shape of the thorax. The side of the red flour beetle is curved, whereas the thorax of the confused flour beetle is straight.

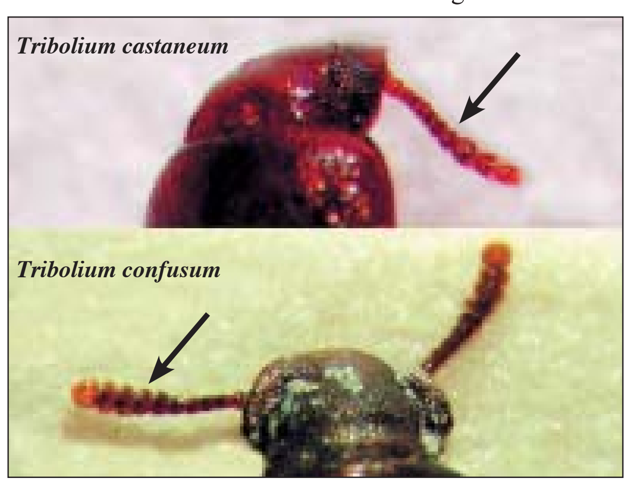


Fig. 2.7. Distinguishing features of *T. castaneum* and *T. confusum.*

The head and upper part of the thorax are covered with minute punctures and the wing covers are ridged lengthwise. The length of the adult beetle of *T. castaneum* is 3-3.7 mm long and 0.9-1.2 mm width. This beetle can fly for longer distances. Mutant *T. castaneum* inherit the black coloration through a single autosomal gene which controls colour variation (Bhatia and Nadarajan, 1978). Black coloration is recessive to the normal rust-red coloration.

The egg of *T. castaneum* is white in colour and cylindrical in shape. It is approximately 0.5 mm long and covered with a sticky secretion. The larva greatly resembles the confused flour beetle, as the colour is yellowish-white, cylindrical and covered with fine hairs. The fully-grown larva is 6-7 mm long. The head is pale-brown. The thoracic legs are fully-grown and the abdomen ends with two brown short spines, the urogomphi. The pupa is naked (without a cocoon) and yellowish-white, becoming brown later. The dorsum is hairy and the tip of the abdomen has two spine-like processes, Fig. 2.8.

Fig. 2.8. Larvae and pupae of *T. castaneum.*

Life Cycle

The life cycle of the red flour beetle, *T. castaneum*, is the same as the confused flour beetle as the adult female lays 400-500 eggs during its lifespan. The incubation period of the eggs is between 3-32 days. The larva has 6 instars, which may increase up to 12 instars according to the type of food. The duration of the larval stage is from 22 to 100 days while the pupal stage lasts from 5 to 18 days. Like the confused flour beetle, *T. confusum*, the red flour beetle, *T. castaneum*, lives for 170-200 days and occasionally may reach up to one and half years.

Adults of *T. castaneum* produce sex and aggregation pheromones. The adult female produces the sex pheromone, Z-2, Nonenyl propionate (Rangaswamy and Sasikala, 1991), while the adult male produces the aggregation pheromone (4R,8R)-(-)-4,8-dimethyldecanal (Suzuki, 1985). This pheromone attracts conspecific females and larvae (Boake and Wade, 1984).

It is worth mentioning that the previously mentioned two insects, the confused and the rust-red flour beetles, are present in wheat silos and mills all over the world. It was reported that together they constitute around 80% of the total number of all the insects inside infested mills and warehouses. Infestations with these two insects were found even in the grains found in the tombs of the ancient Egyptians, which are evidences of their existence since 2500 years BC. However, these insects were the basis of studying the insect colonies in ecology.

Control Measures

Fumigants such as carbon disulphide, ethyl formate, phosphine and methyl bromide have been used against date's stored pests (including *Tribolium castaneum*). However, resistance against phosphine has been reported in *T. castaneum* in different regions of the world (Pacheco *et al*. 1990 and Taylor, 1991).

Ethyl formate has been used to fumigate individual food packages in India. All stages of *T. castaneum* were controlled after an exposure period of 48-72 hours. Food commodities that were fumigated included cereals, pulses, spices, dry fruits, nuts and dried tubers. Residues of ethyl format and formic acid were below the permissible limit of 250 ppm. (Muthu *et al*. 1984). Phosphine and methyl bromide remain the most commonly used fumigants against *T. castaneum* and other storage pests.

2.1.10. Cigarette Beetle

Lasioderma serricorne **Fabricius**
(Coleoptera: Anobiidae)

Distribution

Lasioderma serricorne is known as a pest of dried tobacco leaves, hence its common name, the cigarette beetle. *L. serricorne* is the most important insect pest of tobacco in factories and cigar stores and causes considerable damage to many other products. The cigarette beetle spreads widely in Pakistan, Iraq, Iran, Egypt, Libya, Somalia, USA, Canada and a number of other countries, where it feeds on the stored dates, figs, tobacco, seeds, grains, medicines and animal products. It also spoils herbs and spices like anise, caraway, coriander, chilli pepper and dried root ginger. The cigarette beetles can be spotted in preserved food factories feeding also on the wastes. Haines (1991) mentioned that the cigarette beetle also attacks dried cassava.

Economic Importance

Generally, this insect does not cause great economic damages in the stored dates. However, it usually infests dates stored in warehouses situated near tobacco factories or in which tobacco was stored earlier, where both the larvae and adult beetles attack the stored dates as they feed and burrow inside them.

General Description

The cigarette beetle, *L. serricorne*, is sturdy-built, quite small in size, measures about 2-2.5 mm long, is oval in shape and yellowish red in colour. The elytra are smooth and covered with very short hairs but without striae. The antennae are about half as long as the body and have 11 segments, of which the fourth up to tenth are serrate. It is easy to notice, that when disturbed the adult beetle conceals its head under the large pronotum. The Egg is spindle-shaped (fusiform) resembling a cigar and is yellowish in colour.

The Larva is yellowish white in colour. It is first transparent and turns to a yellowish or creamy white after hatching. It is arched (humped), i.e., scarabaeiform, heavily wrinkled and densely covered with medium length setae. On both sides of the head, there are light coloured bands and two antennae, which are not segmented. The fully grown larva is 4.5-6 mm long. The pupae are formed inside a pupal cell constructed from fragments of food and waste material. The newly formed pupa is white in colour then turns black. It has two red eyes and is about 2.5 mm long, Fig. 2.9.

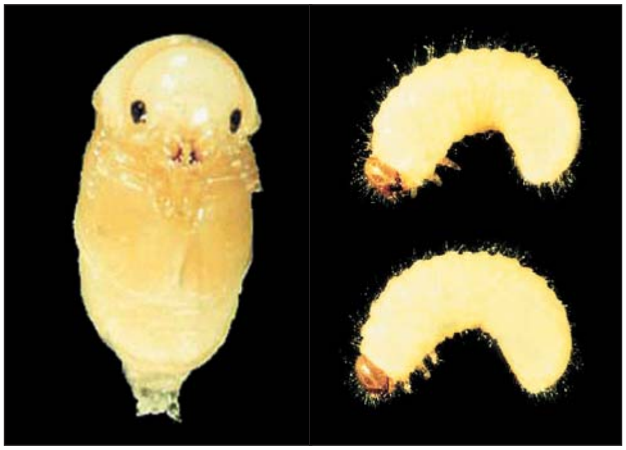


Fig. 2.9. The larvae and pupa of *L. serricorne.*

Life Cycle

The females of *L. serricorne* deposit their eggs singly on stored dates or other foodstuff. Each female can lays up to 110 eggs during its lifespan. The incubation period ranged from 6 to 10 days. On hatching, the larvae often eat their eggshells. The newly hatched larvae, in their early instars, are more active than larvae in later instars. There are 4-6 larval instars depending on the temperature and the type of food. The larval instars continue for a month, and then the fully-grown larva develops into a pupa inside a white silky cocoon made from fragments of food and waste materials. The pupal stage lasts for about one week. It is worth mentioning that, when the pupa turns into an adult beetle, the latter stays inactive inside the pupal chamber for another 7 days. The adult beetle will eventually leave the chamber but will stay in the vicinity for a day or more.

The adult beetle of *L. serricorne* lives for 2 to 6 weeks. In Egypt, the cigarette beetle has three generations per year and the adult beetles appear on stored dates from April until August every year, El-Hafidh (1979). The generation time varies between 25 and 120 days depending on temperature, humidity and type of food. The beetles of L. serricorne are active flier, especially in the late afternoon and evening. The cigarette beetle, *L. serricorne*, is not very cold hardy. Adults are killed by exposure to temperatures of 4°C for 6 days and few eggs survive for 5 days at 0-5°C (Lefkovitch and Currie, 1967).

Control Measures

Control measures are the same as against other store pests, which will be discussed later. Generally, good store hygiene plays an important role in limiting infestation by these species. The removal of infested residues from last season's harvest is essential, as is general hygiene in stores such as ensuring that all spillage is removed and cracks and crevices filled. Kaelin *et al*. (1999) has been tested an anti-coleopteran strain of *Bacillus thuringiensis* (Bt) against *L. serricorne* adults and get results of 60-80% mortality within 7 days.

2.1.11. Hairy Fungus Beetle

***Typhaea stercorea* (Linnaeus)**
(Coleoptera: Mycetophagidae)

Distribution

The hairy fungus beetle, *Typhaea stercorea*, has been recorded in both temperate and tropical parts of the world but is most common in the tropics. It is spread in Pakistan, Iran, Iraq, Sudan, Somalia and other countries in North and South America, Europe, Asia and Africa. Among its hosts are stored dates and dried foodstuff, as well as wheat, rice, corn and tobacco found in warehouses.

Economic Importance

The hairy fungus beetle, *T. stercorea*, is a fungivorous. Its populations will develop in association with mould growth on a wide range of stored foods including cereal grain and flours, nuts, oilseed and copra. It does not cause great economic losses to the stored dates. However, the adult beetles and larvae can infest dates stored in humid warehouses, for long enough time for fungi to grow. In such cases, they feed on both the dates and the fungal growth on them.

General Description

The hairy fungus beetle, *T. stercorea*, is a tiny beetle, pubescent, light to dark-brown, oblong and measure about 2- 3 mm long. On the head, there are circular or oval pits. The elytra are covered with longitudinal rows of setae. The three terminal segments of the antenna are large and clubbed in shape. *T. stercorea* could be confused with small dermestid beetles such as Trogoderma due to their shape and pubescence; however, the tarsal formula (numbers of segments in the tarsi of the anterior, middle and posterior legs) for family Mycetophagidae is 4-4-4 for the female and 3-4-4 for the male, whereas the tarsal formula for family Dermestidae is 5-5-5. Mycetophagidae are generally more elongate than Dermestidae and their hairs are sparser and longer.

The larva is light in colour with visible simple eyes. Its terminal abdominal segment ends with a sharp, dark-coloured anal probe. The body of the larva is straight and covered with dense visible hair. The thoracic legs are fully-grown, Fig. 2.10.

Fig. 2.10. Larva of *T. stercorea.*

Life Cycle

The female beetles the hairy fungus beetle, *T. stercorea*, deposit their eggs on rotten or fermented dates, which are infected by fungi. The eggs hatch into larvae, which feed on the fungi and dates. The larvae burrow inside the date fruits making several tunnels. When the larvae are fully-grown, they develop into pupae outside the date fruits. The hairy fungus beetle has many overlapping generations each year.

Control Measures

It is unlikely that pest control treatments need to be undertaken specifically for *T. stercorea*. However, this species is often present in pest complexes. Generally, good store hygiene plays an important role in limiting infestation by *T. stercorea*. The removal of infested residues from the previous season's harvest is essential, as is general hygiene in stores, such as ensuring that all spillage is removed, and all cracks and crevices filled.

2.1.12. Khapra beetle

***Trogoderma granarium* Everts**
(Coleoptera: Dermestidae)

Distribution

The Khapra beetle, *Trogoderma granarium*, was originally native of the Indian subcontinent. In Hindi & Urdu languages, Khapra means destroyer. In Egypt, it is called Upper Egypt beetle. *T. granarium* occurs in hot, dry conditions, predictably in areas, which for at least 4 months of the year, have a mean temperature greater than 20°C and a relative humidity below 50%. It is especially prevalent in certain areas of the Middle East, Africa and South Asia. *T. granarium* does not appear to be established in South-East Asia, South America or Australia. The pest is infrequent in the USA and Mexico and may have been eradicated, but this is doubtful (Banks, 1977).

The Khapra beetle, *T. granarium*, spreads in Tunisia, Algeria, Morocco, Libya, Egypt, Sudan, Palestine, India, Pakistan, Iraq, and other countries, where it feeds on the stored dates, grains, plant and animal foodstuff.

Economic Importance

The larvae of *T. granarium* are serious pests of grains, seeds, flour, and cereal products, hay and straw, dried fruits and nuts, dried blood and milk and fish meal. The larvae of *T. granarium* can live for as long as three years without food. They congregate in cracks and crevices and are very difficult to remove by ordinary sanitation. The adult beetles of *T. granarium* rarely, if ever, eat or drink. The adults possess wings, but have never been known to fly.

The khapra beetle, *T. granarium*, does not cause great damages to stored dates. However, it was noticed that it infests dates stored in bags made of jute fibres, as the adult beetles and the larvae are found in the dates and the jute bags as well. The infestation usually happens when dates are stored in or near grain warehouses. The damages exclusively occur in the larval stage, during which it feeds on the dates and grains.

General Description

The adult beetle of *T. granarium* is small in size, oval in shape, and covered with pubescence. The female is 3 mm long while the male is shorter, only 2 mm long. The overall colour of this beetle is murky brown or black. The dorsal surface is moderately clothed in fine hairs. A median ocellus is present between the compound eyes. The number of antennal segments is usually 11, but some fusion of the segments may take place so that there can be as few as nine; the last four segments enlarge gradually while the terminal segment is pointed on its anterior tip. The distinct antennal club consists of 3-5 segments, depending on the degree of fusion of the distal segments. In the male, the apical segment of the club is elongated in comparison with that of the female. The antennae fit into ventral grooves in the prothorax. The elytra leave only a small portion of the abdomen uncovered. There are irregularly arranged white scales on the elytra.

