12 Pest Management in Organic Almond

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Introduction

Almonds possess economic, medicinal and nutritional benefits and are consumed in nearly every country worldwide. Major production areas, however, are limited to Mediterranean-like climates, which are broadly categorized as hot, dry summers and mild, wet winters. Even though the almond tree is native to western Asia, the USA has the highest production of almonds in the world. In 2013, roughly 82% of the almond production was within the USA with an estimated 840.91 thousand t (Tables 12.1 and 12.2). Other major production areas include EU-27 (the 27 countries of the European Union) (predominantly Spain), Australia and Turkey. The export value of the almond crop for the USA is US$3387 billion in 2012 (Anonymous, 2013a).

Within agricultural systems, the almond tree is unique. Almond trees can grow on a variety of soil types, which include high pH and moderately saline soils, even though they perform best on well-drained, deep, fertile soils. Almond trees are able to survive on as little as 180 mm of water annually, and respond to increased water applications with increasing yield. Almonds bloom earlier than other *Prunus* spp., however, and therefore are susceptible to late spring frosts. They are also susceptible to a number of diseases and insects. These risks can be minimized by selecting later blooming or more resistant varieties.

Almonds are affected by a number of insect pests (Table 12.3). These pests attack the tree or kernel, reducing orchard vigour or yield. Pest pressure, however, tends to be lower than other crops due to the protection of the kernel/seed from the environment by a shell and hull, and the production areas being primarily in arid areas which tend to have low insect pressure. This provides an opportunity to grow almonds organically or without the requirement of a large amount of pesticides.

Organic production within almond is reliant on the use of variety selection or cultural practices to reduce insect infestation rates. Cultural methods include good sanitation practices in the orchard, which include removing or shredding old debris, dried nuts from the previous year's crop, and dead wood from the trees. Organically approved pesticides have been shown to be effective for some, but not all pests. Specific control measures for the pests listed in

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Table 12.1. Production-wise ranking of different almond-growing countries of the world. (From Almond Board of California and International Nut and Dried Fruit Council (INC), 2013, cited in Anonymous, 2013a.)

Countries	Production (%)
USA	82
EU-27[a]	6
Australia	5
Turkey	2
Others	5

[a]EU-27, The 27 countries of the European Union.

Table 12.2. Forecasted world almond production in 2013–2014. (From Almond Board of California and International Nut and Dried Fruit Council (INC), 2013, cited in Anonymous, 2013a.)

Country	Production (thousands of kg)
USA	840.91
Australia	69.13
Spain	32.04
Turkey	15.04
Iran	15.04
Tunisia	13.04
Chile	10.00
Morocco	6.00
Greece	5.00
Italy	5.00
Others	30.04
World total	1041.24

Table 12.3 are outlined below. Please note that there are other pests which are not listed that are minor or limited to smaller areas of production.

Major Pests

Monosteira unicostata (Mulsant & Rey) (Hemiptera: Tingididae) (poplar lace bug)

Description

The body of *Monosteira unicostata* is light yellowish grey in colour and about 2.5 mm long. The hemelytra are divided in appearance (Lodos, 1982).

Life cycle

M. unicostata overwinters in the adult stage in hidden places, under debris or in the crevices on the trees in orchards. Females lay their eggs by inserting them in the plant tissue under the leaf. The surface of the inserted egg on the leaf tissue is covered with a dark-coloured liquid excreted by the female from its anus. It reaches high population numbers on poplar trees in August and September. Additionally, the other two species of Tingidae, *Monosteira lobulifera* Reuter and *Stephanitis pyri* (Fabricius) have also been found in almond orchards in Turkey (Bolu, 2007).

Damage

Adults and nymphs feed on the underside of leaves by sucking the sap which results in damage to the chlorophyll and in white patches on leaves. The leaves drop prematurely as a result of feeding by either adults or nymphs of the pest (Lodos, 1982). *M. unicostata* has three generations in 1 year (Russo *et al.*, 1994).

Distribution and host plants

The poplar lace bug is reported from Mediterranean countries, Turkistan, Hungary and the Caucasus. The host plants include poplar, *Salix*, apple, pear and almond (Lodos, 1982).

Management for organic farming

The efficacy of kaolin, azadirachtin and potassium salts of fatty acids combined with thyme essential oil against adults and fourth instar nymphs was evaluated in laboratory assays. It was concluded that the products tested have shown high and different efficacy on nymphs and adults of *M. unicostata*. This activity might be suitable for the practical application of these compounds to control its populations under real field conditions (Sanches-Ramos *et al.*, 2014).

The number of coccinellid and hemipteran predators feeding on *M. unicostata* has been determined in almond orchards (Bolu, 2007).

Table 12.3. Pests in almond orchards.

Species	Common name	Order: family
Amyelois transitella (Walker)	Navel orangeworm	Lepidoptera: Pyralidae
Quadraspidiotus perniciosus (Comstock)	San Jose scale	Hemiptera: Diaspididae
Monosteira unicostata (Mulsant & Rey)	Poplar lace bug	Hemiptera: Tingididae
Capnodis carbonaria (Klug)	Almond borer	Coleoptera: Buprestidae
Cerambyx dux (Faldermann)	Longhorn beetle	Coleoptera: Cerambycidae
Anarsia lineatella Zeller	Peach twig borer	Lepidoptera: Gelechiidae
Tropinota (= *Epicometis*) *hirta* (Poda)		Coleoptera: Scarabaeidae
Ectomyelois ceratoniae (Zeller)	Carob moth	Lepidoptera: Pyralidae
Cimbex quadrimaculatus (Müller)	Almond sawfly	Hymenoptera: Cimbicidae
Eurytoma amygdali Enderlein		Hymenoptera: Eurotomidae
Tetranychus pacificus McGregor, *Tetranychus urticae* Koch, *Tetranychus turkestani* Ugarov and Nikolski	Web-spinning spider mites (Pacific spider mite, two-spotted spider mite, strawberry spider mite)	Trombidiforma: Tetranychidae
Anthonomus amygdali Hustache[a]		Coleoptera: Curculionidae
Brachycaudus amygdalinus (Schouteden)[a]		Hemiptera: Aphididae
Panonychus ulmi (Koch)[a], *Bryobia rubrioculus* (Scheuten)[a]	European red mite, brown almond mite	Trombidiforma: Tetranychidae
Tetramorium caespitum (L.)[a], *Solenopsis xyloni* McCook[a], *Solenopsis molesta* (Say)[a]	Ants (pavement ant, southern fire ant, thief ant)	Hymenoptera: Formicidae

[a]Secondary pests.

Capnodis carbonaria (Klug) (Coleoptera: Buprestidae) (almond borer)

Description

Adults of *Capnodis carbonaria* are black or bronzed in colour and the pronotum is slightly shiny and ornamented in black and white. The body of adults becomes tapered from the anterior to the posterior. The length of the adult is 20–35 mm, and the forewings are very hard. The eggs are 1 mm in length and oval in shape. Larvae are flattened with 13 segments and yellow in colour. The young larva is very pubescent, but from the second instar on it changes and becomes hairless and smooth. The length of the developed larvae can reach up to 12 cm (Lodos and Tezcan, 1995), depending on geographic area and on which host they are feeding. The pupa is oval in appearance and resembles the adult in shape.

