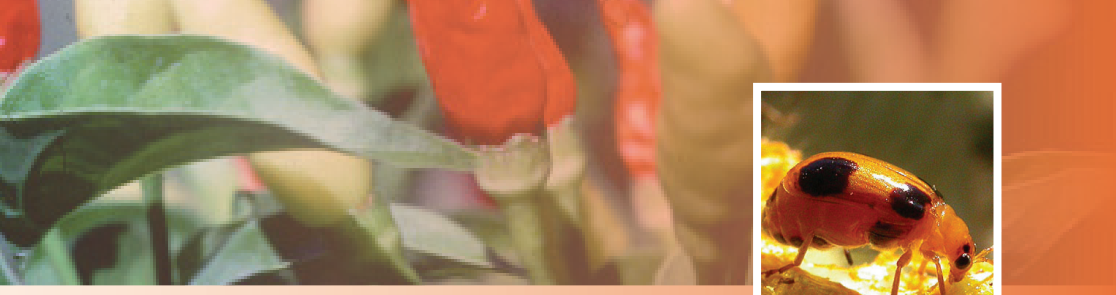

FIELD GUIDE

to Pests, Beneficials, Diseases and Disorders of Vegetables in northern Australia

Northern Territory Government

HAL

Horticulture Australia

Field Guide to Pests, Beneficials, Diseases and Disorders of Vegetables in northern Australia

November 2014

Department of Primary Industry and Fisheries

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DISEASES

DISORDERS

Foreword

The Horticultural industry in the Northern Territory (NT) is expanding at a fast rate, just 25 years ago it was valued at less than $500,000 a year and now it has an estimated annual value close to $120 million and is expected to increase further.

One of the prominent sectors of horticulture in the NT is the vegetable industry. Growth in this sector has been rapid and impressive over the past 10 years. There are also new growers joining the industry, bringing with them a wealth of knowledge and expertise and producing a range of vegetables for commercial and local markets.

Due to the growth in the industry it has become even more important to address the issues of product quality and the adoption of integrated pest and disease management (IPDM).

IPDM is a common sense approach to minimising crop damage by pests and diseases. It uses a number of simultaneously applied control methods which, collectively, discourage pests (or diseases) and encourages beneficial organisms, leading to a more balanced crop ecosystem that produces improved quality produce with minimal adverse effects to the environment.

The correct identification of pests, beneficials, diseases and disorders is a fundamental part of IPDM. This guide is a comprehensive resource which will be useful to growers, agronomists, extension officers and researchers. The publication was produced by entomologists, plant pathologists and horticulturalists with many decades of experience working in the dry tropics of Northern Australia and overseas. Other field guides in this series produced by the Department include: *Pests, Beneficials, Diseases and Disorders of Mangoes; and Biological Control with Natural Enemies in the Top End.*

The format of these field guides provides easy to view ‘at a glance’ text and images which have been invaluable to growers from diverse cultural backgrounds in helping them identify complex pest and disease problems when communicating to their farm suppliers, agricultural consultants and government officers. An edition of this field guide will also be available in Vietnamese.

The department will continue to consult the industry and develop other publications and training resources to assist growers in improving their crop management skills. I look forward to receiving comments on the practical use of this field guide as well as any suggestions for the next edition.

All the best to vegetable growers for the coming seasons and I encourage your contribution to the development of this important industry sector.

BOB WILLIAMS
Director, Plant Industries
Department of Primary Industry and Fisheries
Darwin, Northern Territory

Introduction

Introduction

This publication is the first comprehensive field guide to pests, beneficials, diseases and disorders of commercially grown vegetables in the Northern Territory. The information has been derived from more than 20 years research and extension experience with commercial vegetable crops by staff of Entomology, Plant Pathology and Horticulture, within the Plant Industries Group, Northern Territory Department of Primary Industry and Fisheries. The vegetable field guide is a useful resource for primary producers, researchers, extension staff and students.

The format of the book has been designed to provide easy and quick access to assist in the recognition of pests, diseases or symptoms in the field. Each opening includes text on the left page and photographs on the right page. The tabs along the right edge are labelled and colour-coded, making it easier to navigate.

Due to regular updates and changes in the recommendations of pesticides, specific products have not been listed. However, growers are encouraged to contact Department staff if they require assistance with pest or disease management.

