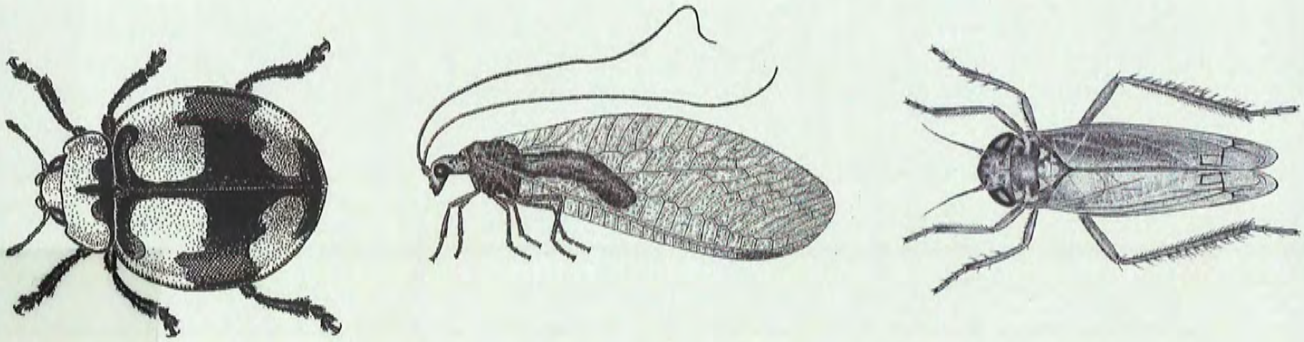
Department of Employment, Economic Development and Innovation

Identification of insects, spiders and mites in vegetable crops

Workshop manual

Second edition

Sue Heisswolf, Iain Kay and Bronwyn Walsh



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Introduction

Many small creatures reside in your crop. Insects, spiders and mites will make up a large number of these. Some can easily be seen, while others can only be found with the aid of a magnifying glass or microscope.

Insects are very important members of the animal world. They make up about three-quarters of the known animal species, with over one million species of insects known throughout the world. Many are as yet unknown—there could be up to 30 million species in total. It is estimated that there are at least 205 000 species of insects in Australia. Spiders and mites are part of a group called arachnids, which includes around 30 000 species.

The vast majority of insects and arachnids are not pests of agricultural crops. Many have a beneficial role as pollinators of plants and as predators or parasites of pests and weeds. However, these beneficial insects can easily be harmed by the same insecticides used to control crop pests. With careful management, parasites and predators can prevent the build-up of pests. Enlisting the aid of these natural enemies of pests can help reduce the amount of pesticides you have to use.

We use the terms 'beneficial insects', 'beneficials' or 'natural enemies' to describe insects and arachnids that kill pests in crops. These include predators such as spiders, predatory mites, lacewings and ladybirds, and insect parasites such as wasps and flies.

Accurate and confident identification of the insects and arachnids in your crop is the first step towards successful management of pests and natural enemies. This is an essential prerequisite for crop monitoring, which is the backbone of an effective pest management program.

This manual is designed as the main resource for delivering a workshop program on pest and beneficial identification in vegetable crops.

Please note:

- **The drawings used in this manual are intended for general identification only. They are not to scale and do not represent the size of an adult in relationship to its eggs, young or other insects.**
- **We have tried to keep technical terms to a minimum. A glossary has been included on page 67. Please ask if there are terms or expressions that you do not understand.**
- **As the manual is based around the major insect orders, an index has been provided on page 71 so that identification information on individual species can be easily located.**
- **The CSIRO (www.csiro.au) and Entomology Australia (www.entomology.edu.au) websites provide lots of information on insect classification, life cycles and identification. They are very useful references for this workshop.**

Workshop summary

By the end of this workshop, you will:

- know how to collect and preserve insects for identification
- be able to classify most common insects (particularly those of horticultural significance) into broad groups
- appreciate the importance of these groups in pest, predator and parasite identification and management
- have collected and classified some insect pests, predators and parasites of horticultural importance.

The workshop will consist of at least 8 hours of training, including:

- 4–5 hours of classroom/laboratory sessions
- 4–5 hours of field sessions.

In the laboratory/classroom sessions, you will learn about:

- insect classification (relationships with other animal groups, particularly spiders)
- insect groups
- identifying examples from each of the major groups
- collecting and preserving insects
- the significance of the groups in identification and management.

In the field sessions, you will gain practical experience in finding insects and crop damage, and understanding the interactions between insects.

You may be asked to collect specimens of pests, parasites and predators for a small insect collection to help with pest identification in the crops you work with. Participants and facilitators will decide whether a collection is necessary, but making a collection is a useful and beneficial exercise.

Field collection list

This exercise will start during the first field training session but participants are encouraged to collect specimens whenever they have the opportunity.

Collect and preserve 15 insects, spiders and mites. Try to find these specimens in vegetable crops (or on vegetables in the backyard) to increase your knowledge about pests and natural enemies in commercial crops. The collection will be used during the workshop and the greater the number of specimens, the more valuable the training sessions will be.

Aim to collect specimens from the following orders.

Order	Specimens
Lepidoptera (moths and butterflies)	2 adults (1 moth, 1 butterfly)
Hemiptera (bugs, aphids etc.)	2 adults (1 bug and 1 aphid, leafhopper or whitefly)
Thysanoptera (thrips)	1 specimen
Coleoptera (beetles)	1 adult
Diptera (flies)	1 adult
Orthoptera (grasshoppers and crickets)	1 specimen
Dermaptera (earwigs)	1 specimen
Hymenoptera (wasps and ants)	1 adult
Neuroptera (lacewings) or Odonata (dragon and damsel flies)	1 adult
Class Arachnida (spiders and mites)	1 specimen
	Plus 1 nymph 1 larva 1 egg

The collecting and preserving of insects, spiders and mites is a specialised entomological skill. The following section provides notes on the basics of collecting and preserving specimens to help you prepare the field collections. The book *Methods for collecting, preserving, and studying insects and allied forms* (Upton 1991) provides more detailed information. The Entomology Australia (www.entomology.edu.au) and CSIRO (www.csiro.au) websites also provide useful information.

Collecting and preserving

If possible, collect specimens from your crops or from crops you work with to help you learn about the insects in them. Home vegetable gardens are also a rich source of pest and beneficial insects.

Insects are likely to be more abundant in the warmer months of spring through to autumn (September to April), so collecting then will be easier. Many insects hibernate during the colder months, particularly in southern subtropical and temperate parts of the country. Various insects are active at different times of the day, so your collecting activities may need to reflect that (e.g. moths are nocturnal, so they will be active and can be collected at night). Some species may be found more easily in the early morning as they move to the top of the crop canopy to bask in the sunlight (e.g. green vegetable bugs), or are more sluggish in the cooler morning temperature and so are more easily caught (e.g. silverleaf whiteflies).

Collecting techniques

There are many methods that can be used to collect insects. Here are a few simple methods you might use.

You can collect many of these specimens by hand while searching the crop plants, either literally or by placing a container or jar over the insect and trapping it inside.

A sweep or butterfly net is a great tool for sweeping through the crop to gather whatever is there or catch flying insects.

A beat sheet or tray can be useful. Place a piece of material (the beat sheet) or a tray under the plant or part of the crop row, then hit the plant so that any insects fall onto the sheet. You will have to be quick to collect them before they fly away. Thrips that live in flowers, such as western flower thrips, can be collected in a similar way. Hold a sheet of white paper (or a white tray) under the flowers and tap them. The thrips should fall out and can be easily seen on and gathered from the paper. Pick them up with your finger or a brush moistened with water or alcohol and wash them off into a tube or bottle containing alcohol (see the 'Mounting and preserving' section below).

Some insects (e.g. moths, some beetles, mole crickets) are attracted to light at night. Use a light to attract them, then collect them as they gather near it.

Particular insects may be collected in traps baited with lures specific to them (e.g. heliothis moths in a pheromone trap or fruit flies in a fruit fly trap).

Some people have collected butterflies and grasshoppers using the grilles of their cars. While this can be effective, it is not recommended as the specimens are usually left in very poor condition.

Killing the insects

Collected insects can be killed in a number of ways. Insects that are stored in alcohol (e.g. aphids, thrips, whiteflies and mites) can be killed by placing them straight into the alcohol.

For other insects, a simple killing bottle can be made from a glass jar, preferably with a metal lid. Impregnate a piece of cotton wool or tissue with ethyl acetate and place it in the jar with the insect, trying to avoid direct contact with the insect. The fumes kill the insect. Ethyl acetate is often the main solvent in nail polish remover, which can be used instead. Ethyl acetate affects many plastics, hence the recommendation of using a metal lid. Ethyl acetate is not dangerous to use (although it is highly flammable), but do not inhale it directly.

Small insects may be killed by freezing them. Be aware that large insects tend to rot and smell when defrosted, so it is best not to freeze them.

Mounting and preserving your insects

Each type of insect should be pinned or preserved in a specific way. These methods are detailed on the CSIRO and Entomology Australia websites and in Upton's book. The methods for the insects you have been asked to collect are provided opposite. Some of your specimens should be preserved in 80% alcohol (methylated spirits will do for this collection if necessary), while others should be pinned using entomological pins. Insects should be pinned quite soon after death before they become stiff and brittle, or bits may break off. If you cannot pin your specimens, keep them dry in a container of some sort.

Insect	Method
Moths and butterflies	Pin through the thorax with the wings spread
Bugs	Pin just to the right of the centre of the thorax
Aphids, leafhoppers and whiteflies	Preserve in alcohol (leafhoppers can be pinned using a micro-pin)
Thrips	Preserve in alcohol
Beetles	Pin through the right side of the wings towards the front
Flies	Larger specimens should be pinned through the right side of the thorax Micro-pins can be used for smaller specimens
Grasshoppers and crickets	Pin through the right side of the thorax with the left side wings spread
Earwigs	Preserve in alcohol or pin on right hand side of the wings
Wasps	Usually pinned through the right side of the centre of the thorax Smaller specimens can be preserved in alcohol
Ants	Preserve in alcohol
Lacewings, dragonflies and damselflies	Pin through the thorax with the wings spread
Spiders and mites	Preserve in alcohol

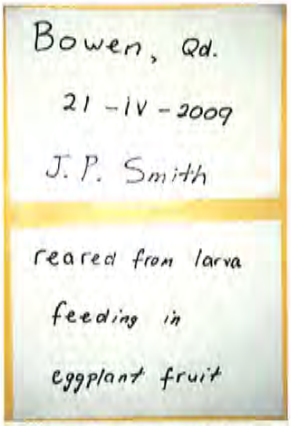
If you want to keep your collection for reference after this workshop, it should be kept in a storage box that can be well sealed and kept dry. Place some moth balls or naphthalene in the box to deter various small pests that can attack the insects and damage the collection.

Labels

If you look at any good insect collection, you will see small labels on each specimen. These labels give the location where the insect was collected (e.g. property number, nearest town, GPS coordinates), the date of collection, the collector's name and any other useful information (e.g. feeding on a particular plant, predating on another insect, reared from a host, collected at light). These records help tell us the geographical range of the insect species, the times of year it is active and information on what it does. Label your specimens so this information is retained with the insect. Another label with the insect's name can be added once the insect has been identified.

Collecting and preserving equipment

Equipment such as sweep nets, entomological pins, storage boxes and tubes can be ordered from the Australian Entomological Supplies website at www.entosupplies.com.au



Typical collection labels for a pinned insect

A pinned eggfruit caterpillar moth with collection labels

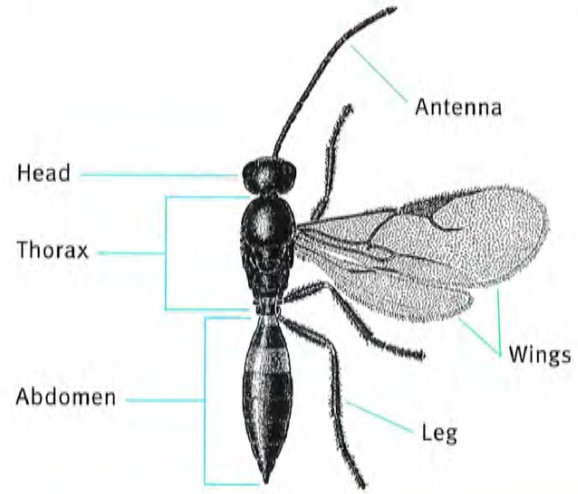
Basic classification

Insects and arachnids belong to a large division of animals called arthropods, which are defined by having segmented bodies, an external skeleton and jointed legs. Mammals such as cats, elephants and humans have an internal skeleton (bones), while arthropods have a hard external skeleton.

Crustaceans (crabs and crayfish) and myriapods (millipedes and centipedes) are other common arthropods. Crustaceans are almost entirely aquatic.

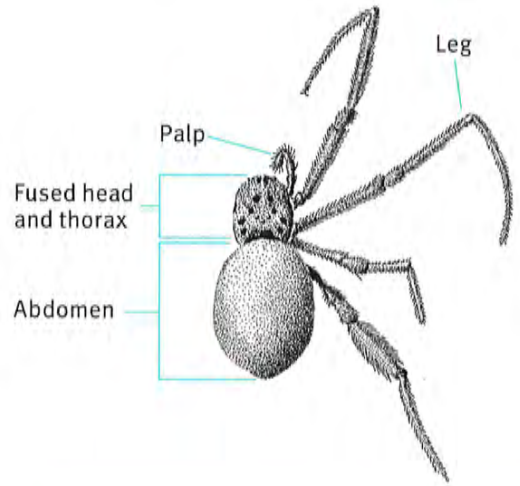
The different arthropods can be most easily identified by the number of legs (including claws) and antennae.

Insects have six legs and one pair of antennae. They also have a distinct head, thorax and abdomen (the thorax roughly corresponds to the chest in other animals). Many insects have wings, and the wings and legs are attached to the thorax. Not all species have wings, and only adult forms have them fully developed. The young do not always resemble the adults (see 'Life cycles', p. 8).



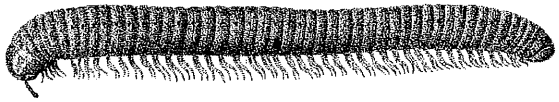
Wasp

Arachnids (spiders, mites and ticks) have eight legs and no antennae. They have a fused head and thorax, and an abdomen.

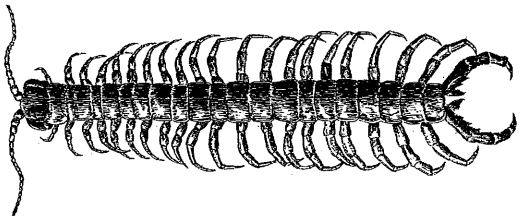


Spider

Myriapods have 10 or more legs and one pair of antennae. Myriapods have many body sections. They are predominantly scavengers on organic matter and so have little relevance to crops, although many centipedes are voracious predators and so may have a beneficial influence.



Millipede



Centipede

Orders

Insect and arachnid species are classified into groups called orders. Species that belong to the same order have similar characteristics that can be used for identification. However, there are always exceptions and it is not possible for this manual to outline all those exceptions.

There are many orders of insects and arachnids. In this workshop we will concentrate on identifying the orders that are important to agriculture.

Important insect orders include:

- moths and butterflies (Lepidoptera)
- bugs, leafhoppers, aphids, whiteflies, mealybugs and scale insects (Hemiptera)
- thrips (Thysanoptera)
- beetles (Coleoptera)
- flies (Diptera)
- crickets and grasshoppers (Orthoptera)
- earwigs (Dermaptera)
- wasps, bees and ants (Hymenoptera)
- lacewings (Neuroptera)
- dragonflies and damselflies (Odonata).

Important arachnid orders include:

- mites (Acarina)
- spiders (Araneae).

Life cycles

The process of developing from egg to mature adult is called the life cycle. Species within the same order will have similar life cycles. Understanding these life cycles helps to identify pests and natural enemies, and contributes towards a better understanding of how pests cause damage and when control measures are best applied.

Life cycles are influenced by temperature—they are shorter in warm weather and longer in cooler conditions.

