CHAPTER – PISTACHIO PESTS AND THEIR MANAGEMENT

Overview

Top

Currently Australian pistachio orchards are in the enviable position of having very little insect pest pressure. However, as seen with *Carpophilus* species in almonds, it only takes a minor shift in some factors (climate or genetics) and what was a minor pest has the ability to become a major pest. This is presumed to be a change in the insect species 'biotype'.

Biotypes refer to the infraspecific (any taxon below the rank of species) category of insect populations with similar genotypes for biological attributes. "Broadly considered, the term biotype is an intraspecific category referring to insect populations of similar genetic composition for a biological attribute. The biotype populations may be partially and temporarily sympatric, allopatric or parapatric with other compatible populations, but differ in one or more biological attributes." (Downie, 2010)

They have been encountered mostly in association with cultivation of resistant crop cultivars and in well-studied cases a gene-for-gene relationship between pest virulence and host plant resistance has been documented. Biotypes represent evolutionary transients in the process of speciation and develop through natural selection acting upon genetic variations within the pest populations. To slow down the process of biotype selection, ideally crop cultivars with broad genetic bases are needed.

We can learn lessons from specific insect problems in similar crops to pistachio such as almonds – particularly as they are grown in the regions that pistachios are cropped. The majority of the pests listed below are currently not – or are only minor – pests of pistachio but we need to be aware of them as possible future pests of pistachio crops.

References:

Downie DA. 2010. Baubles, bangles, and biotypes: A critical review of the use and abuse of the biotype concept. *Journal of Insect Science* 10:176 available online: insectscience.org/10.176

Navel orangeworm moth (10 mm) on pistachio (Image: Kathy Keatley Garvey, Agriculture and Natural Resources, University of California).

Endemic Pests

Top

Managing pests and predators in pistachios

Lacewing egg on pistachio stem.

Commercial pistachio production in Australia is predominantly based along the Murray Valley and the Mallee zones of southern Australia. Despite being grown commercially since the early 1980’s, the industry has had no major insect pest outbreaks.

However, the detection of major insect pest species in other tree nut crops, in similar growing regions to pistachio, indicates the need for a better understanding of insect pest threats.

A research project into the pest status of pistachio orchards in Australia has recently been completed. Funded by Hort Innovation, the project (Understanding and managing insect pests of pistachio orchards) was undertaken by Ag Dynamics, a horticultural consulting company with the support of Swan Hill Chemicals and Retallack Viticulture.

Insect monitoring in commercial pistachio orchards at Pinnaroo (SA), Robinvale (VIC) and Kyalite (NSW) confirmed that a wide range of pests were found in low numbers in all orchards but equally, a wide range of beneficial arthropods (primarily predators such as lady beetles, lacewings and spiders) were also found in high numbers.

The observation that beneficial arthropod numbers were high even with low pest levels warranted further investigation. Therefore, the focus in the final year of the project was to determine potential alternative food sources for beneficial insects in surrounding local/native vegetation and on the orchard floor. Surveys were conducted at a commercial pistachio orchard at Robinvale (VIC) and a small trial orchard at the Dareton Research Centre (NSW DPI).

High diversity and abundance of beneficial arthropods were found in vegetation surrounding the orchards, particularly early in the season. This diversity fell away quickly as summer progressed though.

The highest richness of arthropods was observed at the commercial orchard at Robinvale (VIC) (66 morphospecies), which is surrounded by native vegetation. Out of a total of 44 predatory morphospecies, 20 were found in a native plant mix (consisting of Sheoak, Allocasuarina sp., emu bush, Eremophila sp., gum, Eucalyptus sp., spider flower, Grevillea sp., Hakea sp. and Macadamia sp. compared with areas of limited diversity (for example, 15 on an area of only saltbush, 13 on Acacia sp., and 12 each on silver cassia and bottlebrush, compared to 10 on the pistachios.

This work demonstrates the potential to increase the functional diversity of predatory arthropods (and thereby reducing pest pressure) by incorporating these native insectary plants in association with pistachios.

Insectary plants provide valuable habitat (food, shelter and alternative prey) for predatory arthropods (as well as pollinators). They will also enhance biodiversity and conservation biological control efforts.

This work contributes to a growing body of knowledge being developed across a variety of horticultural crops. Ongoing work in macadamias, wine grapes and vegetables, to name a few, continues to demonstrate the impact a diverse range of insectary plantings can have on pest management and orchard biodiversity.

In addition to the work carried out on beneficial arthropods, this project also undertook surveys of mummy nuts during winter and found low numbers of overwintering pests. Carpophilus beetle (C. nr. dimidiatus) in mummy nuts varied between the three orchards, but greater numbers of Carpophilus beetle were found in mummy nuts located on the orchard floor compared to those in the tree canopy, and in drip-irrigated orchards compared to sprinkler-irrigated orchards.

As a result of this work, as well as research work underway in other tree nut crops, growers are encouraged to focus management on two areas of production:

1. Orchard hygiene

The presence of overwintering pests in mummy nuts points to a potential threat. Improving orchard hygiene post-harvest needs to be the focus of managers, supported by further industry research and communication.

2. Enhance native vegetation around orchards

The wide range of beneficial arthropods found in native vegetation around commercial orchards should prompt further work on identifying the best plant species to be incorporated into the orchard system. This needs to be done at a local or orchard level but should be coordinated as an industry-wide activity.

Spined Predatory Shield Bug - *Oechalia schellenbergii*. Photo courtesy: Brisbaneinsects.com

By Stuart Pettigrew of Ag Dynamics is an agribusiness consultant currently engaged as Project Manager for a large macadamia development in northern NSW. For 30 years he has worked across a range of tree crops including nuts and citrus, and has undertaken projects in most growing regions of Australia, as well as more than 20 countries. From: https://www.treecrop.com.au/news/managing-pests-and-predators-pistachios/

Carpophilus Beetle

Top

Tunnels chewed by carpophilus larvae are often flattened in cross-section.

Photo: Agriculture Victoria Reasearch

Nitidulid beetles (primarily Carpophilus spp.), are worldwide pests of a variety of fruits and grains before and after harvest. In southern Australia the larvae of these beetles are serious pests of ripening stone fruit and more recently due to a presumed biotype change, have become a serious pest of almond crops now being found in approximately 70% of almond orchards in Australia (Hossain, 2018).
Carpophilus beetles are also known as Dried Fruit Beetles. Interestingly the Carpophilus species attacking almonds is not the same species that attacks stone fruit, which is *Carpophilus dimidiatus*. The species attacking almonds has been temporarily named *Carpophilus* ***near*** *dimidiatus* due to its similarity – and differences!

Fruit loss is caused primarily by adult beetles penetrating ripening fruit causing rapid breakdown. Beetles can enter fruit by chewing through the skin mostly around the stem end or in sutures. However, they often enter at sites of mechanical damage. The beetles also serve as mechanical carriers (vectors)of brown rot disease. The importance of Carpophilus spp. in stone fruit production has increased in recent years, following a decline in insecticide use for the control of other key pests such as oriental fruit moth.

Since the harvest of 2013, Australia's almond industry has been suffering significant losses in its major production regions due to kernel damage by carpophilus beetles, a group of pests better known for damaging fresh stone fruit. Average damage levels as high as 5-10% are now not uncommon in almond orchards, and costs to industry from this insect have escalated well into the millions. (Hossain, 2018)

Life Cycle

Carpophilus beetle do not breed in fruit on the tree. Adults lay eggs in rotting or damaged fruit on the orchard floor. Mature larvae emerge from the fruit and pupate in the ground.

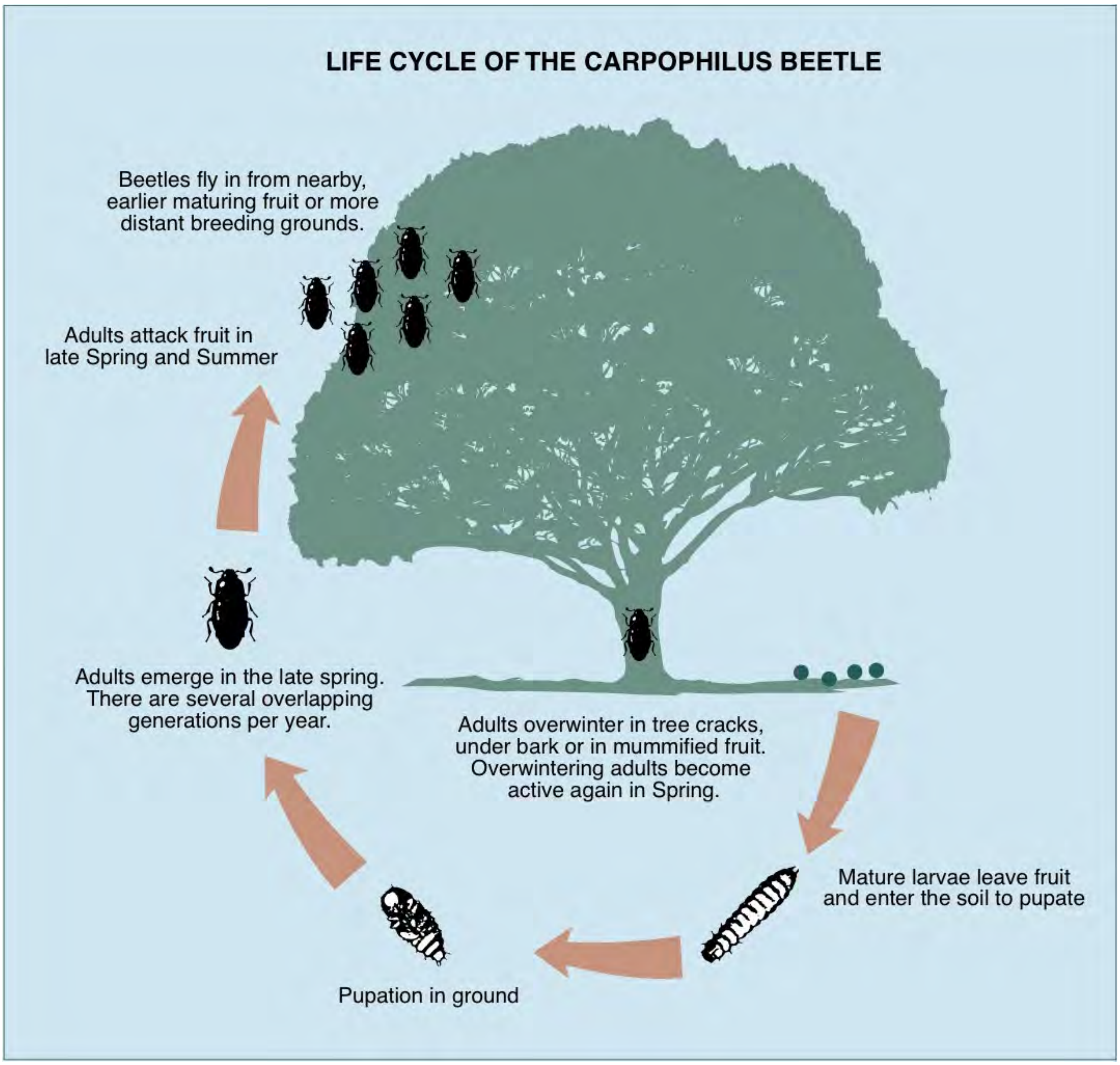
Adults emerge from the pupae and attack fruit in late spring and summer. If no hosts are available they overwinter in cracks in the tree, under bark or in mummified fruit. It takes about a month in summer to develop from egg to adults so there are many generations per year.