Information regarding pesticide registrations is available from the Australian Pesticides and Veterinary Medicines Authority (APVMA) website: www.apvma.gov.au

A comprehensive Agvet chemical database is available free online from Infopest which is owned and managed by Growcom www.infopest.com.au

Monitoring and Integrated Pest Management (IPM)

Growers are encouraged to use this guide as a resource to assist in the identification of pests and their natural enemies as well as diseases and disorders when monitoring vegetable crops. Correct identification of pests and diseases is important when considering management options. Integrated pest management (IPM) is the management of pest populations using all relevant control practices in a complementary manner, so that the pest will be maintained below the economic injury level and adverse effects to the environment will be minimal. When diseases are incorporated, IPM is referred to as integrated pest and disease management (IPDM).

The majority of vegetables are grown over the ‘dry season’ (May to September) and many pests and diseases are suited to the dry and warm conditions with mean temperatures in the range of 15-36°C (for the Darwin area). The ‘build-up’ to the wet season starts in September and higher temperatures and humidity is generally experienced. Most of the rainfall occurs in the ‘wet season’ between October to April.

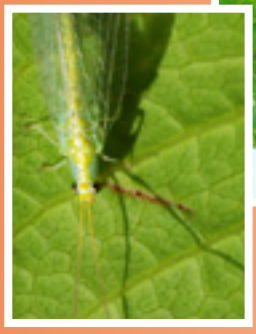
This guide provides descriptions, life cycles and biology along with colour photographs to help recognise and distinguish pests from beneficials (which includes natural enemies that attack pests as well as pollinators). Since beneficials help regulate the levels of pests, it is important to monitor pest numbers to assess the level of natural control by predators or parasites before considering other pest management options. Regular monitoring of the crop will assist in the detection of pests and diseases, as well as providing an indication of the change in populations or spread of symptoms.

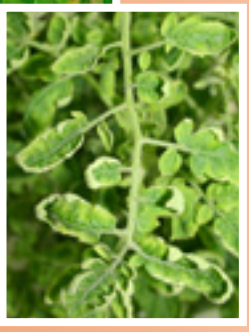
Departmental contact information

Entomology (pests and beneficials)
Telephone: 08 8999 2258
Email: insectinfo@nt.gov.au

Plant Pathology (plant diseases and disorders)
Telephone: 08 8999 2265
Email: plant.pathology@nt.gov.au

Horticulture (growing advice)
Telephone: 08 8999 2222
Email: horticulture@nt.gov.au





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Authors
Deanna Chin, Haidee Brown, Barry Condé, Lois Ulyatt, Brian Thistleton, Stuart Smith and Lanni Zhang.

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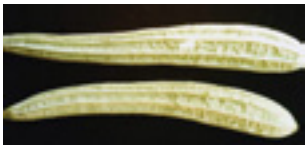
Vegetables

Vegetables

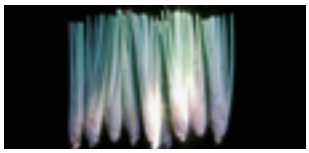
Commercial vegetable crops grown in the Northern Territory

VEGETABLES	Common name	Scientific name
	**Amaranthus, en choy, edible amaranth**	*Amaranthus tricolor*, *A. oleraceus*
	**Angled loofah, sin qua, ridged loofah, ridged gourd**	*Luffa acutangula*
	**Asparagus**	*Asparagus officinalis*
	**Bamboo shoots**	*Dendrocalamus latiflorus*
	**Basil, sweet basil**	*Ocimum basilicum*
	**Thai basil, Vietnamese basil, Asian basil**	*Ocimum basilicum* var. *thyrsiflora* *O. tenuiflorum*
	**Bitter melon, bitter gourd, fu qua**	*Momordica charantia*
	**Buk choy**	*Brassica rapa* *(Chinensis* group*)*

	**Cabbage**	*Brassica oleracea* (*Capitata* group)
	**Cucumber**	*Cucumis sativus*
	**Cucumber 'Lebanese'**	*Cucumis sativus*
	**Capsicum**	*Capsicum annuum*
	**Ceylon spinach, Malabar spinach, basella, vine spinach**	*Basella alba*, *B. rubra*
	**Chilli**	*Capsicum frutescens*, *C. annuum*
	**Chinese broccoli, gai lan, Chinese kale, white flowering broccoli, kailan**	*Brassica oleracea* (*Alboglabra* group)
	**Chinese cabbage, wombok**	*Brassica rapa* (*Pekinensis* group)

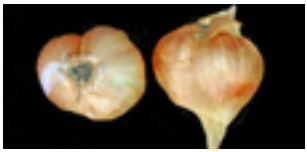
Commercial vegetable crops grown in the Northern Territory