Metamorphosis

Insects and arachnids shed their external skeleton periodically during development. This is called moulting. Between periods of moulting the insect is called an instar. The adult stage is reached when the insect or arachnid is fully developed with functional reproductive organs and (in the case of winged insects) functional wings.

Newly hatched insects and arachnids change as they develop into adults. The process of change is called metamorphosis. The three different types of life cycle changes are:

1. without metamorphosis
2. incomplete metamorphosis
3. complete metamorphosis.

All three types are found in insects. Arachnids undergo incomplete metamorphosis.

Without metamorphosis

The 'without metamorphosis' cycle is characteristic of primitive insect species (none of which are included in this manual).

During this life cycle:

- insects in the larval stages (also called nymphs) look like adults
- larvae undergo numerous moults (usually more than 10) and continue to moult after they are sexually mature.

Examples include silverfish and springtails.

Incomplete metamorphosis

During the 'incomplete metamorphosis' cycle:

- nymphs (young insects) generally look like adults
- changes from nymph to adult are gradual (nymphal stages correspond to instars)
- wing development is external, with wings first showing as small buds that get larger with each moult
- nymphs often feed in the same habitat as adults (dragonflies are an exception).

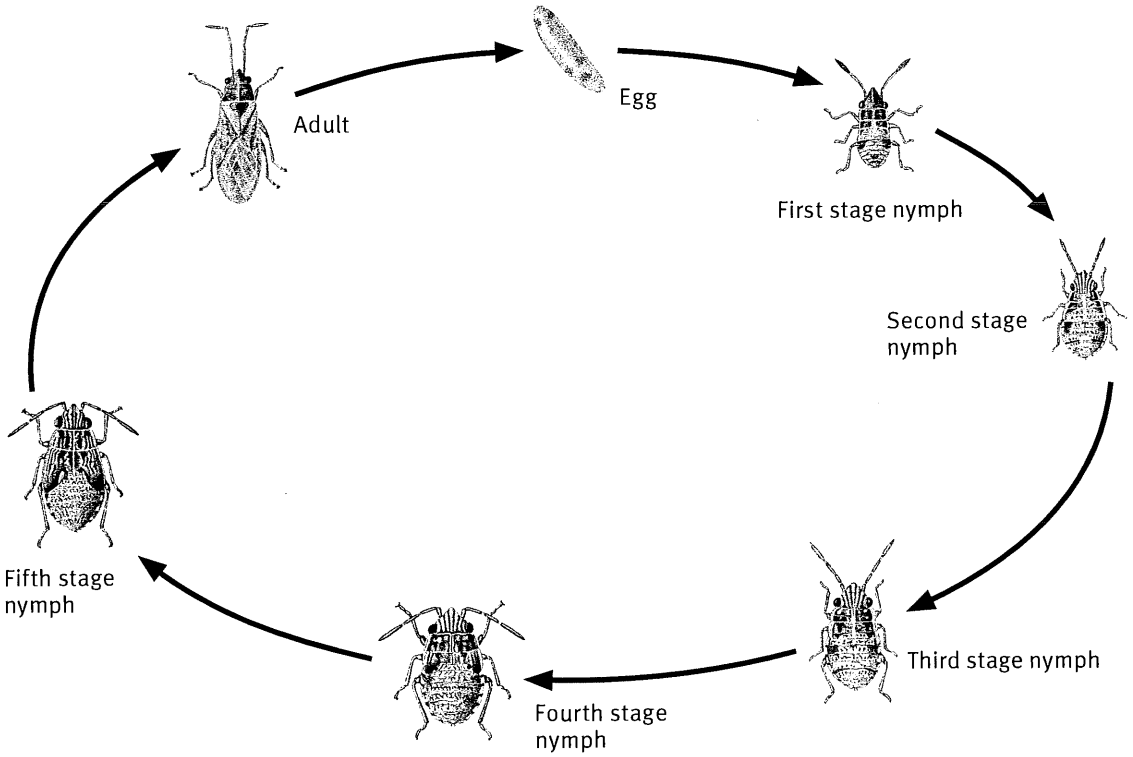
Examples include bugs, grasshoppers, thrips, earwigs and dragonflies.

Complete metamorphosis

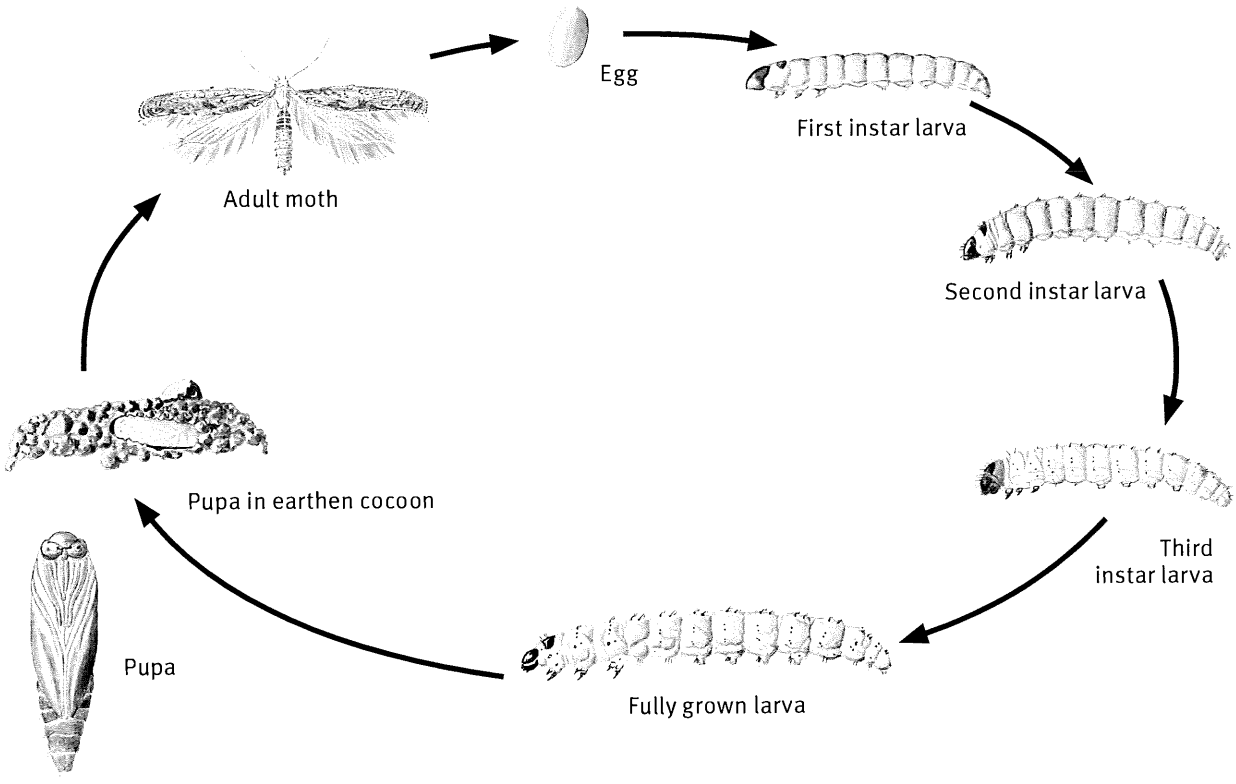
During the 'complete metamorphosis' cycle:

- larvae (young insects) do not look like adults
- larvae often feed in habitats that are quite different from those of the adults
- the change from larva to adult is very distinct
- the larva forms a pupa when it is fully grown. This is a stationary, non-feeding stage during which the adult structures (including wings) are formed. The adult then emerges from the pupa.

Examples include butterflies, moths, beetles, bees, wasps, flies and lacewings.



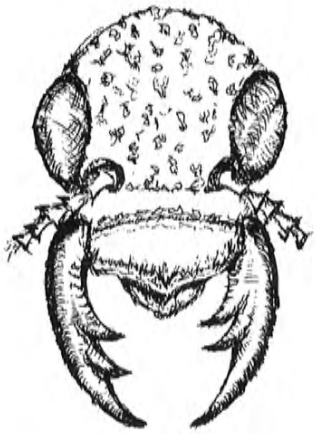
An example of incomplete metamorphosis—life cycle of the Rutherglen bug



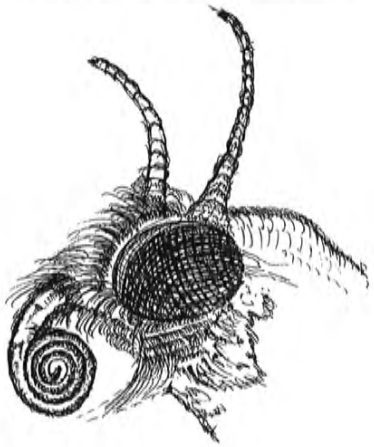
An example of complete metamorphosis—life cycle of the potato moth

Mouthparts

Mouthparts are hard to see on most insects (particularly small ones) without the aid of a microscope or magnifying hand lens. However, it is important to look at mouthparts as they can be used to identify the order of an insect, how an insect feeds and what damage it is likely to do. The pictures below show the main types of mouthparts, but there are many variations. Some insects may have combinations of two or more types.

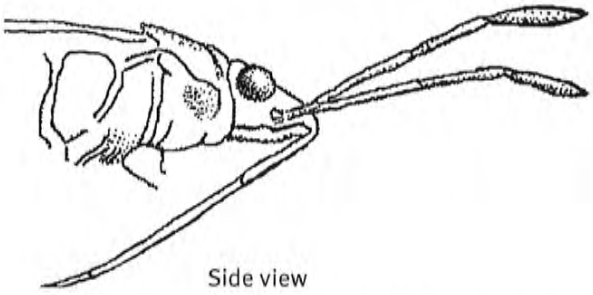


Chewing mouthparts—jaws are scissor-like for cutting food into small pieces

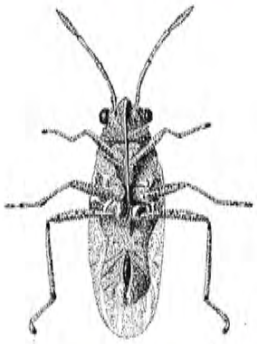


Coiled sucking mouthparts (side view)—mouthparts form a tube to suck liquids; the coiled tube can be extended into difficult-to-reach places

Sponging mouthparts (side view)—designed to 'mop up' liquids



Side view



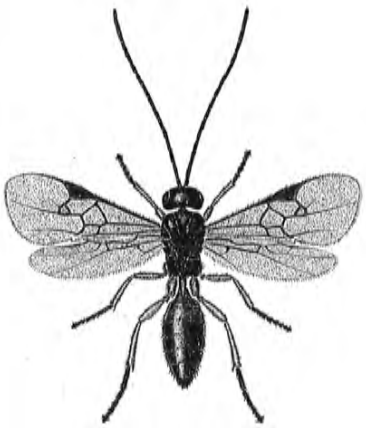
View from below

Piercing/sucking mouthparts—mouthparts form a strong hollow tube to pierce the surface and suck liquid

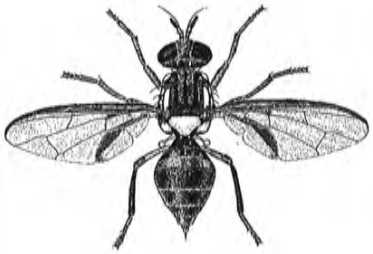
Wings

Most adult insects have wings. The different types of wings can be a good way to separate the main groups of insects. Different wing characteristics are detailed below.

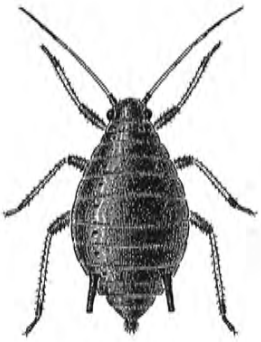
Number of wings



Four wings

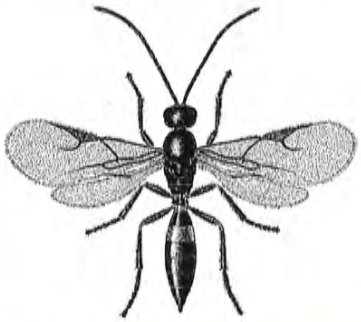


Two wings



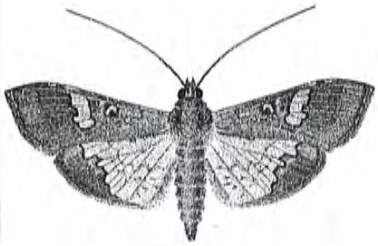
No wings

Texture of wings

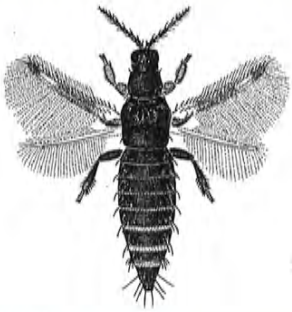


Membranous

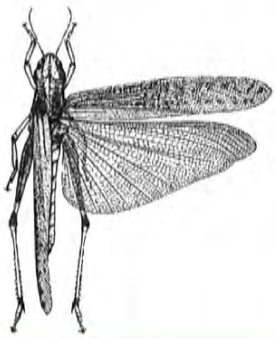
Ends of wings membranous



Scaled



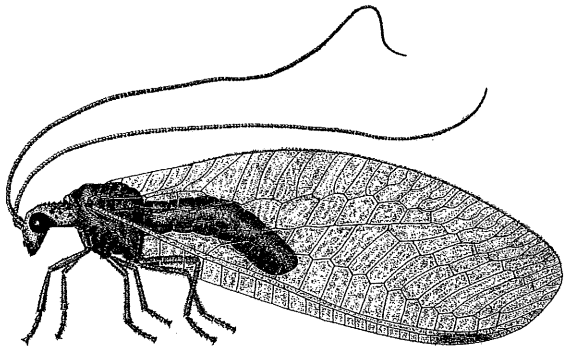
Feathered



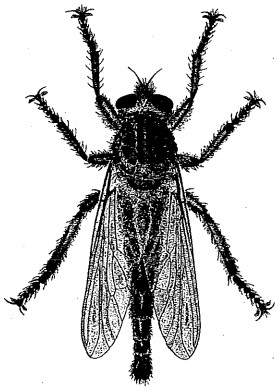
Leathery forewing

Hard forewing

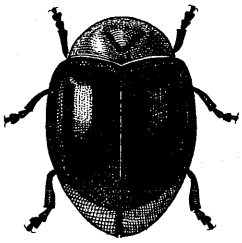
Position of wings at rest



Held roof-wise over abdomen



Held flat over abdomen



Membranous hind wings folded under hard forewings meeting in centre line

Damage caused to plants by insects and mites

Most insect and mite damage to plants is caused when the pests feed. Other damage can be caused as they lay eggs or as they seek shelter. Some insects and mites also spread plant diseases.

The type of damage done by a particular insect or mite depends on:

- its basic feeding or egg laying habits—sucking or chewing mouthparts, or a short or long ovipositor
- its size—larger insects not only eat more, they take bigger bites, make bigger holes and feed on older and tougher parts of the plant
- the stage of the life cycle—older is usually bigger. In its developing phase as a larva or nymph, an insect or arachnid uses most of its energy to grow so it will consume large amounts of food. Pests will usually do the most damage during this phase. During adulthood, the insect uses most of its energy on reproduction and moving around, so it may not eat as much (e.g. caterpillars consume large amounts of food as opposed to the adult butterfly or moth, which may consume little or none)
- the number of insects—an individual an insect may not do much damage, but swarms of very small insects can do considerable damage
- the part of the plant that is attacked—soft, actively growing tissue can show quite different damage symptoms to similar feeding on harder, mature plant parts.

Insects can be responsible for virus damage in crops, as some species of insects spread (vector) viruses from plant to plant.