Carpophilus beetles are strong fliers and can travel several kilometres in search of hosts. Summer rainfall and rotting of fruit provides the best conditions for beetle breeding. Dry summer and autumn conditions reduce the threat in the following season by providing less favourable breeding conditions.

Adult Carpophilus are small at around 3mm long, oblong shaped beetles with short wing covers such that the end of the abdomen is not covered and have clubbed antennae. They can be black, brown or mottled yellow. Larvae are yellowish with a brown head and forked tail and are about 5mm long when fully grown.

Damage

Most commercial feeding damage is done to ripening stone fruit. Stone fruit can be attacked on the tree, beetles burrow into the fruit, particularly near the stem end suture line. They also enter through splits and mechanical damage. In other fruits such as citrus, apples and figs, only fallen fruit is attacked. Carpophilus beetles are a major vector of brown rot. As they crawl through damaged fruit, the spores of brown rot stick to their bodies and are spread through the tree canopy and from orchard to orchard. The disease is carried on the body of the insect and fruit can become infected with the disease simply by contact, without the beetle actually feeding on fruit. Control of Carpophilus, where they are present, is an important part of controlling brown rot.



Control (for stone fruit)

Carpophilus beetles are introduced pests in Australia and they have no known natural enemies to limit their abundance.

Good hygiene is the most important aspect in the management of this pest. Fallen fruit should be removed or destroyed regularly during summer to break the life cycle, because eggs are laid only in damaged and rotting fruit. Sweeping fruit from under drip lines and mulching is an option. Good fruit fly control will help ensure that there are less damaged fruit on the tree or on the ground.

As Carpophilus beetles can move several kilometres, area wide cooperation is needed for most effective control. Growers should inspect fallen fruit to assess beetle activity and the potential for damage.

A lure trap for both monitoring and management of Carpophilus beetles is available commercially. This approach could be considered where Carpohilus beetles are a consistent pest. For details on the trapping system, consult the Australian Pesticides and Veterinary Medicine Authority website.

Insecticides registered for the control of Carpophilus beetles in deciduous fruit tree orchards in Western Australia are listed in the Pome and summer fruit orchard spray guide, refer also to Infopest for information on chemical registrations. There are no registered chemicals for control of Carpophilus beetles in Pistachio. Insecticide control is not as effective a control as removing unwanted fruit. Trees should be monitored as the fruit approaches maturity and becomes susceptible to attack. Sprays are applied to cover the fruit and foliage before the beetles can reach damaging levels. Decisions to respray trees should be based on monitoring and label recommendations. Insecticides do not give long-term protection against the adult beetles that can migrate into the area.

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Hossain, M, **2018**, Management of Carpophilus Beetle in Almonds – AL15004, Hort. Innovation Final Report. 2018

Florida Pink Scavenger Moth

Top

Florida Pink Scavenger Moth adult (Pyroderces badia), note fringed hind wings in inset. Image Betsy Higgins 2014

Scavenger moths, family Blastobasidae, total over 296 species worldwide, with many known from North America and Europe, in three subfamilies; actual fauna probably exceeds 600 species.

Adults small (5 to 35 mm wingspan), with head smooth-scaled; haustellum scaled; maxillary palpi 4-segmented. Maculation mostly somber shades of gray with few markings. Adults nocturnal as far as is known.

The larvae are mainly scavengers, feeding on dry or decaying fruit, dead floral parts, and sooty mould among fruit clusters and under sepals. The larvae have been recorded feeding on cones of several species of Pinus and Cassia pods, dead fruits of peach and loquat, lime, grapefruit, banana, cabbage, coconut blossoms and elm leaves. During summer, larvae may nibble on rind of ripe oranges, often near the stem end or on the sides of fruit in a cluster. The feeding is usually superficial and does not cause appreciable damage.
It is unknown if the Florida Pink Scavenger Moth larvae damage pistachio nuts.

References:

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Apple Dimpling Bug

Top

Apple Dimpling Bug, female on the left, male on the right. Size approximately 3mm. Image courtesy Agriculture Western Australia.

Two species of Australian native insects are called apple dimpling bug. The pest commonly called apple dimpling bug in Tasmania (*Niastama punctaticollis*), is a different insect from the pest called
apple dimpling bug on the mainland (*Campylomma liebknechti*). It is the mainland species that will be discussed in this fact sheet.

Apple dimpling bug is a strange species of insect as it is both good and bad. Apple Dimpling bugs are well known as predators of helicoverpa eggs and mites – in other words they act as a beneficial insect when it comes to those pests. However, they are also plant feeders and commonly feed on any of 62 species of plants, including apple as well as Australian native and introduced tree species such as tagasaste, (*Chamaecystisus proliferus*), Chinese hawthorn, (*Photinia robusta*), Geraldton wax and wattle (*Acacia sp*.). Wattle is an important host across mainland Australia, and large numbers of the bug can breed up on a single tree. They feed on the flowers and immature fruitlets, causing cell damage that results in scarring and dimpling of the fruit as it expands, rendering fruit unmarketable.

Description

Adult Apple Dimpling Bugs are pale yellow-green or greenish-brown insects about 3 mm in length with spines on their hind legs. Male bugs are often slightly darker in body colour than females from the same population. Females have a needle like ovipositor to insert eggs into plant tissue. Apple Dimpling Bugs are extremely active insects that are easily startled and will fly off at the slightest disturbance.

Apple Dimpling Bug eggs are kidney-shaped and translucent white in colour. Nymphs are smaller, wingless versions of the adult bug. The first instar nymphs are initially almost white in colour and as they mature, they gradually become pale to bright yellow.

Dimple bugs can be identified with the aid of a 10x hand lens. They have spiny legs, a triangular shape formed by the wing covers and dark bands at the base of the antennae.

Another reliable distinguishing characteristic is the distinctive sweet smell emitted when a bug is squashed. They also tend to avoid direct light. By squashing and smelling any insects found hiding under flower petals in a sampling container, dimple bugs will be identified correctly.

Life Cycle

Apple Dimpling Bugs develop through a life-cycle of gradual metamorphosis – egg, nymph, adult.

Apple Dimpling Bugs lay their egg singly into the plant tissue leaving only the egg cap exposed, and the eggs hatch after about a week. Apple Dimpling Bugs develop through five nymphal stages before becoming adult bugs. They complete their life-cycle from egg to adult in about three to four weeks.

Female Adult Dimpling Bugs lay about 50 eggs over their lifetime of about two weeks.

Apple Dimpling Bugs (*Campylomma liebknechti*) complete one generation in apples, then, the new generation of adults fly off to other hosts such as various wattles, grevilleas and eucalypts.

Damage

The insects feed by inserting their sucking mouthparts into the developing bud, piercing the ovary and sucking the sap. Scarring associated with the 'sting' site will fail to expand and may become calloused. This failure to expand leads to distortion of the fruit as the surrounding healthy tissue grows normally. This gives affected the fruit its dimpled appearance.

Apple dimpling bug shows a marked preference for flowers in full bloom. Fruit damaged severely by apple dimpling bug may be shed, resulting in a reduction in yield. The greater the number of apple dimpling bugs, the greater damage to fruit.

Monitoring

The main risk period for Apple Dimpling Bug – for apples - occurs between early pink and petal fall. The danger is especially acute if fruit tree flowering coincides with or immediately follows the flowering of native trees in surrounding bush. In particular be aware of tree lucerne, and wattle. Monitoring Apple Dimpling Bug activity in these species in the lead-up to apple flowering can indicate the likely level of seasonal risk.

Monitor Apple Dimpling Bug numbers at least twice weekly from late spurburst through to complete petal fall by tapping bud and flower clusters over a 4 L white ice cream container (or equivalent). The bugs are very active and quick inspection of the container is required to see the bugs before they escape. For much of the risk period (until 100% petal fall), the potential for significant Apple Dimpling Bug damage is considered high, even if bugs are present at only low numbers (i.e. 2 to 5 bugs per 250 flower clusters). Be aware that bug numbers can quickly escalate to significant levels with changes in weather. Experience has shown that Apple Dimpling Bug numbers often increase following the arrival of warm northerly winds.

Management

Cultural and physical

Maintain vigilance on blocks or rows which neighbour native trees and shrubs. Consider removing nearby host species, particularly wattle and lucerne trees.
In apple orchards, hand-thinning for crop load during late November to early December is a good opportunity to preferentially remove any apples that have signs of dimpling damage. A percentage of damaged fruit will drop naturally between petal fall and harvest.

Biological

There are no known biological control agents for apple dimpling bug. Interestingly, after complete petal fall, Apple Dimpling Bug might actually be a beneficial insect in the orchard, feeding on Heliothis moth eggs and pest mites.

Chemical controls

There are no registered chemicals for control of Apple Dimpling Bug in pistachios.

Wattle flowers near pistachio orchards should be monitored for Apple Dimpling Bug if flowering coincides with pistachio flowering.

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Rutherglen Bug

Top

Rutherglen Bug (*Nysius vinitor*) adult – image courtesy of Andrew Weeks, Cesar Australia

The Rutherglen bug (*Nysius vinitor*) is a native species that can migrate into crops in very large numbers in favourable seasons. Rutherglen bug is a pest of many crops across Australia including: grains, sunflower, canola, sorghum and some vegetables such as lettuce. Favoured weed hosts are wireweed and common purslane (summer-autumn) and capeweed (winter-spring).

In strawberries, Rutherglen bugs are not considered a regular pest, but in suitable high pest pressure seasons, adults and nymphs can damage flowers, seeds and fruit. Large numbers of bugs in strawberry flowers during pollination can result in deformed fruit that remains small, dry and take on a 'cat face' appearance.

Rutherglen bug is primarily a seed-feeding species, and has the capacity to damage crops during grain filling – but little is known about how much damage can occur in any crop other than sunflower. The main issue with Rutherglen bug around harvest time of wheat and barley crops is that it becomes a contamination pest of harvested grain.

Rutherglen bug breed on a wide range of native and weed hosts, building up to large numbers in inland areas when winter and spring rainfall allows the growth of native herbs and weeds. When their host plants dry out and die during spring and summer, adults migrate to eastern cropping regions to feed and breed.

Major infestations have been known to be associated with the winds of storm fronts. During wetter winter/spring seasons, weeds in cropping regions can also be key breeding hosts. It is hard to predict which plants drive Rutherglen bug invasions in any one season.

Description

Adults are 4 mm long and grey-brown in colour with clear wings folded flat on their back. They have a narrow body with prominent dark eyes, sucking and piercing mouthparts and they are highly mobile. Nymphs are wingless and have a dark red, pear-shaped body.