	**Choy sum**	*Brassica rapa* (P*arachinensis* group*)*
	**Coriander**	*Coriandrum sativum*
	**Thai Coriander, culantro, long coriander**	*Eryngium foetidum*
	**Eggplant, eggfruit, aubergine, brinjal**	*Solanum melongena*
	**Lebanese eggplant, long eggplant**	*Solanum melongena*
	**Thai eggplant, garden egg, Thai brinjal**	*Solanum undatum*
	**Thai pea eggplant**	*Solanum torvum*
	**Galangal, Siamese ginger, Siamese galanga**	*Alpinia galanga*

	**Garland chrysanthemum, chrysanthemum greens, edible chrysanthemum, tung ho**	*Chrysanthemum coronarium*
	**Garlic chives, Chinese leek, Chinese chives**	*Allium tuberosum*
	**Hairy melon, chi qua, hairy gourd, fuzzy gourd**	*Benincasa hispida* var. chiehqua
	**Hot mint, Vietnamese mint**	*Persicaria odorata*
	**Kang kong, water spinach, water convolvulus**	*Ipomoea aquatica*
	**Lemon grass**	*Cymbopogon citratus*
	**Lettuce**	*Lactuca sativa*
	**Long melon, seng qua**	*Lagenaria siceraria*

Commercial vegetable crops grown in the Northern Territory

	**Mint**	*Mentha arvensis*
	**Mustard greens, Chinese mustard, gai choy**	*Brassica juncea*
	**Okra, gumbo**	*Abelmoschus esculentus*
	**Onion**	*Allium cepa*
	**Pak Choy**	*Brassica rapa* (*Chinensis* group)
	**Potato**	*Solanum tuberosum*
	**Pumpkin Butternut**	*Cucurbita moschata*
	**Pumpkin Jarrahdale**	*Cucurbita maxima*

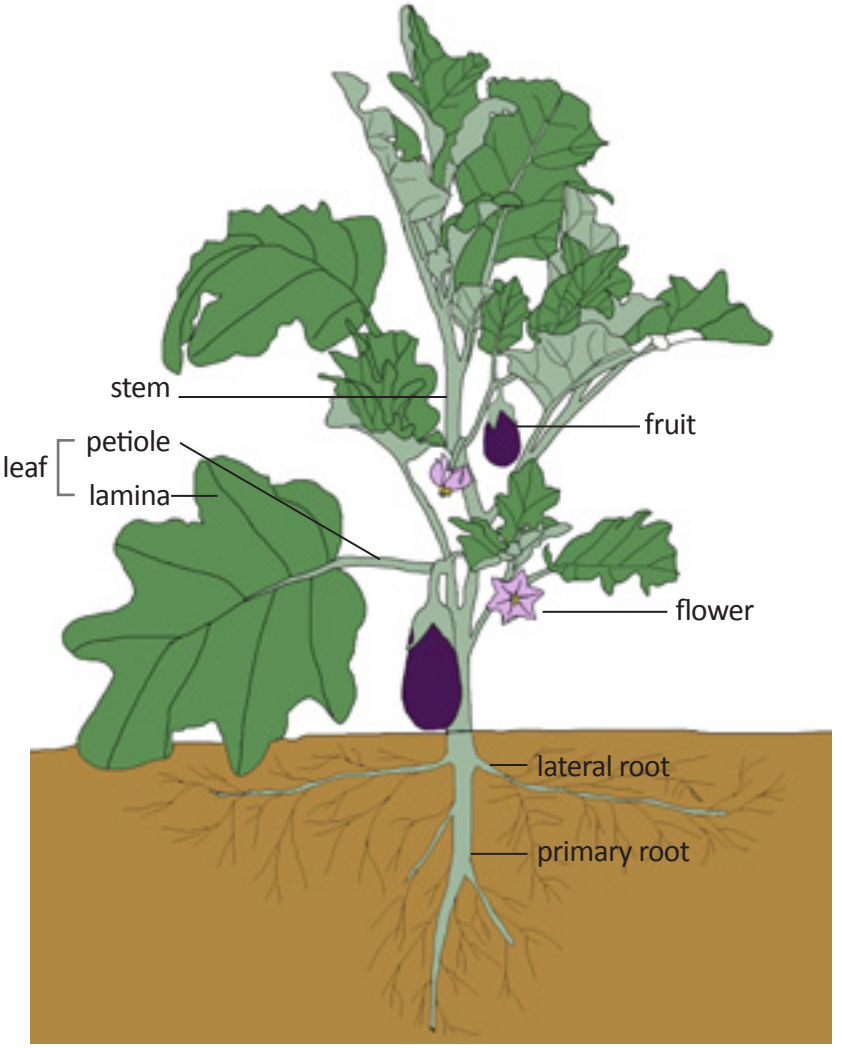
	**Pumpkin Kent**	*Cucurbita moschata*
	**Rockmelon**	*Cucumis melo*
	**Shallots, potato onion, multiplier onion**	*Allium cepa* (*Aggregatum* group)
	**Smooth loofah, sponge loofah, sponge gourd, shui qua**	*Luffa aegyptiaca*
	**Snake bean, long bean, yard long bean**	*Vigna unguiculata* subsp. *sesquipedalis*
	**Spring onion**	*Allium fistulosum*
	**Squash, yellow button squash**	*Cucurbita pepo*, *C. pepo* var. *sunburst*
	**Sweet corn**	*Zea mays*