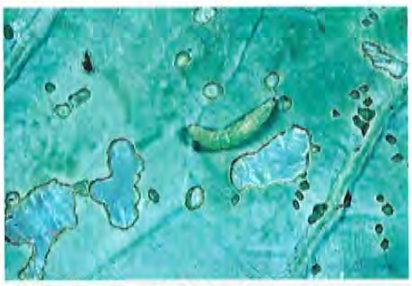
Other sources of plant damage that can sometimes be confused with insect damage are:

- plant diseases caused by fungi, bacteria, viruses and virus-like organisms
- physical damage from other animals, people or machinery
- damage from pesticide sprays, herbicides, fertilisers and other chemicals
- weather damage from dry, wet, windy, hot or cold conditions at crucial plant growth stages
- growth disorders such as mutations.

Chewing damage

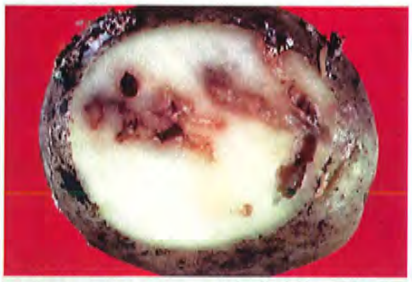
Pumpkin beetle damage to rockmelon leaf
(photograph courtesy of DA Ironside, DEEDI)

Cutworm damage to seedlings
(photograph courtesy of J Wessels, DEEDI)



Cabbage moth damage

Boring and tunnelling damage



Potato moth larvae tunnelling in potato

Heliothis boring into tomatoes

Bean podborer in damaged pod
(photograph courtesy of DA Ironside, DEEDI)

Leaf mining damage

Leaf mining damage caused by potato moth

Egg laying damage

Egg laying sting of fruit fly

Sucking and piercing damage

Green vegetable bug damage to tomato

Damage from viruses transmitted by insects

Lettuce necrotic yellow disease caused by a virus spread by aphids

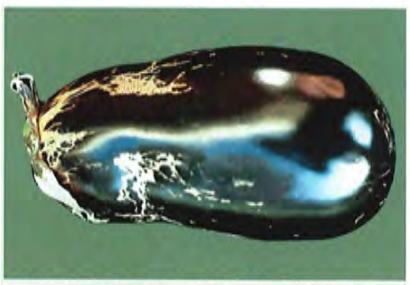
Mosaic disease on zucchini caused by a virus spread by aphids

Spotted wilt in lettuce caused by a virus spread by thrips

Rasping damage

Severe damage to tomato by tomato russet mite

Broad mite damage to capsicum fruit



Thrips damage to eggplant

Identification of the major orders

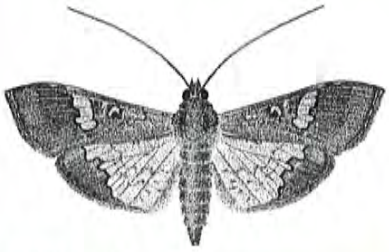
Insects undergoing complete metamorphosis

Moths and butterflies (Lepidoptera)

Basic identification

Adults

- Wings covered with small, coloured scales
- Moths fold wings along body
- Butterflies fold wings vertically
- Moths generally have thicker bodies
- Coiled, sucking mouthparts



Moth adult

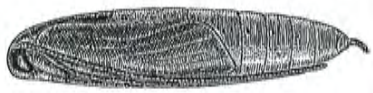
Larvae

- Soft-bodied and elongated
- Chewing mouthparts
- Six legs on thorax and four to eight false legs (prolegs) on abdomen
- Often called caterpillars or grubs

Moth larva

Feeding habits

Adults feed on nectar and other liquids. They may be minor pollinators. Larvae are usually the damaging stage. Most species are plant feeders. Many species are surface feeders on leaves, stems and fruit, while some are leaf miners or fruit borers and occasionally stem borers. A few species are predators of other insects.



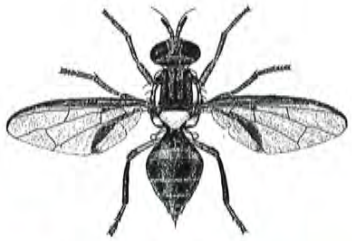
Moth pupa

Flies (Diptera)

Basic identification

Adults

- Two clear, membranous forewings
- Hind wings replaced by small, club-like structure (halteres)
- Usually compound eyes



Adult

Larvae

- Soft-bodied, small, legless and elongated
- Often called maggots

Egg

Pupa

Feeding habits

Larvae of most species feed on decaying organic matter. A few (such as hover flies) are predators of other insects, while others are parasitic. Some are fruit, leaf or stem borers. Adults feed on nectar, plant sap or liquid from rotting organic material. A few suck blood from other animals. Some are important pollinators.

Larva

Lacewings (Neuroptera)

Basic identification

Adults

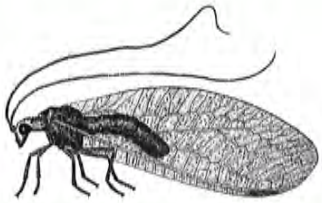
- Four clear, multi-veined wings that are much larger than the body
- Chewing mouthparts
- Fragile appearance
- Weak, erratic fliers

Larvae

- Well-developed thoracic legs
- No abdominal legs
- Large mandibles for grasping and piercing prey
- Some (like antlions) dig pits to catch prey
- Some carry the debris of their prey on their backs

Feeding habits

Adults of some species are predators of other insects and arachnids. Larvae of all species are active predators.



Adult

Eggs

Larva camouflaged with debris

Wasps, bees and ants (Hymenoptera)

Basic identification

Adults

- Four clear, membranous wings (worker ants are usually wingless)
- Constricted waist between abdomen and thorax
- Mouthparts mainly biting/chewing (adapted in some species to lap up liquids)
- Female wasps and bees with a strong ovipositor, sometimes developed as a defensive sting
- Some are social insects and live in colonies

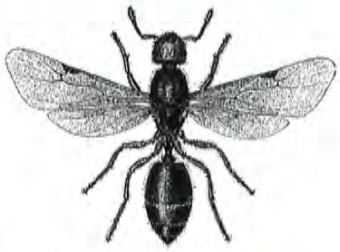
Larvae

- Usually soft bodied and legless
- Rarely seen as they are protected in nests, hives or in the bodies of parasitised hosts
- Most ants, many bees and some wasp species are social insects living in hives or nests

Feeding habits

Most wasps are predators or parasites of other insects and arachnids. Parasitic wasps lay their eggs in the eggs, larvae or adults of their hosts. Wasps feed on nectar and pollen. A few wasp species are plant parasites and lay their eggs in leaves or stems of plants. Bees feed on nectar and pollen, are important pollinators and produce honey and beeswax. Ants are usually scavengers. They often protect and spread sap-sucking insects like scales, mealybugs and aphids in return for their sugary secretions. They may harvest planted seeds. Some ants are predators of other insects.

Wingless worker ant



Winged ant

Parasitic wasp

Beetles (Coleoptera)

Basic identification

This is the largest order of insects. Beetle species vary widely in size and shape.

Adults

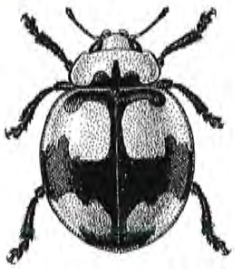
- Four wings
- Forewings form a hard cover over the clear, membranous hind wings
- Chewing mouthparts
- Usually hard-bodied

Larvae

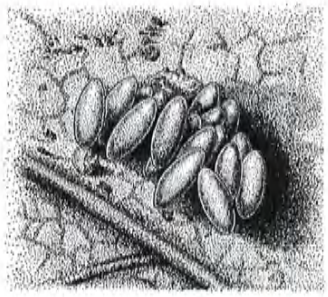
- Six thoracic legs (usually, although some are legless)
- No abdominal legs
- Chewing mouthparts

Feeding habits

Most beetle species feed on plants and stored products. Adults feed on the leaves, stems and fruit of many plants. Larvae attack leaves, stem and roots. Many species are stem borer or scavengers, while a few are predators of other insects (e.g. most ladybird species are valuable predators).

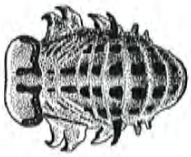


Adult



Eggs

Larva



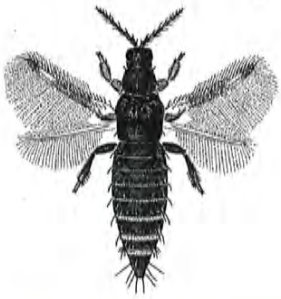
Pupa

Insects undergoing incomplete metamorphosis

Thrips (Thysanoptera)

Basic identification

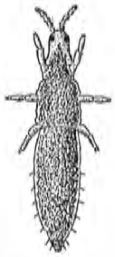
- Adults have four long, narrow wings, fringed with hairs to give a feathery appearance; larvae are wingless
- Very small and elongated (up to 3 mm long)
- Relatively large eyes
- Mouthparts are designed to pierce surface cells of plants and suck their contents



Adult

Feeding habits

Many species feed on plants, usually on soft tissue in protected areas like flowers and buds. Damage is often seen as scarring and bronzing or silvering of leaves and fruit. Some species transmit viral diseases. A few species are predators of mites and other small insects.



Larva

Bugs, leafhoppers, aphids, whiteflies, mealybugs and scale insects (Hemiptera)

There is a wide variation in shapes and sizes of species belonging to this group.

Bugs

Basic identification

- Four wings (a few species are wingless)
- Forewings thickened with clear, membranous tips
- Hind wings are clear and membranous
- Piercing, sucking mouthparts

Adult

Feeding habits

Most species are plant feeders, piercing fruit and softer stems and sucking sap. Some are predators of other insects (e.g. assassin bugs). Adults and nymphs generally feed on the same plant species.

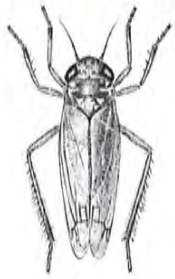
Eggs

Nymph

Leafhoppers and planthoppers

Basic identification

- Four clear or coloured membranous wings, often folded roof-wise along the body
- Long hind legs used for jumping
- Most are less than 10 mm long
- Piercing, sucking mouthparts



Leafhopper

Aphids

Basic identification

- Winged and wingless adult forms—winged aphids have four clear, membranous wings with obvious veins (winged aphids are generally the colonising phase of the pest)
- Small, soft-bodied and ovoid in shape (rarely more than 3 mm long)
- Piercing, sucking mouthparts
- Tend to cluster in groups at the feeding site
- Females generally give birth to nymphs

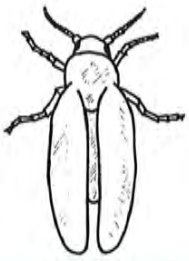
Winged aphid

Wingless aphid

Whiteflies

Basic identification

- Adults are less than 2 mm long
- Bodies and wings are covered in powdery white/yellowish wax
- Nymphs look like small, white to clear flakes or scales on the underside of leaves
- Piercing, sucking mouthparts



Adult

Mealybugs

Basic identification

- Soft-bodied with sluggish movement
- Pinkish or white in colour and covered with waxy filaments
- Piercing, sucking mouthparts
- Often form large groups in protected feeding sites (e.g. calyx of eggplant fruit)
- Not common in vegetables

Scale insects

Basic identification

- Soft-bodied, wingless, legless and sedentary
- Covered with a waxy or hard scale for protection
- Piercing, sucking mouthparts
- Rare in vegetable crops

San José scale

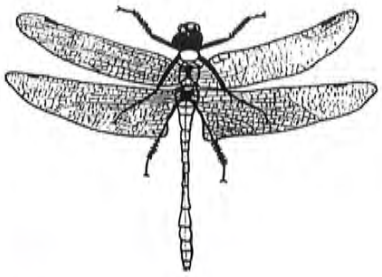
Feeding habits of leafhoppers, aphids, whiteflies, mealybugs and scale insects

These pests feed by sucking sap, usually from younger and softer parts of plants. Individual insects are usually too small to do significant damage, but large populations affect plant growth. Some species of leafhoppers, aphids and whiteflies transmit viral diseases and small numbers can cause significant damage by spreading viruses in crops. Many species secrete sticky honeydew on to the plant and a black fungus (sooty mould) will sometimes develop on it. Scale insects and mealybugs are not common in vegetable crops.

Dragonflies and damselflies (Odonata)

Basic identification

- Adults have four long, narrow, clear, membranous, net-veined wings
- Wings are held rigidly at right angles to the body, which is elongated and slender
- Chewing mouthparts
- Nymphs are aquatic and do not resemble adults



Adult

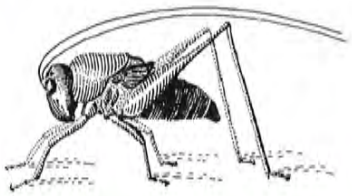
Feeding habits

Adults are predators of flying insects. Nymphs are predators of small, aquatic animals.

Grasshoppers and crickets (Orthoptera)

Basic identification

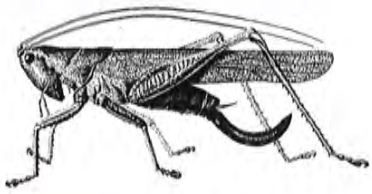
- Four wings (a few species are wingless)
- Forewings are leathery and cover the membranous hind wings
- Large hind legs are used for hopping
- Large head and chewing mouthparts



Nymph

Feeding habits

They are mainly plant feeders, chewing the leaves, stems, roots and tubers of a range of plants. Some crickets are predators of other insects. Grasshoppers live and feed above ground, while many species of crickets live in underground burrows and feed on roots and tubers. Some grasshoppers form migratory swarms and cause extensive damage to crops and pastures.



Adult

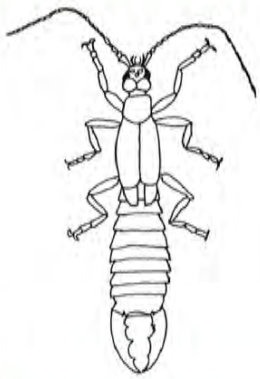
Earwigs (Dermaptera)

Basic identification

- Usually four wings with very short and hard forewings covering clear, membranous hind wings
- Body elongated and flattened
- Forceps on the end of abdomen
- Chewing mouthparts

Feeding habits

Most species are nocturnal scavengers living in soil cracks, under logs or rocks, and in rotting timber or other organic matter. They eat both plant and animal material and will occasionally chew on live plants, such as young seedling as they emerge from the soil. A few species are predators of other insects.



Adult

Spiders (Araneae)

Basic identification

- Eight legs and no wings
- Head and thorax fused together
- Chewing mouthparts with strong jaws

Feeding habits

All spiders are predators of insects and other small animals. Many species stalk their prey, some ambush it and others snare prey in webs.

Adult

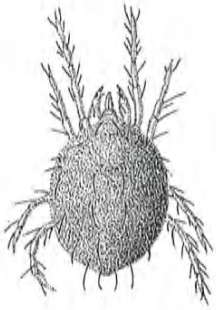
Mites (Acarina)

Basic identification

- Very small (most are less than 1 mm long and are not visible to the naked eye)
- Adults usually have eight legs; the microscopic nymphs have six legs
- No eyes and no antennae
- Body made up of only one section
- Mouthparts like forceps

Feeding habits

Many species of mites are predators of other mites and small insects. Some feed on plants, mainly by piercing the surface cells of leaves and stems and sucking the contents. Others cause russeting (reddening) of leaves and stems, and some cause blisters and galls.



Adult

Important pests in vegetable crops

This section gives descriptions of common pests found in Australian vegetable crops. They are listed according to the insect order they belong to.

Moths and butterflies (Lepidoptera)

Heliothis (corn earworm, tomato budworm, native budworm)

***Helicoverpa* spp.**

Heliothis larvae feed as leaf eaters and bud and fruit borers on a wide range of plants, including many weeds. Adults lay round, domed, ribbed eggs that are cream when newly laid, turning brownish ('brown ring' stage) as they mature. Larvae grow up to 40 mm long and vary in colour from green through yellow and brown to almost black, with a pale stripe down each side. The moths have a wing span of 35–45 mm.