Life cycle

Almond borer beetles overwinter in the adult stage under debris or in the ground. They become active and copulate when the temperature increases over 25–26°C. Mated females deposit their eggs in the crevices of the bark very near to ground level, or on the ground near to the trunk of trees. Oviposition begins in May, but most of the eggs are laid in July and August (Lodos and Tezcan, 1995). A single female can deposit almost 2000 eggs during its lifespan. The eggs are wet when laid and are covered by debris and soil adhering to them, so that they are camouflaged. Hatching larvae from the eggs are quite active underground. They can move by using hairs on their body to reach for the roots. The hairs are lost when they tunnel into roots. Young larvae feed in cambium tissue of the root by tunnelling in 30–45 cm length. It takes 1–2 years to develop from larvae into pupae. They pupate near the root in the ground. Adults hatch from pupae after 4 weeks. Adults' emergence from pupae mostly occurs in July–August. This group of adults copulate and deposit their eggs in September–October. The second group of adults appears in October–November, and they become active in the next spring and oviposition takes place in July–August

(Anonymous, 2008b). The life cycle takes 12–15 months to be completed (Talhouk, 2009).

Damage

C. carbonaria adults feed on leaves and young shoots, but economic damage is rare. Young trees, between the ages of 1 and 4 years, are at the greatest risk due to tree collapse and death from larvae feeding in the roots. Older trees may die if many years of root feeding occur.

Distribution and host plants

The pest is known in Italy, the former Yugoslavia, Greece, Bulgaria, Cyprus, Lebanon, Israel, Syria, Iraq, Iran, south Caucasus and Afghanistan (Avidov and Harpaz, 1969; Lodos and Tezcan, 1995). Host plants include primarily almond and other fruit trees such as apricots, peaches, plums, cherries and sour cherries (Lodos and Tezcan, 1995) and additionally pistachios in Turkey (Nizamlıoglu, 1957).

Management for organic farming

CULTURAL PRACTICES. Weed control can help to destroy the adult habitat under the canopy. Tree trunks can be painted with whitewash on the bark to prevent egg laying by adult females. Early in the morning and late evening, adults can be hand collected when they are partly inactive on the trunk of trees. When damaged leaves drop from the trees, it is an indication of the damage by *Capnodis*, and *Capnodis* can be collected and removed by shaking the branches of young trees (Anonymous, 2008b).

BIOLOGICAL CONTROL. No information on biological control of *C. carbonaria* could be found in the literature, however, the nematode, *Steinernema carpocapsae* (Weiser) was reported to be very effective (96–100% efficacy) against neonate larvae of *Capnodis tenebrionis* (L.) in laboratory trials (Garcia Del Pino and Morton, 2005). *S. carpocapsae* in a chitosan formulation was found to be very effective against *C. tenebrionis* in field trials in apricot plantations in Spain (Martinez de Altub *et al.*, 2008).

There are very few natural enemies of *C. tenebrionis*. Only *Sclerodermus cereicollis* Kieffer (Hymenoptera: Bethylidae) and some entomopathogenic fungi were reported in south Italy. Additionally, two commercial formulations of *Bacillus thuringiensis* (Berliner) were found to be ineffective against this pest (Marannino and Lillo, 2007).

***Cerambyx dux* (Faldermann) (Coleoptera: Cerambycidae) (longhorn beetle)**

Description

The adult of *Cerambyx dux* is dark brown and 50–52 mm long. The antennae are longer than the body. The eggs are 4.5 mm long, oval and dirty white in colour. The newly hatched larvae are very small, around 4.5 mm long. The larvae are soft and creamy white in colour and cylindrical in shape. The larva may reach 9–10 cm just before it pupates (Talhouk, 1969). The pupae are initially dirty white, but become dark in colour over time (Avidov and Harpaz, 1969).

Life cycle

The longhorn beetle overwinters as the adult stage after hatching from the pupa in the late autumn within a tunnel inside the trunk of a tree. The following year, the beetle will emerge from the tunnel in the late spring or early summer. The adult female deposits eggs singly under the bark in crevices or cracks. A single female can deposit 30–40 eggs during its lifetime. The newly hatched larvae start boring into the trunk or main branches of the tree and feed on the wood (Avidov and Harpaz, 1969; Talhouk, 1969). Large amounts of sawdust or frass are evacuated from the gallery holes on the trunk. The larvae feeding in the wood produce tapping sounds. The larval development is completed in 15–17 months, from June until August or October in the Middle East (Talhouk, 1969).

Damage

The damage is caused by the larvae boring the tunnel in the wood tissue. This damage

weakens the tree which may lead to the breaking of affected branches or scaffolds under the weight of heavy loads or the pressure of the wind (Talhouk, 1969).

Distribution and host plants

The longhorn beetle is reported in countries of the Middle East (Talhouk, 1969), and Mediterranean countries including Bulgaria, Crimea, Greece, Italy, Israel, Syria, the Lebanon, Macedonia, north-west Iran and Turkey (Avidov and Harpaz, 1969; Anonymous, 2011). The list of host plants includes stone fruits, such as peach, apricot, almond (Avidov and Harpaz, 1969) and plum (Talhouk, 1969).

Management for organic farming

CULTURAL PRACTICES. Wood-boring pests of trees are attracted to weak woody plants in order to deposit their eggs (Talhouk, 1969). Hence cultural practices such as regular irrigation, pruning and proper fertilization can help to maintain the trees in a healthy state so they are resistant to pest attack.

Anarsia lineatella Zeller (Lepidoptera: Gelechiidae) (peach twig borer moth)

Description

Anarsia lineatella moths are grey in appearance with grey forewings. The wings may have darker and lighter spots and lines. The hindwings are lighter in colour than the forewings. The wingspan is 14–18 mm and the body length is 7–8 mm. The wings are fringed with long hairs (Avidov and Harpaz, 1969; Talhouk, 1969).

The eggs are oval and 0.5 × 0.3 mm in size, and when laid they are initially creamy white in colour, but later turn to orange and brown (Anonymous, 2008b). The newly hatched larva is light brown and later it turns to reddish brown in colour. Its head, pronotum and legs are black with whitish intersegmental areas giving the larvae a banded appearance. The body of the larva is covered with numerous hairs on the dorsal surface and when mature, the larval length is 10 mm. The pupa is elongate and 6 mm long with numerous hairs (Avidov and Harpaz, 1969; Talhouk, 1969).

Life cycle

The peach twig borer overwinters as a young larva in a cavity, which is termed a hibernaculum, approximately 2 mm beneath the bark of twigs and branches. In spring, the larva becomes active and leaves the cavity to feed on flower buds, leaves, nutlets, growing tips and the small buds. The larvae can change their feeding site and may attack several growing tips before they become mature. The larvae will burrow into a shoot tip travelling 2–5 cm down into the wood, killing the terminal bud. When fully grown, the larvae leave their tunnels to become pupae, spinning a cocoon on the branches (Avidov and Harpaz, 1969; Talhouk, 1969). Adults hatch from the pupae in early to mid-spring, depending on geographic area (Anonymous, 2008b). Females deposit their eggs, more than 140 in number (Avidov and Harpaz, 1969), on fruit or foliage after copulation. The peach twig borer produces four generations/year in Israel (Avidov and Harpaz, 1969), California (Strand, 2002) and in Syria (Talhouk, 1969), and three to five generations in Turkey (Anonymous, 2008b).