The adult beetles are incapable of flying although they can spread their elytra and hind wings while walking. The newly deposit eggs are milky white, afterwards turning to pale yellowish. It is cylindrical and measure about 0.7 by 0.25 mm, one end is rounded, the other is pointed and bearing spine-like projection.

The larvae are typically very hairy. Spicisetae of various lengths are arranged over the dorsal surface and a 'brush' of long spicisetae on the ninth abdominal segment projects posteriorly like a tail; the length of this brush decreases relative to body size as the larvae grow, Fig. 2.11. Hastisetae are present, and are inserted on the tergites, often in distinct tufts. The first instar larva is yellowish-white, about 1.6 mm long, and has two tufts of 4-10 hastisetae on each of the seventh and eighth abdominal tergites. On reaching the fourth instar, the larvae become golden-brown, measure about 3 mm in length, and have dense tufts of hastisetae inserted on the poster lateral parts of the abdominal and thoracic tergites; the tufts become larger and denser posteriorly. The full grown larva measures about 5 mm. The pupa of *T. granarium* usually remains inside the skin of the final-instar larva.

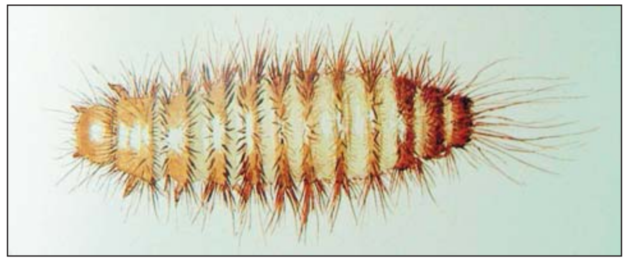


Fig. 2.11. Larva of *T. granarium.*

Life cycle

Female beetles can produce eggs without having fed once emerged from pupae (Hinton, 1945). The female of *T. granarium* lays the eggs singly and the number of eggs lays per female is 50-60 eggs. The incubation period is about 4-11 days. After the egg hatching, the emerged larvae feed inside the date fruits and moult repeatedly for five times. The duration of the larval stage takes around 22 days, from egg hatching to pupation. The duration of the pupal stage takes 3-15 days. On adult emergence, the pupal skin is pushed to the posterior end of the larval skin; the adult remains within the skin for a day or more.

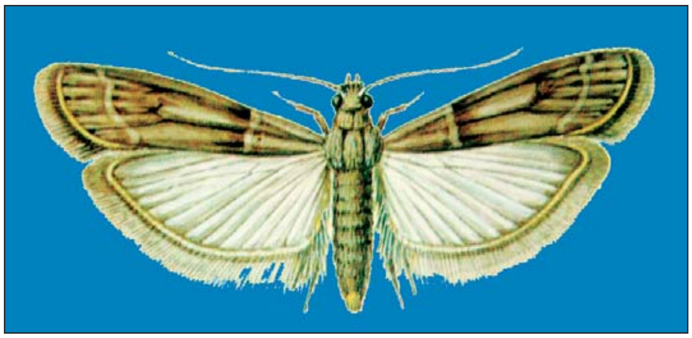
The adult of *T. granarium* do not live long after emerging from the pupal stage. The females die soon after oviposition is complete; the males live 1-4 days longer. The adult beetles do not even feed, but mate and females start to lay their eggs immediately then die after 10-15 days of emergence. The whole life cycle of khapra beetle, *T. granarium*, is completed in a month, one and half months or a little longer.

It is worth mentioning that the adult beetles of *T. granarium* have weak capacity to crawl or move and as was said before, they do not use their wings to fly. This leaves the larva as the only active stage in the life cycle of the khapra beetle, which has several generations each year. Control measures of *T. granarium* are the same as in the case of other warehouse pests, which will be discussed later.

2.2. Order: Lepidoptera

2.2.1. Almond Moth

***Cadra* (*Ephestia*) *cautella* (Walker)**
(Lepidoptera: Pyralidae)



Distribution

The almond moth, *Cadra cautella*, which is a Pyralid snout moth, is also called fig moth, dried currant moth or tropical warehouse moth. It is present in Europe, Asia, Africa, North and South America. It is spreads widely attacking stored dates in many countries like; Morocco, Algeria, Tunisia, Libya, Egypt, Sudan, Somalia, Bahrain Kuwait, Qatar, United Arab Emirates, Saudi Arabia, Yemen and Oman. It is considered as one of the most important stored dates pests.

Economic Importance

The almond moth, *C. cautella*, has many hosts. Its larvae infest dates and many dried fruits like fig, apricot, scaled almond. It also attacks coffee beans, dried onion, peanuts, chocolate as well as the fallen fruits from the trees like citrus, pomegranates, pears among others.

As aforementioned, the almond moth, *C. cautella*, is considered one of the most serious pests attacking stored dates. Its larvae feed on dates fallen on the ground below the palms, on harvested dates during pressing and storing and on dates on palms, where harvesting is delayed, or if they are late ripening varieties. The larvae enter the dates through the perianth orifice or any cracks or fissures present on the pericarp. It is easy for the larvae to enter from the perianth side, as it was found that infestation is higher in the dates from which their caps are removed. It was reported that the infestation incidence was 35% in these dates while it is only 10% in intact dates.

It was also found that the larvae feed on the date flesh especially in the area enclosed between the mesocarp and the seed. There, the larvae leave their dark faecal pellets and shed skins (exuviae) inside the dates. The infested dates may contain living as well as dead larvae because each larva is capable of infesting more than two dates during its lifetime.

The infestations can be spotted when the stores dates are piled in heaps as the larvae spin silk-like threads to which their frass and excreta are attached on the upper side of the piled dates. The infestation by almond moth causes great economic losses to the dates from their harvesting to marketing and consumption. When the infestation is heavy, the dates become unsuitable for human consumption causing great economic losses.

General Description

The moth of *C. cautella* is small in size and 10-12 mm long. The forewings of the moth are greyish-brown with a wavy (crimped, curly) white or yellow line surrounded by two bands, one brown and the other lighter in colour. The wingspan is 14-20 mm and both fore- and hind-wings have broadly rounded tips and only short fringes of hairs. The labial palpi curve upwards in front of the head and are rather blunt at the tip.

The egg is oval and translucent yellow with a distinctly sculptured surface pattern. It is 0.33-0.38 mm long and 0.22-0.32 mm wide. On the eggshell surface, there are longitudinal and transverse elevations. The longitudinal ones are coarse, short and arranged in 24 irregular rows.

The mature larvae are scarlet in colour, which change into light yellow before pupation. Generally, the overall colour of the larva is dirty white. On the dorsal side, there are rose coloured spots arranged in longitudinal rows. On the tergum of the prothorax and the tergite of 10th segment, there is dark coloured scutum. The larvae have a sparse covering of hair and in the males, the testes can be seen through the cuticle as a dark patch in the posterior region. The fully-grown larva is 9.5-12.5 mm long, Fig. 2.12. The pupa is light yellow in colour and 7-8 mm long. It is obtect type and lives inside a silken cocoon, which is dirty white in colour, 10-12 mm long and 3.5 mm wide. At the end of the abdomen, there are eight hooks, Fig. 2.13.

Fig. 2.12. Full-grown larva of *C. cautella.*

Fig. 2.13. Larvae and pupae of *Cadra cautella.*

Life cycle

The female moths of *C. cautella* lay their slightly sticky eggs on stored food. Up to 300 eggs are laid in the first 4 days but few, if any, in the remaining 4 or 5 days of life. At 30°C the incubation period, take about 3 days. Under optimum conditions (32.5°C and 70% RH) the total larval duration is about 22 days. There are normally five larval instars. In heavy infestations, the mature larvae leave the produce in search of pupation sites, such as the walls of the store or the spaces between bags. The pupal stage is completed in about 7 days. Under optimum conditions, development from egg to adult takes 29-31 days. The female adult lives 1 day longer than the male.

Al-Hafidh (1979) in Egypt studied the life cycle of almond moth, *C. cautella*, and found that it has only four generations per year. However, Hussain (1974 and 1985) mentioned that the almond moth, *C. cautella*, has five overlapping generations under the normal conditions of the storage of dates in Baghdad area, in Iraq. These five generations which described exhaustively by Hussain, which can be summarized as follows:

First Generation

It is considered the longest in duration as it continues for five months. The insects of the first generation infest the dates, which have fallen below the palms. They also attack the dates in the packaging houses or in warehouses. The females of the 1st generation start to lay their eggs shortly after mating and usually lay the eggs at noon or during the night. Generally, the adult females begin to lay the eggs during the last week of August for a period as long as two months. They deposit their eggs singly on the surface of the dates. On a single fruit, from one to 13 eggs, with an average of five eggs, may be deposited. The incubation period takes about 14 days.

Then the eggs hatch and the larvae emerge from the eggs and start feeding inside the dates as described earlier. When the larvae become mature, they usually leave the dates to pupate on the walls of the warehouses preferring acute angles between walls. The larva takes around nine days to spin the cocoon. After 19 days of departure from the dates, the larva pupates inside the cocoon.

It is important to note that few of the mature larvae do not leave the dates. Instead, they spin their cocoons and pupate inside the infested dates. This does not happen only in the first generation, but is also observed in other generations and hence the larvae enter the diapause period in the winter inside the stored dates. The duration of the larval stage lasts about 113 days including five larval instars. The pupal stage in the 1st generation lasts 13 days, and then the moths start to emerge in the spring season. The highest number of adult moths appears during the last week of March, when they live for about nine days.

Second Generation

This generation lasts for 48 days. The females begin to lay the eggs on the stored dates for no more than 3 weeks starting from mid-March. The incubation period of the eggs is around 7 days. The larval stage in the 2nd generation is around 27 days. After a period of feeding, the mature larvae spin their cocoons within 3 days and pupate after about 7 days of leaving the dates. The pupal stage takes around 8 days, after which the adult moths emerge in the first week of May to live for about 6 days. The adults' emergences continue for 5 weeks and the largest number of adults' emergence can be observed during the third week of May.

Third Generation

The duration of the 3rd generation takes about 54 days. The females start to lay their eggs in mid May and continue doing so for 5 weeks. The incubation period is about 8 days. The mature and fully-grown larvae spin their cocoons within 3 days and pupate after 5 days of leaving the infested dates. The total duration of the larval stage lasts for about 26 days, while the pupal stage takes up to 12 days. In the 3rd generation, the adult moths start to emerge in the third week of June and continue for 5 weeks. The largest number of the adult moths emerges in the first week of July and the moth lives for 8 days.

Fourth Generation

The duration of the 4th generation is about 36 days. The females start laying their eggs in the fourth week of June and continue for a month. The incubation period is around 4 days. The larva spins the cocoon within 2 days and pupates after 3 days of leaving the dates in the warehouse. The larval duration lasts around 18 days, while the pupal stage takes about 7 days. Generally, the moths of this generation begin to appear at the end of July, but most of the moths appear in early August and the moth can live up to 7 days.

Fifth Generation

The 5th generation takes about 58 days. The females start to lay eggs in mid July and continue for 6 weeks. The incubation period takes about 5 days. The mature larva spins its cocoon also after 5 days and pupates 6 days after leaving the infested dates. The duration of the larval stage takes about 26 days, while the pupal stage takes about 11 days. The moths begin to emerge in early August but the majority of them appear in early October. The adult moth of the 5th generation lives for about 14 days.

Table 2.4. The various generations of almond moth, *Cadra cautella* Walker.

Stages	Duration of the different stages in each generation (in days)				
	1st Generation	2nd Generation	3rd Generation	4th Generation	5th Generation
Oviposition period	60	21	35	60	42
Incubation period	14	7	8	4	5
Larva	113	27	26	18	26
Pupa	13	8	12	7	11
Adult	9	6	8	7	14
Period of generation	150	48	54	36	58

Susceptibility of Different Date Palm Varieties

Dhiab (1979) noticed the differences in the intensity of infestation with the almond moth, *Cadra cautella*, between different varieties of date palms. Generally, the dry or semi-dry date fruits are more susceptible to infestation.

Control Measures

1. Biological Control

The larvae of the parasitoid wasp *Habrobracon hebetor* Say (Hymenoptera: Braconidae) predate on the larvae of almond moth, *Cadra cautella*. This parasitoid is an ecto-parasitoid. Females of the parasitoid wasp *H. hebetor* seek out and sting wandering-stage larvae of Pyralid moth pests. The wasp lays a group of eggs on the body of the paralyzed caterpillar, and wasp larvae hatch out and feed gregariously on the host. Because of the development time of *H. hebetor* from egg to adult is half that of its host and several adult wasps can be produced from one parasitized host, this wasp species is considered an excellent candidate for biological control since its population can increase rapidly and overtake that of the host.

Hussain (1974) studied the life cycle of this parasitoid wasp in Iraq and found that it had five generations each year. Urban and Schmidt (1993) mentioned that the Pyralid, *Plodia interpunctella* and *Cadra cautella*, have been successfully controlled by mass releases of the parasitoid *Habrobracon hebetor* in a sultana store in South Africa. It was found that this Bracon wasp, *H. hebetor*, attacks the larvae of *Cadra cautella* present on the fallen date fruits in the field or those in the warehouses. The incidence of death among the larvae of the almond moth, *C. cautella*, may reach up to 65% when attacked by *H. hebetor*. In addition, Dhiab (1979) reported that there are three other species of natural enemies which attacking *Cadra cautella* in Egypt. These three species are *Nemeritis canescens* Gravenhorst (Hymenoptera: Ichneumonidae), *Pyemotes herfsi* (Oudemans) (Acari: Pyemotidae) and *Blattisocius tarsalis* Berlese (Acari: Ascidae).

2. Chemical and Cultural Control

The almond moth, *C. cautella*, may be controlled by the following measures:

- After harvesting, the dates can be fumigated by methyl bromide gas in concentration of 24 g/mm3 for 24 hours. All the precautionary measures in the warehouses should be taken before and during the fumigation process. The use of methyl bromide for insect control in stored dates will be discuses later in details.

- The dates can be exposed to hot air currents in special ovens at 50-60°C. The solar energy also can be utilised by spreading the date fruits on a wooden floor, covering the piled dates with plastic sheets and continuously shuffling them.