These are some examples of heliothis damage to vegetable crops:

- On lettuce and brassicas, larvae feed on the outer leaves or tunnel into the heart of the plant.
- In tomato crops, eggs are laid on the leaves, flowers and fruit. Young larvae burrow into flowers causing them to fall and they cause pinhole damage to very young tomato fruit. Older larvae burrow into the fruit, creating holes and encouraging rots to develop.
- In capsicum, larvae feed on the fruit and the seed inside the fruit. Eggs are laid mainly on leaves, but also on flowers and buds.
- In sweet corn, eggs are laid on the silks and leaves. Larvae feed on the developing grains on the cob, sometimes on the leaves and often inside the tip of the corn cob.
- In green beans and peas, the larvae feed on the flowers, pods and developing seed inside the pods.

Heliothis moth at rest

Heliothis eggs on tomato shoot

Stages of heliothis egg development—freshly laid (left) to mature (right)
(photograph courtesy of B Scholz, DEEDI)

Heliothis larva

Loopers

***Chrysodeixis* spp.**

Looper larvae feed on the leaves and fruit of a wide range of vegetable crops, including brassicas, lettuce and tomatoes.

The moths are mottled grey or brown with silvery markings on the forewings. They lay round, flattish, ribbed eggs that are white, turning bone as they mature. They are very similar to heliothis eggs, except that the looper eggs are flatter. The larvae grow up to 35 mm in length, are green in colour and older larvae have fine, white lines along the body. Loopers are easily distinguished by their distinctive 'looping' movements.

Looper larva

Looper damage to tomato leaf
(photograph courtesy of DA Ironside, DEEDI)

Cabbage white butterfly

Pieris rapae

The larvae of the cabbage white butterfly are leaf eaters. Young larvae feed on the outer leaves of cabbage, cauliflower and broccoli plants. Mature larvae feed on outer leaves of cabbage heads and the curd of broccoli and cauliflower.

Adults lay bullet-shaped, ribbed eggs that are pale yellow, turning orange-yellow as they mature. Young larvae are light green and opaque with some fine hairs, while mature larvae are 20–30 mm long, dull green and velvety with yellow stripes along the mid line of their bodies.

Cabbage white butterfly

Eggs turn from light yellow (left) to deep yellow (right) to orange-yellow just before hatching

Larva and pupae

Cutworms

Agrotis spp.

Cutworms feed on most vegetable crops. Larvae usually feed at night on the stems of seedlings near ground level. The seedling is often completely severed and wilts and dies. Occasionally, cutworms climb mature plants and feed on the foliage. Moths are a dull brown-black colour. Larvae grow to about 30 mm long, are hairless, with dark heads and darkish bodies, often with longitudinal lines and/or dark spots. They curl up and remain still if picked up. Larvae may be found during the day in the topsoil near damaged plants.

Cutworm larvae and damage to seedlings
(photograph courtesy of J Wessels, DEEDI)

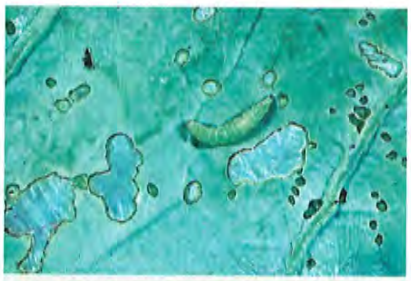
Cabbage moth (or diamondback moth)

Plutella xylostella

Larvae mine leaf tissue when they first hatch. Within a day or so they emerge to feed on the underside of leaves causing holes or windows. Larvae can damage the heart of cabbages and heads and stems of broccoli and cauliflower.

The moths are about 10 mm long, greyish-brown with a row of pale diamond-shaped markings when the wings are folded at rest. The moths lay very small (0.4–0.5 mm long) oval, flat, smooth eggs that are pale yellow in colour. They turn dark yellow with brown markings at one end as they mature, and are stuck singly or in a small group near leaf veins. The larvae are creamy green when mining the leaf tissue and bright green, plump and 10 mm long when mature. They wriggle backwards and drop from the plant on a thread when disturbed.

Cabbage moth



Larva with windowing damage to cabbage

Cabbage moth eggs

Cluster caterpillar

Spodoptera litura

Young larvae feed in groups, while older larvae are solitary. Larvae feed on the leaves of many vegetables and can cause severe leaf damage. They may also bore into the hearts of cabbage and gouge large holes in fruit (e.g. tomatoes and capsicums).

Moths are greyish-brown, with silvery markings on the forewings and silvery white hind wings, and a wing span of 30–40 mm. Eggs are laid in clusters covered with a mat of grey-brown hairs. Larvae are brownish-purple in colour, widest several segments behind the head and grow to 40–50 mm long. Older larvae have a row of dark triangular markings along each side of the body.

Cluster caterpillar moth
(photograph courtesy of J Wessels, DEEDI)

Cluster caterpillar egg mass
(photograph courtesy of J Wessels, DEEDI)

Cluster caterpillar larva

Cluster caterpillar damage to tomato fruit
(photograph courtesy of I Kay, DEEDI)

Cabbage cluster caterpillar

Crocidolomia pavonana

Larvae feed on the leaves of crucifers and can cause severe damage to head tissue, while outer leaves often are less damaged. Adults are light brown moths with a wing span of about 25 mm. Eggs are laid in masses resembling overlapping scales on the underside of leaves. Young larvae feed in clusters. Older larvae produce a silken web under which they feed. Fully grown larvae are about 20 mm long, green or green with light brown backs, and they have black spots and light longitudinal markings.

Cabbage cluster caterpillar larva

Cabbage cluster caterpillar damage to cabbage

Cabbage cluster caterpillar hatching egg raft

Potato moth

Phthorimaea operculella

Larvae are leaf miners and fruit borers in tomato, potato, eggplant and capsicum. They mine the leaf causing irregular windowing. They may also tunnel into the leaf stalk and stem causing extensive damage. Larvae enter the fruit under the calyx or where two fruit touch. They also tunnel into growing or stored potato tubers.

The adults are small, greyish moths with a wingspan of 12 mm. They lay very small, white eggs singly on the fruit calyx, on the underside of leaves or in the soil. The eggs are very difficult to find in the field. Larvae grow to 10–12 mm long and are cream, pale green or pale pink in colour with a dark head.

Potato moth

Potato moth leaf mining damage to potato leaf

Cabbage centre grub

Hellula hydralis

Larvae are stem borers in brassica crops. Young larvae burrow into the growing point of the plant. This tunnelling causes the death of seedlings or multiple branching, making the heads unmarketable. In older plants, larvae tunnel into leaf midribs.

The moth lays small, oval, pale yellow eggs on the young parts of brassica plants. These eggs are almost impossible to find in the field. The larvae are pale yellow with a dark head and seven brown stripes along the body.

Cabbage centre grub larva

Cabbage centre grub damage to cabbage seedling

Bean podborer

Maruca vitrata

Larvae bore into flower buds and pods of beans and other legumes. Pods and flowers are often webbed together to form shelters for the feeding caterpillars.

Moths have smoky brown forewings with translucent spots and translucent hind wings with large smoky brown spots on the tips, and a wing span of 25 mm. Moths lay oval, creamy yellow eggs near flower buds. The mature larvae grow up to 20 mm long, are yellowish-green with several rows of dark spots along the body and a dark head.

Bean pod borer moth
(photograph courtesy of J Wessels, DEEDI)

Bean pod borer larva
(photograph courtesy of DA Ironside, DEEDI)

Eggfruit caterpillar

Sceliodes cordalis

Larvae tunnel in eggplant fruit, occasionally in tomatoes and capsicums, and in some solanaceous weeds. Their feeding causes extensive internal damage—tunnels are filled with frass and they leave a large (4–5 mm) exit hole when they emerge to pupate.

The moths are mottled yellowish-brown, with a 25 mm wingspan. They sit distinctively with the abdomen curled upwards. Small, flattened eggs are laid singly, mainly on the calyx. They are initially whitish but develop red markings. Newly emerged larvae tunnel into the fruit and spend their entire life in the fruit. Young larvae are creamy white, while mature larvae are pink with a brown head. Mature larvae emerge from the fruit and pupate in a tough, whitish silken cocoon.

Eggfruit caterpillar moth

Eggfruit caterpillar larvae placed on fruit surface (note the exit holes)

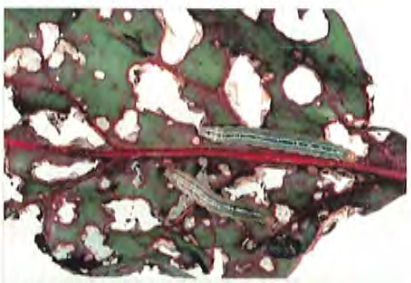
Beet webworm

Spoladea recurvalis

The larvae feed on the leaves of beetroot and silverbeet, and on weeds such as pigweed. They feed on the underside of the leaves, leaving the top surface, which results in a window-like effect. Eventually the leaves are destroyed, with the remains twisted and held together by silken webbing and frass.

The moths are brown with two white bands on the forewings and one on the hind wings, with a wingspan of 20 mm. Bluish, scalelike eggs are laid in small groups on the lower leaf surface. Initially the larvae are whitish, but then become grey-green in colour with a dark band along the middle of the back. Mature larvae are about 20 mm long. They pupate in the soil.

Beet webworm moth
(photograph courtesy of J Wessels, DEEDI)



Beet webworm larvae on a damaged leaf
(photograph courtesy of DA Ironside, DEEDI)

Cucumber moth

Diaphania indica

Larvae feed on many types of cucurbits. They normally feed on leaves, which they can destroy, leaving fragments bound together by silk and frass. They will also feed on flowers, soft stems and shallowly on the skin of fruit.

The moths have white wings bordered by a broad dark band, with a wingspan of about 25 mm. Small, whitish eggs are laid on the undersurface of leaves. The larvae, which grow to about 25 mm long, are green with two white stripes along the length of the body.

Cucumber moth

Larva of cucumber moth

Armyworms

***Mythimna* spp. and *Spodoptera* spp.**

Larvae of several species from several genera damage sweet corn by feeding on the leaves, resulting in the plants having a tattered appearance.

The moths are quite large, with wingspans of about 40 mm. *Mythimna* moths are pale grey-brown in colour. *Spodoptera* moths have darker grey-brown forewings with dark and pale markings, and pale white hind wings. Larvae can grow to 40–45 mm long and may be pinkish, brown or green in colour with white, pinkish and dark stripes running along the body. Mature lawn armyworm larvae have rows of triangular black markings. Armyworm larvae superficially resemble heliothis larvae but look smoother and are relatively hairless in comparison.

Common armyworm moth
(photograph courtesy of J Wessels, DEEDI)

Common armyworm larva
(photograph courtesy of J Wessels, DEEDI)

Dayfeeding armyworm larvae damaging corn
(photograph courtesy of DA Ironside, DEEDI)

Chevron cutworm

Diarsia intermixta

A pest in Tasmania, chevron cutworms chew on the foliage of a variety of brassica vegetables and on tubers of turnips and swedes. They also feed on the leaves of vegetables such as carrots, lettuce, rhubarb and potatoes and occasionally on corn silks.

Moths have a wingspan of about 37 mm and at rest their wings overlap flat on the body. Males are beige or dull orange in colour and females are dull purple. Larvae grow to 30 mm. They are dark brown to black on top and paler underneath, with a series of paired black, short V-shaped marks along the back and a pale mark across the rear end.

Chevron cutworm moths
(photograph courtesy of the Department of Primary Industries, Parks, Water and Environment, Tasmania)

Larva of chevron cutworm
(photograph courtesy of the Department of Primary Industries, Parks, Water and Environment, Tasmania)

Green cutworm

***Neumichtis* spp.**

Minor pests in Tasmania, larvae of the three species feed on leaves of brassica crops and other vegetables such as lettuce, celery and carrots.

Moths are brown (two species) or black (one species) with 34–38 mm wingspans. At rest, the wings are held steeply inclined. Larvae grow to 35 mm. They are green or brown in colour, with pairs of faint, pale, almost inconspicuous spots along the back and a pair of small but very distinct white spots on top of the rear end.

Larva of the green cutworm
(photograph courtesy of the Department of Primary Industries, Parks, Water and Environment, Tasmania)

Bugs, leafhoppers, aphids, whiteflies, mealybugs and scale insects (Hemiptera)

Green vegetable bug

Nezara viridula

Adults and nymphs feed by sucking sap from young plant tissue, fruit and seeds. A wide range of vegetable crops are attacked. Feeding causes distorted growth, death of seeds and dry and corky fruit tissue. Attacked fruit are small, mottled and blemished.

Adults lay dark, barrel-shaped eggs in groups known as rafts. The emerging nymphs are bright orange to orange-brown and wingless. As nymphs mature they are first marked with patterns of black, yellow and red, then they turn green and develop wings. Adults are up to 15 mm long and shield-shaped. They are green with three small white spots between their shoulders in warm weather, and are brownish-grey in cooler weather.

Green vegetable bug adults and nymphs on damaged beans
(photograph courtesy of DA Ironside, DEEDI)

First instar green vegetable bug nymphs hatching from egg raft
(photograph courtesy of J Wessels, DEEDI)

Rutherglen bug

Nysius vinitor

Adults and nymphs suck sap from leaves, stalks and fruit of a wide range of crops. They often attack in large swarms. If the infestation is severe, leaves and shoots will wilt and die. They can be a problem as a contaminant in harvested products such as lettuce.

Adults are 5 mm long and grey-brown in colour. The nymphs are pear-shaped, wingless and reddish-brown.

Rutherglen bug adults and nymphs

Vegetable leafhopper (or vegetable jassid)

Austroasca viridigrisea

Adults and nymphs feed by sucking the sap from young shoots, fruit and leaves, often leaving small white spots. Leafhoppers are pests of a wide range of vegetables, including tomatoes, capsicums and potatoes. Large populations may retard crop growth. Adults are up to 4 mm long and torpedo-shaped. Both adults and nymphs are bright green.

Vegetable leafhoppers and typical damage
(photograph courtesy of DA Ironside, DEEDI)

Greenhouse whitefly

Trialeurodes vaporariorum

Adults and nymphs are pests of many vegetable crops. They are found on the underside of leaves, sucking sap and so reducing plant vigour. They produce copious amounts of honeydew that can contaminate produce and encourage the growth of black sooty mould.

Adult greenhouse whiteflies are small (1.5 mm), delicate insects covered in a whitish waxy powder. The wings are held quite flat and overlapping (the way the wings are held is an important feature distinguishing greenhouse whiteflies from silverleaf whiteflies). Eggs are bullet-shaped, initially yellow but later dark. The nymphs are scalelike, pale yellow-green and grow to about 0.5 mm long. The final instar nymph (or pupa) has a flat top with numerous waxy tendrils around its circumference, and steep cliff-like sides.

Greenhouse whitefly adult
(photograph courtesy of M Steiner)

Greenhouse whitefly pupae
(photograph courtesy of M Steiner)

Silverleaf (B biotype) and Q biotype whiteflies

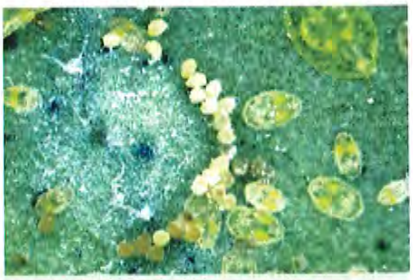
Bemisia tabaci

Several biotypes of *Bemisia tabaci* occur in Australia, with silverleaf whitefly (biotype B) and Q biotype being serious pests with a wide host range of broadleaf crops and weeds. The different biotypes are morphologically indistinguishable and can only be separated by biochemical or molecular techniques. They live on the underside of leaves and cause damage by sucking sap (affecting plant vigour), producing honeydew, sooty mould growth on honeydew and transmitting plant viruses. Silverleaf whiteflies cause physiological reactions in some plants.

Adult silverleaf and Q biotype whiteflies are small (about 1 mm), white, waxy insects. They hold their wings quite steeply like a tent, with a clear gap between the wings along the length of the body. Eggs are bullet-shaped and pale yellow to dark in colour. Nymphs are scalelike, pale green-yellow to clear and 0.3–0.6 mm long. The final instar nymphs (or pupae) are dome-shaped, with sloping edges and very few waxy projections.