Commercial vegetable crops grown in the Northern Territory

	**Sweet potato**	*Ipomoea batatas*
	**Taro, cocoyam, dasheen**	*Colocasia esculenta*
	**Tomato**	*Solanum lycopersicum*
	**Watermelon**	*Citrullus lanatus*
	**Winter melon, wax gourd, dong gua**	*Benincasa hispida*
	**Yam bean, jícama, Mexican yam bean**	*Pachyrhizus erosus*
	**Zucchini**	*Cucurbita pepo*

Plant Structure

Structure of a plant (dicotyledon)



Biology of insects, mites and spiders

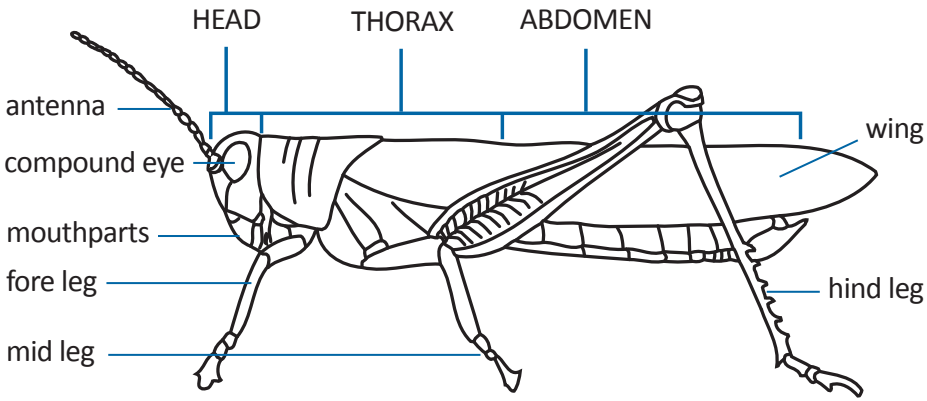
Biology

Class Insecta

Basic body structure

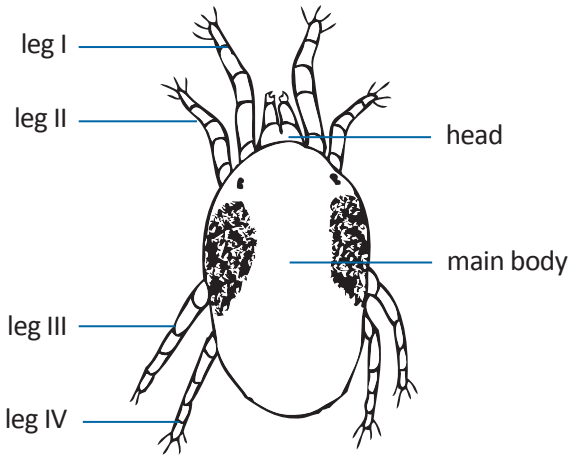
- **Exoskeleton divided into 3 parts**
  (head, thorax and abdomen)
- **Three pairs of legs**
- **Usually 2 pairs of wings in adults**
- **One pair of multi-segmented antennae**