- Good store hygiene plays an important role in limiting infestation by *C. cautella*. The removal of infested residues from the previous season's harvest is essential, as is general hygiene in stores such as ensuring that all spillage is removed and cracks and crevices filled.
- Hodges *et al*. (1984) and Prevett *et al*. (1989) mentioned that Pheromone confusion techniques have some potential for controlling *C. cautella* in stores, which have low ventilation rates. They also mentioned that the the synthetic sex pheromone component (Z,E)-9,12-Tetradecadienyl acetate (ZETA) was found to be most effective.

2.2.2. Currant Moth

Cadra (_Ephestia_) _calidella_ Guenée
(Lepidoptera: Pyralidae)

Distribution

The currant moth, *Cadra calidella*, is also called date moth. In Egypt, it is known as Al Wahat moth, which mean Oasis moth, because it is localised in the Oases area; Al Wahat and hence named Wahat dates moth. *C. calidella* is spreads widely in Egypt, Algeria, Morocco, Libya, Iraq, Lebanon, Cyprus, Saudi Arabia, and a number of other countries.

Economic Importance

The currant moth, *C. calidella*, does not cause economically serious damages in the stored dates in most countries. However, it is considered an important pest on the stored dates in Egypt. The damages caused by the currant moth are similar to those caused by the previously mentioned almond moth. It infests the fallen dates on the ground and the dates in the packaging or storage places. It was found that the adult female deposit its eggs on the dates while still on the palms. After hatching the larvae burrow in the flesh and seeds of the dates making several grooves in them. The larvae also devour the white membrane enclosing the seed, the endocarp. Late in the season, the larvae start to dig between the pericarp and the mesocarp of the dates.

General Description

The adult moth of *C. calidella* is 8-10 mm long. The forewings are grey or light brown in colour. Two dark grey lines divide each forewing; one lies before the middle from the basal side, the other near the apex. The hind wings are white in colour with grey margins.

The egg is oval, white in colour when newly lay and turns orange before hatching. It is 0.75 mm long and 0.55 mm wide. The egg of *C. calidella* looks like the eggs of most of the Cadra species but it is the broadest of them all.

The Larva is scarlet red in colour at first then changes to yellow before pupation. There is a dark coloured scutum on the prothorax and the tenth abdominal segment with brown spots on the other body segments. The fully-grown larva is 12-15 mm long. The newly formed pupa is white, and then becomes darker. The pupa is 7-9 mm long and about 1.8 mm wide.

Life Cycle

The currant moth, *C. calidella*, has several generations per year. In Egypt, for example, it has four overlapping generations. The females lay their eggs singly on dates. Each female can deposit around 150-300 eggs during its lifespan. The incubation period is about 4 days. It was observed that the larval stage has five instars and lasts from 30 to 45 days, while the pupal stage needs 7-10 days to complete. The pupa is of obtect type living inside a silken cocoon and is characterised by having eight hooks at the end of the abdomen. Generally, one generation of the currant moth, *C. calidella*, takes from one and half to two months inside the date warehouses.

Control Measures

The currant moth, *C. calidella*, could be controlled biologically or chemically as mentioned before with the almond moth, *Cadra cautella*.

2.2.3. Tobacco Moth

***Ephestia elutella* Hübner**
(Lepidoptera: Pyralidae)

Distribution

The tobacco moth, *Ephestia elutella*, is a Pyralid snout moth. It is also known as chocolate moth, walnut moth, currant moth, red streaked knothorn, warehouse moth, cocoa moth or stored dates moth. It is widespread in temperate regions, but very rare in the tropics.

The tobacco moth, *E. elutella*, can infest a wide range of commodities, especially stored dates, tobacco, cereals, cereal products, dried fruits, chocolate, cocoa beans, nuts, coffee, spices, pepper and other stored foodstuff. It is a well-known pest in chocolate factories and tobacco warehouses.

Economic Importance

The tobacco moth, *E. elutella*, is of little economic importance to the date industry. The moths are more seen in chocolate factories, tobacco warehouses and grain silos and mills. The female moths deposit their eggs on the fallen dates then the larvae enter the fruit to feed on its flesh. The signs of infestation are almost identical to the previous Pyralid moths.

General Description

The moth of *E. elutella* is about 20-25 mm long and 40-50 mm wide when the forewings are fully spread. The head and thorax are greyish-brown with the abdomen usually paler. The colour of the forewings is greyish-brown, variably suffused with darker brown, while the hind wing is white. The egg is about 0.5 mm long and 0.35 mm wide, with irregular star-shaped sculpturing on the surface.

The Larva has six larval instars. The full-grown larva is 15 mm long. It is yellowish-white in colour and sometimes tinged with brown or pink. The spiracles, prothoracic and anal plates and thoracic legs are reddish or yellowish-brown, Aitken (1963). The head is reddish-brown or yellowish-brown with darker brown markings. Usually the mature larvae pupate on an external surface, but sometimes amongst the food source. The Pupa is pale yellow at first, becoming reddish-brown, with slightly raised spiracles. It is of obtect type, forming inside a silk cocoon.

Life Cycle

The females of the tobacco moth, *E. elutella*, deposit their eggs singly or in clusters in short rows in crevices, sacking or other sites near the food source or in dates. *E. elutella* lays 150-200 eggs per female, singly or in short rows in crevices, sacking or other sites near the food source. Egg-laying takes place chiefly at dusk or during the night in the first week of adulthood. The incubation period lasts 4-7 days 3-5.

The larval stage lasts 4-5 weeks. However, the larvae of *E. elutella* eat only a small amount, but foul the food source extensively with their webbing and frass. The full-grown larvae are often reaching the ceiling of the store, covering surfaces with a sheet of silk. In cooler climates, *E. elutella* overwinter as fully-grown larvae, Ashworth (1993).

Bell (1975) mentioned that the pupal stage of *E. elutella* lasts from 10 days at 30°C to 45 days at 15°C and the pupation takes place on external surfaces in the warehouse. Generally, the adult moth of *E. elutella* lives for 6-7 days but they can live up to three weeks. *E. elutella* moths are active at dusk and rest by day on ceilings or walls. Each generation needs seven weeks to complete. In Iran, Kamali and Taheri (1985) mentioned that *E. elutella* had at least two generations per year under storage conditions.

Control Measures

The tobacco moth, *E. elutella*, can be controlled as mentioned with the previous Pyralid moths.

2.2.4. Raisin Moth

***Cadra* (*Ephestia*) *figulilella* (Gregson)**
(Lepidoptera: Pyralidae)

Distribution

As mentioned before, several species of genus *Cadra* attack dates and most of them are considered stored date pests, but some species attack dates on the palms. The raisin moth, *Cadra figulilella*, is one of the better-known species, which attack date fruits on the growing palms in California State in USA, thus this species is also known as California date moth.

Carpenter and Elmer (1978) mentioned that *C. figulilella* infests the date palms in the field, and clarifying that this happens only in California while in North Africa and the Middle East it infests the stored dates. The raisin moth, *C. figulilella*, attacks the dates, apricots, raisins, and figs and the rest of stored dried fruits. It has been spreads mainly in Egypt, Iraq, Palestine, Saudi Arabia, India and USA among other countries.

Economic Importance

The raisin moth, *C. figulilella*, causes great economic damages California State. However, in Egypt it is less damaging than currant moth, *C. calidella*. In California, the infestation occurs in late autumn when the fruit collection periods are long. This explains why the damages in California are higher than in Egypt because most Egyptian date varieties are earlier harvesting than those in California are. In other areas, *C. figulilella* causes serious damages to the stored dates as its larva feeds on the stored dates by burrowing the flesh leaving behind its frass and silken threads. The raisin moth, *C. figulilella*, attacks dates and causing serious damage in Deglet Nour and Al Zahdi varieties in Palestine, while it attacks Medjool date palms in California.

General Description

The moth of *C. figulilella* is about 10 mm long. It is grey in colour, striated with undistinguished spotted dark lines. The Larva is scarlet white in colour with six spotted lines, which are light purple in colour. The mature larva is about 15 mm long. The pupa is brown in colour and of obtect type, live inside a silk cocoon spun by the larva in fissures in the trunk of the palm, in the soil, or under the woods and boxes in the warehouses, or in any suitable fissures or holes.

Life Cycle

The moth of *C. figulilella* is most active early in the night and rests during the day in shaded places. The female lives around two weeks in warm weather during which it lays an average of 350 eggs. The maximum number of eggs that can be deposited by a female moth is 692 eggs. The eggs are deposited on the surface of the dates. The incubation period is around 4 days. The emerged larvae feed on the contents of the dates for approximately one month then spin the cocoons and pupate on the date palm or on soil surface. It is observed that the raisin moth, *C. figulilella*, overwinters as mature larvae inside the warehouse.

Control Measures

In California, *C. figulilella* is controlled in the field by dusting the date bunches with Malathion 5%. The control measure may include other insect pests like Nitidulid beetles and Indian meal moth, which will be discuses later.

In addition, Dowsoniella Moth, *Ephestia dowsoniella* (Richard & Thompson) is another Pyralid moth, which recorded in Iraq and known to attack stored dates in the warehouses and the fallen dates in the field. It is not causing any economic damages to dates and has not necessitated any control measures up to now.

2.2.5. Indian Meal Moth

Plodia interpunctella **(Hübner)**

(Lepidoptera: Pyralidae)

Distribution

The Indian meal moth, *Plodia interpunctella*, is widespread in Europe (France, Germany, Italy, Switzerland), in Asia (India, Pakistan, Lebanon, Palestine, Iraq, Saudi Arabia, Yemen Japan and Korea), in Africa (Egypt, Morocco, Algeria, Tunisia, Libya, Somalia, Lesotho and Malawi) and in South and North America (Nicaragua, Mexico and USA).

The Indian meal moth, *P. interpunctella*, attacks stored dates, milled cereal products, dried fruits, nuts, spices, peas, beans, lentils, chocolate and other commodities. Italso infests grains (in which it eats the embryo) and their products like gritted corn, gritted wheat, coarsely ground flour as well as grains previously infested by other insects. It rarely infests intact grains.

Economic Importance

As mentioned earlier, *P. interpunctella* is a pest of dates, either under plantation conditions on the field or during the postharvest in warehouses. The larvae feed on the ripened dates when on bunches, the fallen dates under the palms or the dates in the packaging or warehouses. The larvae enter inside the dates through the orifice left after cap removal or any crevices on the surface, and then they eat the flesh, dig in the pit, and consume its contents. While feeding and crawling, the larvae spin numerous silk threads to which their dark coloured frass attach. The presence of their silk threads with frass and shed skins are the key signs of infestation. In the USA, it is estimated that Indian meal moth, *P. interpunctella*, causes as much as 8% damage of the dates.

General Description

The moth of *P. interpunctella* is 10 mm long with wingspan 12-16 mm and the labial palps point directly forwards. The basal two-fifths of the forewings are cream coloured while the rest of the wing is dark reddish-brown with a copper sheen and some dark grey markings. The hind wings are silver grey in colour with silky edges, which have long hair on them. During rest time, the wings are folded closely together along the line of the body and antennae flat on the wings. The adult moths are nocturnal, flying and active at night. The Egg is greyish white in colour, flattened sideways and too small to be easily seen with naked eye. It is ranges from 0.3 to 0.5 mm in length.

The Larva is almost yellowish white except the head, the prothorax and the terminal abdominal segments, which may be yellow, brown or light brown in colour. The larva has six simple eyes, the first and second of which may coalesce. The mandibles contain three teeth, the middle of which is large. The eighth spiracle is circular and the hooks on the abdominal pro-legs from 3-6 forming a complete circle (Peterson, 1960). The full-grown larva is 10-14 mm long. The pupa is obtect type as the full-grown larvae pupate inside cocoons, which hang between the date fruits on bunches, on the palm tree trunk, the walls or packaging boxes, Hussain (1974). It is 9-10 mm long and fuscous pale brown in colour, Fig. 2.14.

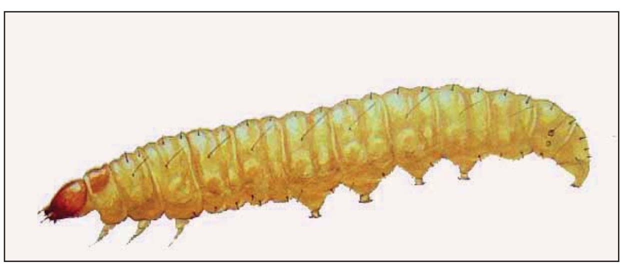


Fig. 2.14. The larvae and pupa of *P. interpunctella.*

Life Cycle

The adult moths of *P. interpunctella* usually emerge, mate and lay eggs at night. During its lifetime, the female moth deposits from 170-400 eggs, which are deposited singly or in clusters on the surface of the date fruits whether on the palms or warehouse. Eggs may also be placed directly on the exterior of packaging material. The incubation period is 4-8 days, after which the eggs hatch and larvae emerge to feed on the ripened dates. The larvae pass through 5-9 instars during their larval stage, which lasts 21-28 days in the warm months in the fields. However, in case of infesting dates in the warehouses, the larval stage may range from as short as 13 days to as long as 288 days, overwintering inside the warehouse, as a result they take a long time to develop into mature larvae.

The full-grown larvae leave the dates to pupate on the date bunches or trunk in the field or on the walls or the boxes inside the warehouses. The pupation period lasts from two to three weeks. In California, it was found that one generation of *P. interpunctella* lasts about 36 days in summer and 150 days in cold months. In addition, the adult moth lives for two days in the summer and ten days in the cold months under field conditions.

In dates warehouses, it is observed that the adult moths appear during the night hours as they are seen flying in the evening or early morning. It was found that these moths escape from the light of the day and remain resting on the walls, the package boxes or other materials present in the warehouses. The mating between the male and female adult moths starts after one hour of emergence. It was also observed that the adult moth lives for 5-13 days depending on the temperature inside the warehouse. In dates warehouse, each generation of *P. interpunctella* lasts 21-30 days.