Damage

The first generation larvae hatching from the eggs prefer to feed on the fruits causing damage and fruit drop. Attacked fruits indicate a gummy point where the larva enters into the fruit, and larva can feed on the kernel or between the hull and the shell. The larvae of the peach twig borer may also attack both twigs and fruit during summer. In nurseries and young orchards, the larvae of the pest could cause severe damage on vigorous growing shoots and cause undesirable growth and lateral branching of the shoots (Anonymous, 2008b).

Distribution and host plants

The peach twig borer moth is reported to be found in North America, many European

countries, the Mediterranean countries, Syria, Lebanon, Palestine, China, Japan, Australia (Avidov and Harpaz, 1969; Talhouk, 1969), Iraq (Ahmad and Khadhum, 1986) and Iran (Oloumi-Sadeghi and Esmaili, 1983). The list of host plants includes peach, nectarine, almond, apricot, plum, cherry and apple (Anonymous, 2008b).

Management for organic farming

CULTURAL PRACTICES. Infested shoots should be cut into 8–10 cm lengths weekly between March and September. They should be placed in cages covered with mesh so that once parasitoid adults hatch from the parasitized larvae the adults can escape and increase the parasitoid population in the orchard. During this practice, undesirable lateral shoots should also be cut off to prevent new infestations (Anonymous, 2008b). The infested fruits should be collected and destroyed, so that the population of the pest will be reduced in the next growing season.

BIOLOGICAL CONTROL. There are numerous parasitoids and predators controlling the peach twig borer populations. These include the following parasitoids that have been determined to date:

- *Apanteles anarsiae* Faure et Alab., *Apanteles glomeratus* L., *Ascogaster* sp., *Bracon gelechiae* Ashmead, *Macrocentrus ancylivorus* Rowher and *Spilochalcis* n.sp. *aff torvina* (Cresson) (Hymenoptera: Braconidae);
- *Paralitomastix pyralidis* (Ashmead) and *Paralitomastix varicornis* Nees. (Hymenoptera: Encyrtidae);
- *Ephialtes subglobiatus* L., *Aptesis* sp., *Mastrus* sp., *Phaeoganes rustigatus* Wesm., *Pimpla instigator* F. and *Pristomerus vulnelator* Panz. (Hymenoptera: Ichneumonidae);
- *Periclora gestroci* K. (Hymenoptera: Belulidae);
- *Brachymeria intermedia* Perk. and *Hyperteles lividus* (Ashmead) (Hymenoptera: Chalcididae);
- *Andreana* sp. (Hymenoptera: Apidae);
- *Dibrachys offinis* M. (Hymenoptera: Pteromalidae);
- *Haematopoda pluviallis* L. (Diptera: Tabanidae);
- *Erynnia tortricis* (Coquillett) (Diptera: Tachinidae);
- *Euderus cushmani* Crawford (Hymenoptera: Eulophidae); and
- *Pyemotes ventricosus* (Newport) (Acarina: Pyemotidae) (Daane *et al.*, 1993; Strand, 2002; Anonymous, 2008b).

The grey field ant, *Formica aerata* (Francoeur) (Hymenoptera: Formicidae) is reported to prey on the peach twig borer during spring and summer, but it was not able to keep the pest population below economically damaging levels (Strand, 2002).

It was also reported that dormant-season application of *Steinernema carpocapsae* (Weiser) (Rhabditida: Steinernematidae) and *Heterorhabditis* sp. (Rhabditida: Heterorhabditidae) reduced overwintering larval populations of the peach twig borer in hibernacula on almond trees in California orchards (Agudelo-Silva *et al.*, 1995).

MATING DISRUPTION. Mating disruption with sex pheromone can help to reduce the pest population. This was reported to reduce the peach twig borer moth populations in plum orchards; however, it was not reliable when used alone. It is effective in orchards when the moth population is low (Strand, 2002).

CHEMICAL TREATMENTS. Sprays of microbial product such as *Bacillus thuringiensis* and the Entrust formulation of spinosad at bloom can control the peach twig borer. Mid-spring sprays of Entrust should be timed to the hatching larvae of the first generation (Strand, 2002).

***Tropinota* (= *Epicometis*) *hirta* (Poda) (Coleoptera: Scarabaeidae) (flower chafers)**

Description

The adult of *Tropinota hirta* is dark brown and 8–12 mm long. The body is covered

with dense and long yellowish-white hairs. There are white patches on the elytra. Eggs are 2.0–2.5 mm in diameter and spherical in shape and white in colour. Larvae are a brown-coloured grub (Anonymous, 2008b).

Life cycle

T. hirta overwinters as the adult stage in the soil. Adults become active in the spring during the blossoming period of the fruit trees. The adult population reaches its peak by the end of the spring. Adults feed on the blossoms, young leaves and buds and even fruits, and deposit their eggs into the soil. The grubs feed on the roots of the weeds after hatching from the eggs, and they develop on decomposing plant matter, and do not cause any damage to the almond trees (Avidov and Harpaz, 1969; Anonymous, 2008b). The grubs complete their development in 6–9 weeks in the soil and pupate. Adults hatching from the pupae overwinter in the soil (Anonymous, 2008b).

Damage

The damage is caused to the flowers, young leaves, buds and even fruits which are attacked by the adults, which then lay their eggs into the soil. The grubs do not cause any damage to the almond trees, as they feed on the roots of weeds after hatching from the eggs, and they develop on decomposing plant matter (Avidov and Harpaz, 1969; Anonymous, 2008b).

Distribution and host plants

Flower chafers are known to occur in Europe, the Near East and North Africa. Its list of host plants includes apple, apricot, cherry, sour cherry, peach, pear, plum and many other plants (Anonymous, 2008b).

Management for organic farming

CULTURAL PRACTICES. The adults, grubs and adults could be destroyed by tillage of the soil. The trees can be shaken during the morning hours when the adults are motionless on the plants, and the adults that are dropped can be picked off by hand (Anonymous, 2008b).

BIOTECHNICAL CONTROL. Traps combined with visual (blue colour) and chemical (1:1 cinnamyl alcohol/*trans*-anethole mixture, known as flower scent volatiles) play an important role in mass trapping of the pest (Knudsen *et al.*, 1993; Toth *et al.*, 2004).

***Ectomyelois ceratoniae* (Zell.) (Lepidoptera: Pyralidae) (carob moth)**

Description

Forewings of the adult *Ectomyelois ceratoniae* are narrow, dull and dark grey in colour; two ‘w’-shaped light stripes stand out on the forewings when the adult is at rest. The hindwings are white in colour with distinctive veins. The body length and the wingspan are 8–11 mm and 16–28 mm, respectively (Avidov and Harpaz, 1969; Anonymous, 2008a), depending on the geographical area where they live.