Life Cycle

Rutherglen bug has up to eight generations a year. In spring and summer, development from egg to adult takes 3-4 weeks. Adults will live up to four weeks, and females will lay up to 400 eggs in this period. Populations of Rutherglen bug in cropping areas will breed on weeds, moving to available crops or weeds when hosts die off. Outside the crop environment, Rutherglen bug will breed on a diverse array of plants found throughout arable and more arid environments. Adults will overwinter, moving to available weeds and crops in spring and starting to breed. In seasons when Rutherglen bug is a major pest, the population is dominated by migrants from outside the local cropping areas which are carried from inland breeding sites to eastern cropping regions.

When their host plants dry out and die during spring and summer, adults migrate to eastern cropping regions to feed and breed; some travel 200–300 kilometres in a single night. During wetter winter–spring seasons, weeds in cropping regions can also be key breeding hosts. It is hard to predict which plants will drive RGB invasions in any one season. Adults generally stop breeding in late February as temperatures drop and days grow shorter.

Damage

Rutherglen bugs are sucking insects that most commonly attack crop plants in spring, during seed set, or in summer on emerging or established summer crops or, less commonly, in autumn during emergence of winter crops. In spring, adults and nymphs feed on sap from stems, leaves, flowers and can potentially decrease yield, oil content and oil quality in canola and sunflowers. Damage to susceptible plants can be heightened if the crop is under moisture-stress.

Feeding wounds will allow entry by bacteria and fungi, facilitating disease and infection.

Monitoring

Rutherglen bug can infest crops at any time, but are most common in spring.. Distribution is typically patchy across paddocks. Inspect flowering parts of crops either visually or by shaking flowering heads into a tray or bucket, or onto a beat sheet.

In autumn, particularly if conditions for summer hosts have been favorable, check crop perimeters, paying particular attention to surviving weed hosts.

Check the crop from flowering to shell hardening at weekly intervals. Examine 20 racemes at 5-10 locations within the crop.

Distribution is typically patchy across tany field or orchard which means that the more samples taken, the greater the level of confidence in estimating the size of the infestation. In seasons with wet, mild summer and abundant weed growth, check weeds around the paddock that may be hosting Rutherglen bug. In particular, *Polygonum aviculare* (Common Knotweed, Wireweed) is known to be a summer host. Capeweed (*Arctotheca calendula*) is a common autumn-summer host for Rutherglen bug

Record:

- Number of RGB adults and nymphs in each sample. Average counts from across the paddock to get a field estimate of density.
- Presence of other pests and beneficials.

- Crop stage, proximity to maturity.

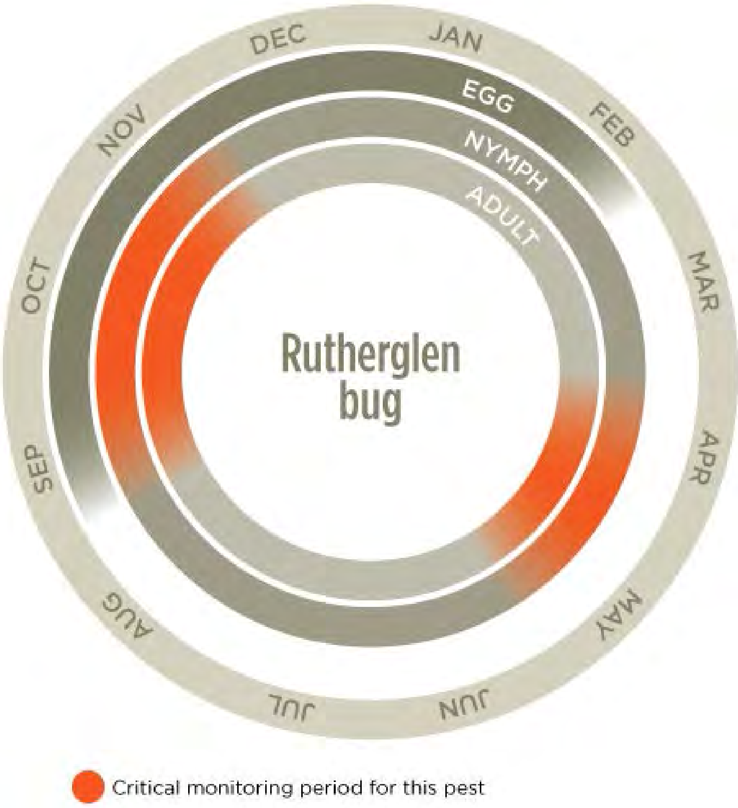

Figure 1: Lifecycle, critical monitoring and management periods for the Rutherglen bug. Infographic by Cesar Australia

Management options:

Biological:
Parasitoids that attack eggs can aid in reducing Rutherglen bug populations.

Cultural:
Rutherglen bug populations will be reduced by controlling summer-autumn weeds in and around paddocks and in fallows, well before sowing. Nymphs will survive on weed seeds, so controlling summer weeds before seed set is crucial.
At harvest, allow the pest to escape from open bins to reduce numbers in deliveries. Rutherglen bug will not survive in storage.
In susceptible areas of summer cropping, plough a deep furrow around the crop edge will prevent wingless individuals migrating from the paddock margin.

Chemical:
There are several organophosphates and synthetic pyrethroids registered against Rutherglen bugs in field crops.

No chemicals are currently registered for Pistachio crops.

Be aware that Rutherglen bugs can readily reinvade a sprayed area due to their migratory behavior and insecticide applications will not guarantee a clean crop.

As there are no soft chemicals available, spraying for Rutherglen bug will directly impact on the beneficials that contribute to the control of other pests such as Helicoverpa, aphid and diamondback moth populations in the crop.

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Carob Moth

Top

Picture: Figure 1: Adult Carob Moth – All pictures courtesy https://agric.wa.gov.au/n/3722

Carob moth (*Ectomyelois ceratoniae*) attacks a broad range of tree crops. It is also known as the date, almond, and locust bean moth The pest is thought to have originated from the Middle East, where it is a major problem in commercial crops of dates, almonds, pistachios and pomegranates. In California it is a pest of almond, date, pistachio and pomegranate. In Israel it is a pest of almonds, carobs, citrus and date palm. It is known as a pest of citrus, dates, figs, carob and almonds in Mediterranean countries causing economic damage by feeding on young fruit and or nuts. The moth larvae contaminate the crops with frass (larvae excreta) and render them unfit for human consumption – despite the direct damage they do to the crop. In recent years in Australia, it has been considered a serious pest of almonds.

The best management decisions for the treatment of orchards for carob moth can only be made if producers have information regarding its presence and population levels. To help producers monitor carob moth effectively, this fact sheet describes carob moth identification, life cycle and some simple monitoring techniques

What is the damage caused?

Damage to the crop begins (Figure 2) shortly after hatching as the second or third instar larvae enter (bore into) and feed from within the fruit or nut.
This feeding can assist in the growth of the Aspergillus fungi. Infested fruit and nuts either rot and drop from the tree, or they may remain on the trees until the end of the season.
Beside the direct damage they do to fruit and nuts by chewing, they make the produce not fit for human consumption by their excreta called 'frass'.

Description and Life Cycle

The insect may have three to four generations a year, before cool weather limits its growth and development. Adult males emerge two days before females and courtship communication is based on pheromones. Adults are inactive during the daytime and begin activity around sunset.

Females emit sex pheromone over a broad time range at dusk. After mating, female moths (Figure 1) lay their eggs on mummified nuts hanging on trees. Carob moth eggs (Figure 3) are about 0.7 mm long, white when fresh, changing to pink as they mature.

Figure 2: Damage to almond kernel

The larvae are typically pale to dark pink coloured and range from approximately 1 mm long when newly hatched to about 15-20mm long when fully mature (Figure 4). The top side of carob moth pupae are marked with a dark ridge and double row of 'teeth' (Figure 5 – next page).

Cool weather in winter is thought to induce diapause (a period of suspended or retarded development) in larvae. The brown pupa is approximately 12mm long.

Pupation can occur inside the pod; under the bark of trees, or under litter on the ground. The entire life-cycle takes between 32-43 days depending on temperature, with adult moths living for 5-10 days and females laying up to 200 eggs during their lifetime.

Local experience in almond crops indicates that carob moth is more likely to be at very low levels or absent in orchards with very few or no nut mummies present over winter.

Figure 3: Carob Moth egg.

Figure 4: Carob Moth larvae

Monitoring for Carob Moth

The primary purpose of monitoring for carob moth is to determine whether it is present in an orchard and whether its population level is above an economic injury level—that is in high enough levels to warrant management action.
Although not found in damaging levels in pistachio orchards yet, standard monitoring can be as follows:

Carob moth flights may be monitored with a species specific pheromone lure.
The lure is placed in a suitable trap such as a delta trap, (Figure 6) with a trap per 1 to 5ha.
Lures last from 4 to 8 weeks.

Check traps weekly to identify peaks in adult activity.
Moths should be counted and removed from traps as you monitor.

Control (for almonds)

Cultural control

Nuts left on the tree or ground serve as breeding sites and a reservoir for the spring generation. The removal and destruction of these nuts is very important as it will reduce the severity of an early infestation the following season.

Figure 5: Carob Moth pupae

Biological control

Overseas several parasites are known to attack carob moth larvae and pupae.

Mating Disruption

Pheromones may be used in a technique known as mating disruption (or male confusion). Artificial female carob moth pheromones are placed within the area to be protected, masking the natural pheromone plumes. Males follow the “false pheromone trails” at the expense of finding mates.

Chemical Control.

No pesticides are registered specifically for control of carob moth in carob.
The organic insecticide *Bacillus thuringiensis* (Bt) can be sprayed just prior to egg lay and will kill the young larvae


Figure 6: Base of pheromone trap showing lure and Carob Moths

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Light Brown Apple Moth

Top


Figure 1: Light Brown Apple Moth adult left, and Figure 2, LBAM larvae, right

Light brown apple moth, *Epiphyas postvittana* is a tortricid leafroller, also known as LBAM and is a widespread pest native to Australia that attacks many plant species both commercial and non-commercial. It has long been established in New Zealand, New Caledonia, Hawaii and the United Kingdom and in California in the US since 2007.

This native pest has a very wide host range and has been recorded feeding on over 1000 different plant species and includes more than 250 fruits and vegetables. It attacks nearly all types of fruit crops, ornamentals, vegetables and greenhouse crops and is an occasional pest of young pine seedlings . Agricultural crops are a main host of this pest. A partial list includes: citrus, apple, avocado, blueberry, corn, grape, kiwifruit, mango, oak, peach, pear, persimmon, strawberry, and tomato.

LBAM larvae feed on leaves and buds reducing photosynthetic rate, deforming growth patterns, which leads to general plant weakness and disfigurement. In grapes, apples, kiwifruit, plums, avocados, and citrus, LBAM larvae can feed directly on the fruit, and resulting feeding damage renders fruit unmarketable. Because of the economically important effects of larval feeding, LBAM has a high pest status in Australia because of zero tolerance requirements for presence in produce destined for the export markets.

- **In Australian pistachio orchards, the adult LBAM have been caught in pheromone traps for the last few seasons (figure 5).**
- **Maximum flight activity occurs 2-3 hours after sunset, with a smaller peak 3-4 hours after sunrise. Flight is also affected by the phases of the moon, with peak activity shortly before and after new moon, and around full moon.**

LBAM leaf and nut damage.

The larvae cause superficial injury to the fruit surface by removal of skin and the outermost layers of fruit tissue.