Control Measures

The attack of the Indian meal moths, *P. interpunctella*, can be prevented in the field by covering the dates fruit bunches by suitable cloth or paper cover when the infestation possibilities are high. Chemical control measures, can be applied if necessary, include dusting with Malathion 5% before harvesting or immediately after harvesting fruits. Inside the warehouses and packaging places, the Indian meal moth is controlled by fumigation of methyl bromide or any other compound as will be discussed later.

2.2.6. Carob Moth

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

Lepigre (1963) and Carpenter and Elmer (1978) mentioned that there are many species of the genus *Ectomyelois*, which are synonyms for the species *Ectomyelois ceratoniae* Zeller, these species are *Myelois ceratoniae* Zeller, *Ectomyelois phoenicis* (Durrant), *Myelois phoenicis* Durrant and *Spectrobates ceratoniae* Zeller.

Distribution

The carob moth, *Ectomyelois* (*Myelois*) *ceratoniae* is one of the serious pests attacking dates and is found in all date growing areas. The carob moth, *E. ceratoniae*, is also known as the date, knot-horn, blunt-winged, and locust bean moth. It is of Mediterranean origin where it is an economic and sometimes major pest of crops such as carob. It is widespread in North Africa, since it is recorded in Morocco, Algeria, Tunisia, Libya, Egypt, Mauritania and Chad. It is also found in Palestine, Iran and Iraq. In Iraq, it is known as pomegranate fruit moth, as it is a very serious pest on pomegranate. In Turkey, it is mainly found attacking pomegranates. In Western Australian, carob moth is mainly a pest of almonds and carobs but it occasionally attacks other fruits. In addition to the previous countries, it is also found in Argentina and USA.

In the Sultanate of Oman *Ectomyelois ceratoniae* is present on the list of insects prohibited to enter Oman according to the Agricultural Quarantine Law issued by the Royal Decree number 49/77 and the ministerial order number 19/88 issued on November 12th, 1988. Among the hosts of the carob moth are stored dates, figs, almond, walnut, pistachio and other stored dried fruits. It can also infest the fruits of dates and pomegranate on the trees, as well as ripe oranges, quince fruits, Indian tamarind and the flowers of some *Acacia* spp. trees.

Economic Importance

The carob moth, *Ectomyelois ceratoniae*, causes economic damages to dates in some countries, e.g. North African countries. It infests both stored dates and date fruits still on the palms and helps in their drop. The larvae feed on the date fruits digging into their flesh leaving many grooves. They also leave behind big amounts of frass inside the infested dates, which greatly undermine their market value. It was also observed that the carob moth prefers to attack dry dates. It is worth mentioning that date fruits left on the palms are the source of infestation by carob moth in the following year.

General Description

The adult moth of *E. ceratoniae* is usually greyish or brown either dark or light. The forewings are light or dark grey in colour and may be brown with a light coloured, slant, transverse line. The hind wings are white or brownish white. It is small in size and approximately about 10 mm long. The distance between the forewings is around 22-24 mm, when they are fully spread. The Egg is white or white yellowish in colour.

The newly hatched larva is usually white or yellowish in colour, which then changes to pale pink or rose. The head and prothorax are brown or black. The fully-grown larva is about 20 mm long, Fig. 2.15.

The pupa is of obtect type, as the full-grown larvae pupate inside cocoons, which generally occurs inside the fruit; however, pupation sometimes occurs under the bark of trees or under litter on the ground. The pupa is brown in colour and 10 mm long.

Fig. 2.15. The larva of *E. ceratoniae.*

Life Cycle

Doumandji (1977) studied the life cycle of the carob moth, *E. ceratoniae*, and mentioned that it has 3-4 generations per year in the USA and Egypt. The 1st generation extends during April-May, the 2nd generation extends during June-July, and the 3rd generation extends during August-October, while the 4th generation extends from November to March of the following year. During cool weather, the carob moth over-winters in the larval stage on the crowns of the date palm. In this case, the larval period would last for about four months.

The female of *E. ceratoniae* deposits from 60 to 120 eggs during its short lifespan, since it lives for 3-5 days only. The incubation period takes 3-7 days, while the larval duration is lasts for about 3 weeks in the first three generations, which are occurs in the hot or mild months. The fully-grown larva leaves the infested dates and spins itself a silk cocoon to develop into an obtect pupa. The pupal duration takes about 7-10 days.

Control Measures

To control the carob moth, *E. ceratoniae*, in case of infestation to the dates still on the palms, it is advisable to cover the date bunches with bags once the fruits start to ripen. Cannibalism has been reported in the larvae of the carob moth, *E. ceratoniae*, hence it is observed that the larvae of *E. ceratoniae* attack and feed on each other, so that covering date bunches encourages the larvae to attack each other thereby reducing its population.

In addition, under field condition biological control measures can succeed to control the carob moth. Several natural enemies such as parasitoids and predators attack the carob moth. For example, the following parasitoids were recorded as parasitoids of the larvae of *E. ceratoniae*:

- *Bracon brevicornis* Wesmael (Hymenoptera: Braconidae).

- *Phanerotoma flavitestacea* Fischer (Hymenoptera: Braconidae).

To control the carob moth, *E. ceratoniae*, which attacking stored nuts like almond and pistachio, they should be heat treated before storing in insect-proof containers. Place nuts in an oven and slowly increasing the temperature to 60°C, then keeping the nuts in the oven at that temperature for one hour.

2.2.7. Pomegranate Butterfly

***Virachola* (*Deudorix*) *livia* (Klug)**
(Lepidoptera: Lycaenidae)

Distribution

Gough (1913) was the first scientist, who recorded the pomegranate butterfly, *Virachola livia*, early in the twentieth century on *Acacia edguorthin*. In addition, Hanna (1939) recorded this butterfly on many hosts in Egypt, and he reported that it principally attacked fruits of pomegranate (*Punica granatum*), date palm (*Phoenix dactylifera*) and the green pods of *Acacia farnesiana* and *A. nilotica*. It is also infest several species of ornamental trees like, e.g. *Acacia mellifera*, *A. lasiopetala*, *A. moderata*, *A. horrida*, *A. catechu*, *A. spaclicigora*, *Cassia bicapsculari*, *Dichroslachys nutars*, *Prosopis piralis* and *Punica vulgaris*. Also, it feeds occasionally on olive flowers. Generally, it is distributed in Egypt, Saudi Arabia, Oman, Iraq, Jordan, Syria, Lebanon and Palestine.

In Egypt, Awadhalla (1966) demonstrated that the pomegranate butterfly, *Virachola livia*, infested pomegranate and date fruits, and the green thorns of the sweet acacia and prickly acacia trees, *Acacia farnesiana* and *Acacia nilotica*, respectively. In addition, it is recorded for the first time on the pods of carob (*Ceratonia siliqua*) and green pods of broad bean (*Vicia faba*). In Saudi Arabia, Abdel Salam (1993) reported that, this pest infests pomegranate fruits, *Acacia* and *Ziziphus* (Jujube) trees.

In Oman, the pomegranate butterfly is a serious pest of pomegranate fruits in Al Jabal Al-Akhdar; the Green Mountain (in Arabic) and although it also attacks date fruits it is not considered an economically important pest.

Economic Importance

The larvae of the pomegranate butterfly feed on the date fruits as they pierce the fruits, feed on their contents and spoil them leading to their drop. The larvae, or caterpillars, have the capacity to move from one fruit to another, thus spoiling several fruits. The signs of infestation are characterised by the presence of holes on the fruits surrounded with black secretion and larval frass.

Generally, most of the damages incurred by the pomegranate butterfly are due to fungal attack, which penetrates the fruits through the holes made by the larvae. As a result, large portion of the fruit around the infestation area become fermented and putrefied. In addition, the odour of fermentation attracts other insects, like the drosophila flies and some dried fruits beetles to enter date fruits. It was also found that the larvae of pomegranate butterfly could feed on the new green leaflets of date palms.

General Description

The upper surface of the forewings of the female of *V. livia* is violet in colour, while the other parts are reddish violet. However, the adult male has orange-coloured forewings with brown coloured margins, which become broader at the basal and the apical sides. There is a small brown-coloured spot near the base of the outer margin of the hind wings. The lower side of the wings in both sexes is grey in colour. There are several wavy ribbons on them with two black spots, two green spots and one or more yellow spots at the outer down angle of the hind wing, Figs. 2.16 and 2.17.

There are two tail-like projections extending from the posterior side of the hind wings. There are long lashes on the body and the posterior area of the hind wings. The antenna is wide sceptre type and the distance between the apexes of the fully spread forewings (wingspan) is approximately 35-40 mm in the female and shorter in male.

The larva has dark red colour, although it is green coloured with black head when newly hatched. The full-grown larva is 15-20 mm long, with slightly flattened body but pointed at both ends. It is characterised by the presence of short black hairs arranged on each segment of its body. The Pupa is obtect type, smooth, round shape and brown in colour. It is about 10 mm long, Fig. 2.18.

Life Cycle

Three days after emerging from the pupal stage the female of the pomegranate butterfly starts to lay its eggs, which is deposited singly on the epicarp of the pomegranate fruits. The eggs are usually deposited on the inner side of the calyx and rarely on leaves, branches or flowers. In the case of the thorns of the sweet or prickly acacia trees, females always deposit eggs directly on the green thorns surface. In the case of dates, they are deposited on the outer surfaces of the date fruits.

Eggs hatch after approximately three days, and then the larva roams on the outer surface of the fruit before piercing it and feeding on the inner contents. The larva moults three times to reach maturity. The duration of the larval stage is about two weeks in summer and 45 days in winter. The full-grown larva pupates inside the fruit near a hole made by the larva on the outer surface.

Fig. 2.17. The lower side of both sexes of *V. livia.*

Female

Male

Fig. 2.16. The pomegranate butterfly *Virachola livia.*

Fig. 2.18. The larva and pupa of *Virachola livia.*

The duration of the pupal stage ranges from one week in summer to one month in winter, then the adult butterflies emerges and repeats the life cycle. The mean duration in the development of both sexes from egg to adult was 36-39 days. The pomegranate butterfly, *V. livia*, has 2-3 generations per year on pomegranate fruit.

Control Measures

1. Agricultural Control

Removing all sweet and prickly *Acacia* spp. trees adjacent to or near the date palm groves thus reduces the possibility of the pomegranate butterfly to find the alternative hosts to continue its generations and life during the absence of the principal hosts. In addition, avoid planting any kind of trees known to be of the preferred hosts of the pomegranate butterfly near the infested orchards.

2. Biological Control

The parasitoid *Brachymeria aegyptiaca* (Masi) found to parasitize the pupal stage. The egg parasitic tiny wasps *Trichogramma* spp. are the most widely used insect natural enemy in the world (Li, 1994) partly because they are easy to mass rear, and they attack many important insect eggs, especially eggs of moths and butterflies. In many countries *Trichogramma* spp. (Homoptera: Trichogrammatidae) are released to control different caterpillar pests attacking corn, rice, sugarcane, cotton, vegetables, sugar beets, fruit trees and pine and spruce trees.

As mentioned before the pomegranate butterfly, *Virachola livia*, is a fruit borer and considered one of the most destructive insect pests attacking pomegranates in many countries, e.g. Egypt, India and Oman. In India the pomegranate fruit borer, *Deudorix isocrates* was successfully controlled by releasing the egg parasitoid *Trichogramma chilotraeae* (Singh, 2001).

In Oman, Kinawy, *et al*. (2008) mentioned that in preliminary studies during 1999 and 2000 the use of the egg parasitic wasp, *Trichogramma brassicae* Bezdenko, against the pomegranate fruit borer, *V. livia*, in Al Jabal

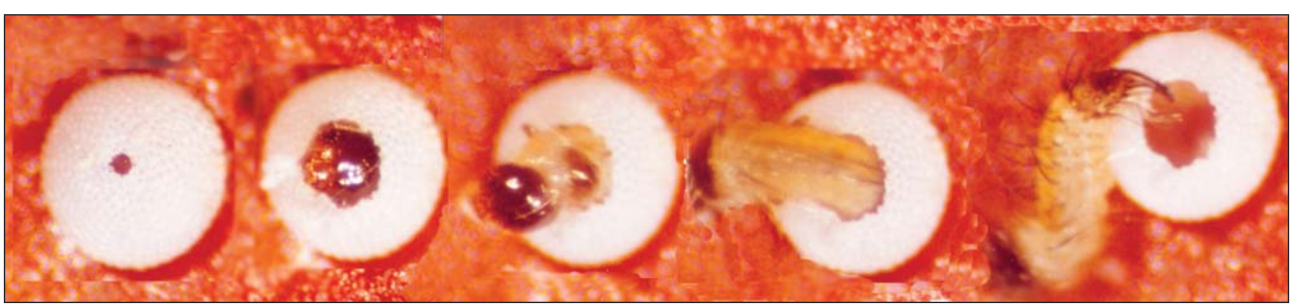


Fig. 2.19. First instar larva of *V. livia* hatching from egg.

Al-Akhdar was very effective. They added that the parasitic wasp, *T. brassicae*, was imported and released during the activity of the pomegranate fruit borer from May until August, and that it was very effective. From 2005 mass production of the egg parasitic wasps, *Trichogramma* spp., was started in Oman. The grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae), was used as a host to rear *Trichogramma* spp. on its eggs. Data in Table 2.5 presented the total number of the egg parasitic wasps, *Trichogramma brassicae*, produced and released by Ministry of Agriculture (Mokhtar, 2007) and by Royal Gardens and Farms (Kinawy, 2007), during years 2006-2011. During 2006 and 2007, about 370 million of the egg parasitic wasps, *Trichogramma* spp., were released at weekly intervals in Al Jabal Al-Akhdar in Oman during the active season of the pomegranate fruit borer. During the last four successive years,2008, 2009, 1010 and 2011 the total number of *Trichogramma* spp. released in Al Jabal Al-Akhdar in Oman were 306.0, 237.0, 253.4 and 261.0 million, respectively.

Now there was no doubt that, the integrated pest management against the pomegranate butterfly, *Virachola livia*, in Oman, mainly depends on the classical biological control by releasing the egg parasitic wasp, *Trichogramma* spp.