Silverleaf whitefly adult
(photograph courtesy of B Scholz, DEEDI)

Silverleaf whitefly eggs
(photograph courtesy of S Subramaniam, DEEDI)



Silverleaf whitefly eggs and nymphs
(photograph courtesy of S Subramaniam, DEEDI)

Silvering of zucchini leaves due to silverleaf whitefly
(photograph courtesy of I Kay, DEEDI)

Potato bug

Closterotomus norvegicus

This mirid bug feeds on the buds, growing points, flowers and foliage of many plants, resulting in wilting, deformation and stunting. Its hosts include peas, beans, carrots, potatoes, asparagus and strawberries.

Adults are 6–8 mm long, with long legs and antennae. They are mainly green, although the folded forewings may be yellowish to grey-green. There is a pair of black spots on the top of the thorax. The membrane section of the folded forewings appears as a clear to dusky diamond shape at the rear of the insect. The nymphs are mainly green to yellowish-green with black hairs.

Potato bug adult
(photograph courtesy of the Department of Primary Industries, Parks, Water and Environment, Tasmania)

Green peach aphid

Myzus persicae

This aphid feeds on a wide range of vegetable crops, stone fruit and weeds by sucking the sap of leaves, growing points and fruit, and produces honeydew that contaminates the plants. Severe aphid attacks may result in leaves and fruit turning yellow, shrivelling and falling off. Adults are 1.5–3 mm long. Wingless adults can be green to pale yellow to pink. Winged adults have a dark head and thorax and a reddish or green abdomen with a distinctive dark patch. Nymphs are olive green. The green peach aphid is distinguished from other aphids by having a deep notch at the front of the head.

The adults and nymphs of many aphids can transmit viruses such as watermelon mosaic, papaya ringspot type W and zucchini yellow mosaic when they feed. The green peach aphid can transmit potato leaf roll virus, as can the potato aphid. Winged aphid adults are known as alatae and wingless adults as apterae.

Potato leaf infested with green peach aphids

Green peach aphids on a capsicum leaf

Cotton aphid (or melon aphid)

Aphis gossypii

Cotton aphids (also called melon aphids) have a very wide host range. They suck sap (affecting plant vigour), produce honeydew that contaminates fruit (particularly when sooty mould grows on it) and transmit many plant viruses. Winged adults (1.1–1.8 mm) are blackish-green in colour. Wingless adults (0.9–1.8 mm) are variable in colour, with large ones dark green and smaller ones pale yellow. Most are mottled light to dark green with short dark siphunculi (tubular structures at the end of the abdomen).

Currant lettuce aphid

Nasonovia ribis-nigri

Currant lettuce aphid is primarily a contamination pest of lettuce. They infest lettuce hearts and rosettes (their presence makes the lettuce unsaleable) and transmit several plant viruses. Winged adults have a black thorax and a greenish abdomen patterned with irregular, narrow dark bands. Wingless adults (1.3–2.7 mm) are pale yellow to green with a pattern of dark bands on the abdomen and dark-tipped siphunculi. Nymphs are yellow-green.

Currant lettuce aphids
(photograph courtesy of S McDougall)

Cabbage aphid

Brevicoryne brassicae

Adults and nymphs feed on crucifers by piercing softer tissue and sucking the sap. Under heavy infestation, plant growth may be suppressed and leaf curling may occur. Adults are 2–3 mm long, greyish-green in colour and have a mealy covering. Nymphs are greenish.

Many cruciferous plants also are hosts of turnip aphids (*Lipaphis pseudobrassicae*, also known as *L. erysimi*), which may be found on the undersurface of leaves or in flowers. Leaf curling may occur and they also transmit viruses. Turnip aphids are medium size and yellow-green, grey-green or olive green in colour with a white waxy bloom.

Carrot aphid

Cavariella aegopodii

The aphids feed on the underside of carrot leaves, causing the leaves to curl and plant vigour to be affected. They produce copious honeydew and transmit several viruses. Winged and wingless forms vary in colour from green to yellow to brown, and the winged adults have a black patch on the upper (dorsal) surface of the abdomen. Wingless adults are medium size, elongate oval and flattened with small depressions on the upper surface.

The fennel aphid (*Dysaphis foeniculus*) also attacks carrots. Colonies of grey-green wingless aphids usually occur at or below ground level. Winged adults have a dark green abdomen with a large black patch on the upper (dorsal) surface.

Sowthistle aphid

Hyperomyzus lactucae

Sowthistle aphid breeds on the sowthistle weed and spreads necrotic yellows virus to crops such as lettuce. Winged and wingless adults are 2–3 mm long. Adults and nymphs are light green in colour.

Corn aphid

Rhopalosiphum maidis

Corn aphid is a pest of sweet corn and other grasses. The aphids suck sap from the leaves and can reduce plant vigour. Contamination from honeydew, sooty mould and the aphids themselves on cobs is a problem. Corn aphids are yellow-green to dark olive green, with short antennae and short, dark siphunculi.

Note: In many cases, laboratory microscopic techniques are necessary to properly identify aphids.

Corn aphids—note the dark siphunculi and cast skins
(photograph courtesy of DA Ironside, DEEDI)

Solenopsis mealybug

Phenacoccus solenopsis

Female adults are wingless, around 4 mm long, oval-shaped and covered by waxy filaments, giving them a mealy appearance. Females often have two dark stripes on the upper (dorsal) surface of the abdomen. Nymphs or 'crawlers' are smaller but similar in appearance. This sap-sucking insect forms dense, white, cotton-like, waxy colonies on stems, shoots and leaves of plants. Males (which do not feed) are small, aphid-like, winged insects.

The pest is known to affect a range of plants, including cotton, tomatoes, eggplants, chillies, melons and potatoes. Their feeding can reduce plant vigour and cause contamination from honeydew and sooty mould.

Solenopsis mealybugs
(photograph courtesy of S Subramaniam, DEEDI)

Thrips (Thysanoptera)

Note: Specialised training and laboratory microscopic techniques are necessary to properly identify thrips species.

Onion thrips

Thrips tabaci

Adults and larvae feed on many vegetable crops and other plants. On onions they rasp the leaf surface and suck the sap, leaving a white, flecked or silvery white leaf. Bulb size may be affected if the thrips population is large (more than 50 thrips per plant). Adults are 1–1.2 mm long and yellowish-grey to brownish in colour, with grey simple eyes (ocelli) in fresh specimens. Only females are found in Australia. Immature thrips (larvae) are white to pale yellow. Onion thrips are vectors of tomato spotted wilt virus and iris yellow spot virus.

Plague thrips

Thrips imaginis

Adult plague thrips feed by rasping the surface cells and sucking the sap from the blossoms of weeds, fruit trees, vegetables and ornamental garden plants. Immature thrips feed on young leaves and the pistil and stamens inside the flowers. This can interfere with fruit set and damage young fruit. Adults are light brown to grey and 0.8–1.3 mm long. Immature plague thrips are creamy yellow.

Melon thrips

Thrips palmi

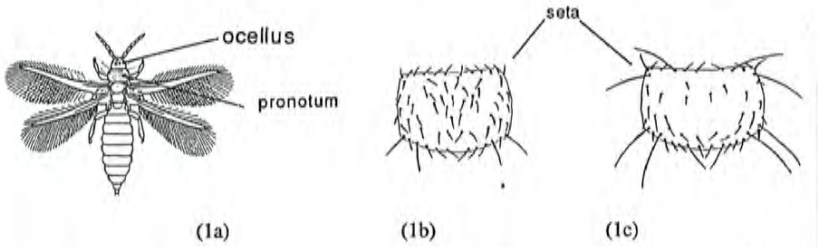
Melon thrips feed on many weeds and vegetables, and are important pests of cucurbits, eggplant, capsicums and beans, damaging leaves and fruit with their feeding. They transmit tomato spotted wilt virus and capsicum chlorosis virus. Adults are about 1 mm long and yellow with red simple eyes. Both females and males occur in Australia. Immature melon thrips are white to pale yellow.

Melon thrips

Western flower thrips

Frankliniella occidentalis

Western flower thrips have a very large host range that includes many vegetables. They are usually found in flowers. They cause damage with their feeding and they are very effective vectors of tomato spotted wilt virus. Adult western flower thrips are 1–2 mm long and yellow to pale brown in colour. Larvae are white to yellow. Species of *Frankliniella* (western flower thrips, tomato thrips and corn thrips) can be distinguished from other pest thrips by the presence of pairs of strong hairs (setae) on the anterior (front) corners of the pronotum (first part of the thorax), which are not present in other genera. Separating the three species of *Frankliniella* requires more detailed microscopic examination.



(1a) Overview of thrips (1b) onion thrips (*Thrips tabaci*) (1c) WFT or tomato thrips (*Frankliniella* spp)

The differences between thrips in the genus *Frankliniella* and *Thrips*
(diagram reproduced from *Western flower thrips* by M Hill)

Western flower thrips

Tomato thrips

Frankliniella schultzei

Tomato thrips have a wide range of hosts, including many vegetables. They usually live in flowers. They cause damage with their feeding and can transmit tomato spotted wilt and capsicum chlorosis viruses. Tomato thrips adults are yellow to brown and 1–1.8 mm long. Larvae are white to yellow.

Bean blossom thrips

Megalurothrips usitatus

Adults and larvae feed by rasping and sucking in bean flowers when the pod is formed. This feeding causes the pods to twist and curl and become unmarketable. Adult thrips feeding on maturing pods may cause russeting. Adults are dark brown and about 1.5 mm long. Immature thrips are pale yellow and emerge from eggs laid in plant tissue. Older larvae are deep yellow or orange-red.

Bean blossom thrips in a flower
(photograph courtesy of DA Ironside, DEEDI)

Young French beans damaged by bean blossom thrips

Beetles (Coleoptera)

Pumpkin beetle and plain pumpkin beetle

***Aulacophora* spp.**

Adults may be present as individuals or in swarms or clusters, and are the main damaging stage. They feed by chewing on leaves, flowers and small fruit in cucurbit crops. Seedlings can be completely defoliated. Larvae feed on roots causing swelling and discolouring. This can check the growth of the plant. Fruit lying on the ground can also be attacked by larvae.

Pumpkin beetle adults are orange-yellow with four black patches across the wings. Plain pumpkin beetle adults are orange-yellow with no markings. Adults are 6 mm long. Larvae grow up to 12 mm long and are cream in colour.

Pumpkin beetles and plain pumpkin beetles on a damaged rockmelon leaf

Twentyeight-spotted potato ladybird, twentysix-spotted potato ladybird and cucurbit ladybird

Henosepilachna vigintisexpunctata, H. vigintioctopunctata* and *H. cucurbitae

Adults and larvae feed by chewing on a range of vegetable crops, including potatoes, eggplant, beans and cucurbits. They feed mostly on leaves, but can damage flowers and developing fruit. Adults feed on the upper surface of the leaves and larvae mostly feed on the underside of leaves. This results in a fine, transparent window remaining between the network of veins. Adults are 6–10 mm long, oval and yellowish-brown with many black spots on the wing covers and thorax. Larvae are creamy yellow and covered in many black, branched spines. Smooth, bullet-shaped, yellow eggs are laid in clusters on the underside of leaves and on plant stems. They turn orange/yellow as they mature.

The original describers of these beetles miscounted the spots. The twentyeight-spotted potato ladybird has 28 spots but its Latin species name means 26, while the twentysix-spotted potato ladybird's Latin name means 28!

Twentyeight-spotted potato ladybird adults, larva and eggs

False wireworms

Tenebrionidae—northern false wireworm (*Gonocephalum carpentariae*), southern false wireworm (*G. macleayi*) and vegetable beetle (*G. elderi*)

False wireworm larvae live in the soil and feed on organic matter, including germinating seeds and young seedlings. Adults and larvae chew the stems of young seedlings. Adults may also feed on the leaves, resulting in retarded plant growth or the death of the seedlings.

False wireworm larvae grow up to 30 mm long and are slender, hard-skinned, cylindrical and segmented, with a rounded head and three pairs of legs just behind the head. They are shiny cream to yellow to tan in colour with a darker head. Adults are found on the soil surface or under surface organic matter or soil clods. They are oval-shaped beetles, about 10 mm long, with flanges around the outline of the thorax. They are dark grey to black in colour, often with a dusting of soil.

False wireworm beetle and larva
(photograph courtesy of DA Ironside, DEEDI)

True wireworms

Elateridae—important wireworms include species of *Agrypnus* and *Conoderus*, and the potato wireworm (*Hapatesus hirtus*)

A number of species of wireworms are pests of vegetables. Larvae live in the soil where they normally feed on organic matter. They will damage seeds, roots and tunnel into stems. They are particularly damaging to crops like carrots, sweetpotatoes and potatoes, where they bore deeply into the roots and tubers.

Wireworm larvae grow to 35–40 mm long. They are cream, yellow, orange-yellow to tan in colour with a darker head, and with three pairs of legs behind the head. The body is segmented and distinctly flattened, the head is wedge-shaped and there is a flat plate with two short prongs at the rear end. Adults are the well-known click beetles—elongate grey to brown beetles with the ability to flip their bodies upright with an audible click.

Wireworm adult or click beetle
(photograph courtesy of J Wessels, DEEDI)

Wireworm larva
(photograph courtesy of J Wessels, DEEDI)

Cucurbit stemborer

Apomecyna histrio

Larvae are stem borers in cucurbits. This feeding causes the stem and leaf nodes to swell as they are filled with the excreta of the stem borer. They are minor pests of chokos, cucumbers, marrows, melons, squash and zucchini. Adults are 10 mm long and grey with white spots that make three conspicuous V-shaped marks across the wing covers. Larvae grow up to 20 mm long and are cream in colour.

African black beetle

Heteronychus arator

African black beetles are members of the scarab family of beetles. Adults damage many different vegetables (particularly seedlings) by chewing on the stems at or just below ground level, causing the plants to wilt, lodge or die. The larvae, which live in the soil, damage potatoes by burrowing into the tubers.

Adults are shiny black beetles, 10–15 mm long, with their front legs modified for digging. They live in or on the soil and can fly. Larvae are typical scarab larvae, commonly called white grubs or curl grubs. They are C-shaped, with a distinct brown head capsule and legs, and usually a swollen end of the abdomen. They are white to bluish-white and grow to about 25 mm long. Similar looking larvae of many other scarab beetles are occasional pests of tuber and root vegetables such as potatoes and sweetpotatoes.

African black beetle adult
(photograph courtesy of L Benson

African black beetle larva
(photograph courtesy of L Benson

Whitefringed weevil

Naupactus leucoloma

Whitefringed weevil larvae live in the soil and feed on the roots of plants, including vegetables such as carrots, cabbages, beans and cucurbits and on potato tubers. If vegetables are grown in a weevil-risk location, knowing whether a pest population of larvae is present before planting is important in taking appropriate preventative action to protect the crop. Adults feed on the foliage of a wide range of plants, occasionally stripping leaves.

Adults are grey beetles about 12 mm long with a short broad snout and a distinctive white band along the sides of the body. The wing covers are fused so the beetles cannot fly. The larvae are legless, white to grey in colour with brown mouthparts on the head. They appear wrinkled, have a slightly curved body and grow to about 12 mm long.

Whitefringed weevil adult

Whitefringed weevil larvae

Vegetable weevil

Listroderes difficilis

Vegetable weevils damage a wide range of vegetables, including crucifers, carrots, parsnips, lettuce, silverbeet, spinach and potatoes. Adults feed on the foliage, which can be left holed or completely destroyed, and they will chew gouges in carrots. Larvae can damage the centres and growing points of plants and will chew ragged holes in leaves. Both adults and larvae feed at night and hide in the soil during the day.

Adult vegetable weevils are a dull grey-brown colour with a V-shaped pale grey marking near the end of the wing covers. They are box-shaped with a prominent snout and 9–12 mm long. Larvae are cream or greenish-yellow to green in colour with a flattened, legless, slug-like body; a small, dark brown head; and a brown plate on the top of the thorax behind the head. They grow to 12–15 mm.