Damage can be extensive and one larva entrenched in the centre of a fruit cluster can damage the entire cluster— in some cases increasing fungal incidence.

They are called “leaf rollers” because the older larvae commonly roll up leaves to create a shelter in which they can feed. They may also web two leaves together or spin silken nests between fruits that are close together. When caterpillars feed on leaves, they eat everything except for the veins, causing a “skeletonized” appearance and reducing the amount of leaf surface for photosynthesis.

Description and Life Cycle

Moths mate soon after emerging from their pupae in late winter or early spring, and each female lays her egg masses over a 2–3 week lifespan. Females can lay up to 1500 eggs each but the average is about 300. The time to egg hatch may range from 1 to 3 weeks, depending upon temperature (i.e. 2–3 weeks in spring, and about 7 –8 days in summer). Eggs are most commonly laid on the upper surfaces of expanded leaves. Individual eggs are 0.7–1.0 mm across and are laid in an overlapping pattern. Newly emerging LBAM caterpillars are pale green to yellow and about 1 mm long, and grow to approximately 1.5 cm in length. Adult caterpillars are pale green with a dark green central stripe.

Figure 3, LBAM pupae

Figure 4, LBAM egg mass on leaf rib

Moths are pale brown (8–10 mm long) and may be confused with other moths within and around the orchard. The males are smaller than the females and have dark markings on the lower parts of their wings – see Figure 1. Moths are generally active from dusk until dawn. The adult moth about 10 mm long when resting with the wings folded in a characteristic bell shape. Colouring is variable but they are generally yellowish-brown with darker brown markings on the forewings. The females often have a dark spot on the hind margin of the forewing.

Monitoring for LBAM

For larvae, look early in rapid shoot growth in early spring, start monitoring for webbing on leaves caused LBAM to map out areas of concern for future monitoring.

Alternatively and perhaps a better methods is the use of pheromone traps for LBAM, which are commercially available. Lure pots containing a port wine/water mixture can be used to monitor flight periods of the adult moth but can be difficult to interpret.

The size of the over wintered population can be estimated by checking broad-leaved weeds such as capeweed in the orchard during late winter/early spring.

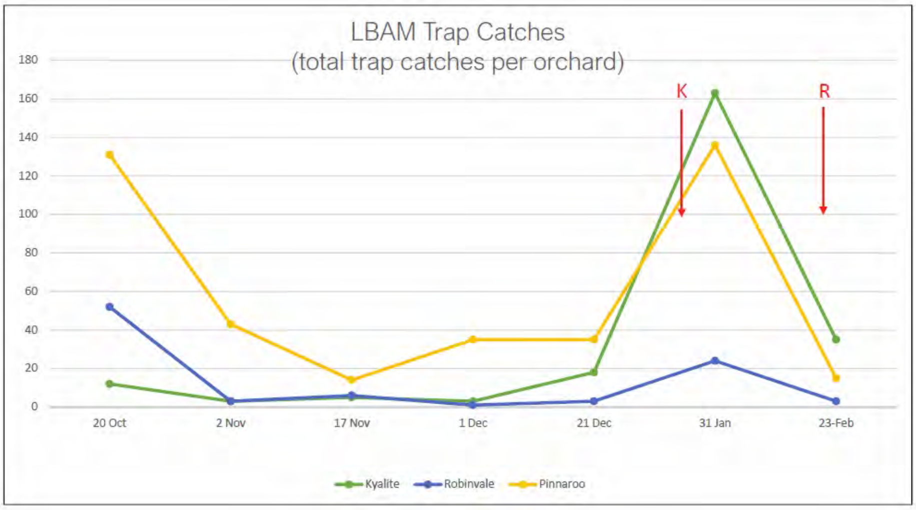

Figure 5: Graph of LBAM pheromone trap catches (Adult) Source: Stuart Pettigrew

Figure 6: Example of a pheromone lure delta trap

Control

Chemical:

As LBAM have not previously been a major problem in pistachio orchards in Australia, currently there is not a permit for chemical control.

Biological Control:

General insect predators and several species of spiders may influence LBAM populations by feeding on eggs or larvae. High mortality has been reported during the initial dispersal of the newly hatched larvae. The egg parasite *Trichogramma funiculatum* (a tiny wasp) is often active during autumn. LBAM larvae and pupae are killed by various parasitoids, predators, and diseases. Infection by a nuclear polyhedrosis virus has been known to decimate localised LBAM populations. Spiders and earwigs (*Forficula auricularia*) are the most important predators.

PGAI currently has a project investigating the importance of beneficial insects for pest control in Australian pistachio orchards

Mating Disruption:

Mating disruption by flooding the orchard with LBAM pheromone (males can't find the females) is also available for commercial use.

Cultural Control:

Appropriate sanitation practices during the dormant season can help prevent a build-up of these leafrollers. Mow broad-leaved weeds in and around the vineyard before bud break. Remove mummified clusters when pruning and place them in the row middles to be chopped and incorporated into the soil.

Figure 7: Orchard sanitation, mulching of cuttings and mummies to minimise reinfection.

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Mango Shoot Looper – A potential pistachio pest.

Top

Figure 1: Mango Shoot Looper (MSL) larvae left, and Figure 2: adult MSL on right.

In September 2021, Mango Shoot Looper (*Perixera illepidaria*) was detected at a commercial mango orchard in Mutchilba, north Queensland, causing severe damage on a mango plant (*Mangifera indica)*. The pest is currently spread over a significant distance in northern Queensland, with detections from both commercial mango and lychee properties. It has since been detected in the Darwin rural area of the Northern Territory, with the first case confirmed in early April 2022.

It is currently not widely distributed and not under official control.

As the Mango Shoot Looper's (MSL) hosts include pistachio, growers in Australia should become familiar with and be on the lookout for this 'exotic' pest.

The Problem:

Severe infestations of *Perixera illepidaria* can cause 80–100% leaf and flower damage on affected trees and significant crop losses due to damage to flowers and immature fruit. In north Queensland, in the absence of effective chemical control the pest has been observed causing significant damage on mango plants, which includes totally stripping back flowers and destroying young fruit. Monitoring for the pest during flowering to ensure early detection and application of chemical controls can significantly reduce its impact.

Description and Life Cycle

Larvae vary in colour from yellow, brown to black, with a mottled "tiger" patterned appearance. When mature, they can be up to 22mm in length.   Larvae have a 'looping' appearance when moving and may make silken threads that hang vertically between flower panicles and leaf material. These threads allow them to move on the plant to reach new feeding areas.

The pupae have a distinctive elongated triangular appearance. They are first green in colour and then darken to brown as they mature, prior to moth emergence. They are up to 9mm in length. Pupae may be seen on upper surfaces of leaves in large numbers.
The insect completes its full life cycle in 15 to 19 days, and the larval period is typically 8 or 9 days.

Figure 3: Mango Shoot Looper pupae (chrysalis)

Mango Shoot Looper adult moths have 3 rows of brown patterns on the wings, with the last 2 having dark brown spots scattered along the length. Their wingspan is 20mm across. Female moths are pinkish in colour and the males are very pale brown or pinkish fawn.

Female moths mainly lay eggs in abandoned or old spider webs, or webs with juvenile spiders near new vegetative growth.

Feeding Damage:

Infestations can cause:

- loss of leaves (leaf defoliation)
- reduced photosynthesis and
- fruit and flower damage resulting in reduced fruit production.

Larvae feed on the top layer of the leaves, giving them a skeleton-like appearance. They also feed on young shoots, flower panicles and immature fruit. Large populations can leave the panicles bare of any flowers or small fruit within a week.
Severe infestations can cause 80 to 100% leaf and flower damage. It is most likely to be a problem during the flowering season.
Larvae move in a “looping” fashion and can move to undamaged areas of the tree by suspending themselves on silken threads and dropping between branches.

Adults can fly and spread naturally in localised areas from tree to tree. Their spread may be enhanced by strong winds.
MSLs may also be spread by human-assisted movement of infested plant material. You should have biosecurity measures in place at your property to reduce and prevent

biosecurity risks. Road traffic may inadvertently move adult MSLs as they are attracted to lights of vehicles and caravans.

Figure 4: Mango Shoot Looper damage on a mango tree.

When monitoring for mango shoot looper, look for caterpillars stripping leaves and or flower panicles. Inspect new shoots and immature fruit for similar symptoms. The small larvae are often difficult to see so vigorously shake flower panicles or new flush into a tray or bucket.

The importance of reporting

If you suspect you have seen mango shoot looper, you need to contact your state or territory department of agriculture or primary industries. ***You can do this by phoning the Exotic Plant Pest Hotline on 1800 084 881***.

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Exotic Pests

Exotic pests are organisms that are introduced into an area beyond their natural range and become pests in the new environment. They are also referred to as alien, non-native, or introduced pests.

Most introductions have been unintentional and accidental. Having evolved in a different ecosystem, these non-native species may have few natural enemies in their new locations, which can often lead to population increases that can overwhelm native species by out-competing them for resources (e.g., food, water, light, space).

An invasive species is a species that does not occur naturally in a specific area and whose introduction does or is likely to cause economic (including agricultural) or environmental harm or harm to human health.

Khapra Beetle (*Trogoderma granarium*) Top

Figure 1: Adult Khapra Beetle (left) and larvae. Picture courtesy of International Cargo Express.

The Problem:

Importers and exporters are exposed to the dangerous biosecurity risk of the **Khapra Beetle**, a small oval-shaped insect that hitchhikes on cargo entering Australia, posing a serious threat to the natural environment

Khapra beetle is an exotic pest. If it were to establish in Australia it would pose a serious threat to many of our food and other plant-based agricultural industries. Khapra beetle poses no immediate risk to human health or animals.
It can cause stored grain losses of up to 75% from direct feeding. Infested grain can also become contaminated with beetles, cast skins and hairs from larvae that are difficult to remove from stored grain and transport vessels, and can be a health risk.

Khapra Beetle is rated as the world’s second most damaging plant pest.

In California, stored pistachios have previously been found to be infested with the Khapra beetle.

Description Life Cycle and Spread:

Adults are small at around 2-3mm long and 1-2mm wide. They are brownish in colour with a smooth oval shaped body. Adult beetles have many fine hairs and indistinct markings on their wing covers. When viewed from the side (Figure 2), the adult beetle's partly concealed head and downward facing mouthparts can be seen.

Figure 2: Adult khapra beetle, side view (Image: Simon Hinkley & Ken Walker, Museum Victoria)

Eggs are less than 1mm long and milky white to pale yellow. They hatch into small hairy larvae that can range from 1.6-5mm long, are golden brown in colour and darken as they mature.

Larvae range from 1.6-5mm long when fully mature, are golden brown in colour and have distinctive hairs across the body, including longer hairs at the rear end that resemble a tail (Figure 3). Larvae are initially pale yellow and become golden-brown when they grow.
This is the major feeding stage and therefore the most damaging. Larvae moult four or more times, resulting in numerous cast larval skins. The larval development stage may be as short as 30 days, however larvae can survive in a dormant state for many years in unfavourable conditions.

Figure 3. Khapra beetle adult and larva on grains of rice. The adult is much smaller than the larva (Image: Science and Surveillance Group, Department of Agriculture Water and the Environment

Pupae have a smaller appearance to late stage larvae except that they are slightly shorter and more rounded.