The eggs are oval and 0.7 × 0.5 mm in size, and when laid they are initially white in colour, but later they turn to red-brown. The larvae are 15–18 mm long, and the larval body is pinkish with a brown head and pronotum. The pupa is 3 × 10 mm in size, and pupation takes place in a light grey cocoon (Avidov and Harpaz, 1969; Anonymous, 2008a).

Life cycle

The carob moth overwinters as larvae within the almond ‘mummies’ (mummified fruit), under the bark or in the crevices of the trees. First adults appear between April and June depending on the geographical area. One female deposits 100–350 eggs on the fruits during its lifespan. Larvae start to feed on fruits right after they emerge from the eggs. The carob moth produces four to five generations in a year (Avidov and Harpaz, 1969; Anonymous, 2008a).

Damage

The first generation develops from mid-April until late June (Avidov and Harpaz, 1969) and is harmful to the almond. It can be considered that from late June onwards the almond fruits

become rigorous so that the second generation larvae are not capable of penetrating into the fruits as long as the fruit skin is not injured or split. The second and following generations develop mainly in carob, citrus (Avidov and Harpaz, 1969) and pomegranate.

Distribution and host plants

The carob moth is distributed in Africa, central and southern Europe, Central and South America and the Near East, and it is likely to be introduced into many temperate countries inside food consignments (Avidov and Harpaz, 1969). The list of host plants includes carob, orange, grapefruit, pistachio, pomegranate, apple, pear, hazelnut, almond, walnut, chestnut, date, fig, grape, olive, persimmon and quince (Avidov and Harpaz, 1969; Anonymous, 2008a).

Management for organic farming

CULTURAL PRACTICES. All infested fruits both on trees and on the ground should be collected regularly from the almond orchards and destroyed. The almond orchards preferably should be established in areas that are free from the other hosts of the carob moth.

BIOLOGICAL CONTROL. The predator *Orius minutus* L. (Hem.: Anthocoridae) and the parasitoids *Phanerotoma flavitestacea* Fish., *Habrabracon hebetor* Say., *Habrabracon brevicornis* (Wesmael), *Bracon lactus* Wesmael, *Apanteles* sp. (Hym.: Braconidae), *Pristomerus vulnerator* Panz. (Hym.: Ichneumonidae) and *Trichogramma* spp. (Hym.: Trichogrammatidae) are common natural enemies in Turkey (Anonymous, 2008a). It was reported that *P. flavitestacea*, *Clausicella suturata* Rond. (Dip.: Tachinidae) and the ectoparasitic mite *Pyemotes* (= *Pediculoides*) *ventricosus* (Newp.) (Acarina: Pyemotidae) were common natural enemies in Israel (Avidov and Harpaz, 1969). *Apanteles myeloenta* Wilkinson (Hymenoptera: Braconidae) was found to be very common in Iran (Kishani-Farahani *et al.*, 2012). *Apanteles* spp. group ultor (Hym.: Braconidae) was reported as a very common parasitoid species of the carob moth in Iraq (Al-Maliki and Al-Izzi, 1986). Enhancement of the natural enemies could help to reduce the carob moth population in almond orchards.

In addition to natural enemies, *Bacillus thuringiensis* can control carob moth populations when sprayed regularly at intervals of every 10–15 days from the first larval emergence (Anonymous, 2008a).

MATING DISRUPTION. There are some commercial mating disruption products to control the carob moth in dates, which could be tested in almond orchards.

***Amyelois transitella* (Walker) (Lepidoptera: Pyralidae) (navel orangeworm)**

Description

Adult moths have silvery grey and black patterns on the forewings and legs. The hindwings are light, darkening at the apex and along the veins. A pair of palps in front of the head forms a snout-like projection. The body length and the wingspan are 8–12 mm and 19–23.5 mm, respectively (Wade, 1961). Females have a larger wingspan, with a range from 18 to 27 mm.

Eggs are oval and 0.5–1 mm in diameter, and when laid are initially white in colour. As the eggs mature, they turn pink and then to red-brown. Newly hatched larvae are reddish brown in colour, but change to pink or white depending upon diet. The head and pronotum are dark in colour in all instars, and a pair of crescent-shaped marks on the second segment helps distinguish the moth from other larvae. Larvae grow to 15–18 mm long, and the larval body is pinkish, and head and pronotum are brown. The pupa ranges in length from 7.25 mm to 12 mm, is light to dark brown, and is often found within shells or between the shell and the hull.

Life cycle

The navel orangeworm moth (NOW) overwinters as pupae and larvae within dried, shrivelled mummified fruit that remain on the tree after the previous year's harvest. Larvae do not enter diapause, so adult emergence may occur during warm periods within the

winter. Pupation occurs within the mummies in early spring, and emergence marks the beginning of the first flight. First generation eggs are laid on mummy nuts, and these serve as the only food source for the developing larvae. First generation female moths emerge in late spring or early summer for the second flight and lay eggs on mummy nuts or fruit damaged by other moth pests. Developing larvae will feed on almond hulls and kernels, but develop faster on almond kernels. Successive flights will increase egg-laying female populations. As the almond-ripening process begins, and hull-split is initiated, female moths will lay eggs on the exposed shell and kernel. On average, a female deposits 84.6 eggs, with as many as 250 being observed (Wade, 1961). NOW typically produces four generations a year in California with the second, third and fourth flight potentially causing damage to the almond crop (Strand, 2002).

Damage

Kernel feeding by NOW larvae causes economic losses, especially in areas of higher population densities (Strand, 2002).

Distribution and host plants

The NOW is commonly found in Mexico and throughout the south-western USA (Wade, 1961). The list of host plants includes citrus, apples, apricots, figs, nectarine, peach, pear, plum, quince, almonds, pecans and walnuts. It is commonly found within trees or shrubs that produce seed pods. These include carob pods, bottle-tree seeds, dates, jujube, loquat, pomegranate, *Acacia farnesiana*, *Genipa americana*, Texas ebony and yucca pods (Wade, 1961).

Management for organic farming

CULTURAL PRACTICES. Cultural practices that can help with control of this pest include:

- Sanitation – all infested fruits both on trees and on the ground should be collected regularly from the almond orchards and destroyed. Mummy nuts can be removed from the tree by mechanically shaking or by hand pulling.
- Early harvest – almonds should be harvested as soon as feasible. An earlier timed harvest can reduce the exposure to NOW flights, leading to a reduction in damage.
- Varietal selection – hard-shelled or other varieties that have a tight shell seal are more resistant to infestation by NOW.

BIOLOGICAL CONTROL. There are two parisitoid wasps introduced into California to manage this pest. The encyrtid wasp, *Copidosoma plethorica* (Caltagirone) lays its eggs inside the NOW larva, and each egg develops into a large number of larva that consume the host and pupate inside the exoskeleton. The bethylid wasp *Goniozus legneri* Gordh lays eggs on the surface of the NOW larva and the egg hatches into a larva that consumes the NOW larva from the outside. Both wasps can occur within the same orchard, and control is greater when both species are present. Even with high densities, natural populations do not provide reliable control of NOW.

Flocks of birds that move into the orchard during the dormant period will often feed upon mummy nuts. This feeding assists the sanitation process and effectiveness is determined by the type of bird and proximity of the orchard to bird flight patterns.