Vegetable weevil adult
(photograph courtesy of L Benson

Vegetable weevil larva
(photograph courtesy of the Department of Agriculture and Food, Western Australia)

Apple weevil

Otiorhynchus cribricollis

Apple weevils attack vegetables (including crucifers), as well as ornamentals, fruit trees and grape vines. Adults feed on leaves and can strip plants, growing tips and stems of seedlings. Adults are shiny dark brown weevils about 9 mm long, with a slightly bulbous abdomen. They feed at night, hiding in the soil by day.

Apple weevil adult on a leaf
(photograph courtesy of the Department of Agriculture and Food, Western Australia)

Spotted vegetable weevil

Desiantha diversipes

Adults feed on the leaves and stems of young vegetables, including crucifers and on other plants such as strawberries. The soil-dwelling larvae feed on seedling roots. Adults are mottled grey-black beetles about 6 mm long, with the typical weevil snout and are active day and night. Larvae are legless and white with an orange-brown head.

Spotted vegetable weevil adult
(photograph courtesy of the Department of Agriculture and Food, Western Australia)

Spotted vegetable weevil larva
(photograph courtesy of S Eyres
© Western Australian Agriculture Authority, 2004)

Small lucerne weevil

Atrichonotus taeniatulus

Adults damage the leaves and stems of vegetable seedlings as well as feeding on many other plants. The soil-dwelling larvae will damage roots. Adults are grey weevils with some brownish mottling, similar in shape to whitefringed weevil but smaller (8–10 mm). Larvae are creamy white with small, pointed, brown jaws. They are legless and grow to 8 mm long.

Small lucerne weevil
(photograph courtesy of the Department of Agriculture and Food, Western Australia)

Sweetpotato weevil

Cylas formicarius

Sweetpotato weevil larvae tunnel in the stems and storage roots of sweetpotatoes, making the roots unusable. Adults feed on stems and leaves and excavate small cavities in which to lay eggs.

Adults are antlike, shiny beetles 5–6 mm long, with a narrow head and pronotum, long legs and a slightly distended body. The head, wing covers and abdomen are blue-black and the pronotum and legs are red.

Sweetpotato weevil adult on a damaged sweetpotato stem
(photograph courtesy of J Lovatt, DEEDI)

Sweetpotato weevil larvae in a damaged root

Flea beetles

Chrysomelidae

Adults of a number of species of flea beetles damage vegetables by chewing small, irregularly shaped holes in the leaves, resulting in a shot-hole appearance. Seedlings can be severely affected. Flea beetles are usually small (2–4 mm long), stout beetles, often a dark metallic colour. They are characterised by having enlarged femora (thighs) on their hind legs that enable them to hop or jump rather like a flea. Larvae live below ground and feed either internally or externally on plants, but rarely cause significant damage. Specific examples include the potato flea beetle (*Psylliodes* spp.) and the striped or brassica flea beetle (*Phyllotreta undulata*), which is 2.5 mm long and black with a longitudinal yellow stripe on each wing cover.

Potato flea beetle adult
(photograph courtesy of J Duff, DEEDI)

Striped flea beetle adult
(photograph courtesy of T Dennien)

Dried fruit beetles

***Carpophilus* spp.**

Adult dried fruit beetles are small (3–4 mm), flattish beetles with clubbed antennae and short wing covers that do not reach the tip of the abdomen. They are black or brown, usually with pale patches on the wing covers. Larvae are cream coloured with a pale brown head, short legs, a slightly hairy appearance and a forked tip to the abdomen. Adult beetles are attracted by rotting fruit and vegetables. Dried fruit beetles do not cause primary damage but they can cause secondary damage and introduce rot organisms. They can be a problem in sweet corn cobs as a contaminant.

Adult dried fruit beetle

Earwigs (Dermaptera)

Black field earwig

Nala lividipes

Adults and nymphs feed mainly on decaying organic matter but may chew young seedlings of many vegetables as they emerge. They also feed on the roots of some crops. Adults are small, shiny black and up to 12 mm long. They have short wings and a pair of pincers at the end of the abdomen. Nymphs are pale but become darker as they mature.

Black field earwig adult (top) and nymphs

European earwig

Forficula auricularia

European earwigs feed on organic matter and a wide range of plants. They chew on the leaves of plants, seedling roots and on fruit and vegetables, and their faeces can contaminate harvested produce. Damage can be serious when populations are large.

Adults are 12–22 mm long with slender, flattish bodies. They have smooth, shiny, dark brown bodies with pale yellow legs, shoulders and pincers. Females have straight pincers and the males have curved pincers with a distinguishing straight section at the base of the pincers. Adults have wings. Nymphs are similar to but smaller and paler than adults.

European earwig adults
(photograph courtesy of M Widmer
© Western Australian Agriculture Authority, 2002)

Grasshoppers and crickets (Orthoptera)

Australian plague locust

Chortoicetes terminifera

Australian plague locusts are active from spring to autumn, spending winter as eggs in the ground. They can occur as solitary individuals, but when conditions are suitable they form gregarious bands and swarms typical of locusts. Their feeding can cause serious damage to vegetables, crops and pastures.

Adult Australian plague locusts are 25–42 mm long. The usual body colour is brown, but grey and green specimens occur. They often have a pale stripe down the back. The forewings are narrow, mottled with darker patches and are semi-transparent. The hind wings are transparent and colourless except for a large smoky black spot at the tip of each wing. The shanks (tibia) of the hind legs are bright red. The hind wings and the red shanks are the characters that distinguish Australian plague locusts from other locusts and grasshoppers. Nymphs resemble adults but with no wings and dark shanks, and grow to about 25 mm. They are brown to grey, sometimes with a white stripe along the back. Wing buds develop in later instars. The nymphs have a white X-shaped marking on top of the thorax, which distinguishes them from the wingless grasshopper.

Australian plague locust
(photograph courtesy of DA Ironside, DEEDI)

Wingless grasshopper

Phaulacridium vittatum

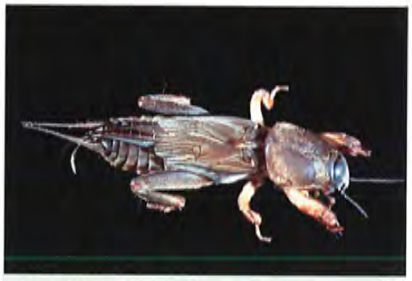
Adult males are smaller than adult females, which are about 20 mm long. Their colour and pattern are variable but generally brown. The hind femur (thigh) has a black mark at the mid point and the tibia is orange. There may be two white stripes running the length of the body. Wings are reduced to small scales, although at high densities adults may develop wings. Nymphal stages are known as hoppers and resemble adults, but are smaller in size. Adults and hoppers chew the leaves of grasses, weeds and a range of vegetable and fruit crops.

Wingless grasshopper adults

Mole cricket

Gryllotalpa spp.

Mole crickets burrow in the soil and chew on the roots or tubers of potatoes, pasture grasses and other crops. They also feed on seedlings. Adults are 40 mm long and brown in colour. Their forelegs are broad and flat to assist in digging. Nymphs resemble adults but are smaller.



Mole cricket

Mole cricket damage to a potato

Black field cricket

Teleogryllus commodus

The adults and nymphs feed on vegetables, pastures and field crops causing seed, seedling and root damage. Some crops fail to emerge because of damage to germinating seed. Adults are 25–30 mm long and black in colour. Adult males have rough wings that produce a song when rubbed together.

Adult black field cricket

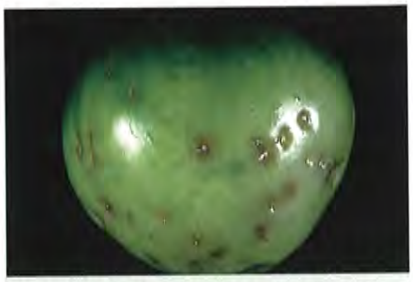
Flies (Diptera)

Queensland fruit fly

Bactrocera tryoni

Fruit fly larvae are borers. The maggots feed on most cultivated fruit, including tomato and capsicum. Adult females lay small batches of eggs beneath the surface of the fruit. The larvae hatch as the fruit ripens, then tunnel into the flesh. Rot soon develops and skin discoloration occurs around the sting mark. The adult is 8 mm long and is wasplike in appearance. It has a reddish-brown body, yellow patches on the shoulders, two yellow stripes on the upper surface of the thorax and a triangular yellow section at the rear of the thorax. Larvae (maggots) are white, grow to 7 mm long when mature and can spring by curling and then releasing back into the straight shape. Eggs are laid into fruit and are white and sickle-shaped.

Queensland fruit fly (left) and cucumber fly (right)



Green tomato showing stinging by Queensland fruit fly

Fruit fly eggs laid beneath the skin surface

Fruit fly larvae in a tomato

Cucumber fly

Bactrocera cucumis

Cucurbits are the main hosts of cucumber fly, but papaws and tomatoes also are hosts. The adult fly is wasplike and about 8 mm long. It has an orange-brown thorax with three yellow stripes on the upper surface (which distinguishes it from Queensland fruit fly) and a reddish-brown abdomen. The larvae are carrot-shaped, creamy white maggots that tunnel in the flesh of the fruit. They can spring by curling and then releasing back to the straight shape.

Mediterranean fruit fly (or medfly)

Ceratitis capitata

Hosts include many fruit and solanaceous vegetables. The adult fly is 3–5 mm long. Its thorax is mottled with black and yellowish-white markings, and its abdomen is yellow-brown with two pale cross bands. The wings have characteristic yellowish-brown bands and spots. Larvae are white maggots, growing to 8 mm long, that tunnel inside the fruit.

Mediterranean fruit fly
(photograph courtesy of E Laidlaw

Bean fly

Ophiomyia phaseoli

Bean fly larvae are leaf miners and stem borers of beans and some other legumes, first mining the leaves and then tunnelling into the lower stem where they pupate. Infested young bean plants will wilt and die. In mature plants, larval tunnelling will cause leaf stalks and stems to swell and crack. The plant is then susceptible to breaking in the wind at ground level. Surviving plants will have reduced yields. White puncture marks on bean leaves are symptoms of a bean fly infestation. Adult flies are 2–3 mm long and glossy black. Maggots are whitish and the pupae are brown and about 2.5 mm long. Both can be found inside damaged stems.

Adult bean fly on leaf showing oviposition sites
(photograph courtesy of J Wessels, DEEDI)

Bean stalk damaged by bean fly—note the larvae
(photograph courtesy of J Wessels, DEEDI)

Beet leafminer and cabbage leafminer

Liriomyza chenopodii and *L. brassicae*

Adult leafminers are small flies (1–2.5 mm long), grey to black in colour with a yellow head and yellow markings on the body. Beet leafminer larvae, which are small, tunnel in the stalks and veins of leaves of beetroot, silver beet, spinach and some weeds. They make thin mines that enlarge to distinct tunnels as the larvae grow. The white to yellowish larvae pupate to form brown pupae about 2 mm long. Cabbage leafminer larvae tunnel in the upper surface of leaves of cruciferous vegetables, forming narrow mines. They pupate outside the mines.

Several *Liriomyza* species that are serious pests of vegetables overseas are considered a threat to the Australian vegetable industry, were they to arrive here. They look very similar to the beet and cabbage leafminers, requiring a skilled taxonomist to identify them correctly.

Liriomyza leafminer adult
(photograph courtesy of M Malipatil)

Mines in a leaf caused by *Liriomyza* leafminer larvae
(photograph courtesy of E Jovicich, DEEDI)

Onion maggot (or seedling maggot)

Delia platura

Onion maggots usually feed on and damage seedlings of vegetables such as onions, beans, crucifers and cucurbits but will also damage cauliflower curds. The adults are small (3–5 mm), greyish-brown flies that look a little like small house flies. The larvae are yellowish-white maggots up to 6 mm long that bore into the stems of seedlings below ground. Pupae are brown, barrel-shaped and about 5 mm long.

Onion maggot adult
(photograph courtesy of the Department of Agriculture and Food, Western Australia)

Atherigona

Atherigona orientalis

Atherigona flies are usually associated with damaged fruit. The adult flies are grey-brown in colour, 3–4 mm long and look like small house flies. The eggs (which are laid on the surface of the fruit, often around the calyx or at damage sites) are creamy white and rectangular in shape with a sculptured surface. The larvae are whitish, grow to about 6 mm long, look similar to fruit fly larvae but have two raised, often darker coloured prominences at the rear end.

Vinegar fly

Drosphila spp.

Vinegar, ferment or rot flies are attracted to and feed on well-ripened fruit and decomposing organic matter. The adult females lay their eggs on fruit that is decaying or damaged. Maggots develop and feed in the fruit. Adults are 3 mm long and reddish-brown with bright, red eyes. Maggots are 4 mm long.

Ants (Hymenoptera, family Formicidae)

There many species of ants and their beneficial effects are often counteracted by their pest activities. Ants can be scavengers, predators or plant feeders. They may also feed on the sugary secretions of aphids, mealybugs and scale insects, and in return may protect the pests from parasites and predators. They are sometimes involved in spreading young pests from plant to plant. Seed-harvesting ants remove and carry off small seeds and the germ of large seeds. Ants live in colonies in which individuals have different functions. Foraging workers are the most commonly seen.

Mites (Acarina)

Two-spotted mite

Tetranychus urticae

Adults and nymphs feed by puncturing surface cells on leaves and soft stems on a wide range of plants. Individual mites are just visible to the naked eye, being about 0.5 mm long. Females are oval and pale green to yellow. They may change colour to orange or light red. Two dark spots can be seen on the female's body. Males are smaller and elongated. Eggs are small, clear and round. These mites are usually found on the underside of leaves surrounded by the webs that they spin. Feeding causes mottling and yellowing of leaves, and reduced production. The bean spider mite (*Tetranychus ludeni*) is uniformly red in colour and without spots. Immature stages are yellow-green and may show dark spots near the middle of the body.

Two-spotted mite adults and eggs
(photograph courtesy of J Wessels, DEEDI)

Eggplant leaf damaged by two-spotted mites
(photograph courtesy of S Heisswolf, DEEDI)

Tomato russet mite

Aculops lycopersici

Adults are very small and can only be seen with magnification using a hand lens or microscope. They are cream coloured and carrot-shaped. Typical feeding damage is russeting (reddening) of stems and loss of stem hairs. Damage to tomatoes can be very severe and they will also affect other solanaceous vegetables such as eggplant, potato and capsicum.

Tomato russet mites

Damaged tomato stems with undamaged stem (bottom)

Broad mite

Polyphagotarsonemus latus

Broad mites infest a wide range of vegetables and other plants. Usually found in young growth, they cause twisting and distortion of leaves similar to that caused by 2,4-D, and can cause scarring, discolouration and distortion of fruit (e.g. in capsicums).

Adults are shiny, translucent white to pale yellow, with oval bodies 0.2–0.25 mm long. Males are very active, and may be seen carrying females in a crosswise position. The eggs are very distinctive. They are about 0.1 mm long, oval-shaped, translucent, with a convex upper surface covered with five or six rows of white tubercules (knobs).

Broad mites and broad mite eggs

Redlegged earth mite and blue oat mite

***Halotydeus destructor* and *Penthaleus* spp.**

These mites (while primarily pests of pastures) are important pests of vegetables, including peas, beets, crucifers and lettuce. They feed on the upper surfaces of leaves by puncturing the plant cells and sucking the sap. Their feeding causes silvery or white blemishes on leaves, distorted leaves and wilting and death of seedlings. The mites are similar in appearance but have distinguishing characteristics, so can quite easily be separated.

Redlegged earth mites are about 1 mm long (i.e. pinhead size), with a velvety black, somewhat flattened body and eight pinkish-red legs. The immature stages look like the adults. They generally feed in largish groups and prefer broadleaf plants.

Blue oat mite adults are about 1 mm long with a purplish-blue rounded body, a distinguishing red spot near the rear end of the body and eight red legs. The immature stages are pink-orange, then brownish, then green. Blue oat mites usually feed separately or in small groups. They prefer grasses but will feed on broadleaf plants.