Khapra beetle is almost identical to warehouse beetle, (*Trogoderma variabile*) and the native *Trogoderma* species which is established in Australia. If you find any beetle or hairy larvae fitting the description of the Khapra beetle, report it immediately to have it identified by an expert.

Life cycle

Adult male and female beetles mate immediately after emergence. Adult females begin laying eggs shortly after mating, in or near host material and generally lay 50-100 eggs during their lifetime.
Eggs hatch within 5-7 days into larvae. This is the major feeding stage and therefore the most damaging. Larvae moult four or more times, resulting in numerous cast larval skins. The larval development stage may be as short as 30 days, however larvae can survive in a dormant state for many years in unfavourable conditions.

Spread
Khapra beetle is found in India, Middle East, Asia, Africa and Europe. It spreads through shipments of imported grain and other foodstuffs, personal effects, machinery, straw and packaging.
Khapra beetle is generally a pest of stored grain however it can stowaway as a hitchhiker on a wide range of cargo including plastic beads, nuts and bolts, timber flooring, foodstuffs and white goods.

It is important to check any imported item and all packaging for any signs of pests or anything unusual. Preferably open the packaging inside in a semi-confined space so that if you do see something unusual you can capture and or isolate the insect/s straight away. They are likely to be found where stored products are kept or transported and can also be found between cracks and wall linings of your home or in storage containers.

Khapra beetles are highly thermophilic, but they can also lapse into a state of rest or torpor (diapause) to survive unfavourable conditions in the long run. The adult beetles do not feed, but the larvae have a very broad nutritional spectrum and live on all kinds of plant and animal products. Larvae feed on grains and seeds as well as processed vegetable and animal products including spices, herbs, nuts, dried fruits and dried animal skins.

As Khapra beetle is a stored grain pest it will only be found in stored products and around places where stored products are kept or transported. It can also be found between cracks and wall linings of storage containers. **It will not be present in the field**.

Be careful that you don't confuse the Khapra Beetle with the warehouse beetle.

Report sightings
If you suspect that you have seen Khapra beetles or their larvae, report it to the **Exotic Plant Pest Hotline on 1800 084 881**
This will put you in contact with your local department responsible for biosecurity. If you require further information about the response to khapra beetle phone your state or territory department of agriculture or primary industries.

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Brown Marmorated Stink Bug (*Halyomorpha halys*) Top

Figure 1: Brown Marmorated Stink Bug BMSB (*Halyomorpha halys*) Adult. Photo courtesy of Warren H. L. Wong.

The Problem:

Brown Marmorated Stink Bug (BMSB) is an exotic 'declared pest' that could cause major damage to agricultural crops including pistachio, nursery stock and ornamental plants. BMSB can attack over 300 types of fruit, ornamental trees and vegetable crops and has caused significant yield losses in fruit and nut crops around the world. It is the saliva of BMSB that causes damage via feeding to plant tissues – of which more later. It is also a nuisance because it seeks shelter in large numbers, in buildings and equipment during the winter months. It has a foul-smelling odour when crushed or disturbed.

Figure 2: External and internal stink bug induced pistachio damage: Epicarp lesions (marked with red 'X') right, and kernel necrosis, left. (Photos courtesy of J. Stahl and K. Daane)

Both the nymphs and the adults feed by inserting their needle-like mouthparts into a variety of plant tissues including stems, leaves, and especially reproductive structures, secreting digestive enzymes and sucking up the liquified plant material.

Feeding damage to fruit can result in sunken areas, corky spots and scarring. As the fruit develops, it may become discoloured and deformed. Premature fruit drop can also occur. Feeding can also damage plant vegetative tissues which can result in plant wilt and reduced vigour.
The mechanical damage and specifically the chemical changes due to the excreted enzymes can lead to discoloration, deformation and the abortion of fruiting structures, all of which make the crop unmarketable. Many stink bug species are known mainly as secondary pests in various crops. Often, an individual species has different host plants to fulfil their nutrient requirements and can therefore behave as a pest in different crops or take refuge in a naturally occurring host.
BMSB has more known host plants than other stink bugs; in the US alone, more than 170 plant species have been reported, many of them economically important crops. Worldwide, the BMSB feeds on more than 300 plant species. These include vegetables, leguminous crops, fruits, nuts (including pistachios), and ornamentals.

This particular bug is a high priority pest which needs to be kept out of Australia. It is well known to stow away in cargo arriving from the northern hemisphere between September and April each year.

Description Life Cycle and Spread:

Figure 3: Adult BMSB, The easiest way to identify the insect is from the white bands on their antennae and alternating black and white markings on the abdomen - characteristic markings circled. Its underside is a white/tan colour. Adult BMSB are a brown 'shield' shape and about the size of a 10 cent coin.
Like other stink bugs they emit a pungent smell when harassed
Image courtesy of Ministry for Primary Industries, New Zealand

As the Brown Marmorated Stink Bug (BMSB) hosts include pistachio, growers in Australia should become familiar with and be on the lookout for this 'exotic' pest.

Appearance:

Adults

- Adults range in length between 12-17 mm.
- The upper surface is mottled and speckled brown with no pronounced stripes and have a shield-shaped appearance.
- The head is blunt rather than tapering to a point.
- The antennae have at least one white band.
- The edges of the abdomen are strongly banded.
- There are no spines on the body.

Nymphs

- There are 5 flightless nymphal stages.
- Size ranges from less than 3mm to 12mm long.
- Orange and black when they first hatch but quickly develop a similar colouration to the adults.

Eggs

- Laid in clusters of 25 to 30 on the underside of leaves.
- Light green to white/cream in colour.
- Barrel-shaped.
- Approximately 1.6mm long x 1.33mm wide.

Figure 4: Hatched BMSB egg mass and 1st instar nymphs.

Spread:

BMSB uses cargo containers and freight vehicles to hitchhike across continents and oceans. The bug's ability to hitchhike, fly, and to feed on a wide range of plant hosts, enables it to spread rapidly when it is introduced to new areas.
It has the ability to survive in cargo for long periods by remaining in a dormant state.

Look for, and report Brown Marmorated Stink Bug!

Pistachio growers in all regions are asked to remain vigilant for the bug and monitor their fruit and other host plants for unusual damage.
If you think you have spotted what could be a BMSB in the area, contact your local department responsible for biosecurity. You can do this by phoning the **Exotic Plant Pest Hotline on 1800 084 881**

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Integrated Pest Management (IPM)

Top

Cryptolaemus montrouzieri, **larvae on left and adult on right consuming mealybug.** ***Cryptolaemus*** **are a Ladybug (Coccinellidae)**

Definition of IPM

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious, targeted use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

It was in the 1950's when agriculture researchers introduced the concepts of economic thresholds, economic injury levels (see below), and ***integrated*** control of pests in horticulture.

IPM is NOT a magic bullet. It relies on accurate record keeping on pest and disease levels, action thresholds and knowledge of the pest and disease life cycles and the most appropriate time for action. A knowledge of beneficial insect species is also important as these can contribute greatly to non-chemical control of pests.

It may take several seasons to get an IPM program 'right' for your orchard where pests, diseases and beneficial insects and control methods are balanced and understood. "Patience is important. Although information about the density of insects in a field is recorded, action is only taken when pests reach a specific threshold level (see below).

How do IPM programs work?

IPM is not a single pest control method but, rather, a series of pest management evaluations, decisions and controls. In practicing IPM, growers who are aware of the potential for pest infestation follow a four-tiered approach. The four steps include:

Set Action Thresholds

Before taking any pest control action, IPM first sets an action threshold, a point at which pest populations or environmental conditions indicate that pest control action must be taken. Sighting a single pest does not always mean control is needed. The level at which pests will become an economic threat is critical to guide future pest control decisions.

Back in 1959 Dr. Vern Stern, an entomologist at UC Riverside and one of the early pioneers of the integrated pest management (IPM) concept, proposed the term “Economic Injury Level” (EIL) and defined it as “the pest population at which pest control measures must be taken to prevent the pest population from rising to the economic injury level." IPM programs use the concept of an economic threshold level (ETL or ET), also known as an action threshold, which are related to the EIL.

To simplify these terms we’re talking about using sampling data to determine whether insect pest numbers have reached a pre-determined level above which economic loss will occur, and thus an insecticide application or other action is needed to prevent loss (Fig. 1).

Economic injury level, economic threshold and pest populations

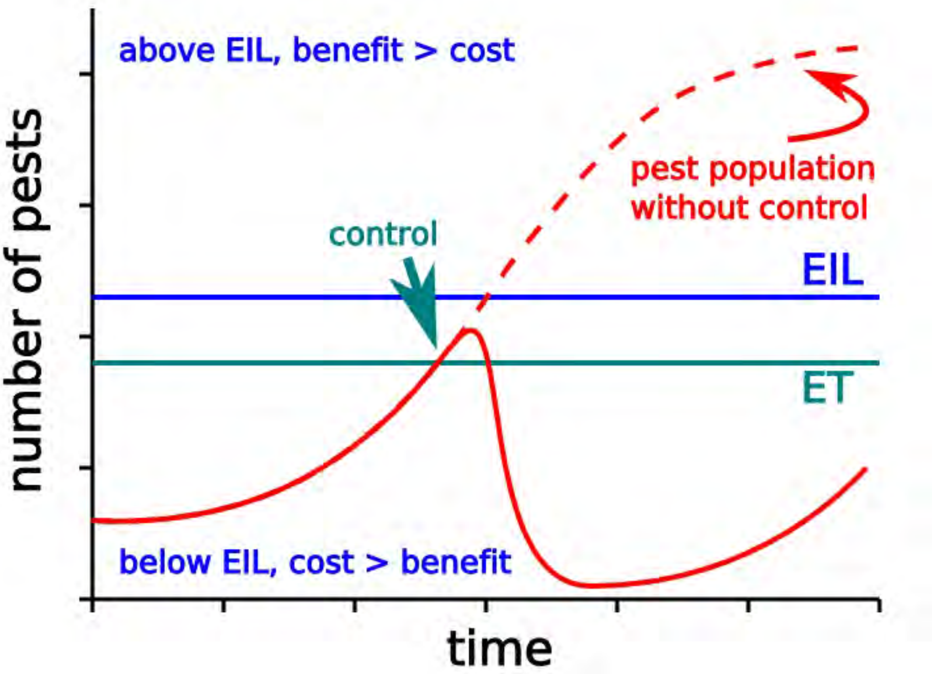


Figure 1. In Integrated Pest Management, the Economic Injury Level (EIL) is defined as that pest population level at which the dollar cost of crop yield loss to the pest begins to exceed the dollar cost of the recommended control measures for the pest. The Economic Threshold (ET) is that level of pest population at which the pest, if left untreated, is likely to reach or exceed the EIL. Therefore, the ET is almost always lower than the EIL, and is considered the point at which the farmer should take action against the pest. Therefore, the ET is sometimes called an Action Threshold (AT). Figure credit: Ed Zaborski, University of Illinois.