INSECTS



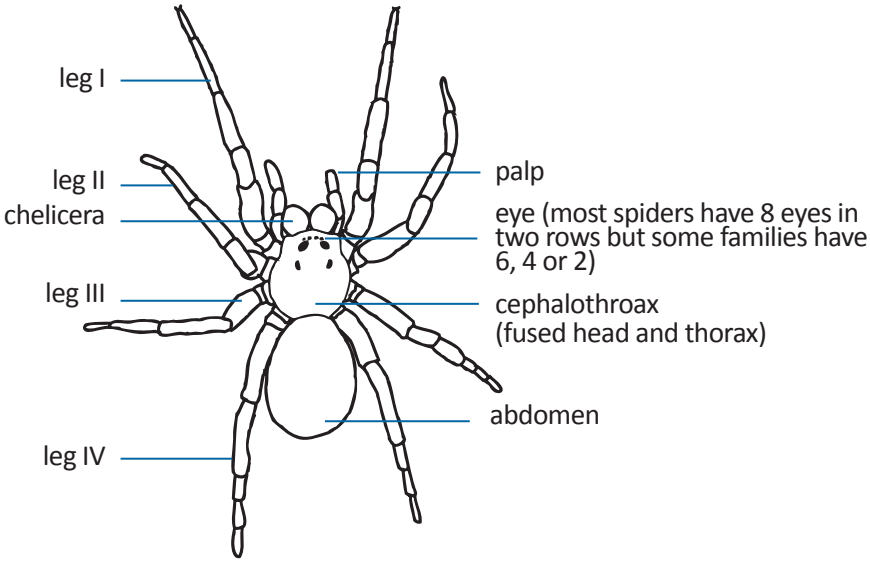
Class Arachnida

MITES



➔ **4 pairs of legs** (immature mites have 3 pairs)

SPIDERS



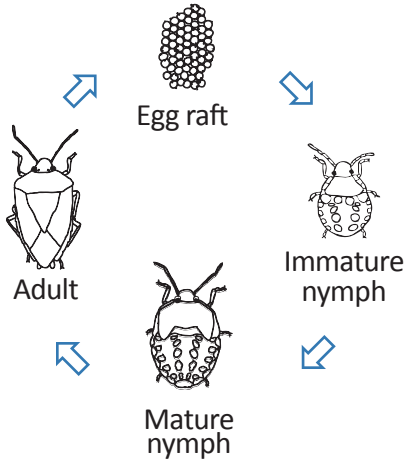
➔ **4 pairs of legs attached to the cephalothorax**

Life Cycles

Incomplete metamorphosis

Incomplete metamorphosis is found in grasshoppers, cockroaches, mayflies, dragonflies, termites, and true bugs. The very young nymphs have no wings but as they moult they develop wing buds.

At each moult the wing buds get longer until the adult emerges after the last moult with fully developed wings.

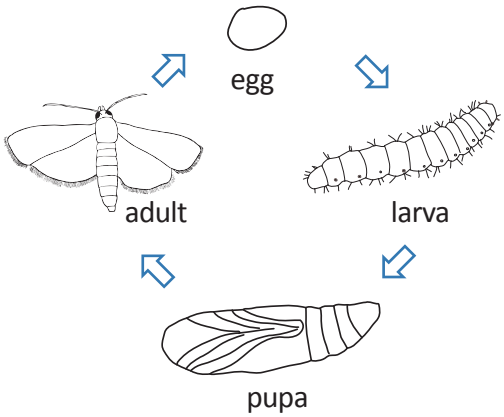


Life cycle of a true bug

Complete metamorphosis

Complete metamorphosis is found in wasps, bees, ants, flies, beetles, cicadas, fleas, butterflies, moths, and others. Eggs hatch into larvae (e.g. caterpillars, maggots or grubs).

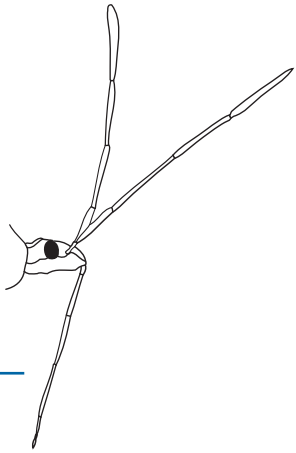
The larva grows and moults several times before turning into a pupa. In the pupal stage the body is restructured to form the winged adult.