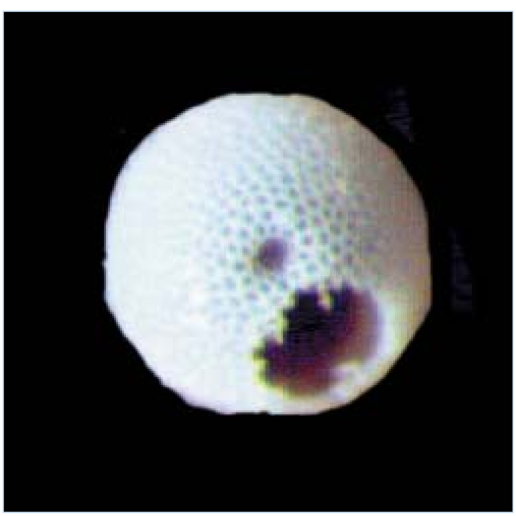


Fig. 2.20. Exit hole of the egg parasitic wasp, *Trichogramma brassicae* from *V. livia* egg.

3. Chemical Control

There is no need to follow a chemical pest control program for this pest on the date palm trees because of its limited economic importance. When necessary, the infested trees can be sprayed with one of the recommended insecticide as Deltamethrin (Decis®). Temerak and Sayed (2001) evaluated the natural product Spinosad (Tracer®) for the control of the pomegranate butterfly, *Virachola livia* (Klug), on date palm fruit in the New Valley in Egypt. They mentioned that all rates of Spinosad 24 SC even the lowest 10 ml/HL showed 100% reduction of infestation with *V. livia*. Spinosad proved to have some ovi-larvicidal activity. In addition, Spinosad proved to be working under dry hot condition up to 52^{o}C with no phytotoxicity to date palms, and they recommended using Spinosad at the rate of 10 ml/HL to control the pomegranate butterfly, *Virachola livia*.

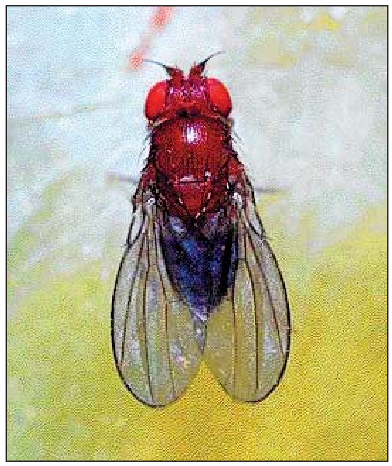
Table 2.5. The total number of the egg parasitic wasp, *Trichogramma brassicae*, released in Al-Jabal Al-Akhdar in Oman during years (2006-2011).

Year	Total number of the egg parasitic wasp, *Trichogramma brassicae*, released in Jabal Akhdar in Oman (in millions)
2006	178.5
2007	191.5
2008	306.0
2009	237.0
2010	253.4
2011	261.0

2.3. Order: Diptera

2.3.1. Vinegar Fly

***Drosophila melanogaster* Meigen**
(Diptera: Drosophilidae)



Distribution

The vinegar fly, *Drosophila melanogaster*, is also called the common fruit fly. Shtakel'berg (1970) mentioned that the vinegar fly, *D. melanogaster*, is probably present in most parts of the world occupied by man outside of the Arctic and Antarctic areas with 60° latitude considered to be its northern limit. It is worth mentioning that Drosophila flies are of quintessential importance in genetic studies.

It is widespread, especially where there are fermented materials. Adults of *D. melanogaster* are primarily attracted to fermentation products, while the larvae usually develop in rotting or fermenting fruit. There is no reliable evidence of them ever attacking intact fruit in the manner of true fruit flies (Tephritidae). However, they are known to transmit micro-fungi, notably yeasts, and in this respect can cause damage to some fruit crops, particularly grapes (Laurent, 1998).

It infests the fermented or rotten date fruits with high moisture content, but rarely infests intact dates fruits. It also feeds on fruits and vegetables with high moisture content. Drosophila flies are widely present in Morocco, Algeria, Tunisia, Libya, Sudan, Iraq and Oman among many other countries.

Economic Importance

As mentioned above, the Drosophila flies infest fermented fruits including dates. The presence of large numbers of the adult flies inside a warehouse contaminates stored dates. Even though this insect rarely attacks intact fruits, they are considered one of the most damaging pests if large numbers are present in packaging facilities, where they infest the fermented fruits and swarm over the intact dates leaving their excreta leading to contamination. Thus, all the necessary precautions should be taken to prevent the entry of the vinegar flies, *D. melanogaster*, inside the packaging facilities including the regular disposal of any fermented fruits present there.

General Description

The adult insect is yellow in colour. The abdomen is black-coloured with a yellow band on the first, second and third abdominal segments. It is a small fly, wing length approximately 2-2.5 mm long, first flagellomere at most 1.5 times as long as broad and male sex-comb restricted to apex of front tarsal segment one and comprised of 9-12 closely adpressed black teeth set obliquely. The egg is shiny white in colour, oval in shape and in average about 0.5 mm in length. The eggs of *Drosophila melanogaster* have two long respiratory processes, which help to distinguish them from the eggs of most other Diptera. Its outer chorion shell surface shows hexagonal sculpturing due to the flattened follicle cells surrounding it. Near one end of the egg, which corresponds to the anterior end of the embryo, is a pair of slender filaments. These filaments are about 0.5 mm long and serve not only a respiratory function, but also prevent the egg from sinking in soft media. The larva is creamy in colour or transparent, thus colouring according to the type of food in its alimentary system, Fig. 2.21. The mature larva is about 5 mm long. Smith (1989) noted that the life cycle of *Drosophila* spp. is so short, and the flies easy to rear, that it is more practical to rear larvae through to adults rather than attempt their identification. The pupa is yellow in colour when newly formed and then turns to brown colour. The length of a pupa is 3 mm. The puparia of Drosophilidae are distinctive in having both the anterior and posterior spiracles at the ends of long processes (Smith, 1989), but separation of individual species is not practical.

Fig. 2.21. Larvae of Vinger fly, *Drosophila* spp.

Life Cycle

After two days of developing from a pupa, the female fly starts to lay eggs in new fissures on ripened or rotten fruits. A single female of *D. melanogaster* can continue to deposit eggs for a period of three weeks, totalling about two thousand eggs during its lifespan. The eggs hatch after one day of depositing, releasing larvae (maggots), which feed on the rotten fruits, repeatedly moult, and then develop into pupae; all in four days. The duration of the pupal stage is about five. Thus, the whole life cycle of the *Drosophila melanogaster* (from oviposition to adult flies) averages a period of 10 days.

However, the different developmental forms are influenced by the surrounding environmental conditions, like the sun heat, the winds and the vicissitudes in temperature. Generally, life cycle of *D. melanogaster* under natural conditions is little known, but clearly, in warm conditions it could complete 40 generations in a year. In temperate areas, some *Drosophila* spp. can overwinter outside either as dormant adults or as larvae (Shorrocks, 1972), but there are no specific records for *D. melanogaster* doing so.

Control Measures

1. Agricultural Control

Fruit tree species, which are commonly infested by the vinegar fly, *D. melanogaster*, should not be planted beside or near dates packaging or storing houses. Fruit orchards and date warehouses, should be cleaned and any rotten fruits should be regularly removed. In addition, fruits on trees near the date warehouses should be harvested promptly once they are ripened and not left to become overripe. The collected fruits should be transported and marketed as soon as possible and not stay overnight, in order to prevent the flies from attacking them and depositing their eggs.

2. Chemical Control

Dusting the boxes or crates of fruit, if necessary, with powder consisting of 1% pyrethrine, 1% piperonyl butoxyde and talcum decreases the number of drosophila flies. This can be repeated whenever needed. It is recommended to spray the walls of the date warehouse from outside with suitable pesticide to prevent entrance of flies inside the warehouse.

2.4. Order: Acarina

2.4.1. Mushroom Mite, *Tyrophagus lintneri* Osborne

2.4.2. Grain or Mould Mite, *Tyrophagus putrescentiae* (Schrank)

There are a number of species of mites that infest stored food, dried eggs, herring meal, copra, cheese, and different kinds of nuts, grain products, dried fruit, dried meat, cheese, stored dates and other food products. Examples of these mites are the Mushroom mite, *Tyrophagus lintneri* Osborne, and the Grain or Mould mite, *Tyrophagus putrescentiae* (Schrank).

These two mites are classified as belonging to the subclass Acari, order Astigmata and family Acaridae. These mites often prefer moist, tropical environments. Sometimes the surface of infested materials appears to move due to the enormous numbers of mites. Sass (2006) showed that in a wet condition, mould mites in the 20ºC and 25ºC temperature range remained alive for 31 days without food.

Economic Importance

Mites feed on old dates stored in warehouse with high humidity, and infected dates attain an unpleasant odour and become unfit for human consumption. In correctly stored dates, these mites cause no economic damage.

General Description

Tyrophagus spp. mites are whitish in colour, oval shape, Fig. 2.22, and so small (280-415 µm) as to be barely discernable to the naked eye. The female laid their eggs promiscuously over the food materials. The young larva has three pairs of legs, and then the nymphs and the adult have four pairs of legs. When conditions are unfavourable, the mites pass into a very non-active, non-feeding, but very resistant stage, known as the hypopus. In this stage, the body wall hardens and suckers are formed on the underside with which they may attach to other insects or mice and be carried to other new and suitable locations. The mites may remain in this condition for a number of months without food, but when conditions become favourable to their growth, they moult and again become active.

Fig. 2.22. The Grain or Mould mite, *T. putrescentiae.*

Life Cycle

Under moist conditions (12-18% moisture content) and warm summer temperature, a generation of most species of genus *Tyrophagus* can be completed in 8 to 21 days. As the temperature falls the length of the life cycle increases greatly. The mould mite will breed readily above 30ºC. The mould mite is less tolerant to low temperature and cannot develop below 10ºC. However, in an inactive state, this mite can survive at zeroºC. At favourable temperatures and 90 to 100% relative humidity, the female can lay an average of 437 eggs (Rodriguez and Rodriguez, 1997). At a given temperature, larval and nymphal stages require about equal time for development.

Control Measures

Tyrophagus spp. mites does not cause economic damage to stored dates require to use special programs to control them, and despite of that, follow some preventive measures are sufficient to avoid any infestation with these mites. The most important of these measures include:

- Ventilated dates warehouses to prevent the raise of humidity.
- Store dates only in a clean, dry area. Never store dates under damp, poorly ventilated conditions. If necessary, increase air circulation to reduce relative humidity and prevent moulds and mildews.
- Do not leave any old dates on the floor of the warehouse. The removal of these dates and disposal greatly help in reducing the number of mites and dates infected.

Fungi and Yeasts That Infect Stored Dates

There are many fungi and yeasts, which affect stored dates causing damage making them unfit for human consumption. The following are the most important fungi, which infested stored dates and cause rotting: *Aspergillus* sp., *Alternaria* sp. and *Penicillium* spp.

The above-mentioned fungi infect dates with water content more than 20%. Since the moisture content in some dates varieties may reach 25 or 30%, the possibility is high that fungal infections would cause such dates to rot, in particular during storage. It is easy to detect fungal infection of stored dates by looking for their mycelia and for changes in colour and taste of the decay-infected dates. The above-mentioned three fungi also affect date fruits before harvest, causing fruit rot disease (see chapter IV).

In addition to the previous fungi that cause rotting of dates, there are many species of yeasts, which attack stored food materials that contain a high proportion of sugar such as date fruits. The most important yeasts attacking date fruits are *Zygosaccharomyces cavarae*, *Z. barkeri*, *Z. globiformis*, *Saccnaromyces cervesiae*, *Hansenula fermentans*, *Candida chalmeris*, *Candida krusei*, *Torulopsis dactylifera* and *Torulopsis pulcherrina*.

The yeasts infecting stored dates cause gradual change in the taste and colour of dates and emission of undesirable odour from the affected dates. It was observed that yeast infection is particularly high when fermented and healthy dates are together in stores, or when contaminated equipment is used and when dates are packed at high humidity. The following are the most important methods recommended to prevent rotting and fermentation of stored dates:

- Do not store damaged and fermented dates with sound ones.
- Pay attention to hygiene and disinfection of the hands of workers employed in the preparation and pressing of date fruits.
- Sterilization of instruments used in pressing dates.
- Store dates in refrigerated warehouses.
- Use heat to sterilize dates.
- Fumigation of dates, as soon as possible after harvesting and before storage.

Procedures to Reduce Infestation of Dates Store Insects

There is no doubt that the control of insect pests which affect stored dates after harvesting, during handling or storing to be consumed at a later point in time, is an intricate process, which is closely related to all steps of date production. Pest control starts with protecting the dates from the pests while still on the palms, collecting the date fruits at the proper time, keeping them clean, and then the speedy transfer to the packing or processing facilities. All these measures, if properly done, help to minimise future infestation of dates by the pests in the warehouses, especially if these warehouses are thoroughly cleaned and completely free from insect pests.

There are several measures that should be considered to decrease infestation by stored date pests, whether in the fields before harvesting or post-harvesting during handling and transferring the date fruits to the warehouses.

I. Under Field Conditions

1. Inspection of date fruit on the palm

A specialist should inspect the date fruits on the palms before collection with enough time to identify the level of infestation by stored date pests known to be capable of field infestation and are transferred with the date fruits to the warehouses, e.g. *Plodia interpunctella*, *Ectomyelois ceratoniae*, *Ephestia* spp. and *Carpophilus* spp.

The specialist assesses the population density of these pests, if any, to be controlled in the field at the proper time. Pest control can be done either by the application of the chemical insecticides or covering the fruit bunches to prevent the insects from reaching the date fruits to lay their eggs. This is the practice in the USA against the dry fruit beetles to acquire clean dates before being transferred to the packaging, pressing and storing warehouses (Carpenter and Elmer, 1978).

2. Disposal of fallen date fruits

In many date varieties, the fruits start to fall long before the proper time to harvest. These dropped fruits are easily infested by pests and become important hosts for the stored pests to proliferate on. They also become a source of infestation when mixed with other harvested date fruits. For these reasons, the newly harvested date fruits should not be mixed with fallen fruits, which should be collected and disposed of immediately. There are several ways to dispose of the fallen date fruits and prevent them from being mixed with the properly harvested ones. One of these ways is allowing animals like cattle or sheep to roam in the date plantations allowing them to feed on the dropped date fruits before and after harvesting and storing. Hussain (1985) reported that when newly harvested dates were stored alone in one case and mixed with fallen dates in the second case, and stored in two separate stores for nine months, infestation was greater in the latter than in the former, Table 2.6.