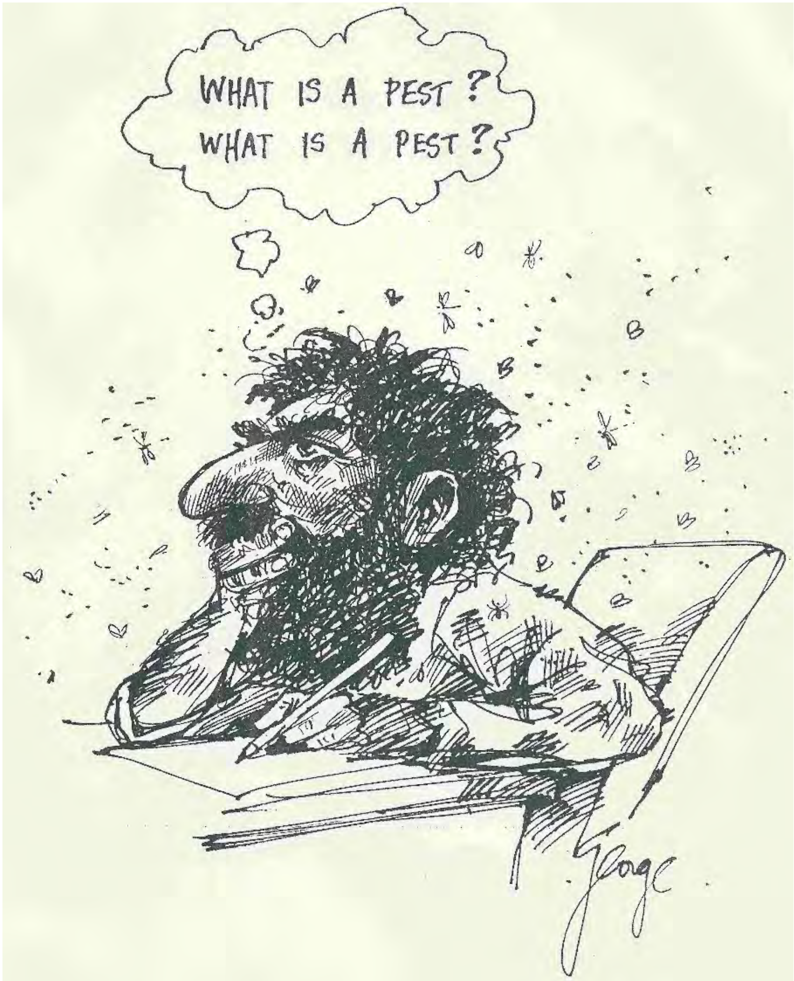
Threshold levels have been painstakingly developed for a number of pest/crop systems in Australia and overseas and when available are sometimes provided by state Agriculture Department IPM Programs in their pest management guidelines for specific crops. However, not many insect pest thresholds have been developed for organic systems. One reason for this is because the focus of pest management in organic systems is on proactive and long-term preventative pest management strategies. Thus in organic farming approved insecticides are only considered and used as a last resort.

Furthermore, organic systems are more complex than conventional farming systems. In addition to determining relationships between pest and crop life stage, damage and economic loss, development of treatment thresholds for organic systems would have to take into account additional factors that are difficult to quantify, including:

- A more complex crop ecosystem typical of organic farms
- The presence and impact of all potential natural enemy species
- Available hand labour to remove pests or wash crops
- Consumer willingness to accept some insect damage
- Lower toxicity and shorter residual activity of approved insecticides

Monitor and Identify Pests

Not all insects, weeds, and other living organisms require control. Many organisms are innocuous, and some are even beneficial. IPM programs work to monitor for pests and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. This monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used.



Optimal timing of sampling depends upon the life history and behavior patterns of the pest or beneficial insect and also on the crop and environmental conditions. Both insects and plants develop quickly under warm conditions and more slowly when it is cool. But in general it is a good idea to begin sampling as soon as the trees begin flowering – or shortly before.

Sampling should be done at least once per week. More frequent sampling is usually needed if insect pest numbers are in the low-to-moderate range and on the increase. It is truly amazing how quickly insect pest populations can develop, and once-a-week sampling may not detect a surge in insect numbers until it is too late.

Tools to aid in identification:

- Hand lens - aids in identification of tiny insects and arthropods like thrips, minute pirate bugs and mites

- Digital camera - you can use a digital camera to take and record insect images that can be sent to the local extension office for identification. Once the insect is identified the digital image can be labelled and saved for future reference
- Small vials with alcohol - useful for preserving specimens that are sent off for identification

Sampling Procedures
There are different sampling procedures that can be used depending on the crop, size of field, etc. Growers usually develop their own customized sampling plans once they have experience with their orchard.

Some guidelines for getting started.
Upon entering the orchard, make a quick visual examination of the trees. Look for any atypical areas that might affect your sampling pattern; i.e. areas with poor stands, obvious topographical variation in the field, varietal growth differences, etc. Sampling can be done in these areas but any unusual conditions that could affect insect numbers should be noted on the sampling sheet.

Once you have an idea of the field conditions and layout, think about an efficient sampling pattern for the orchard. For example, "W" or "U" or even diamond shaped sampling patterns are more commonly used in a square-shaped orchard. In a long narrow forchard, a "zig-zag" or “Z” sampling pattern is usually more efficient.

In the Fig. 2 diagrams below a single sample or subset of samples would be taken at each marked location. A single sample could be a visual count of all insects on one raceme. A subset of samples could be a visual count of all insects on each of 10 adjacent raceme at each location. Subset samples can provide a better population estimate for insects that are not randomly distributed in the field but have an aggregated or clumped distribution.

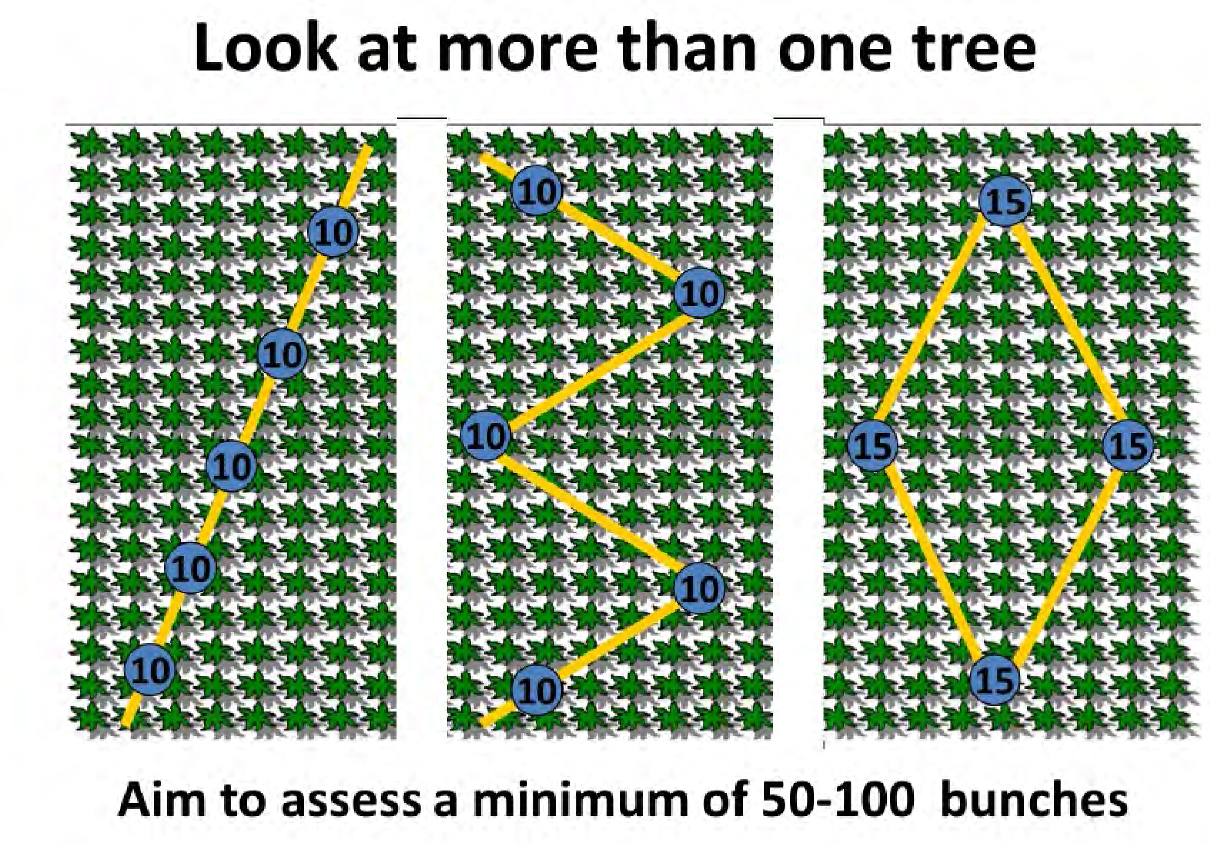


Figure 2: Orchard Monitoring Patterns

For most pests it is important to walk a few rows into the field before sampling the first plant to avoid edge effects. However, edge sampling is commonly done for pests like spider mites that commonly invade into the field from the field borders. You may wish to keep a separate data sheet for sampled plants on the field edges.

The more plants in the field that are sampled, the more reliable the sampling data. Obviously there is a trade-off between the number of plants that can be practically inspected and the level of confidence in the data that one will accept.

Recordkeeping

Develop a field data sheet template that you can use to record insect counts. It will probably require a few sampling periods to refine the data sheet for a particular crop, pest and beneficial insect system.

Data sheets are most commonly organized in a matrix format with sample number along one axis and labels for key pests and beneficials (by life stage) along the other axis. Thus at each sample location the actual numbers of each specific insect and stage can be entered. It is helpful to include a “total” column for each insect and stage to facilitate calculation of averages. Averages can be used as a relative measurement to determine population trends over time.

The data sheet should also include the sample date, time of day, field number or field location if sampling from separate locations, plant growth stage, and space to record other pertinent information such as atypical environmental conditions

Sample Data Sheet

Date	Field #	Time	Crop	Growth Stage

Weather/field observations:

Plant #	1	2	3	4	5	6	7	8	9	10	Total
Pest 1 *[Name]*											
Larvae											
Adults											
Parasite/Predator *[Beneficial Insect Name]*											
Parasite/Predator *[Beneficial Insect Name]*											
Parasite/Predator *[Beneficial Insect Name]*											

Notes:

Plant #	1	2	3	4	5	6	7	8	9	10	Total
Pest 2 [Name]											
Larvae											
Adults											
Parasite/Predator *[Beneficial Insect Name]*											
Parasite/Predator *[Beneficial Insect Name]*											
Parasite/Predator *[Beneficial Insect Name]*											

Notes:

Entering sampling data into a computer spread sheet program has many advantages. In addition to simplifying data analysis, storage and retrieval, converting your data into electronic form facilitates information sharing across farms and regions. A hand held computer can also be used to record data directly from the field.

Prevention

As a first line of pest control, IPM programs work to manage the crop, lawn, or indoor space to prevent pests from becoming a threat. In an agricultural crop, this may mean using cultural methods, such as rotating between different crops, selecting pest-resistant varieties, and planting pest-free rootstock. These control methods can be very effective and cost-efficient and present little to no risk to people or the environment.