Life cycle of a moth

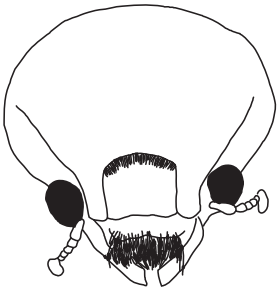
Types of feeding

Insect mouthparts vary according to what they feed on



Piercing needle-like mouthparts
for piercing and sucking plant sap.

e.g. Aphids, sucking bugs, mealybugs

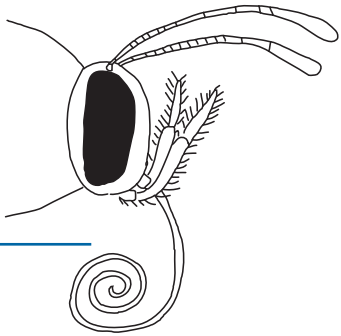


Chewing mouthparts
for chewing plant material or boring into wood.

e.g. Beetles, caterpillars, grasshoppers and termites

Sucking tubes
for extracting nectar from plant parts such as flowers.

e.g. Butterflies, moths



Sponge-like mouthparts
for lapping up and absorbing liquid.

e.g. Flies, bees

Pests of Vegetables

Pests

Cowpea aphid

Aphis craccivora (Family Aphididae)

Host plants:

Cowpea, snakebean, sesame, mungbeans, many other legumes and fruit trees.

Description:

Immatures: Nymphs are pear-shaped, dull grey in colour with pale yellow and black legs and are covered with a light dusting of wax.

Adults: Pear-shaped and shiny black with two prominent black siphunculi (tube-like projections) at the rear of the abdomen. There are both winged (alates) and wingless forms. Size: Up to 2.5 mm in length.

Life cycle and biology:

Females give birth to live young with or without mating, this allows for rapid population increase over a short period of time. Nymphs go through five instars. Most adult aphids are wingless. Winged aphids (alates) are only produced if the colony is stressed due to over-crowding or a shortage of food. A generation is completed in 5-7 days in warm weather.

Damage:

The infestation usually starts at the tip of new growth or flowers and then spreads down the stem. Cowpea aphids feed by sucking sap and damage is seen as leaf curling, wilting, and distortion of new shoots. Aphids secrete honeydew, which provides a substrate for the growth of sooty mould which hinders photosynthesis and reduces plant vigour. If the crop is infested during flowering, this may reduce or prevent the development of pods. Ants are often seen tending aphids for their honeydew.

Cowpea aphid is capable of transmitting legume viruses if they establish in the Northern Territory. In Queensland the aphid is able to transmit cucumber mosaic virus and bean yellow mosaic virus.

Monitoring and pest management:

Monitor regularly especially prior to flowering. Look for wilted growing tips and yellowish plants. Early detection is important in managing the population before it builds up and spreads throughout the crop. Select suitable pesticides specific to aphids that do not harm beneficial insects.

Natural enemies:

There are various natural enemies including predatory ladybirds, lacewing larvae, hover fly larvae, parasitic wasps, big-eyed bugs and minute pirate bugs. Ants tending the colony may protect the aphids from predators.

Cowpea aphid, *Aphis craccivora* adults and nymphs.

Cowpea aphid, *Aphis craccivora* nymphs.

Melon aphid

Aphis gossypii (Family Aphididae)

Host plants:

Cucumber, okra, rockmelon, squash, zucchini, capsicum and many other fruit crops, vegetables, ornamentals, native plants and weeds.

Description:

Eggs: Initially yellow and then become shiny black.

Immatures: Nymphs are light green, mottled with darker green. They are rounded or pear-shaped with two tube-like projections siphunculi at the rear of the abdomen.

Adults: Vary in colour from brown, dark green, dull black to yellow or whitish (if they are stressed). They are pear-shaped with two siphunculi at the rear of the abdomen. There are winged (alates) and wingless forms. Size: 1-2 mm in length.

Life cycle and biology:

Winged (alates) which are all female are only produced when the colony is overcrowded or there is a shortage of food. Alates are able to fly to new food sources where they can start reproducing without the need to mate. Female melon aphids can produce eggs or live young. In warm weather a generation can be completed in about 5-7 days from nymph to adult and numerous generations can be produced per season.

Damage:

Melon aphids feed on the undersides of leaves by sucking sap from the soft growing tips. The aphids tend to aggregate and may be seen only on a few leaves. Feeding may cause leaf curling, distortion of new shoots and even death of foliage. In heavy infestations the crop may be destroyed. Aphids produce honeydew, which accumulates on the leaves and promotes the growth of sooty mould which hinders photosynthesis and may also downgrade the quality of produce. Ants are often seen tending aphids for their honeydew.

Melon aphids are capable of transmitting viruses such as the mosaic viruses of cucurbits.