Table 2.6. Percentage of infestation with stored date pests in newly harvested dates stored together with fallen ones, compared with those stored alone.

Month	% of infestation with stored date pests	
	Newly harvested dates stored with fallen dates	Newly harvested dates stored alone
November	70	22
December	82	37
January	81	39
February	90	51
March	92	53
April	92	56
May	92	53
June	93	58
July	93	58

3. Collecting or harvesting date fruits at the appropriate time

Date fruits harvesting by either picking individual dates or cutting the whole bunch should be done at the appropriate time to decrease the time left for stored pests to attack dates. It is known that date fruits do not all ripen at the same time in the field for many reasons. In addition, among date palm varieties, some are early ripening, while others are late ripening. The age of the palm and the surrounding environmental conditions, affect the ripening time within the same variety. Fruits of old and tall date palms ripen before those of younger and smaller palms of the same variety.

Generally, it is noticeable that stored pests infestations appear and increase on date fruits if they are harvested when already over-ripe or if they are late varieties. There are several methods to prevent the infestation in the field, e.g. by covering the fruit bunches by special coverings made of paper or cloths or by dusting bunches with Malathion insecticide long enough before the harvest time to protect from the pest infestation.

4. Disposal of fruits dropped from date palms and other fruit trees

In some areas the farmers plant different fruit trees under the date palms such as citrus, pomegranate, guava, fig and others. In these cases, great care should be given to harvest these fruits in their due time, gather the fallen fruits and dispose of them as quickly as possible as they are important hosts to many of the stored date pests.

5. Transport of dates

Harvested dates from the palms should be transported to the stores immediately. This should be done in clean transportation containers, which are free from any wastes or residues of other agricultural crops, especially any dates from previous harvests. During transportation from the farms to the warehouses, it is prudent to cover the date fruits with a wrap to prevent the adult pests from reaching the fruits to lay their eggs on.

6. Dates stored in farms

Occasionally, the date growers resort to storing the date fruits in the farms for long periods-up to several months. The dates are stored in the farms on mats placed on appropriate heights and sheltered with fitting covers of date leaflets or mats. These "stored" dates are subject to insect pest infestations. However, using the right covers would prevent moths of *Ephestia* spp. from depositing their eggs on the date fruits and thus decreasing the severity of infestation by pests of stored dates. It was found that using cloth covers, to protect the date fruits, is better than using the traditional mats. It was also reported that the best protective covers are those made from textile pre-treated with Malathion pesticide, one gram of the active substance for each square metre of fabric. Hussain (1985) demonstrated the importance of using such covers on the date fruits in the farms to protect them from infestation, Table 2.7.

Table 2.7. Demonstration of different materials used to cover the dates stored in the farms and % of infestation with stored pests.

Type of cover	% of infestation with stored date pests
Fabric pre-treated with Malathion	1.5
Mats pre-treated with Malathion	4.5
Cloth (not treated)	6.0
Mats (not treated)	21.0
No cover	30.0

II. In the warehouses

Several precautions and treatments should be followed before and during the storage of dates in the storing, squeezing and packaging facilities to provide the suitable conditions to keep the dates and prevent pest infestation. These measures can be summarized in the following:

- Cleaning the warehouses and pressing facilities of any dates left over from the previous seasons and sterilizing stores by spraying them with Malathion 57% in the ratio of 1 cm3 per 1 m2 of the floor, ceiling and walls of the room. The inside and outside of warehouses should be sprayed well before receiving the new harvest.
- Making sure that all the vents and windows are carefully sealed and covered with narrowly meshed screens to prevent the stored pests from entering the warehouse.
- Using a rodent-proof door on the main entrance, by fixing metal kick plate and gnaw-proof edge guards to prevent entry of rats or mice.
- Insuring general hygiene in presses by collecting any fruits dropped on the floor, cleaning and washing the premises and equipment daily and not storing any infested dates.
- Inside the warehouses, the boxes or bags of packaged dates should be arranged in rows leaving enough spaces for easy inspection of the packages periodically.
- If the dates are stored loosely in heaps without packaging, the heaps should be arranged in such a way to allow inspectors to check their condition and spot any infestation at the proper time for the pest control measures.

Prevention and Control Measures of Dates Store Insects

I. Refrigerated warehouses

The use of refrigerated warehouses to store dates is considered one of the best ways to protect them from insect pests. When the dates are stored in refrigerated warehouses, they may need several days to cool. The temperature inside such warehouses ranges from 5°C to -17°C according to the variety, the package and the moisture contents of dates among others. In Jordan, dates “Medjool variety” (at tamer stage) can be refrigerated at (-18°C) for one year or at (-28°C) for about five years, and then these dates can be used as fresh product (Personal communication).

The humidity of the warehouse is one of the important factors to consider. Stored dates require that the relative humidity inside the refrigerated warehouse is in the range from 65% to 70% lest they absorb additional moisture. At 58% relative humidity inside the warehouse, the stored dates absorb around 1.5% of this moisture every month. It was found that when the dates were stored in refrigerated warehouses they are not infected by insects. When dates were stored at a temperature of 3 degrees below zero, their moisture content rose from 10% to 17% in nine months of storage. While, when they were stored at -5°C the moisture content rose from 11% to 14% during the same period.

In addition, it was found that dates with high moisture are infected by a number of fungi when stored in refrigerated warehouses at a temperature near zero degrees. However, when storing dates with high moisture content at temperature below zero degrees, the fungi development was suppressed. Hussain (1985) mentioned that the growth of rotting fungi was supressed when storing dates with 20% moisture content at a temperature of 12-17 below zero degrees.

The low temperature degrees in the refrigerated warehouses affect many stored dates insects. At a temperature of -5°C to -6°C, the larvae of the fig moth can live for a period of 85 days, while the larvae of the saw-toothed grain beetle would die in less than two weeks if subjected to a near zero degree. At the same temperature, the adults of the same insect and the larvae of the Indian meal moth will die after approximately one month of storing the dates.

II. Fumigation of Dates

One of the most important pest control measures in stored dates is chemical control using fumigants in a process called fumigation. Fumigation is usually employed against insect pests attacking the stored grains, dates and other stored food materials. It is one of the most effective measures in controlling those pests, against which dusting or spraying of chemical pesticides is difficult or impossible to use. This is because the vast majority of these pests actually live inside the stored grains and date fruits, which make it impossible to kill them except by using gases or fumigants.

It is worth mentioning here that the purpose of fumigating the dates is to kill all the stages of the insect present on and inside them. However, the effect of the fumigants against insect stages will be only during the fumigation time, i.e. when the dates are removed from the fumigation chamber, they are again subject to become re-infested. Therefore, after fumigation it is indispensable to store the fumigated dates in sterile warehouses and to cover them with sterile wrappers to prevent any re-infestation.

Fumigation is considered a dangerous and complicated process, which requires knowledge and expertise. Usually, the used fumigants are classified by many countries as Restricted Pesticides, i.e. chemical compounds that are prohibited to be used by other than specialists. Generally, specialists or people with extensive experience in handling such dangerous materials should carry out the fumigation. The most important fumigants employed in fumigating stored dates are Methyl Bromide and Phostoxin (Aluminium or Magnesium phosphide).

There are many precautions that should be considered to avoid problems during fumigation. These can be summarized as follows:

1. Stay within permissible safety limits of the fumigants used to control date insects, because humans and animals directly consume dates. In addition, study the effects of fumigants used on the quality of dates regarding their taste and odour.

2. Awareness of the conditions, which lead to the success of fumigation. The fumigation process depends upon temperature, dates moisture content and the surrounding environmental conditions. The suitable dose against a particular insect varies with weather conditions and many other factors.

3. Take all-necessary precautions against the dangers of gas poisoning. Among the most important of these precautions is ensuring that the fumigation space is tightly sealed. It is known that the gases emitted from fumigants are extremely toxic to human beings.

However, the speed of inducing the toxic effect varies from one gas to another. For example, poisoning and death occur in a matter of seconds upon exposure to hydrogen cyanide, while poisoning by carbon disulphide is relatively slow and the victim can be saved when the signs of poisoning appear. Some of these gases have distinct, strong odours that can give enough warning to the practitioners if there is a leakage or spread of the gas. Carbon disulphide has an unacceptable odour while phosphine gas has garlic-like odour, whereas many of fumigants cannot be detected by odour especially in low concentration like methyl bromide, as its danger increases when inhaled and the human being is poisoning without feeling it. Thus, these gases are generally mixed with some others, known as warning gases, which either have strong, distinct odours or can induce increased tear secretions like chloropicrin gas, which is irritant and generating tears and coughing.

4. The place or the warehouse should be checked for the absence of any gas residue by using special equipment that depend on the type of gas used. Methyl bromide, for instance, is detected by halides indicators, which are gas lamps utilising the change in the colour from the usual yellow flame to green then blue when exposed to methyl bromide according to the concentration. When

readily inflammable gases are used like carbon disulfide, extreme caution should be exerted to keep away any source of flames or electric sparks that might cause fire or combustion.

5. Difficulty in handling and transferring the fumigants as most of them are present under pressure in liquid form in special containers. In all cases, the gas may leak leading to poisoning of the persons handling or transferring the containers. What makes thing even worse is that many of these gases are inflammable which adds the hazard of fire to toxicity. Hence, extreme care should be taken when transporting and storing these gases with periodic inspection for the concentrations of gases to make sure that nothing is leaking.

Notes about fumigants

1. Methyl Bromide (CH_3 Br)

Methyl bromide is used extensively since 1947 in fumigating stored foodstuffs, as it is employed with stored dates, dried fruits, and cereal grains as well as fresh vegetables and living plants to kill the insect pests. In addition, it is used in fumigating cargo ships and train cars and the like. Commercially, methyl bromide is sold liquefied under high pressure in iron cylinders. It is also used on a large scale in sterilizing soil before planting to exterminate all the micro-organisms harmful to the crops like nematodes, soil insects, soil born-fungi and bacteria.

• Physical Properties of methyl bromide

The chemical name is bromomethane. It is a colourless liquid, which boils at 3.56°C; it is colourless in low concentrations and has a strong rotten odour in high concentrations. It dissolves in water at 20°C in the rate of 1.75 g/10 g and dissolves in the low concentrations of alcohol, ether, esters, ketones, halogenated hydrocarbons, aromatic hydrocarbons and sulphur dioxide. The gas is heavier than air and when both are mixed, it is not inflammable. Methyl bromide is a strong solvent of organic matter like natural rubber. It has no effect on metals but the liquid form erodes aluminium.

• Toxic effects of methyl bromide

When exposed to lethal concentrations of methyl bromide, the victim has trouble in breathing, dyspnoea, and cardiac arrest and CNS depression. Overexposure may cause toxic neurological effects with poor and slow prognosis. Generally, the oral LD_{50} in mice is 214 mg/Kg body weight and LC_{50} by inhalation is 3210 part per million in 15 minutes. The key symptoms of toxicity in humans, which may appear one hour after exposure to the gas, are blurred vision, lack of concentration, anorexia, slow speech and muscle spasms. Because of its high toxicity, halides indicators should be used routinely to detect any traces of the gas in the treated areas. Normally, methyl bromide is considered harmful to humans, if present in the air in the following concentrations:

1. 20 ppm allowed for 8 hours one time per week.
2. 100 ppm allowed for 7 hours.
3. 200 ppm allowed for 1 hour.
4. 1000 ppm allowed for 5 minutes.

• Methyl bromide as one of the ozone-depleting substances

Ozone (O_3) has three oxygen atoms and is continually formed, decomposed then reformed in the stratosphere layer, which lies 15-55 kilometres above the earth surface. It is found that the optimal conditions for the balanced cycle, of forming and breaking up of the ozone, exist at an altitude of 20-25 kilometres above the Earth's surface. As a result, this layer of the stratosphere is the richest in ozone and is termed the ozone layer.

The ozone layer absorbs most of the harmful ultraviolet radiation in the sun light and thus prevents high levels from reaching the Earth's surface. Exposure to ultraviolet radiation leads to skin cancers in man and animals, harms the eyes and has deteriorating effects on the immune system. In addition, many plants that are highly susceptible to this type of radiation and their exposure to high levels may cause their destruction. Ultraviolet radiation can do damages to the marine environments and other ecosystems. Generally, ultraviolet exposure can harm all forms of life on Earth. Based on these facts and much other scientific evidence a correlation between some synthetic chemical substances and depletion of the ozone layer was established. All efforts had to be unified to find an immediate and appropriated solution to this problem that is affecting all forms of life on Earth.

This international collaboration culminated in the ratification of Vienna Convention for the Protection of the Ozone Layer in 1985, which stressed the importance of formulating a detailed protocol that specifies the duties of nations regarding ozone-depleting substances. The scientific efforts were crowned by the approval of the Montreal Protocol on Substances That Deplete the Ozone Layer. This treaty was ratified on September 16, 1987 and became law on January 1, 1989. Since then, it has undergone five revisions, i.e. in 1990 (London), 1992 (Copenhagen), 1995 (Vienna), 1997 (Montreal), and 1999 (Beijing). These revisions were made to hasten and increase the commitment of the nations in the process of phasing out ozone depleting substances. Methyl bromide is regarded as one of the most serious ozone depleting substances according to Montreal Protocol on Substances that Deplete the Ozone Layer, which also includes chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform.

The Sultanate of Oman has a pioneering role in the field of environmental protection, and its interest in the ecological issues whether local or international has made it one of the leading nations to join most of the international conventions concerning environmental protection issues. The Sultanate of Oman shared with other nations of the world the concerns and commitments about the ozone layer issue. According to the Royal Decree No. 73/98 dated 28/9/1998, the Sultanate of Oman became a party to the Vienna Convention for the Protection of the Ozone Layer, the Montreal Protocol on Substances That Deplete the Ozone Layer, and its revisions of London and Copenhagen. Based on the above, Oman as one of the members is committed according to Article 5 in Montreal Protocol and its Revisions to gradually phasing-out the use of ozone depleting substances. Accordingly, the amounts used of methyl bromide will be decreased as show in Table 2.8.