Blue oat mite
(photograph courtesy of DA Ironside, DEEDI)

Slugs and snails (Gastropoda)

Slugs and snails are gastropods, not insects, but they are mentioned here as the damage they cause to plants may be confused with insect damage.

Slugs and snails can range in size from 10 mm to 100 mm. They have a soft, unsegmented body and a prominent head with eyes and two tentacles. Many snails have a single, coiled shell into which they retreat. Slugs and snails move by gliding along mucus or slime produced by glands on their large muscular foot. They prefer moist environments.

Most pest species of slugs and snails are introduced species. They cause damage by feeding on seeds, underground tubers, seedlings and young plants, and can be a contaminant at harvest. Typical damage on seedlings and young plants is irregular pieces chewed from leaves or shredded leaf edges.

Common pest snails and slugs include the common garden snail (*Helix aspersa*), white Italian snail (*Theba pisana*), vineyard snail (*Cernuella virgata*), pointed snail (*Cochlicella* spp.), black keeled slug (*Milax gagates*), reticulated slug (*Deroceras reticulatum*) and brown slug (*Deroceras panormitanum*).

Black keeled slug (bottom) and reticulated slug (top)
(photograph courtesy of P Mangano

Common garden snail
(photograph courtesy of C Carson)

Important natural enemies in vegetable crops

This section describes common natural enemies found in Australian vegetable crops. They are listed according to order.

Predators and parasites

Predators hunt and capture their prey, killing it as they feed on it. Parasites invade the body of their host (endoparasites) or attach themselves to their host (ectoparasites), and feed on it while it is still living. They weaken the host but may not necessarily cause death. However, insect parasites (which feed on other insects) invariably kill their host and are known as parasitoids. Parasitoids have a free-living adult stage (i.e. the adults live independently of the host) and a parasitic immature stage.

Many parasitoids and predators are very susceptible to insecticides, while others have some degree of tolerance. Most parasitoids and predators are very important in the 'natural' control of pests. There are many that we don't know about, and many that may play only a minor role in some seasons.

Only a small selection of the many insect predators and parasitoids are mentioned here.

Parasitic wasps and predatory wasps (Hymenoptera)

Parasitic wasps

Parasitic wasps lay their eggs in a wide range of eggs, larvae and pupae of other insects and arachnids. The wasp larvae feed and develop inside the host, with some pupating inside and some outside the host. In vegetables, wasp parasites are important in controlling heliothis, potato moth, cabbage white butterfly, cabbage moth, whiteflies and aphids. The adult wasps feed on nectar and pollen from flowering plants. Some feed on the honeydew secretions of their target hosts.

Large wasps (more than 10 mm long)

Adults are often slender-bodied with long antennae, and are red or orange in colour with black or steely blue markings. Female wasps have a long ovipositor to penetrate the host insect when laying her eggs. Hosts include many moth, butterfly and beetle larvae. Some species included in this category are orange caterpillar parasite (*Netelia producta*), two-toned caterpillar parasite (*Heteropelma scaposum*), banded caterpillar parasite (*Ichneumon promissorius*) and yellow flower wasp (*Campsomeris tasmaniensis*). The female of the banded caterpillar parasite lays its eggs in moth pupae in the soil, while the yellow flower wasp parasitises scarab beetle larvae in the soil.

Orange caterpillar parasite parasitising heliothis larva
(photograph courtesy of DA Ironside, DEEDI)

Two-toned caterpillar parasite that has emerged from host pupa
(photograph courtesy of DA Ironside, DEEDI)

Small wasps (1–10 mm long)

A number of species of small wasps also parasitise a wide range of moth, butterfly and beetle larvae, as well as scale insects, aphids and mealybugs. The adults are slender-bodied and many of them are black. Examples are *Aphidius* spp. that parasitise aphids; *Orgilus lepidus*, *Apanteles subandinus* and *Copidosoma* spp. that parasitise potato moth; species of *Cotesia* that parasitise brassica pests; and *Diadegma* spp. and *Apanteles* spp. that parasitise diamondback moth. *Microplitis demolitor* and *Cotesia kazak* parasitise heliothis larvae.

Aphidius colemani with parasitised aphids or 'mummies'

Copidosoma sp. cocoons in parasitised potato moth larvae

Cotesia pupae on cabbage white butterfly larva

Diadegma sp.—a parasite of cabbage moth

Microplitis pupa attached to a parasitised heliothis larva
(photograph courtesy of J Wessels, DEEDI)

Tiny wasps (less than 1 mm long)

There are also many species of tiny wasps that parasitise insect pests. Native species of *Encarsia* and *Eretmocerus* parasitise whiteflies. The introduced *Eretmocerus hayati* parasitises silverleaf whitefly. The adult wasps are 0.8–1 mm long and yellow to yellow-brown in colour. The females lay their eggs under young whitefly nymphs, and the wasp larvae penetrate the nymphs and feed and develop within them. *Encarsia formosa* is an important parasite of greenhouse whitefly. The wasps have a dark head and thorax and yellowish abdomen.

Other tiny wasp parasites such as *Trichogramma* spp., *Trichogrammatoidea* spp. and *Telenomus* spp. are important egg parasites of moths and butterflies. They are known to parasitise eggs of heliothis and looper caterpillars, although most species have a preference for a single-host species. Up to five wasps may emerge from each host egg. The *Trichogramma* wasp adult (which is a minute, black wasp) lays up to three eggs into the eggs of insect pests like heliothis. Host eggs turn black as the *Trichogramma* larvae develop within. The adults are too small to be easily seen in the field and often the first sign of their presence is when parasitised eggs turn black.

The imported *Trissolcus basalis* (green vegetable bug egg parasite) is an important parasitoid of green vegetable bug eggs.

Eretmocerus wasp with silverleaf whitefly nymphs—note the wasp exit hole in empty pupal shell
(photograph courtesy of S Subramaniam, DEEDI)

Trichogramma sp. on a heliothis egg
(photograph courtesy of ME Badgley)

Telenomus sp. on a heliothis egg
(photograph courtesy of B Sholtz, DEEDI)

Trissolcus basalis and parasitised green vegetable bug eggs
(photograph courtesy of DA Ironside, DEEDI)

Predatory wasps

Many wasps are predators of insect and arachnid eggs, larvae, nymphs, pupae and adults. Some are both predators and parasites. Predatory wasps usually collect a large number of prey and can be very effective in controlling pests. They build nests of paper or mud (which may be single or multi-celled) into which spiders, caterpillars, flies, bugs and other soft-bodied insects are placed. The prey is usually stung and then stored in the nest in a partly paralysed state. Adult wasps are usually yellow to orange in colour with black or brown markings.

Some species create a nest by burrowing in the soil. Others nest in cavities in plants or protected places. Mud-dauber wasps, also known as slender mud nest builders (*Sceliphron* spp.), are predators of a range of insects and spiders. Prey are sealed in mud nests where they are devoured by developing larvae. Adults are black and yellow with a long, threadlike waist. They are a relatively large wasp, between 12 mm and 20 mm long. Mud nests are built on stones and walls.

Parasitic and predatory flies (Diptera)

Many flies are predators or parasites of a range of insect and arachnid eggs, larvae, nymphs, pupae and adults. Some are both predators and parasites.

Parasitic flies

Tachinidae

Tachinid fly larvae are internal parasites of a wide range of insect larvae and adults. Larvae of moths and butterflies are often targeted, and bugs are also parasitised. The eggs are generally laid on the surface of the host. When they hatch, the larvae enter the host through openings such as breathing pores. In some species the eggs are laid in protected places and the newly hatched larvae have to find the host. After hatching, the maggots bore into the host and feed on its tissue. Adults are small- to medium-sized flies, 4–10 mm long. They are thick-bodied, hairy and may be dull black, grey or metallic in colour. Many have an abdomen with a checkerboard appearance. Examples include *Carcelia* spp. and *Chaetophthalmus* spp. The green vegetable bug parasitic fly (*Trichopoda giacomellii*) parasitises green vegetable bugs. Adult flies feed on nectar or honeydew secretions from other insects.

Adult tachinid fly
(photograph courtesy of B Ingram, DEEDI)

Adult *Trichopoda* fly
(photograph courtesy of J Wessels, DEEDI)

Predatory flies

Hover flies

Syrphidae

There are many species of hover flies. The larvae are sluggish, legless maggots, often green in colour, which feed by puncturing their prey and consuming the fluid contents. They are important predators of aphids and other small, slow-moving insects, including moth and butterfly larvae. All stages of the prey, including eggs, are attacked. Adult hover flies are up to 12 mm long and resemble bees and wasps due to the black and yellow bands on the abdomen. They feed on nectar and pollen, and are often seen hovering around weeds.

Hover fly adult

Hover fly pupa (left) and larva (right)

Robber flies

Asilidae

Both adults and larvae prey on a wide range of insects. Adults 'pounce' on their prey from the air. The adults range in size from 10 mm to 25 mm in length. They are slender-bodied and hairy, and are mainly grey or black in colour, sometimes with red or yellow markings.

Predatory bugs (Hemiptera)

Spined predatory shield bug

Oechalia schellenbergii

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, lateral spike on each side of the thorax.

Adult spined predatory shield bug piercing a heliothis larva
(photograph courtesy of C Freebairn, DEEDI)

Spined predatory shield bug egg raft
(photograph courtesy of J Wessels, DEEDI)

Spined predatory shield bug nymph
(photograph courtesy of J Wessels, DEEDI)

Glossy shield bug

Cermatulus nasalis

Adults and nymphs are predators of caterpillars such as heliothis and loopers. The adults are similar to the spined predatory shield bug but without the spines on the thorax. The nymphs, like those of spined predatory shield bug, are dark red and brown.

Adult glossy shield bug
(photograph courtesy of J Wessels, DEEDI)

Glossy shield bug nymph
(photograph courtesy of J Wessels, DEEDI)

Assassin bug

Reduviidae

A number of species, including the beekiller (*Pristhesancus plagipennis*), are useful predators of pest insects. Adults and nymphs are predators of a range of insects, many of which are pests. They have very strong, curved, piercing/sucking mouthparts that are used to pierce the hard, outer skeleton of their prey. Adults range in size from 10 mm to 30 mm depending on the species. They are usually drab red-brown in colour and ambush their prey by waiting quietly near flowers and other places frequented by insects. Nymphal stages sometimes camouflage themselves with plant debris.

Adult assassin bug with prey
(photograph courtesy of P Grundy, DEEDI)

Assassin bug nymph
(photograph courtesy of J Wessels, DEEDI)

Bigeyed bug

***Geocoris* spp.**

These bugs are easily recognised by their very large eyes. Adults are about 3 mm long, grey/steely black in colour with brown translucent wings and are very fast moving. They prey on small, soft-bodied insects and mites.

Bigeyed bug adult

Damsel bug

***Nabis* spp.**

Nymphs and adults pierce and suck the contents of eggs and caterpillars of heliothis and loopers, and also feed on leafhoppers, aphids and spider mites. Adults are 7–9 mm long, with a tan or grey, slender body and long legs and antennae.

Damsel bug adult
(photograph courtesy of DA Ironside, DEEDI)

Damsel bug nymph
(photograph courtesy of J Wessels, DEEDI)

Mirids

Miridae

A number of species of mirids are predators of other insects and also sometimes feed on plants. Most are less than 3 mm long and range in colour from brown and yellow to green. One common species is the brown smudge bug (*Deraeocoris signatus*). It will feed on heliothis eggs and aphids. Apple dimpling bugs (*Campylomma liebknechtii*) will feed on mites and heliothis eggs, although they also feed on soft plant tissue.

Adult brown smudge bug with prey

Brown smudge bug nymph
(photograph courtesy of J Duff, DEEDI)

Apple dimpling bug adult
(photograph courtesy of RH Broadley, DEEDI)

Minute pirate bugs

Anthocoridae—*Orius* spp.

These small bugs (2–3 mm) are dark brown to black in colour. They feed on insect eggs and thrips, and are an important predator of western flower thrips.

Adult minute pirate bug

Ladybirds

Coccinellidae

There are a large number of ladybirds that are effective predators of vegetable pests. They prey on a wide range of soft-bodied insects and mites, including aphids, mealybugs, scale insects, two-spotted mites and European red mites. Most are small, between 2 mm and 4 mm in length. Their bodies are generally rounded with red, orange, yellow and black markings, although a few are predominantly black. Ladybird larvae have a tapered abdomen and some may be covered with a waxy substance and appear similar to mealybugs. Eggs are laid in clusters of 5 to 100, are generally yellow or cream in colour and are cylindrical with tapered ends.

The major ladybird species are:

- **mite-eating ladybird** (*Stethorus* spp.)—small, black ladybirds about 1.5–2 mm long, which are very efficient predators of mites and aphids
- **transverse ladybird** (*Coccinella transversalis*)—adults, which are about 4 mm long, are yellow-orange with black, V-shaped marks on each wing cover
- **striped ladybird** (*Micraspis frenata*)—adults are 4 mm long and have a striped pattern on the wing covers
- **maculate or three banded ladybird** (*Harmonia octomaculata*)—adults are 5 mm long with three rows of spots across the wing covers giving a banded appearance
- **minute two-spotted ladybird** (*Diomus notescens*)—adults are 2.5 mm long and dark in colour with two orange spots on the wing covers
- **common spotted ladybird** (*Harmonia conformis*)—larger species up to 7 mm long with prominent spots
- **variable ladybird** (*Coelophora inaequalis*)—adults are 5 mm long with variable wing cover pattern
- **spotted amber ladybird, also known as the white collared ladybird** (*Hippodamia variegata*)—adults are 5 mm long, with red to orange to yellow wing covers with several black spots. The front of the thorax (pronotum) is black with a white edge, or collar.

Mite-eating ladybird adults, larvae and pupae with remains of mite infestation
(photograph courtesy of D Smith, DEEDI)

Transverse ladybird adults and larva attacking aphids

Striped ladybird adults and larva
(photograph courtesy of BA Franzmann, DEEDI)

Three banded ladybird adults, larva and pupa
(photograph courtesy of DA Ironside, DEEDI)

Three banded ladybird eggs

Minute two-spotted ladybird adults and larva
(photograph courtesy of DA Ironside, DEEDI)

Common spotted ladybird adult

Common spotted ladybird larva

Variable ladybird adults
(photograph courtesy of RH Broadley, DEEDI)

Variable ladybird larva feeding on aphids

Spotted amber ladybird adult
(photograph courtesy of T Dennien)

Ground beetles (or carab beetles)

Carabidae

This is a very large family of beetles, most of which are predators. Almost all are ground-dwelling, sheltering under rocks and other debris. They are mainly nocturnal feeders and because they are not often seen, their importance tends to be overlooked. They prey on a wide range of insects, spiders, worms, slugs and snails—all stages of which are consumed. Size varies from 5 mm to 25 mm in length and they are usually dull black or brown in colour. A few species have brighter metallic colours. They have long legs, strong mandibles and the protective plate behind the head has a distinctive 'shield' shape. Larvae are slender with strong mouthparts.

Lacewings (Neuroptera)

Green lacewing

***Mallada* spp.**

Green lacewing larvae are predators of a wide range of caterpillars, aphids, scale insects and moth eggs. They are squat, six-legged voracious hunters that clamp their well-developed jaws on soft-bodied insects or eggs and then suck up the contents. They camouflage themselves with the carcasses of their prey. Adults are green to yellow, 10–18 mm long and have lacy, see-through wings. They lay their eggs on long, flexible stalks that may be 4–8 mm long.

Green lacewing adult
(photograph courtesy of J Wessels, DEEDI)

Green lacewing larva with prey corpses on its back
(photograph courtesy of J Wessels, DEEDI)

Green lacewing eggs
(photograph courtesy of J Wessels, DEEDI)

Brown lacewing

Micromus tasmaniae

Adults and larvae are predators of moth caterpillars and aphids and their eggs. Larvae are smooth with brown and white markings. They are longer and thinner than green lacewing larvae and do not camouflage themselves with the corpses of their prey. They suck the contents of their prey through their large jaws. Adults are pale brown and smaller than green lacewings. Their wings have a brown, speckled appearance. Females lay their cream, oval eggs singly, attached by one side to the underside of leaves. Adults chew their prey.