Where we have a monoculture such as a pistachio orchard, this is more difficult but not impossible. Prevention may include row-cropping cover crops that provide a food source for beneficial insects

Control
Once monitoring, identification, and action thresholds indicate that pest control is required, and preventive methods are no longer effective or available, IPM programs then evaluate the proper control method both for effectiveness and risk. Effective, less risky pest controls are chosen first, including highly targeted chemicals, such as pheromones to disrupt pest mating, or mechanical control, such as trapping or weeding. If further monitoring, identifications and action thresholds indicate that less risky controls are not working, then additional pest control methods would be employed, such as targeted spraying of pesticides. Broadcast spraying of non-specific pesticides is an absolute last resort.

Definitions

- **Cultural control** is the non-chemical management of pests using manual or mechanical means to change the soil and crop environment to discourage pest establishment.
- **Biological control** is where predatory or parasitic insects and mites known as ‘beneficials’ or ‘good bugs’ help to control chewing and sucking insects that affect the quality and productivity of crops by killing them or disrupting their breeding cycle.
- **Chemical control** involves the use of pesticides in the management of pests. It is used in IPM when biological and cultural control has not been enough to protect the productivity of the crop. Where chemical control is required, selective insecticides are chosen which target the pest, leaving the beneficial population unharmed.

Beneficials – Insects and Others

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Figure 1: A parasitoid wasp egg-laying in caterpillars. Image provided by Wageningen University

Just under 100 years ago, in 1922 the UK Ministry of Agriculture and Fisheries issued a small publication on “Beneficial Insects”. It contained little-known information, written in a non-technical style, on those insects that are beneficial to the farmer, fruit-grower and gardener (*Grantham et. al. 1939*).

So, we have known about the benefits of ‘good bugs’ in food production for quite a little while.

Insects are key components of life on our planet, and their presence is essential for maintaining balanced terrestrial ecosystems. Without insects humans would struggle to survive, and on a world scale food production would be severely compromised.

The beneficial role of insects is often overlooked or misunderstood, and in farming circles their very presence on crops is often seen to be unwelcome. In reality, however, many insects are genuinely beneficial, as in the case of parasitic and predacious species. All insects and other invertebrates (such as mites and spiders) have specific roles in the environment. These may include seed dispersal, nutrient cycling and pollination of crops and native plants. Additionally, there are many naturally occurring species that keep pest insect populations in check. These beneficial insects (sometimes referred to as ‘natural enemies’) play a vital biological control role in many cropping systems.
Some species are transient – moving in and out of crops, often following the movement patterns of pests, while others are resident – permanently living within the system and usually having limited dispersal capabilities.

The use of chemical pesticides to control crop pests is becoming more tightly regulated and environmentally undesirable, and low-input farming, in which natural enemies of pests are encouraged to survive or increase, is becoming far more prevalent. Accordingly, Integrated Pest Management (IPM) and Integrated Crop Management (ICM) strategies are increasingly being developed, advocated and adopted.

Beneficial insects can be encouraged by better targeting and reducing insecticide applications, as well as providing alternate food sources and refuge habitat on farms.

Beneficial insects and mites belong to three categories: ***predators, parasitoids,*** and ***pollinators.***

Predators capture and eat other organisms such as insects or mites. Predators include ladybird beetles, ground beetles, lacewings, syrphid (hover) flies, aphid midges (*Aphidoletes*) and some wasp species.

Parasitoids are insects that parasitize other insects. The immature stages of parasitoids develop on or within its host, eventually killing it. Parasitoids may attack all stages of their host (eggs, larvae, nymphs, pupae, adults).

Pollinators include honeybees, leafcutter bees, other wild bees, butterflies, moths and other insects that visit flowers to feed on nectar and pollen. Pollinators transfer pollen in and between flowers of the same species (pollination) which is essential to seed and fruit production for plants.

Beneficials found in *or near* Pistachio Orchards.

Many of the pistachios orchards in Australia are grown in regions surrounded by native bushland. It is the bushland that supports predators, parasites and pollinators, it may be argued, has assisted in keeping pest problems at a low level.

Examples of Beneficial Insects

The range of beneficial insects (and arachnids) is quite broad and covers ladybirds, lacewings, predatory shield bugs, spiders, mantids, parasitic wasps, hoverflies and predatory mites as well as bees, which pollinate the crops. Below is a brief description of the types of beneficial insects you are likely to see in the pistachio orchard.

Ladybirds (Colleoptera, coccinellidae)

Figure 2: A Common Spotted Ladybird adult.

Ladybirds are also known as ladybugs or ladybeetles and (Figure 2) are the most familiar insect predator. There are over 100 species in Australia and the vast majority are beneficial. Lady beetles can rapidly control many developing insect problems, particularly if temperatures are warm.

Appearance: There are many species of ladybird beetles that vary in size, colour and pattern. Most adult lady beetles are round to oval, dome shaped, brightly coloured and most species have coloured spots or markings on their backs. Depending on species, colours are black, red, orange-red to almost yellow.
The immature or larvae stages, however, look very different and often are overlooked or misidentified. Lady beetle larvae are elongated, usually dark coloured, and flecked with orange or yellow (Figure 3).

Figure 3: A Common Spotted Ladybird larva.

Body length: Adult – 1 to 10mm; Mature larva- 1 to 7.5mm

Life Cycle: Overwinter as adults. Eggs (yellow or orange, elongated) are laid in clusters on underside of leaves and branches. Usually only one generation per year. Both the larvae and adults feed on pests.

Insect Pests Attacked: Aphids, whiteflies, scales, mites, mealybugs and other soft-bodied insects. One group of small, black lady beetles (*Stethorus*) is important in controlling spider mites and others specialize in scale insects.

Monitoring: Inspect colonies of aphids for adults and/or larvae**.** This will most likely be in Spring time.

Lacewings (Order Neuroptera)

Figure1: Golden Eyed Green Lacewing adult (*Chrysopa oculata*)

Lacewings (Order Neuroptera) are a relatively small group of insects with around 5000 different species worldwide and more than 600 species known from Australia.
The aphid and scale-eating larvae of the families *Chrysopidae* and *Hemerobiidae* are highly beneficial insects in crops and gardens. Some of these insects are being commercially produced for release as agricultural biocontrol agents

Appearance: Common species of lacewings include green lacewing species from the Family *Chrysopidae*, and one brown lacewing species, *Hemerobiidae*. Lacewing eggs are white and laid singly or in groups on long stalks on the underside of leaves or branches. The brown and green lacewing larvae are very similar except for small differences in body shape and the brown lacewing's habit of moving its head from side to side while walking. Adult lacewings wings vary in colour from bright green to brown, and black.
Larvae of the Family *Chrysopidae* often resemble walking rubbish balls. This is because they attach debris including the husks of their aphid prey to body hairs as a form of camouflage.

Figure 2: Green lacewing larvae (left) and larve camouflaged with debris (right). Photos courtesy of greenmethods (right) and Brisbane Insects (left).

Body length: Adult – 10 to 20mm; Mature larva – 6 to 10mm

Life Cycle: *Chrysopidae* and *Hemerobiidae* overwinter as adults; there can be up to four generations per year depending on temperature. Eggs are commonly laid on stalks, singly or in batches.

Monitoring: Examine aphid- or psylla-infested leaves and shoots for feeding larvae or use limb taps.

Insect Pests Attacked: Aphids, spider mites, whiteflies thrips, leafhoppers, scales, mealybugs, psyllids, small caterpillars and insect eggs. Green lacewing larvae feed on insect pests. Both larvae and adult brown lacewings feed on pests. Green lacewings are commercially available.

Syrphid/Hover fly larvae (family *Syrphidae*)

Figure1: Common Hoverfly adult (*Melangyna viridiceps*)

Hover flies, often referred to as flower flies or drone flies, are beneficial insects that appear in large numbers during the spring and summer. They are often mistaken for bees or wasps and can help pollination in orchards at flowering time. During flight, many hover flies move in a characteristic way. As their name suggests, they hover over objects but will also dart back and forth rapidly. It is however, the larvae that are the true beneficials though The immature hover fly looks like a maggot and can grow up to 10 mm long. The larvae hunts by touch. They have mouth hooks, which grip and pierce the skin of their prey prior to extracting their body contents.

Appearance: Hover fly larvae are flattened, legless maggots with no distinct head and a tapered body. They are variously coloured (yellow, green to brown). Adults frequent flowers over which they hover before landing to feed on nectar and pollen (their only food source). They are often mistaken for bees or wasps which they mimic in colouration. Hover fly eggs are white, elongate, with fine sculpturing and are visible in aphid colonies.

Body length: Adult - 8.0-15.0 mm; Mature larva - 10.0-15.0 mm

Life Cycle: Overwinter as larvae, pupae, or adults depending on the species. Eggs laid on aphid-infested plant parts. Several generations per year depending on temperature and location.

Figure2 : Common Hoverfly larva devouring an aphid

Insect Pests Attacked: Aphids, scales, thrips and other small soft-bodied insects

Monitoring: Examine aphid-infested leaves and shoots for maggot-like larvae. Adults frequent flowers.

Predatory mites

Figure1 : ***Phytoseiulus persimilis***

Phytoseiulus persimilis (Persimilis) are predatory mites that feed on two-spotted spider mite (TSM) and other spider mite species. Persimilis provide excellent control of these pests in a wide range of crops and they are among the most widely used biocontrol agents globally and can be purchased in Australia.

Appearance: Although extremely small (approximately 0.5 mm or 0.02 inches), *P. persimilis* can be distinguished with a hand lens. It is fast moving, orange to bright reddish orange, has a teardrop-shaped body and long legs, and is slightly larger than its prey. Immatures are a pale salmon colour. Eggs are oval, approximately twice as large as the pest mite eggs.

The western predator mite, *Typhlodromus occidentalis* (Nesbitt), and *Zetzellia mali* are the two most common species of predaceous mites in Australia. They are distinguished from their prey by their larger size, pear-shaped body, and translucent colouration. Their eggs are opaque and oval whereas pest mite eggs are round. They are very active and fast moving compared to pest mites.

Body length: Adult - 0.25-0.4mm; Mature nymph - 0.2-0.38mm

Life Cycle: Overwinter as adults. Become active in spring and produce several generations per summer depending on temperature.

Insect Pests Attacked: Spider mites, thrips, fungus gnat larvae.

Monitoring: Visual inspection of leaves or leaf brushing for microscopic examination.

Spined Predatory Shield Bug (Shellenberg’s Soldier Bug)

Figure1 : Spined Predatory Shield Bug adult *(Oechalia schellenbergii)* left, and feeding on larvae right.

The Spined Predatory Shield Bug, also known as Shellenberg’s Soldier Bug is present in New Zealand and Australia. Schellenberg's Soldier Bug is a predator that feeds on free living insects such as caterpillars, including loopers and beetle larvae. It occurs in gardens and parks as well as in native ecosystems, which often surround or partially surround pistachio orchards.

Appearance: Adults and nymphs are predators on caterpillars like loopers and heliothis. The strong, piercing/sucking mouthparts are used to impale the prey and suck the body fluids. The adult is 9–12 mm long and mottled grey to brown with a large and easily recognised by the sharp, lateral spike on each side of the thorax. On the underside there is a long rostrum that holds the stylets used for feeding. Also on the underside is a forward pointing spine extending between the last two pairs of legs.