Table 2.8. Levels of reduction in Methyl bromide in Oman according to article 5 in Montreal Protocol and its amendments.

Date	Reduction Level	Remarks
January 1st, 2002	Consumption freeze	Base level is consumption average in the period from 1995 to 1998.
January 1st, 2005	20 %	
January 1st, 2015	100 %	Possibility of exemptions for necessary uses (exemption for quantities used in quarantine and before shipment).

2. Phosphine gas or Hydrogen Phosphide (PH_3)

The chemical name of this pesticide is Aluminium or Magnesium Phosphide and the active ingredient is hydrogen phosphide (PH_3).

• Physical and chemical properties

Hydrogen phosphide is a colourless gas with carbide or garlic odour. It dissolves in water and carbon disulfide. It is presented as tablets, pellets or plates and strips of aluminium phosphide (or magnesium phosphide) from which phosphine gas (hydrogen phosphide) is released upon exposure to the moisture of the air. It is used widely in pest control of stored materials like; dates, grains and others. By virtue of its low molecular weight and low boiling point, hydrogen phosphide has high ability to spread and diffuse thoroughly inside the stored materials. Hydrogen phosphide is characterised by its high toxicity on the stored foodstuff insects even in low concentrations. Each tablet of aluminium phosphide are mainly composed of pure, finely, ground aluminium/magnesium phosphide, blended with ammonium carbamate. Ammonia (from ammonium carbamate) is a pungent smelling warning gas, being to develop immediately upon removal of tablets or pellets from their airtight package. Each tablet is 3g in weight (corresponding 1g phosphine). When the pesticide is in the form of pellets, each weighs 0.6g, which releases 0.2g of phosphine.

This pesticide is used in the ratio of 16-17g for each square metre by putting the tablets in a carton container not using copper utensils as phosphine reacts with copper metal or its salts in high moisture during fumigation. After the end of the process, ashes of aluminium hydroxide are remaining, which should be disposed of properly to avoid being mixed with the dates or any other food materials.

It is worth mentioning that, the amounts of phosphine gas use are increasing year after year because of its high capacity of decomposition, not leaving toxic residues on the treated foodstuffs and its powerful toxic effects against the insects.

• The toxic effects of phosphine gas

Generally, phosphine gas is considered harmful to man if present in the air in the following concentrations:

1. The critical limit is 0.1 ppm.
2. 0.3 ppm is allowed for 8 hours daily for maximum of five continuous days.
3. One part per million is permissible for 7 hours.
4. 25 ppm for 1 hour.
5. 50 ppm for five minutes only.

3. Hydrogen Cyanide (Hydrocyanic Acid)

It is presented in a liquid or solid form as sodium cyanide to which sulphuric acid is added to react, liberating HCN gas. This pesticide is suitable in fumigating dried foodstuffs because it dissolves in water. It is used in the ratio of 450g for each 28 cubic metres.

• The toxic effects of hydrogen cyanide

1. 10 ppm is permissible to work daily for 8 hours daily.
2. 25 ppm causes the appearance of some signs of poisoning.
3. 50 ppm causes signs of poisoning appear after half or one hour.
4. 100 ppm causes toxicity in half an hour.
5. 200 ppm causes rapid death.

The most important signs of poisoning of this gas are irritation in the eyes and pharynx, headache and sensation of burning in the tongue, pressure on the forehead, loss of balance and vomiting.

4. Carbon Disulfide (CS_2)

This pesticide is used to fumigate the dates, foodstuffs and the soil especially in hot regions. It is extremely dangerous as it is inflammable and combustible. It is in liquid form and the liquid is poured in a shallow pot and hanged from the ceiling of the room or it can be put over the dates pile. Carbon disulphide is used at the rate of 3-6 kg per 28 cubic metres. It is important to store its canisters in cool store with good ventilation. The victim of poisoning from this gas shows symptoms of numbness and coma. Even exposure to low concentrations for several weeks has deteriorating effects on the central nervous system.

5. Sulfur Dioxide (SO_2)

This gas is obtained by burning sulphur in the fumigation chambers and is used only with stored dried foodstuff like dried dates, apricots and figs. Sulfur dioxide affects all metals so it is used mainly in wooden containers like big wooden boxes.

6. Ethyl Formate ($HCOOC_2H_5$)

This fumigant is used for rapid fumigation of packaged pressed dates at the rate of 1 ml per 1.5 Kg of dates or 775 ml per one cubic metre of dates packed in boxes. Ethyl Formate is introduced inside the packages using a syringe.

Field Fumigation

This method is employed when there are no suitable rooms and quantities of products are available for fumigation during the packing. It is done by piling the date boxes over a mat on a completely clean ground. The boxes are arranged in square 5-7 boxes high. Four empty boxes are placed on top to form what looks like a room. Then the boxes are covered with a cover made of a gas-impermeable material like polyethylene or nylon. The edges around the boxes are folded and sand bags are put on them to prevent any leakage of gas. After the end of fumigation, the sand bags are removed and the cover is removed from two opposing sides first to get rid of residual gas, then it is removed from all sides. Phosphine gas can be used at the rate of 45 tablets or 165 pellets for each 28 cubic metres for 5 days at a temperature degree from 12°C to 15°C, 4 days at 16°C-20°C and only 3 days at 21°C or more.

Fumigation in ordinary room

This method is used extensively in pressed dates to fumigate dates in rooms under normal atmospheric pressure provided that they are perfectly sealed. In this method, Phosphine gas can be used at the same rates as above.

Fumigation in vacuumed room (Vacuum Fumigation)

This method is usually used in the agricultural quarantine in rooms in the shape of tight cylinders made of steel with enforced walls and attached to a vacuum pump. Vacuum fumigation is used in Sultan Qaboos Port in Muscat, Fig. 2.23, and Salalah port in Oman where the foodstuff, agricultural and wood products are fumigated using methyl bromide in the concentrations explained in Table 2.9. Vacuum fumigation has the advantage of shortening

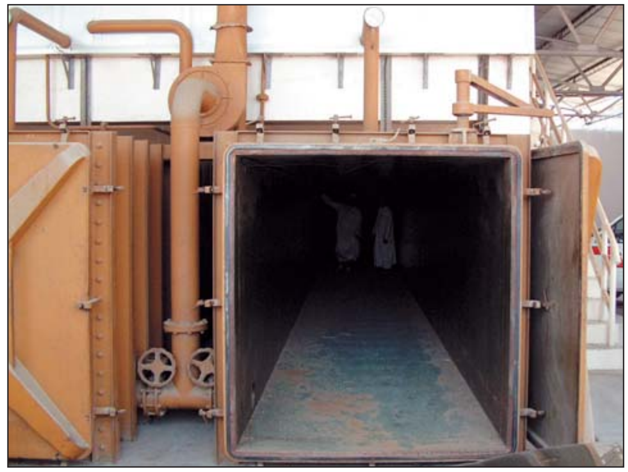


Fig. 2.23. Fumigation vacuum chamber in Sultan Qaboos Port in Muscat, Oman.

the time needed for fumigation, which ranges between 2 and 4 hours. This is due to the lack of oxygen in the vacuum, which forces the insects to increase respiration, and subsequently the fumigant gases enter much faster to kill them. In addition, low pressure has a fatal mechanical effect on the insects present in the treated dates.

In this method, the dates are placed inside the cylinder and after closing the two hatches, air is sucked out by a suction pump for 10-15 minutes, which decreases the pressure to 25-150 mm Hg. After vacuuming, the fumigant is introduced into the cylinder to take the place of the sucked air. The dates are kept in the vacuum and exposed to the effect of the fumigant for 2-4 hours. This method increases the penetration of the fumigant gas inside the dates, especially packaged ones, which enhances the effectiveness of fumigation. After that, the poisonous gas is pumped out of the cylinder and fresh air is introduced to replace it. The process is repeated several times before opening the cylinder and taking out the dates. To fumigate the dates, methyl bromide is used in a concentration of 500 cc for 3 hours, 750 cc for 2 hours or 1000 cc for 1 hour all per 28 cubic metres.

Table 2.9. A List of the most important doses of methyl bromide used in the vacuum fumigation stations in Sultan Qaboos Port, Muscat, Oman.

Dose (g/m^3)	Time (Hour)	Vacuum (kg/cm^2)	Treated materials and possible infestation with insect pests
48	2	60	Stored grains (rice, corn, beans or lentil) *Tribolium* spp., *Silvanus* spp., *Ephestia* spp.
64	2	64	Green coffee beans *Aerocerus fasciculutus*
64	4	64	Wood (Wood borers, such as: *Ips* spp., Family: Buprestidae, Cermabycidae).
24 without chloropicrine	2	5	Living offshoots (Scale insects-aphids- Mealybugs).
24 without chloropicrine	1-2	5	Fresh fruits (Scale insects- wooly aphids- Mealybugs).
80	4	70	Rice straws (sterilization) Fungal diseases and rust *Puccinia* sp. Enough ventilation by adding half an hour to the normal time of ventilation.

N.B.: In case of overnight fumigation (approximately 18 hours) use half the stated doses.

III. Exposing Dates to High Temperature

The use of insecticides in controlling the stored date insects, whether by spraying or by fumigation, is increasingly becoming an unwanted method of pest control because of the precautions it entails, as aforementioned. Thus, the use of high temperature on the dates is considered one of the safest methods to eradicate stored date insects and to disinfect or sterilize the dates by killing bacteria and fungi responsible for turning the dates sour or fermented.

Heat is used on dates by several methods and for different purposes. These will be reviewed in the following:

1. Killing Insect Pests of Dates by High Temperature

It is important to study and know the relationship between time and temperature needed to kill 100% of the different stages of the stored date insects in order to use this method efficiently. In the study prepared by the Food and Agricultural Organization, FAO (1993). These relationship is presented in Tables 2.10. and 2.11.

Table 2.10. Lethal time, in hours, for 100% mortality of different stages of the Almond moth, *Cadra cautella* (Walker), exposed to different temperatures at different relative humidity levels.

Insect Stage	20% RH				70% RH			
	45°C	50°C	55°C	60°C	45°C	50°C	55°C	60°C
Eggs	15.00	1.50	0.50	0.33	15.00	3.00	0.50	0.33
Larvae	18.00	1.75	1.17	0.50	18.00	1.50	1.11	0.58
Pupae	10.00	4.00	0.75	0.50	10.00	3.00	0.75	0.50
Adults	12.00	1.25	0.66	0.41	12.00	1.25	0.50	0.33

From the previous table it is clear that the time needed to kill each stage of the almond moth differs by the differences in temperature. At a temperature of 45°C and relative humidity of 20 and 70% all the eggs and the first instar larvae are killed within 15 hours. The late instars larvae die within 18 hours, as for the pupae within 10 hours and the adult moths within 12 hours. At the temperature of 50°C and 20 and 70% relative humidity, the time needed to kill the different stages of the almond moth decreases from what was previously mentioned. It was found that all the eggs die within 90-180 minutes, the larvae within 90-150 minutes, the pupae within 180-240 minutes and the adult insects within 75 minutes. When the temperature increases to 55°C, at the same relative humidity of 20 and 70%, the time needed to kill the different stages becomes 30 minutes for the eggs, 70 minutes for the larvae, 45 minutes for the pupae and 36 minutes for the adult moths. At 60°C and relative humidity of 20 and 70%, all the eggs of the same insect die in about 20 minutes only. The larvae and pupae die in approximately 30 minutes and the adult insects only in 22 minutes.

Table 2.11 clarify that the time needed to kill the different stages of the Two-spots dry fruit beetle ranges between 18 to 151 hours for the adult beetles, at 40°C and 70% relative humidity. This time is markedly shortened to 10-20 minutes when the temperature is raised to 55°C. It is also observed that at 60°C, the lethal time for 100% mortality of the different stages ranges only from 5 to 15 minutes.

2. Exposing Dates to Steam

The water vapour is used on the pressed dates, which are stored in refrigerated warehouses. After removing dates from the refrigerated areas, steam is directed on to them to thaw and loosen their clumped mass, to glaze the surfaces and to kill the insect pests and microorganisms like those that bacteria and fungi present inside the dates or on their surfaces. The dates are exposed to direct steam for 2 hours and the steam temperature should be well above 50°C. This method is used by some countries, which import the dates in bulk containers; each weighing up to 25 kg.

Table 2.11. Lethal time for 100% mortality of different stages of the Two-spots dry fruit beetle, *Carpophilus hemipterus* (Linnaeus), exposed to different temperatures at 70% relative humidity.

Insect Stage	Lethal time at different temperature (In hour or minute)				
	40°C	45°C	50°C	55°C	60°C
Eggs	18 h.	4 h.	25 min.	10 min.	5 min.
Larvae	96 h.	4 h.	35 min.	17min.	10 min.
Pupae	72 h.	3.5 h.	30 min.	20 min.	15 min.
Adults	151 h.	4.66 h.	25 min.	20 min.	10 min.

3. Immersing Dates in Hot Water

This method is suitable for dry or semi dry dates by inserting the dates in boiling water for 5-10 minutes depending on their moisture content. After removing the dates from the hot water, they are spread to dry slightly before they are packed by pressing into suitable containers. This method kills the insects that are on and inside the dates.

4. Dehydration of Dates (Solar Drying)

Solar drying is a practical and simple way of preserving food particularly in the tropics. Solar drying temperature in the tropics varies. Produce spread on matting in a layer not greater than 5 cm thick receives a drying temperature of 36°C. Heat of ambient air for drying can be utilized in arid climate where relative humidity is less than 40 and air temperature is 30°C or more with average wind velocity of about 5 meters per second.

Dates with very high moisture content must be dried to preserve them unless they are to be consumed immediately after harvest or placed in low temperature storage. Many dates producing countries use the sun drying method of dates wherever climatic conditions permit. The dates are spread on large pieces of vinyl or mats and left under the direct sun for days until part of the moisture is lost.