Monitoring and pest management:

Inspect plants for honeydew or leaf curling and distortion of young growth. The curled or distorted foliage provides protected areas for the aphids which may make it difficult to control infestations with chemical sprays. Early detection is important in managing the population as this aphid has the ability to increase in numbers at a rapid rate. Select suitable pesticides specific to aphids that do not harm beneficial insects.

There is widespread resistance to many pesticides, if pesticides are used, choose a product specifically targeted at aphids and ensure thorough coverage of the crop. Excessive use of pesticides to control other pests may lead to outbreaks of melon aphid if beneficial insect numbers are reduced.

Aphids are weak fliers and tend to be dispersed by wind; therefore crops downwind from an infested crop may be susceptible.

Infested crops and surrounding weeds should be destroyed after harvest to prevent the spread of aphids to other crops.

Natural enemies:

Many naturally occurring beneficials assist in the control of aphid populations, including predatory ladybirds, hover fly larvae, parasitic wasps and fungal pathogens. Native lacewings or commercially supplied green lacewings are also effective in reducing the population of aphids in a crop.

Melon aphid, *Aphis gossypii* adults, nymph and an egg.

Melon aphid, *Aphis gossypii* (wingless adult and alate).

A cucurbit crop showing leaf deformity and dieback of runners.

Coastal brown ant (big-headed ant)

Pheidole megacephala (Family Formicidae)

Host plants:

Occur on vegetable growing properties but do not feed directly on plants.

Description:

Eggs: White and oval-shaped.

Immature: White grub-like larvae.

Adults: Varies in colour from light yellowish-brown to dark shiny-brown. There are four castes or body forms of which the queen is the largest. The next largest is the males. The most numerous are the sterile female workers of which there are two types; minor workers and major workers (soldiers with large heads). Size: Up to 4.0 mm in length.

Life cycle and biology:

In the Top End, these ants form very large colonies. They tend to avoid direct sunlight and are more numerous in moist shady areas.

The eggs, larvae and pupae are known as the brood. The complete life cycle usually takes about 30-40 days in Top End conditions.

Damage:

Coastal brown ants feed on seeds and may also be attracted to nectar from flowers. Trails are often seen leading to fruit trees or vegetables where the ants tend honeydew producing insects such as mealybugs, scales or aphids. On properties where they are well established they will out-compete other ant species and will also become a threat to invertebrates and may eliminate native insects.

In the Northern Territory, quarantine restrictions are in place to prevent the spread of these ants which may be on produce when it is packed and transported interstate or overseas.

Monitoring and pest management:

Inspect the property for ants and trails. Ant baits developed for controlling coastal brown ant colonies are usually very effective.

Natural enemies:

There are no predators or parasites which are effective in controlling the colonies.

Coastal brown ant, *Pheidole megacephala* major worker (top), minor worker (bottom).

Coastal brown ant, *Pheidole megacephala* major worker.

Entrance to nest in soil.

Ginger ant

Solenopsis geminata, (Family Formicidae).

Host plants:

Rockmelon, snakebean

Description:

Eggs: White and oval shaped.

Immatures: Newly hatched larvae are white, soft and grub-like.

Adults: Orange-brown to red-brown in colour. They are polymorphic (different size workers) with major and minor workers as well as reproductives. Size: 2.5-6.0 mm in length.

Life cycle and biology:

Ginger ants (also known as tropical fire ant) should not be confused with the fire ant, *Solenopsis invicta* which is not established in the Northern Territory.

These ants are usually found in climatically hot areas. They build nests in open areas or under rocks. Ginger ants feed on grass seeds that they gather and store in their nests and sometimes a mound of loose soil and seeds can be seen around the nest entrance. If disturbed these ants will bite and sting.

The queen ginger ant lays eggs which hatch into larvae, these are fed by workers until they pupate. Newly emerged workers tend the nest which includes feeding the larvae and the queen, they also gather food and continue constructing the nest. As the workers mature they tend the larvae, look after the nest and help obtain food for the colony. The oldest workers in the colony are foragers and these have the role of maintaining the chemical trails along which the ants look for food.

Damage:

Ginger ants are associated with sap-sucking insects such as mealybugs, scales and aphids. The ants tend these sap-sucking insects for their excreted honeydew. In some cropping areas, ginger ants have been seen chewing on recently planted seeds, rockmelon seedlings, snake bean pods and plastic irrigation pipe. Other crops such as dragon fruit (and flowers) and various other plant material have also been attacked.