Brown lacewing adult
(photograph courtesy of C Freebairn, DEEDI)

Brown lacewing larva feeding on aphids
(photograph courtesy of C Freebairn, DEEDI)

Dragonflies and damselflies (Odonata)

Adult dragonflies and damselflies feed on flying insects, which they catch 'on the wing'. Their general importance as predators is not fully understood, but they do catch small moths and flies. The larvae are aquatic.

Dragonfly

Adults are predators of flying insects, including moths, bugs and beetles. The aquatic larvae feed on small water animals such as beetles and mosquito larvae. The larvae do not resemble adults. Adults are slender bodied with a large head. The forewings and hind wings differ in shape and venation.

Damselfly

Both adults and larvae prey on a range of insects. The adults catch various insects in flight and the larvae feed in the water on mosquito larvae and other small aquatic insects. Adults are similar in appearance to dragonflies (but are smaller) and the forewings and hind wings are the same shape and have similar venation. The larvae are aquatic.

Other insect predators

Praying mantid

Mantodea

Most species are green, brown or mottled in colour. Prey are caught in distinctive, strong, raptorial (adapted for seizing prey) front legs. They prey on a wide range of insects and other small animals.

Praying mantid

Common brown earwig

Labidura truncata

The common brown earwig is a nocturnal predator of caterpillars and other small animals. It will also attack heliothis pupae in their chambers underground. Adults have distinct 'forceps' at the tail end of the abdomen and the large, membranous hind wings are folded beneath slate blue wing covers. They hide on and in the ground during the day. Adult females guard their oval, white eggs and young nymphs in burrows in the ground.

Common brown earwig attacking a pupa
(photograph courtesy of J Wessels, DEEDI)

Ants

Formicidae

As stated in the previous section on pests (see p. 48), ants have a wide range of feeding habits, but some species are very effective as predators.

Spiders and mites (Arachnida)

Spiders

Araneae

Web spiders

Web spiders build sticky webs to entangle their prey. Orbweavers (*Araneus* spp. and *Argiope* spp.) build large, circular webs. Some species wait under nearby leaves, others in the centre of the web. Tangle web spiders (*Achaearanea veruculata*) build an untidy web, often with no recognisable pattern. Most species hide under nearby leaves.

Orbweaving spider (*Araneus* sp.)

Tangle web spider
(photograph courtesy of RH Broadley, DEEDI)

Hunting spiders

Hunting spiders rarely build webs, except for protection of eggs. They either stalk their prey or hide and ambush it.

Lynx spiders (*Oxyopes* spp.) are active near the tops of plants. The abdomen is narrow and pointed. Wolf spiders (*Lycosa* spp.) generally hunt on the ground. They may build a shallow burrow. Flower spiders (*Diaea* spp.) hide in flowers and ambush small insects. Nightstalking spiders (*Cheiracanthium* spp.) hunt at night. These spiders are pale yellow with a faint, grey mark on the abdomen. The 'head' of one species, the yellow nightstalking spider, is pale orange. Jumping spiders (Salticidae) hunt during the day. They have two very large forward-facing eyes that give them excellent binocular vision.

Female wolf spider guarding her egg sac
(photograph courtesy of DA Ironside, DEEDI)

Flower spider
(photograph courtesy of DA Ironside, DEEDI)

Jumping spider
(photograph courtesy of DA Ironside, DEEDI)

Mites

Acarina

Chilean predatory mite

Phytoseiulus persimilis

This predator is produced commercially for release into crops for the management of two-spotted mite. It is larger with longer legs than the two-spotted mite and has a shiny, orange, pear-shaped body. Eggs are elliptical in shape and also larger than two-spotted mite eggs. Juvenile predatory mites are a pale, salmon colour.

Chilean predatory mite with two-spotted mite in background

Montdorensis predatory mite

Transeius montdorensis

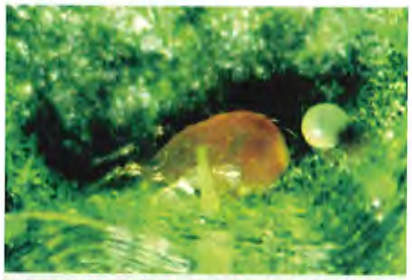
These predatory mites are useful predators of thrips, whiteflies and other small insects, particularly in protected cropping. The pale, pear-shaped adults are about the same size as two-spotted mites.

Montdorensis predatory mite
(photograph courtesy of L Pilkington)

Cucumeris predatory mite

Neoseiulus cucumeris

These small, pear-shaped cream coloured mites are efficient predators of thrips larvae and some mites, particularly in protected cropping.



Cucumeris predatory mite
(photograph courtesy of Australasian Biological Control Inc.)

Hypoaspis predatory mites

***Hypoaspis* spp.**

These soil-dwelling predatory mites are useful predators of fungus gnat larvae.

Hypoaspis predatory mite
(photograph courtesy of Australasian Biological Control Inc.)

Centipedes (Chilopoda)

Centipedes are long animals with many segments and pairs of legs. Contrary to the name, very few centipedes have 100 or more legs. Most are voracious predators, feeding on insects, spiders and other small animals. They have a pair of poison glands (which are actually modified legs of the first body segment) underneath the head and they use these glands to paralyse their prey.

Centipede

Pathogens

Insects and arachnids can become infected with a range of diseases. In nature, these diseases tend to have the most impact when pest numbers are high and the weather is humid or rainy. Some insect disease pathogens are available as commercial insecticides, and examples include the bacterial insecticides made from *Bacillus thuringiensis* and the insecticides made from the nuclear polyhedrosis virus specific to and effective against heliothis.

Viral diseases

Outbreaks of viral diseases, such as that caused by nuclear polyhedrosis virus, may be seen sporadically in vegetable crops. Viruses are usually specific to a particular insect species or group of related species. One nuclear polyhedrosis virus affects the larvae of heliothis and another the larvae of cabbage white butterfly. Infected larvae first become pale, then die, turning into liquidy sacks, and are often found with the head characteristically hanging down. Granulosis viruses infect some insects (e.g. potato moth larvae).

Virus-infected heliothis larva showing characteristic head-down position
(photograph courtesy of J Wessels, DEEDI)

Fungal diseases

Fungal diseases affect aphids as well as larvae of some vegetable pests. The fungal spores invade the body of the host insect and give it a colour and sheen characteristic of that particular fungus. Prolonged wet or humid conditions favour the development of fungal diseases and infected larvae become stiff and are anchored to the plant by fungal threads.

Cabbage moth larva infected with *Entomophthora* fungus (bottom), with healthy larva (top)
(photograph courtesy of R Teakle, DEEDI)

Scarab beetle larva infected by a fungus

Cabbage cluster caterpillar infected with the fungus *Nomuraea rileyi*
(photograph courtesy of R Teakle, DEEDI)

Bacterial disease

Pests may become infected with bacterial diseases. One such disease is caused by *Bacillus thuringiensis*. Commercial preparations of this bacterium that are specific to moth and butterfly larvae are available.

Dark, *Bacillus thuringiensis*–infected heliothis larva
(photograph courtesy of R Teakle, DEEDI)

Bacillus thuringiensis–infected diamondback moth larvae—dead (left), dying (middle) and healthy (right)

Glossary

Abdomen	The third or posterior major division of the insect body
Alatae	Winged forms (e.g. in aphids)
Antennae	'Feelers' at the front of the head, which may be long or short, slender, branched or feathery and sensitive to touch, smell and sometimes sound
Apterae	Wingless forms (e.g. in aphids)
Brassicas	Vegetables in the genus *Brassica* such as broccoli, cabbage, cauliflower, brussel sprouts and turnips (see also 'crucifers')
Biotype	A strain of an insect species
Cocoon	Silken sac covering the pupa
Compound eyes	Eyes on either side of the adult insect head, which consist of many units each made up of a lens system and a smaller number of sense cells
Crucifers	Vegetables in the family Brassicaceae (or Cruciferae), including the brassicas and some other crops such as rocket, radish, horseradish and cress (see also 'brassicas')
Cucurbits	Vegetables in the family Cucurbitaceae such as cucumber, pumpkin, squash and zucchini
Curd	The edible flower head of cauliflower and broccoli
Dorsal	The upper surface
Ectoparasites	Parasites that live on the exterior of their hosts
Egg raft	Cluster of eggs; egg mass
Endoparasites	Parasites that live inside their hosts
Femur	The third and usually the stoutest segment of the leg
Forewings	Front pair of wings
Frass	Solid larval insect excrement; faeces
Halteres	Reduced hind wings that are used as balancing organs in flies
Hind wings	Rear pair of wings
Instar	Immature stage between moults
Larva (pl. larvae)	Immature stage that hatches from an egg and passes through a life cycle involving complete metamorphosis (common terms: grub, caterpillar, maggot)
Mandibles	Part of the insect mouthparts; large and jaw-like in chewing insects and needle-shaped in piercing and sucking insects
Mealy	Floury
Metamorphosis	Progression through stages from egg to adult
Moult	Shedding of skin from previous instar
Mouthparts	Chewing, sucking, piercing and sucking part of the head that takes food
Nocturnal	Active at night
Nymph	Immature stage of an insect that undergoes incomplete metamorphosis
Ocellus (pl. ocelli)	Simple insect eye
Ovipositor	Egg-laying tube at the end of the female abdomen

Parasite	An organism that lives on another, obtaining food, shelter or other needs
Parasitise	To attack or infest as a parasite
Parasitoid	A parasite that slowly kills the host, usually near the end of the parasite's development
Pathogen	A microorganism that causes disease
Predator	An organism that kills and eats other organisms
Prolegs	Soft, fleshy, false legs on the abdomen of some immature stages, such as caterpillars
Pronotum	The upper and dorsal part of the first segment of the thorax
Pupa (pl. pupae)	Resting stage between larva and adult
Raptorial	Adapted for seizing prey, as in the raptorial legs of the praying mantid
Russetting	To make reddish-brown in colour
Setae	Hairlike projections
Siphunculi	Tubular structures at the end of the aphid abdomen
Solanaceous	Vegetables in the family Solanaceae such as capsicum, eggplant, potato and tomato
Thoracic legs	Legs on the thorax
Thorax	The second section of the insect body (between the head and the abdomen) to which the legs and wings are attached
Tibia	The fourth segment of the insect leg
Tubercule	A small knoblike or rounded protuberance
Vector	An organism that transports a pathogen from one host to another
Venation	Pattern of veins on insect wings
Wingspan	The distance between the tips of the outspread wings

Further reading and bibliography

There are many books available on insect pests and their management in vegetables and other crops. The following is a selection of those, but you may find others that are informative and useful. Books aimed at the home gardener can also be useful as they often include colour photos and drawings, sometimes with outstanding pictures of insects and arachnids. Check with your local bookshop, at specialist book suppliers or with the online bookshops of your state agricultural department. Some of the books listed may no longer be in print, but they may be available in libraries or at your local agricultural department's offices.

Specialist book suppliers include Johima Books (www.johima.com.au) and the Rural Bookshop (www.ruralbookshop.com.au). An internet search on 'bookshops and horticulture' or 'bookshops and agriculture' should provide a useful list.

References for collecting and preserving insects and arachnids

Schauff, ME (ed.) 2005, *Collecting and preserving insects and mites: tools and techniques*, Systematic Entomology Laborator, USDA, National Museum of Natural History, Washington DC.

Available online at www.ars.usda.gov

Upton, MS 1991, *Collecting, preserving and studying insects and allied forms*, 4th edn, Australian Entomological Society Miscellaneous Publication No. 3, Canberra.

Available online at www.austentsoc.org.au

Books on insects and crops

Bailey, P (ed.) 2007, *Pests of field crops and pastures*, CSIRO Publishing, Collingwood.

This book includes photographs, descriptions and management notes for pests of field crops, many of which also are pests of vegetables.

Brough, E, Elder, R & Beavis C (eds) 1994, *Managing insects and mites in horticultural crops*, Information Series QI94010, Department of Primary Industries, Queensland.

This book includes descriptions and management notes of major insect and mite pests, but no illustrations.

Fullelove, G (ed.) 1992, *Tomato pests and disorders*, Information Series QI91021, Department of Primary Industries, Queensland.

This book includes an extensive collection of colour photos with management notes.

Heisswolf, S, Carey, D, Walsh, B, Davis, B & Henderson C, 2004, *Brassica problem solver and beneficial identifier*, Information Series QI04005, Department of Primary Industries and Fisheries, Queensland.

This book includes photographs and descriptions of brassica problems, including those caused by insect pests, with a section on beneficial insects.

Hely, PC, Pasfield, G & Gellately JG 1982, *Insect pests of fruit and vegetables in NSW*, Inkata Press, Melbourne, Sydney and London.

This book includes photographs, diagrams and descriptions of pests and their damage. However, the control measures are out of date and should be ignored.

Horne, P, De Boer, R & Crawford, D 2002, *Insects and diseases of Australian potato crops*, Melbourne University Press, Melbourne.

This book has photographs and life cycle and management information on beneficial and pest insects and diseases of potatoes.

Llewellyn, R (ed.) 2002, *The good bug book*, 2nd edn, Integrated Pest Management Pty. Ltd. for Australasian Biological Control Inc.

This book lists suppliers of beneficial insects and mites, and also gives detailed descriptions of these natural predators.

Lovatt, J (ed.) 2004, *Sweet corn problem solver and beneficial identifier*, Information Series QI04008, Department of Primary Industries and Fisheries, Queensland.

This book includes photographs and descriptions of sweet corn problems, including those caused by insect pests, with a section on beneficial insects.

Swaine, G, Ironside, DA & Corocoran RJ (eds) 1991, *Insect pests of fruit and vegetables*, 2nd edn, Information Series QI91018, Department of Primary Industries, Queensland.

This book includes a collection of colour photos with biological and management notes.

Ute guides

Ute guides (field guides) are small, spiral-bound books, usually printed on plasticised paper, containing photographs and information on pest and beneficial insects in a particular crop or a related group of crops. The guides can be taken into the field and used to identify the insects found in the crops. Ute guides have been prepared for many horticultural and field crops and several of particular interest to vegetable growers are listed below.

Brown, J (comp.) 2004, *Insect pest guide: a guide to identifying vegetable insect pests and their natural enemies in the dry tropics*, Department of Primary Industries and Fisheries, Queensland.

Donald, C, Endersby, N, Ridland, P, Porter, I, Lawrence, J & Ransom L 2000, *Field guide to pests, diseases and disorders of vegetable brassicas*, Agriculture Victoria, Victoria.

Available from Crop Health Services on (03) 9210 9356

Draper, V & Napier, T (eds) 2009, *Pests, beneficials, diseases and disorders in cucurbits: field identification guide*, Department of Primary Industries, New South Wales.

Duff, J 2008, *Green beans: insect pests, beneficials and diseases*, Department of Primary Industries and Fisheries, Queensland.

Goodwin, S & Steiner M (eds) 2002, *Pests, diseases, disorders and beneficials in greenhouse vegetables: field identification guide*, NSW Agriculture, New South Wales.

Llewellyn, R 2000, *Sweet corn pests and their natural enemies: an IPM field guide*, BioResources Pty Ltd.

Websites

A lot of information can be obtained from the internet, provided you use reputable sites. Government departments and universities, both in Australia and overseas, often have a lot of information on specific pests available on their websites. Search engines are useful for finding the sites you may need.

Bibliography

Bailey, PT (ed.) 2007. *Pests of field crops and pastures*. CSIRO Publishing, Collingwood.

CSIRO 1991, *The insects of Australia*, 2nd edn, Melbourne University Press, Melbourne.

Hely, PC, Pasfield, G & Gellatley JG 1982, *Insect pests of fruit and vegetables in NSW*, Inkata Press, Melbourne, Sydney, London.

Swaine, G, Ironside DA & Corcoran RJ (eds) 1991, Insect pests of fruit and vegetables, 2nd edn, Information Series Q191018, Department of Primary Industries, Queensland.

Species and disease index

Notes