To reach the desired degree of moisture in the dates, one has to vary the duration of sun drying according to the date variety and their degree of moisture content. The high heat together with the dry air helps in decreasing the moisture in the dates as well as killing the insects and microorganisms like bacteria and fungi. It is worth mentioning, that the dehydration process causes the dates to lose a considerable proportion of their weight as much as 12% in some varieties. In Oman, drying of dates by farmers is carried out in the open sun. The solar drying of dates in Oman, Fig. 2.24, is done as follows:

1. The dates are spread on special mats or date leaflets in flat areas designated as sun dryers.

2. The dates are turned daily for five days until they are dry and the moisture content reaches 18%. The duration of drying may vary according to weather conditions and the date variety.

3. The dried dates are collected at noon while still hot.

4. The dates are sorted to exclude over dried, deformed or unsuitable for storing dates.

5. The dates are piled in small heaps for two days for moisture equilibrium.

6. The dates are packaged by pressing into containers of different sizes of plaited out of date leaflets known locally (in Arabic) as Jirab or Zarf. Otherwise, the dates may be pressed in plastic packages, earthen jars or any other suitable containers.

It worth mentioned that, during open air solar drying, uncontrolled weather conditions reduce drying efficiency as a result of the longer time taken to dry. The ambient drying conditions are uncontrolled and dates is not protected. The dried dates become contaminated and the result is a poor quality product.

Use of solar energy in drying under controlled and protected conditions will result in faster drying and improved product quality. In Oman, solar cabinet dryer designed at the Department of Bio-resource and Agricultural Engineering, College of Agriculture, Sultan Qaboos University, Fig. 2.25.

The solar dryer has the shape of a home cabinet with a slanted transparent hinged top. The cabinet dryer is 1.5 m long, 0.9 m wide and 1.0 m high at the back and 0.5 m high in front. The dryer is set on four casters to make it mobile. The special feature of the design of the dryer is the provision of air inlet and outlet holes at the front and back, respectively. The movement of air through the holes, when the dryer is placed in the path of airflow, brings about a thermo siphon effect which creates an up-draft of solar heated air laden with moisture out of the drying chamber (Anonymous, 1997).

Fig. 2.24. Solar drying of dates in Oman.

Fig. 2.25. Solar cabinet dryer.

5. Sterilising Dates by High Temperature

The purpose of sterilisation is killing the fungi and bacteria that cause fermentation. It was found that exposing dates to 70°C for 20 minutes would kill bacteria and fungi. Although sterilization may kill all the vegetative growth of these microorganisms, it may not affect the spores of some of them. For the sterilisation to be effective, the moisture content in the dates should be not more than 12-17%. If the moisture content is high, moulds and bacteria can grow on the dates in spite of the sterilisation.

Hilgeman and Smith (1937) mentioned that dates of the variety Hayani, which contained 43-47% moisture, became fermented and had mould growths even when sterilized by heat treatment at 70°C for 2-4 days. Whereas, the dates with maximum moisture content of 39% were not spoilt or infested with moulds after sterilization.

Generally, it was found that all bacteria species die after specific periods of exposing dates to the following degrees of temperature and relative humidity:

- Duration 20 minutes at temperature 87°C and 96% moisture.
- Duration 30 minutes at temperature 82°C and 75% moisture.
- Duration 40 minutes at temperature 77°C and 69% moisture.
- Duration 50 minutes at temperature 71°C and 90% moisture.
- Duration 60 minutes at temperature 66°C and 100% moisture.

6. Glazing of Dates by High Temperature

The main purpose of glazing of dates is to give them a shiny and attractive appearance by melting the thin waxy layer on the outer surface of the dates, the epicarp. Glazing is done by placing one layer of dates on metal plates and then put in an oven or a chamber at 72°C- 84°C for several hours. Date can be glazed by exposure to high temperature of 130°C-140°C for five minutes with a fast current of air. This type of treatment kills the insects without affecting the flavour of the dates. It is worth mentioning that, there are several other methods for glazing the dates, in which chemical substances are used.

7. Artificial Ripening of Dates

Artificial ripening of date fruits is done by exposing dates in Rutab stage (soft ripe stage) to high temperature to ripen into Tamar stage (full ripe stage), which is usually free from insect pests infestation. This process is used to ripen the date fruits that need long time to ripen or those fruits that do not reach the ripening stage altogether because of the relative cold weather in some countries.

In addition to the above-mentioned cases, artificial ripening is also used in some countries in hot climatic region that have high humidity. Dates produced in such areas ripen and then rapidly deteriorate in quality. For this reason, cultivators resort to harvesting the date bunches before ripening and ripening them artificially. Naturally, the heat treatment in artificial ripening, for example in plastic tunnels, also kills all the different stages of many insect pests of the dates.

IV. Vacuum Packing

Packaging and preserving of dates in polyethylene bags and removing the air by special machines is one of the easiest and most efficient ways to control the date insect pests and to prevent re-infestation during storage and marketing periods. This is done by placing the dates in polyethylene bag and pumping out the air up to 80- 99%, then tightly sealing the bag, as shown in Fig. 2.26. The vacuum induced inside the bag leads to killing the insect pests inside the dates. It was found that 75% vacuum inside the bags caused death of all larvae of both almond moth and saw-toothed grain beetle. Adult beetles die at 97% vacuum level. When 80-99% vacuum is reached inside the bags the mortality rate is 100% for the larvae of the almond moth and both the larvae and adult beetles of the saw-toothed grain beetles. It was noticed that adult insects require longer periods up to two or more days to die from the effect of the vacuum.

Fig. 2.26. Vacuum packing of dates.

V. Irradiation (Gamma Rays)

El Sayed and Ba'eshen (1983) clarified the potential of using gamma rays to kill stored dates insects. In their study the two researchers exposed clean dates and those infested by saw-toothed grain beetle, almond moth and Myelois moth to doses of zero, 15, 25 or 50 Krad radiated from Cobalt 60 in the concentration of 1.25 × 10 rad per hour. The treated dates were stored under normal room conditions (20°C- 30°C and 85%-90% relative humidity) in bags to prevent re-infestation. It was discovered in the previous study that the dose of 25 Krad of gamma radiation completely prevented the development of eggs, larvae or pupae of the studied insects from one stage to the following. In addition, this dose was sufficient to kill the adult insects in the fruits. The researchers also mentioned that this dose of gamma rays did not cause any significant changes in the nutritional value of the treated dates as evidenced by qualitative and quantitative assessment of the carbohydrates, proteins and amino acids immediately after irradiation and on periods of 3, 6, 9, and 12 months of storage. In addition, from the sensory tests the radiation doses up to 25 Krad had no effects worth mentioning on taste and aroma of the treated date fruits.

Hussain (1985) reported that irradiating dates infested by the saw-toothed grain beetle by doses of 10-20 Krad led to the death of the adult beetles in 20- 30 days. The above-mentioned doses also affect the first instars of the larval development period, as irradiated larvae do not pupate. As for the later instar larvae of this insect, they complete their development into pupae even after exposed to doses up to 40 Krads. Fortunately, a high percentage of these pupae does not complete their development and do not turn into adult insects.

In laboratory studies conducted in Pakistan by Khattak and Jilani (1984), the eggs of *Tribolium castaneum* were shown to be most sensitive to gamma irradiation at 2 days old. Treating the eggs with 1-8 krad followed by incubation at 28°C and 60% RH resulted in significantly lower percentages of hatching, pupal development and adult emergence.

Fontes *et al*. (1996) determined the gamma radiation dose necessary to sterilize adults of *T. castaneum*. After irradiation with doses of 25, 50, 75, 100, 125 and 150 Gy, it was observed that sterilization of the adults was achieved by irradiating larvae with a dose of 25 Gy and pupae with a dose of 50 Gy, the lethal dose for 85% of the population was 150 Gy with immediate kill. Misra and Bhatia (1997, 1998) investigated the susceptibility of adults of a fenvalerate-resistant strain of *T. castaneum* to gamma radiation. The LD_{50} values for the fenvalerate (a synthetic-pyrethroid) resistant and susceptible strains were 89.16 and 97.46 Gy, respectively. The LT_{50} values were 7.58 and 17.20 days for resistant and susceptible strains, respectively, showing that mortality in the resistant strain occurred earlier than in the susceptible strain.

VI. Store Containers of Dates

The packaging process is performed either in the farm or in places near the warehouses known as the pressing houses. There are many types of containers that are used in pressing and packaging the dates including:

• Earthen jars

The dates are pressed inside jars made of clay, which may have a capacity up to 25 kg. After fully pressing the dates in the jars, little olive oil or dates syrup (Dibs in Arabic) is poured in their openings to prevent the entrance of insects, Fig. 2.27.

• Glass containers

High quality dates are sometimes pressed inside glass containers, and then little date syrup is added. Such packaged dates will be insects-free for long periods of time.

• Metal Tins

The dates are packaged in thoroughly cleaned and dried tins applying little and light pressure. The tins are placed in the sun for a week for the natural syrup to flow. This method is considered a good way to prevent insect infestation and even in case of a mild infestation, it is restricted to the upper layers. The capacity of each tin is about 20 kg.

• Baskets

It is considered one of the oldest methods of storing the dates. Large quantities of dates are pressed in "khisaf" (baskets plaid out of date palm leaflets). Each basket, or khisaf, contains 30-50 kg of dates. These are stored in columns of 4-6 baskets high for one month. Then they are rearranged so that the lower basket takes the place of the one above it, and vice versa. This method helps in protecting the dates from insects for few months.

• Animal Skins

In some countries, small quantities of dates are pressed in animal skins like goatskin after carefully removing the hair and drying them well. The dates pressed in this way are usually of the soft varieties. The pressed quantities vary from 8 to 18 kg in each skin depending on the size of the skin. Such dates are stored to be consumed in the winter months. The skin offers a mechanical barrier to the entry of insects. This method of packaging and storing dates preserves the qualities of good dates and helps in preventing insect attacks for several months.

Fig. 2.27. Earthen jars made of clay for pressing and storing dates.

• Wooden or Cardboard Boxes
The fumigated dates are pressed in boxes made of wood or cardboard each has a capacity for 25 kilograms. Modern pressing machines are used to package the dates for export. However, such boxes do not protect the dates from insect infestation during storage. It was found that the incidence of infestation in the stored dates inside a non- sterilized warehouse ranges from 3-17% during the first three months of storage. The incidence markedly increases to 65-71% during the period from fourth to seventh months of date storage.

• Cellophane Bags
Occasionally, the dates are pressed in vacuumed cellophane bags. This method protects the dates from insects for about two months, after which insect infestation begins in the third month of storage in non- sterilized warehouses. Insect infestation in the third month is 3%, which increases to 35% in the fourth month, then to 43% in the fifth month and to 53% in the sixth month.

• Aluminium Bags
Aluminium bags are one of the best containers for packaging and protecting the dates from insects as they cannot penetrate through the bags to infest the pressed dates inside. The dates in aluminium bags can be kept insect-free for about six months in non- sterilized warehouses as long as the bags stay tightly sealed.

• Vacuumed polyethylene Bags
Storing dates in vacuumed polyethylene bags is considered one of the best methods for pressing, packaging and preventing infestation by insect pests of the stores or warehouses. The insects in the non-sterilized warehouses cannot penetrate to the dates inside polyethylene bags. However, rodents or rats puncture polyethylene bags to feed on the contained dates. In this method, the dates are pressed inside the bag, air is vacuumed by 80- 99% which causes the death of the insects inside the dates. Then the bags are tightly sealed.

• Carton Boxes
The dates are pressed in carton boxes of packaging capacities of 2-4 kilograms. The inside of the boxes are lined with the heavy brown paper known (Kraft paper) before pressing the dates. Such packages preserve the dates from insects for two months, after which the infestation appears starting from the third month. In addition, smaller boxes of 0.5 kg capacities can be used which are completely wrapped by cellophane. As usual, these boxes can preserve the dates in non-sterilized warehouses for two months before insect infestation starting from the third month.

VII. Biological Control

We talked at the beginning of this section in detail about the insect pests attacking stored dates and mentioned that many of these pests also attack the dates on the palms or during storage in the orchards. In fact, biological control may not be successful when used against insect pests that attack the dates in stores only, but can be a successful method to control the insect pests that attack dates in both fields and stores.

Among the most important insect pests that attack the dates in both the orchards and stores are *Cadra cautella* (Walker), *Plodia interpunctella* (Hübner), *Ectomyelois ceratoniae* Zeller and *Virachola livia* Klug. The almond moth, *C. cautella*, is the most important examples of insects that attack dates in both the orchards and storehouses. Therefore, biological control will be a great benefit with this economically important pest.

The following are the most important parasitoids that found to affect the spread of these insect pests:

1. *Bracon* (*Habrobracon*) *hebetor* Say (Hymenoptera: Braconidae)
2. *Bracon brevicornis* Wesmael (Hymenoptera: Braconidae)

3. *Phanerotoma flavitestacea* Fischer (Hymenoptera: Braconidae)

4. *Nemeritis* (*Venturia*) *canescens* Gravenhorst (Hymenoptera: Ichneumonidae)

5. *Pyemotes herfsi* (Oudemans) (Acari: Pyemotidae)

6. *Pediculoides ventricosus* (Newport) (Acari: Pyemotidae)

The Braconid parasitoid, *Bracon hebetor*, is the most important parasites that can limit the spread of the almond moth, where the parasite attacks the larvae and pupae of this pest on the dates in either orchards or warehouses.

Tawfik (1997) mentioned that the *B. hebetor* is an external parasite on many Lepidoptrous larvae such as *Cadra cautella* (Walker), *Ephestia kuehniella* Zeller, *Plodia interpunctella* (Hübner), *Hellula undalis* (Fabricius) and *Galleria mellonella* Linnaeus. The antenna of the females of *B. hebetor* consists of 13 to 15 segments and before deposit their eggs, they drugged the host larvae, resulting in a paralyzed caterpillar partially within a period not exceeding five minutes. It was found that a female of *B. hebetor* deposits about 180 eggs throughout their life span, which extends to about 10 weeks, while the adult male of the parasite live only one week. It was also found that the females of *B. hebetor* can reproductive in the absence of males, i.e. parthenogenesis, and in this case, the female lays unfertilized eggs that hatch into males only.