In addition to natural enemies, *Bacillus thuringiensis* can control NOW, but since this bacterium must be ingested, coverage is critical. Sprays must be made regularly at intervals of 10–15 days once hull-split has begun.

MATING DISRUPTION. There are some commercial mating disruption products to control the NOW being tested within almonds in California.

***Quadraspidiotus perniciosus* (Comstock) (Hemiptera: Diaspididae) (San Jose scale)**

Description

The adult male of *Quadraspidiotus perniciosus*, the San Jose scale is a yellow-brown two winged insect that is very small in size, between 1 mm and 2 mm. The female lives under a scale covering and when scraped

away, may reveal a bright yellow body. There is no visible egg stage and nymphs emerge as 'crawlers' during the first instar and migrate to other feeding sites.

Life cycle

There are three stages during the first instar, which include the 'crawler', 'white-cap' and 'black-cap'. The bright yellow crawler is about 0.2 mm in length and will relocate through animal, wind or human intervention. Within 8–24 h of emergence, it will insert mouthparts into the tree, and begin to feed on the tree's sap. As it feeds, a white waxy covering begins to form ('white-cap' stage), and after a week of feeding, the cap will begin to turn black ('black cap' stage). The development of the male requires three moults, and upon emergence it is short lived. Females live under a scale, and emit a sex pheromone to attract males. The male flight and female receptivity tend to peak in the early spring, and within 5–6 weeks the first crawlers emerge. Crawlers that emerge in mid-spring will give rise to the first generation male flight in the summer, and two more generations will follow. Crawlers produced in the late autumn will overwinter as black caps and produce the overwintering flight.

Damage

Damage is from sucking of plant juices and injection of a toxin, which leads to death of twigs, limbs and overall decline in productivity. Red halos often appear around the feeding on green 1-year-old wood, and damage is often visible as necrotic spots when the scale-infested bark is scraped away.

Distribution and host plants

The San Jose scale has a worldwide distribution. The list of host plants includes apple, pear, sweet cherry, peach, prune, other tree fruits and nuts, berry bushes and many kinds of shade trees and ornamental shrubs.

Management for organic farming

BIOLOGICAL CONTROL. San Jose scale has many natural enemies that can keep the pest under control. Within Californian orchards, two predaceous beetles have been identified (*Chilocorus orbus* Casey and *Cybocephalus californicus* Horn) as well as several wasps. The most important wasps are the Encyrtidae species including *Encarsia perniciosi* (Tower) and *Aphytis* spp.

CHEMICAL CONTROL. If large populations are detected, applications of narrow-range oil when the trees are dormant in winter are effective in reducing all the stages of San Jose scale. Spring sprays timed to crawler emergence are also effective, but later sprays are not.

Cimbex quadrimaculata (Müller) (Hymenoptera: Cimbicidae) (almond sawfly)

Description

The adult of *Cimbex quadrimaculata* is 22–24 mm long; its head is dark brown and thorax black in colour. The abdomen is yellow with black crossing, narrow lines. The egg is greenish in colour and about 2.75 mm long. The general colour of the larvae is grey and there are many black dots on the body. The body of the larvae is about 38 mm long when full grown. The pupae are light brown and 25 mm long (Talhouk, 1969).

Life cycle

C. quadrimaculata overwinters as the mature larval stage in the soil. It pupates in March–April depending on the geographical area. Adults emerge in late March and April. They deposit their eggs on the foliage of the trees. The larvae hatching from the eggs feed greedily on the leaves, and can cause severe damage on young trees. The larvae leave the trees usually moving into the soil in May when they attain full size, and they remain in diapause in their cocoons until the following spring (Talhouk, 1969).

Damage

It is not considered as a serious pest, but in some years the larvae can defoliate lonely trees (Talhouk, 1969).

Distribution and host plants

The almond sawfly is known to be found in Cyprus, Lebanon, Palestine, Syria, Turkey and parts of Western Europe (Talhouk, 1969). Avidov and Harpaz (1969) have recorded it in Israel. The pest attacks almond and pear (Talhouk, 1969).

Management for organic farming

C. quadrimaculata is not a serious pest. The parasitization rate in the larval and pupal stage of the pest is quite high. *Listrognathus mactator* (Thunberg) (Hymenoptera: Ichneumonidae: Cryptinae) (Özgen *et al.*, 2010) and *Opheltes glaucopterus* (Linnaeus) and *Phobetes nigriceps* (Gravenhorst) (Hymenoptera: Ichneumonidae: Ctenopelmatinae) (Özbek, 2014) were determined as larva–pupa parasitoids of *C. quadrimaculata*.

Eurytoma amygdali Enderlein (Hymenoptera: Eurotomidae) (almond fruit wasp)

Description

Eurytoma amygdali wasp is black in colour, and forewings are transparent, metallic and shiny and triangular in shape. The tibiae and the connecting other leg segments are yellow in colour. Females bear a distinctive ovipositor (Anonymous, 2008a). The body length is between 4 mm and 8 mm (Avidov and Harpaz, 1969).

The eggs are minute and milky white in colour and bear two prolonged appendages, one being longer than the other. Larvae are without legs, 7–8 mm in length and white in colour. The body of the larvae is covered with scattered hairs. The pupa is white in colour in the beginning, but later turns dark during its development (Anonymous, 2008a).

Life cycle

E. amygdali overwinters as a developed larva inside almond fruits, and before almond blossom time the larvae pupate, and the adults emerge in late February to early March in the Middle East (Talhouk, 1969). However, the majority of the overwintering larvae develop into the pupal stage in the next spring. The duration of the pupal stage takes about 18–51 days depending on the temperature. The first adults appear between March and April in Israel, and also in mid-April and June, depending on climatic and geographic conditions (Avidov and Harpaz, 1969; Anonymous, 2008a). After the adults emerge from the fruit, an emergence hole is visible which is about 2 mm in diameter. After copulation, females can deposit 47–88 eggs into the endosperm of the fresh fruit. The incubation period of eggs is variable; it takes place between 24 days and 27 days. It was reported that emergence usually starts in March in Israel (Plaut, 1971) and in April and May in Greece (Katsoyannos *et al.*, 1992). Males emerge earlier than females, and females deposit up to five eggs per fruit under normal conditions (Plaut, 1971). Laboratory studies have shown that the females of this species use a host-marking pheromone, immediately after oviposition. Therefore, the pheromone enables the females to distinguish the infested and uninfested fruit and to select uninfested fruits for depositing eggs during the oviposition period (Kouloussis and Katsoyannos, 1991). Drilling and deposition of the egg into the nuclear tissue of the young fruits takes about 9–34 min, up to five eggs per fruit being laid under natural conditions (Talhouk, 1977a). It has one generation/year. Mentjelos and Atjemis (1970) stated that when larval development was completed by the end of June or the beginning of July, then the larva enters diapause and remains in this stage for one to three winters in Greece.

Damage

After the eggs hatch, the young larva starts to tunnel into the middle of the fruit. *E. amygdali* is one of the only pests reported to feed on almond fruits in the east Mediterranean countries (Talhouk, 1977a). It can damage up to 50% of the almond orchards in Bulgaria (Ivanov, 1960) and 71% in Macedonia (Cakar, 1980).