Body length: The adults are 8-12 mm long; the males are slightly smaller than the females.

Life Cycle: Several clusters of eggs are laid. The clusters are often made up of 14 or 28 eggs, one or two for each ovariole. The black eggs are usually arranged in rows. Each egg has a prominent ring of white spines on top.

The nymphs that hatch from the eggs are like small, wingless adults. There are five nymphal instars (stages). Nymphs go from one stage to the next by moulting, where the “skin” on the dorsal side splits and the next stage pulls itself out. The first instar nymphs are black and red; the black on the head, thorax and around the scent glands. The fifth instar is mainly coloured black with red on the abdomen around a central area of black. This stage has black wing buds that extend on to the abdomen.

The length of the lifecycle (time from egg to adult) varies with temperature and is faster at higher temperatures. In South Australian laboratory experiments, eggs developed from 15 to 30°C, taking 20 days at 15°C and 8 days at 20°C. At 20°C the five instars took 2.3, 4.6, 4.8, 7.6 and 11 days to complete development respectively.

Insect Pests Attacked: Like other Hemiptera, Schellenberg's soldier bug has sucking mouth parts. The long stylets, special shaped rods, are held in the rostrum. Schellenberg's soldier bugs are predators. The feed on insects such as caterpillars which they stab with their stylets, mandibles and maxillae. During feeding the insect is held by at the end of the rostrum the mandibles. The maxillae are inserted further into the prey. They form two tubes, a narrow duct down which saliva is pumped into the prey, and a larger tube up which the partly digested food is sucked. The first instar nymph is the only stage that is not a predator.

Monitoring: Visual inspection of leaves and limbs or beating braches into a sample tray.

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Native and 'Insectary' plants to promote beneficials

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Stuart Pettigrew's research into pests of pistachio (*Hort Innovation project PS16000, 2021*) had as one of its recommendations to 'manage native vegetation around orchards to increase the diversity and populations of beneficial arthropods'.

Arguably, one of the reasons we currently may have very light insect pest pressure in Australian pistachio orchards is because of their remoteness. The majority of large orchards are many kilometres from other agriculture and often surrounded by native scrub. This native scrub offers a haven and food source for many natural enemies (beneficials) of pest insects.

With re-vegetation a part of good farm practice, incorporating native plants that provide excellent habitat for beneficial insects into re-vegetation projects will vastly improve conservation biological control as a crucial mechanism for good integrated pest management.

Naturally occurring beneficials, at sufficient levels, can take a big bite out of your pest populations. To exploit them effectively, you must:

1) identify which beneficial organisms are present;
2) understand their individual biological cycles and resource requirements; and
3) change your management to enhance populations of beneficials.

Developing and introducing methods, such as native vegetation 'insectariums' which allow growers to better understand the diversity of beneficial insects on their farm, the services these insects provide, the timing of their abundance or critical life stages for bio-control alongside softer pesticide options, will mean growers can vastly improve their IPM strategies and environmental assurance.

The concept of planting flowering native vegetation to provide nectar and habitat for beneficial insects is a simple farm practice that can be achieved at relatively low cost. The potential economic gain easily counteracts the short-term outlay with long term financial advantages including reduced labour and pesticide inputs.

Areas suitable for orchard native plantings

Looking at your orchard, think about areas that would be suitable for incorporating alternative vegetation plantings in addition to native trees listed later:

Orchard production area

- Mid row and under trees

Orchard surrounds

- Headlands (non-producing land required for machinery access)
- Borders (including windbreak and shelter belts)
- Non-producing areas around infrastructure (sheds, loading pads, water storage)
- Riparian zones along waterways (creek lines, rivers), and
- Land unsuitable for productive pistachio growing due to salinity, water logging or requirements for wastewater disposal

Examples of native shrubs that will enhance beneficial insect populations by providing a food source, whether pollen or nectar as well as a habitat include:

• acacia • banksia • bottlebrush (*Callistemon*) • brush box (*Lophostemon*) • gum trees (*Corymbia*, *Eucalyptus*) • grevillea • hardenbergia • tea tree (*Leptospermum*) • melaleuca • myoporum • native violet *(Viola hederacea*) • pandorea.

The great thing about Australian natives is their long flowering cycle. Many exotic flowers have a much shorter flowering window and are also more likely to succumb to dry conditions and require watering.

For beneficials found on pistachio and native trees, see Table 1 below from Stuart Pettigrew's research.

Table 1. Arthropods found in association with each plant species

Plant	Predator and herbivore arthropods found in association
  pistachio, *Pistacia vera* (focal crop)	**Predators:** • green lacewing, *Mallada signata* • brown lacewing, *Micromus tasmaniae* • red and blue beetle, *Dicranolaius bellulus* • transverse ladybird beetle, *Coccinella transversalis* • ladybird beetle (undetermined) • Hymenoptera wasp (undetermined 1) • Hymenoptera wasp (undetermined 2) • Hymenoptera wasp (undetermined 3) • garden sac spider, *Cheiracanthium* sp. • winged black garden ant, *Lasius niger* **Herbivores:** • Cicadellidae leafhopper (undetermined 1) • Cicadellidae leafhopper (undetermined 2) • Rutherglen bug, *Nysius vinitor* • looper caterpillar, *Phrissogonus* sp. (undetermined)
 *Jacaranda* sp. (introduced)	**Predators:** • common spotted ladybird, *Harmonia conformis* • ladybird beetle (undetermined) • red and blue beetle, *Dicranolaius bellulus* • big-eyed bug, *Geocoris* sp. • Thomisidae crab spider (undetermined) • garden sac spider, *Cheiracanthium* sp. **Herbivores:** • 28-spotted potato ladybird, *Epilachna vigintioctopunctata* • Rutherglen bug, *Nysius vinitor*
 bottlebrush, *Callistemon* sp. (native)	**Predators:** • green lacewing, *Mallada signata* • Mantispidae, mantid lacewing • common spotted ladybird, *Harmonia conformis* • ladybird beetle (undetermined) • Pacific damsel bug, *Nabis kinbergii* • Hymenoptera wasp (undetermined 1) • Hymenoptera wasp (undetermined 2) • Hymenoptera wasp (undetermined 3) • Chalcidoidea wasp (undetermined) • Salticidae Jumping spider (undetermined) • Thomisidae crab spider (undetermined)

	Herbivores: • Cicadellidae leafhopper (undetermined) • Rutherglen bug, *Nysius vinitor* • coon bug, *Oxycarenus arctatus*
Plant	**Predator and herbivore arthropods found in association**
 wattle, *Acacia* sp. (native)	**Predators:** • green lacewing, *Mallada signata* • transverse ladybird beetle, *Coccinella transversalis* • ladybird beetle (undetermined) • predatory shield bug, *Oechalia schellenbergii* • big-eyed bug, *Geocoris* sp. • Hymenoptera wasp (undetermined 1) • Hymenoptera wasp (undetermined 2) • Hymenoptera wasp (undetermined 3) • Braconidae wasp (undetermined) • bethylid wasp, *Goniozus jacintae* • Araneidae spider (undetermined) • Oxyopidae lynx spider (undetermined) • Thomisidae crab spider (undetermined) **Herbivores:** • rosette crown weevil, *Trichosirocalus briesei* (biocontrol of thistles) • Cicadellidae leafhopper (undetermined) • crusader bug, *Mictis profana* • Rutherglen bug, *Nysius vinitor* • looper caterpillar, *Phrissogonus* sp. (undetermined)
 sticky hop bush, *Dodonaea viscosa* (native)	**Predators:** • ladybird beetle (undetermined) • Salticidae Jumping spider (undetermined) • Hymenoptera wasp (undetermined) • Mantodea. praying mantis **Herbivores:** • Cicadellidae leafhopper (undetermined 1) • Cicadellidae leafhopper (undetermined 2) • Fuller’s rose weevil, *Pantomorus cervinus*

 desert quandong, *Santalum acuminatum* (native)	**Predators:** • ladybird beetle (undetermined 1) • ladybird beetle (undetermined 2) • Hymenoptera wasp (undetermined) • Anthocoridae pirate bug • Araneidae spider (undetermined) **Herbivores:** • Cicadellidae leafhopper (undetermined) • Tingidae lace bug (undetermined

Plant	Predator and herbivore arthropods found in association
 saltbush mix (native)	**Predators:** • predatory shield bug, *Oechalia schellenbergii* • big-eyed bug, *Geocoris* sp. • Hymenoptera wasp (undetermined 1) • Hymenoptera wasp (undetermined 2) • Chalcidoidea wasp (undetermined) • Oxyopidae lynx spider (undetermined) • Salticidae Jumping spider (undetermined) • garden sac spider, *Cheiracanthium* sp. **Herbivores:** • rosette crown weevil, *Trichosirocalus briesei* (biocontrol of thistles) • Rutherglen bug, *Nysius vinitor* • brown stink bug, *Dictyotus caenosus*
 silver cassia, *Senna artemisioides* (native)	**Predators:** • ladybird beetle (undetermined) • Melyridae beetle (undetermined) • predatory shield bug, *Oechalia schellenbergii* • wrap-around spider, *Dolophones* sp. • bethylid wasp, *Goniozus jacintae* • Hymenoptera wasp (undetermined 1) • Hymenoptera wasp (undetermined 2) • Braconidae wasp (undetermined) • Chalcidoidea wasp (undetermined) • Salticidae Jumping spider (undetermined 1) • Salticidae Jumping spider (undetermined 2) • garden sac spider, *Cheiracanthium* sp. **Herbivores:** • Cicadellidae leafhopper (undetermined 1) • Cicadellidae leafhopper (undetermined 2) • Leaf footed bug, *Leptoglossus* sp. • Rutherglen bug, *Nysius vinitor* • Lepidoptera (undetermined) • Fuller's rose weevil, *Pantomorus cervinus*

Plant	Predator and herbivore arthropods found in association
   native plants mix (sheoak, *Allocasuarina* sp., emu bush, *Eremophila* sp., gum, *Eucalyptus* sp., spider flower, *Grevillea* sp., *Hake*a sp. and *Macadamia* sp.) (native)	**Predators:** • green lacewing, *Mallada signata* • brown lacewing, *Micromus tasmaniae* • transverse ladybird beetle, Coccinella transversalis • ladybird beetle (undetermined) • ground beetle (undetermined) • big-eyed bug, *Geocoris* sp. • Pacific damsel bug, *Nabis kinbergii* • predatory shield bug, *Oechalia schellenbergii* • Katydid, bush cricket (undetermined) • Syrphidae hoverfly (undetermined) • bethylid wasp, *Goniozus jacintae* • Hymenoptera wasp (undetermined 1) • Hymenoptera wasp (undetermined 2) • Hymenoptera wasp (undetermined 3) • Chalcidoidea wasp (undetermined) • garden orb spider, *Eriophora* sp. • Araneidae spider (undetermined) • Linyphiidae money spider (undetermined) • garden sac spider, *Cheiracanthium* sp. **Herbivores:** • Cicadellidae leafhopper (undetermined) • Lygaeidae bug (undetermined) • Tingidae lace bug (undetermined) • Rutherglen bug, *Nysius vinitor*

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