Distribution and host plants

The geographical distribution of *E. amygdali* includes the Middle East and east

Mediterranean countries (Plaut, 1972; Talhouk, 1977a). The pest develops on almond, apricot and plum (Anonymous, 2008a).

Management for organic farming

CULTURAL PRACTICES. All infested fruits both on trees and on the ground should be collected from the almond orchards after harvesting, and destroyed.

BIOLOGICAL CONTROL. Many natural enemies of *E. amygdali* have been reported from almond-growing countries. The parasitoids, *Aprostocetus bucculentus* (Kostjukov) (Hymenoptera: Eulophidae), *Gugolzia bademia* Doganlar (Hymenoptera: Pteromalidae) and *Adontomerus amygdali* (Boucek) (Hymenoptera: Torymidae) are common in Turkey (Bolu and Özgen, 2007; Anonymous, 2008a). *Adontomerus amygdali* (Hymenoptera: Chalcidoidea: Torymidae) and *Aprostocetus bucculentus* (Hymenoptera: Chalcidoidea: Eulophidae) are gregarious ectoparasitoids on the larvae of *E. amygdali*. *Pyemotes amygdali* Cobanoglu and Doganlar (2006) (Acarina: Pyemotidae) is a gregarious ectoparasitoid on prepupae, pupae and newly hatched adults of all of the hymenopterous insects (Doganlar *et al.*, 2006). *Thanasimus* sp. (Coleoptera: Cleridae) is a predator of hymenopterous insects in almond fruits. The natural parasitism on *E. amygdali* by *A. amygdali* reached 0.38–35.2% in places where the parasitoid was present. But, in the case of *A. bucculentus* it was less than 5%. Parasitism/predation rates by *P. amygdali* and *Thanasimus* sp. which have been found in Hatay province (Turkey) ranged from 7.56% to 44.53% and 0.38% to 11.2%, respectively (Doganlar *et al.*, 2006). It is likely that the natural enemies help to keep the pest population at a lower level, so the habitat in almond orchards should be amended and protected to ensure the survival of populations of parasitoids.

CHEMICAL CONTROL. Determination of the first emergence of adults is very important in the spring. Cages covered with mesh cloth can help to determine the first adult emergence by observing the infested fruits from the previous year placed in the cages. Chemical spraying that is acceptable in organic production can be started after emergence of the adult in the spring. The emergence period of adults can vary between 24 days and 45 days. If the emergence period were extended, one more spray may be needed to control the pest effectively.

Web-spinning spider mites

Web-spinning spider mites that are pests on almond include the following species:

- *Tetranychus pacificus* McGregor (Acari: Tetranychidae) (Pacific spider mite);
- *Tetranychus urticae* Koch (Acari: Tetranychidae) (two-spotted spider mite); and
- *Tetranychus turkestani* Ugarov and Nikolski (Acari: Tetranychidae) (strawberry spider mite).

Description

Mites are tiny arthropods (< 1 mm) belonging to the class Arachnida (other examples: spiders, ticks). The web-spinning mite species described in this section are more or less similar in morphology (adult stages), life cycle, feeding habit and nature of damage to the plants. Therefore, the same management strategy applies to all three species.

Adult mites are pale green to black in colour, which changes into red or orange during the winter. Male mites are smaller than females and they do not overwinter.

Life cycle

Adult females overwinter under bark, leaf litter and winter weeds on the orchard floor. Upon reaching the conducive environmental conditions in spring, mites migrate from their overwintering sites to the trees for egg laying. Mites deposit eggs on the underside of the leaf surface, and upon hatching first instar larvae start feeding on leaves. At least three moults occur. Early in the season, mites are abundant in the bottom half of the trees, but will become widespread throughout the tree later in the season depending on temperature and the degree of infestation.

Temperature plays a significant role in increased mite reproduction, thus maximum population increase occurs between June and September. Spider mites can complete their life cycle within 7 days under high temperature conditions, and can have between eight and ten generations/year in California (Strand, 2002).

Damage

Spider mite infestations often begin on the underside of the leaves. All stages of mites feed on almond leaves by sucking the cell contents. Spider mite infestation is characterized by the presence of webbing covering tree leaves and twigs. The webbing has several biological and ecological functions including dispersal and reproduction of mites, and protection from natural enemies (Gerson, 1985; Kennedy and Smitley, 1985). In the beginning, damage by spider mite feeding results in stippled leaves, which advances to yellowing and dropping of leaves as the infestation progresses. The degree of mite infestation is negatively correlated with chlorophyll content and photosynthetic activity of the leaves (Andrews and La Pré, 1979), and this eventually affects tree health and productivity. Mite damage in the current year translates into the reduction in growth and productivity of the trees in the following years (Barnes and Andrews, 1978).

Distribution and hosts plants

The three spider mite species possess a wide geographical distribution, and they are one of the most widely distributed pests of many wild, ornamental and cultivated plants. In the USA, two-spotted spider mites feed on over 300 host plants, and one-third of them are cultivated crops.

Pest monitoring

Spider mites favour a dry and low-moisture type of environment, thus water-stressed orchards are often at risk of high infestation. Properly irrigated orchards may not require treatment for mites in most cases as almond trees can tolerate low to moderate mite pressure without affecting tree productivity.

Another important aspect of effective mite control is judicial use of available control measures. The mite population in several crops including almond is often well controlled by natural enemies, and the use of broad-spectrum insecticides can disrupt the natural control system resulting in elevated levels of spider mite population. A high natural enemy:mite ratio does not require treatment intervention in almond.

Monitoring of orchards for predators and spider mites is critical. Sampling at least once every 2 weeks during the early part of the growing season and weekly thereafter until harvest is recommended. If the orchard has a history of heavy mite infestation or water-stressed trees, monitoring every few days may be necessary. During the early phase of the growing season, sampling should focus on areas with a greater likelihood of early infestation such as areas near to dirt roads and areas with water-stressed trees. Once infestation has reached the economic threshold, sampling is necessary for the rest of the orchard. Dividing orchards into sampling areas is helpful to determine whether the spot treatment in a high mite infestation area is sufficient. For each sampling area, 15 random leaves should be selected from each of five selected trees, and these should be examined with a hand lens on both sides of each leaf for the presence of spider mites and eggs, predatory mites or eggs, and other predators. The treatment decision can be made based on presence/absence sampling for mite and predator. Details of the sampling protocol are described in Strand (2002).

Management for organic farming

USE OF OIL. Several types of organic oil are available commercially to use both in conventional and in organic productions, although all oil types may not be acceptable for organic use. Since oil works by contact action (including smothering and barrier effects), good spray coverage is crucial for its effectiveness. Due to the potential risk of phytotoxicity, it is important to apply oil to well-watered trees. Oil also kills beneficial arthropods that come into contact during the spray application, but there are minimal

risks on remaining beneficials due to low residual activities. More than one application may be necessary to control a large pest population.

CULTURAL CONTROL. Irrigating the orchard properly to reduce water-stressed trees is critical to reduce overall mite populations in the orchard. In addition, reducing dusty conditions by oiling or watering dirt roads and maintaining a good ground cover in the orchard are preventative measures to minimize mite infestations.

BIOLOGICAL CONTROL. There are several species of biocontrol agents that are effective in reducing the spider mite population in almond. The abundance and effectiveness of species can vary with the geographic region and other environmental factors. The western predatory mite, *Galendromus occidentalis* (Nesbitt), six-spotted thrips, *Scolothrips sexmaculatus* (Pergande) and a black-coloured ladybird beetle species, also called the spider mite destroyer (*Stethorus* sp.) are reported in almond orchards in the USA (Strand, 2002). The western predatory mite is the most widespread and effective predator. Similar in size to a spider mite, the western predatory mite lacks black spots on its body, and is highly mobile. Six-spotted thrips can quickly migrate among leaves and prey on spider mites efficiently. Spider mite destroyer beetles are good fliers and can concentrate their feeding on spider-mite-aggregated areas of the orchard. These natural enemies are available commercially to use as an augmentative release in almond orchards to boost natural populations.

Secondary Pests

Ants

Ants that are pests on almond include the following species:

- *Tetramorium caespitum* (L.) (pavement ant);
- *Solenopsis xyloni* McCook (southern fire ant); and
- *Solenopsis molesta* (Say) (thief ant).

Description

The workers of the pavement ants are dark brown to black in colour with body size ~ 3.5 mm long, consisting of parallel furrows or ridges on the head and thorax (Bruder and Gupta, 1972). Reproductive ants (swarmers) have wings, and are twice as big as workers with similar other morphological structures (Jacobs, 2013). Pavement ants prefer sandy or loamy soil for nesting. Not much information is available about the colony biology for this ant.

Southern fire ants are stinking ants native to the southern parts of the USA. The southern fire ant workers vary from 1.8 mm to 6.4 mm in size. This ant has an amber-coloured head and thorax with a black abdomen. The eyes are noticeably big and the body is covered with golden hairs. Similar to pavement ants, fire ants also have a two-segmented pedicel, a structure that connects the abdomen with the thorax. The distribution of this ant ranges from California to South Carolina (southern part) and Florida (north-west corner) (Smith, 1965; Taber, 2000).

Thief ants are slightly smaller than the fire ants. These ants are present in relatively small numbers and nest in proximity to other ant nests, from which they often steal food.

Ant nests are in small mounds or patches of loose soil, commonly found close to wetted areas in orchards. These nests are closer to berms in orchards with flood irrigation and with clay soil, but are also found in other areas of the orchard that have conditions of loose soil. Fire ants swarm upon disturbance. Southern fire ant nests are often associated with clumps of weeds, such as nuts edge (*Cyperus esculentus* L.) or spotted spurge (*Euphorbia maculata* (L.)). Ants are active as pests in orchards with peak activities in the morning and just before sunset (Strand, 2002).

Damage

The southern fire ants are a more widespread problem in almond, although pavement ants are more problematic in the northern part of the Central Valley of California. Damage on almond by ants is due to direct feeding on the nut kernels; feeding on

kernels results in chewing marks and white dust in the nuts. Ants can completely hollow out the meat from the kernel leaving only parts of the pellicle (i.e. the outer skin of the kernel). Ants can damage nuts still attached to the young trees; however, the major damage occurs to harvested nuts that are on the orchard floor as a part of the harvesting process (Zalom and Bentley, 1985). Orchards with a sprinkler or a drip irrigation system and with cover crops are more at risk of infestation. Almond varieties with a tight shell seal or with minimal splits (< 0.75 mm) experience less damage, and the shell seal can vary according to other factors such as the year, the crop size, the nut size and horticultural practices.

Distribution and host plants

T. caespitum is native to Europe but is also actually reported in North America. *S. xyloni* is found in the USA and Mexico, and *S. molesta* is reported in North America, Mexico and recently in Malaysia. They are omnivorous, and *S. xyloni* feeds on various plant parts such as fruits, seeds, honeydew, plant sap, stems, buds and tubers of several plants including althea, dahlia, citrus, okra, pecan, walnut, almond, tomato, melons, potato, strawberry, yukka, maize and aubergine (Smith, 1937, 1965; Zalom and Bentley, 1985; Taber, 2000). *S. molesta* are present in relatively small numbers and nest in proximity to other ant nests (Thomson, 1989), from which they often steal food.

Pest monitoring

In spring, surveying the orchard floor for ant colonies 2–3 days after irrigation is very important. For sampling, the orchard block should be divided into five survey areas (each survey area ~ 93 m^2 (= 1000 ft^2)) including the area from mid-alley to mid-alley beneath the trees. Active ant colonies should be surveyed and counted from individual survey areas. Based on total colony counts from five survey areas (i.e. 5 × 93 m^2 = 465 m^2) in spring, and the number of days in which nuts are on the ground after the harvest provides estimates of the percentage nut damage caused by ants (Table 12.4). In addition, inspecting a sample of 500 harvested nuts for ant damage provides information on the effectiveness of current pest management practices, and therefore provides guidelines for future pest management planning. Full details of the sampling protocol are explained in Strand (2002).

Management for organic farming

Insect growth-regulator-based baits are effective methods for managing ant population in almonds. Baits are more effective than insecticide sprays to control ants because receiver ants (worker ants) carry baits inside the colony and the whole colony can be destroyed. Since baits are relatively slow-acting products, application should be made several weeks before the harvest. Higher moisture reduces the effectiveness of the baits, so it is recommended to avoid use of baits 1–2 days before and after irrigation. Some of these baits are registered for use in organic production.

CULTURAL CONTROL. Flood irrigating can reduce ant populations. Damage is significantly higher in orchards that harvest the nuts off the ground. Nuts should be removed

Table 12.4. Percentage damage caused by ants to almonds on the ground in an almond orchard. (From Strand, 2002.)

No. of colony entrances/ 465 m^2 (5000 ft^2)[a] in spring	Days nuts are on the ground				
	4	7	10	14	21
15	0.9%	1.6%	2.1%	3.1%	4.9%
45	1.4%	2.3%	3.2%	4.7%	7.0%
185	2.0%	3.6%	5.0%	7.0%	11.1%

[a]Value of 5000 ft^2 is the value according to Strand (2002). This has been converted into square metres (5000 ft^2 = ~ 465 m^2).

from the orchard floor as rapidly as possible following tree shaking to minimize ant damage on harvested nuts. Table 12.4 shows the risks of potential damage by ants depending on the time between tree shaking and the removal of nuts from the ground.

Brachycaudus amygdalinus (Schouteden) (Hemiptera: Aphididae) (short-tailed almond aphid)

Description

The body of the apterous female *Brachycaudus amygdalinus* on almond is dark green, but pale green on the posterior part of the abdomen, and 1.6–2.1 mm long. It has short legs and antennae. The antenna is six segmented, the siphunculi are short and pale green, the apices dark and the cauda is very short. The male is winged, the head and thorax are black, and the abdomen is dark brown. The body is 1.1–1.8 mm long, the cauda and siphunculi are black, and the genitalia are dark brown (Avidov and Harpaz, 1969; Lodos, 1982; Blackman and Eastop, 2000).

Life cycle

B. amygdalinus overwinters in the egg stage, eggs having been laid by gamic females within bark crevices and in bud axils of the almond tree. The eggs hatch in the next spring when the almond trees are in leaf, and reproduce virginoparously. The population of *B. amygdalinus* can reach high levels on the underside of the leaves in the spring as a result of rapid colonization of foundresses (Avidov and Harpaz, 1969). The colonies become overcrowded, and the winged form exists by the summer. They migrate back to the alternative hosts during summer, and the almond trees are free from the aphid during summer until autumn (Swirskii, 1954).

Damage

Infested leaves roll up and drop prematurely, and new growth is stunted as a result of feeding by the aphid pest (Avidov and Harpaz, 1969).

Distribution and host plants

The geographical distribution of the short-tailed almond aphid includes central and western Asia, Crimea, Israel, Europe, South Africa, the Middle East, Ukraine, Pakistan and Turkey (Bodenheimer and Swirski, 1957; Avidov and Harpaz, 1969; Lodos, 1982; Blackman and Eastop, 2000, 2006). The pest develops on almond and peach (Blackman and Eastop, 2000).

Management for organic farming

CULTURAL PRACTICES. Growers should avoid application of excess nitrogenous fertilizer and irrigation to control shoot flushing and leaf formation where there are high population numbers of colonizing aphids.

BIOLOGICAL CONTROL. Enhancing the numbers of natural enemies in the spring may help to control *B. amygdalinus* populations. There are numerous natural enemies that either feed or breed on the aphids. Many species of Aphidiidae, Braconidae, Eulophidae, Encyrtidae and Pteromalidae are parasitoids of aphids; and many species of Chrysopidae, Coccinellidae, Lygaeidae, Miridae, Nabidae, Anthocoridae, Cecidomyiidae, Syrphidae and Trombidiidae are predators of aphids (Anonymous, 2008a).

In addition to *B. amygdalinus* on almond the following aphid species are also reported: (i) *Hyalopterus amygdale* (Blanchard) (Russo *et al*., 1994); (ii) *Brachycaudus amygdalinus* (Schouteden) (Avidov and Harpaz, 1969; Talhouk, 1977b; Sekkat, 1984; Russo *et al*., 1994); (iii) *Brachycaudus helichrysi* (Kaltenbach); (iv) *Pterochloroides persicae* (Cholodkovsky) (Talhouk, 1977b); (v) *Hyaleptorus pruni* (Geoffroy); and (vi) *Myzus persicae* (Sulzer) (Sekkat, 1984).

Anthonomus amygdali Hustache (Coleoptera: Curculionidae) (almond weevil)

Description

The adult of *Anthonomus amygdali* is brown in colour and 3.0–4.2 mm long. The egg is milky white, oval in shape and 0.8 × 0.5 mm

in size. The larva has a cylindrical body and is 4.8–5.5 mm long, and the head of the larva is shiny reddish brown.

Life cycle

A. amygdali overwinters as a larva and feeds on the buds throughout winter. It pupates in the spring months. Adults of the pest are situated in the shelter during the summer and become active in the autumn. They feed on the buds of the almond trees and deposit their eggs on the buds which generate in the next spring. They produce a single generation annually.

Damage

The infestation rate of the pest on the blossom of almond trees was estimated to be 1–5% in west Turkey (Önuçar and Zümreoğlu, 1985).

Distribution and host plants

Distribution includes many countries in Europe and the Middle East (Anonymous, 2013b). The pest develops on almond, apple, cherry, peach, plum, quince, walnut and *Pyracantha coccinea* Roem. (Anonymous, 2008b).

Management for organic farming

CULTURAL PRACTICES. It may help to reduce damage by pruning off the damaged shoots and branches of the trees. Additionally, adults can be picked off when they drop on a sheet placed on the ground by shaking the trees. Also damage can be reduced by picking off the damaged blossoms on the ground (Anonymous, 2008b).

BIOLOGICAL CONTROL. *Scambus pomorum* (Ratzeburg) (Hymenoptera: Ichneumonidae), *Bracon disdiscoidens* Weems and *Syrrhizus delusorius* Foraty (Hymenoptera: Braconidae) are known as common and effective parasitoids (Anonymous, 2008b).

Other pests

Fifty-four species from the superfamily Curculionoidea (Rhynchitidae – two species, Brentidae – 20 species, Curculionidae – 30 species and Scolytidae – two species) were collected from almond trees (Bolu and Legalov, 2008). There were many other pests in almond orchards, namely *Tatianaerhynchites aequatus* (Linnaeus) and *Epirhynchites smyrnensis* (Desbrochers des Loges) (Coleoptera: Rhynchitidae), *Diloba caeruleocephala* (L.) (Lepidoptera: Noctuidae), *Nordmannia acacia* (F.) (Lepidoptera: Lycaenidae), *Polydrosus roseiceps* Pesarini (Coleoptera: Curculionidae), *Hedya nubiferana* (Haworth) (Lepidoptera: Tortricidae), *Aporia crataegi* (L.) (Lepidoptera: Pieridae), *Agrilus roscidus* Kiesenweter (Coleoptera: Curculionidae) and *Capnodis tenebricosa* (Oliver) (Coleoptera: Buprestidae) (Bolu *et al.*, 2011). However, the number of studies on the biology, damage and control methods of these other pests are not sufficient, and they need to be developed.

Other mites in the almond orchard

Other mites in the almond orchard include:

- *Panonychus ulmi* (Koch) (Tetranychidae) (European red mite); and
- *Bryobia rubrioculus* (Scheuten) (Tetranychidae) (brown mite).

Description

Both European red mites and brown mites are not considered a major problem in almond orchards. These mites overwinter as eggs on tree parts such as fruit spurs, buds and twigs. They have red eggs which look similar except the European red mite egg which has a typical spine-like projection (i.e. a stipe) arising from the centre of the egg. Newly hatched larvae are green, which changes into red after feeding. Stipes are lacking in brown mite eggs.

Life cycle

Egg hatching of brown mites coincides with the leaf and flower bud opening time in almonds. Freshly hatched larvae which are red in colour with six legs, eventually change to a brown colour with eight legs

resembling the adults. Brown mites are not active during the hot summer time, and have two to three generations/year, while European red mites are active for a longer part of the growing season and have five to ten generations in California (Strand, 2002).

Damage

Feeding by European red mites causes leaf stippling. Under prolonged feeding, leaf margins initially look yellowish brown, which eventually turns into a burned type of symptom. Healthy trees can tolerate high infestations (up to 50 mites per leaf). Brown mite feeding can cause leaf chlorosis, but leaf dropping is rare. Feeding activities on leaves occur only during the cool parts of the day. Infestation by brown mites is often confined to a few trees in the orchard.

Sampling and management

Generally these mite species are under natural control. In fact, they serve as food sources for important beneficials during the early part of the season. One of the beneficials, the western predatory mite is effective in reducing European red mite and brown mite populations. Although not prevailing in all orchards, the brown lacewing, *Hemerobius* sp., is an effective predator against mite pests. Spur sampling to look at mite egg presence between late autumn and early January is recommended to guide treatment decisions. Late dormant application of oil targeting mite eggs is suggested if infestation exceeds 20% of the sampled spurs. Occasional infestations of brown mite can be seen in a cool spring if the dormant treatment is inadequate. Biological control and certain oil sprays are available for use in organic production.

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