Ginger ants will also attack other insects as well as scavenging on dead insects and animal matter.

In the Northern Territory, quarantine restrictions are in place to prohibit the movement of ants in produce to areas interstate and overseas.

Monitoring and pest management:

Inspect the property for ants and trails. Specific ant baits are available which target this species to provide effective control.

Natural enemies:

No predators or parasites are effective in controlling ginger ant colonies.

Ginger ant, *Solenopsis geminata* workers.

Ginger ant, *Solenopsis geminata,* workers foraging on soil and leaf litter.

Pumpkin beetle

Pumpkin beetle, *Aulacophora hilaris* (Family Chrysomelidae)

Plain pumpkin beetle, *Aulacophora abdominalis* (Family Chrysomelidae)

Host plants:

Pumpkin, squash, watermelon, rockmelon, cucumber, zucchini, angled loofah and other cucurbits.

Description:

Immatures: Larvae are creamy-white in colour. Size: 10-12 mm in length.

Adults:

Pumpkin beetle: Orange with two black spots on each wing cover.
Size: About 6-7 mm in length.

Plain pumpkin beetle: Orange without spots.
Size: About 6-7 mm in length.

Life cycle and biology:

Females lay eggs in clusters on dead leaves or moist soil near the roots. Once the eggs hatch, the larvae start to feed on the roots and will continue to feed and develop until they pupate. When the beetles emerge they tend to feed in aggregations on leaves and flowers. Adults live for up to nine months.

Damage:

Adults chew holes in the leaves of cucurbits and often the entire leaf is eaten and all that remains is a network of veins giving it a skeletonised appearance. Young seedlings are more susceptible to damage as even a small number of beetles can cause defoliation and death of plants. Mature plants can tolerate a greater amount of damage before yields are affected. Flowers can be destroyed and chewing damage may be seen on the surface of the skin of developing fruit.

There is usually only minor damage caused by larvae feeding on the roots.

Monitoring and pest management:

Inspect crops for adult beetles which generally cluster or aggregate on plants. It is important to manage infestations on young plants as they are more likely to be affected by the damage.

Natural Enemies

No known natural enemies are effective in controlling pumpkin beetles.

Pumpkin beetle, *Aulacophora hilaris* and plain pumpkin beetle, *A. abdominalis.*

Skeletonised pumpkin leaf.

Sweet potato tortoise beetle

Aspidomorpha spp. and others
(Family Chrysomelidae)

Host plants:

Sweet potato, kang kong and other plants in the family Convolvulaceae.

Description:

Eggs: Creamy white, oval in shape and laid in a papery golden brown egg case (ootheca). Size: 1.5-2 mm in length; Ootheca: 8-13 mm in length.

Immatures: Larvae are light brown with rows of black dots on the body and covered in black spines. Size: Up to 10 mm in length.

Adults: Tortoise or dome shaped, golden coloured body with various black or brown patterns on the wing covers. Size: 10-13 mm in length

Life cycle and biology:

The ootheca (each contains three eggs) are glued onto the surface of the leaf. The eggs hatch after 7-10 days. The larval period is about 35 days, the pupal period is about seven days and the adults live for about two months.

Damage:

The beetles are not usually a serious pest, however, heavy infestations during root and shoot development can affect the yield of the tubers. Damage to older leaves usually does not affect the yield. Young larvae feed by scraping the leaf surface leaving a see-through membrane. Older larvae and adults chewing on the leaves produces round holes. In heavy infestations, the leaves can be skeletonised or defoliated.

Monitoring and pest management:

Monitor for adults and larvae feeding on the leaves. Control is usually not necessary unless the plants are young.

Natural enemies:

Wasp parasites such as those in the families Eulophidae and Chalcidae are effective in controlling the egg and larval stages.

Sweet potato tortoise beetle, *Aspidomorpha deusta*.

Sweet potato tortoise beetle, *Aspidomorpha* sp.

Feeding damage to leaves of sweet potato.

Sweet potato weevil

Cylas formicarius (Family Brentidae)

Host plants:

Sweet potato and other species of Ipomoea.

Description:

Eggs: Ovoid in shape. Newly laid eggs are translucent white and soft with a wrinkled surface; mature eggs are cream-coloured with irregular specks. Size: 0.65 mm in length.

Immatures: The larvae are white with a brown head and without legs. Size: Up to 8 mm in length.

Adults: The weevil is slender with a smooth hard body and distinct snout, metallic blue head, wing covers and abdomen. The legs and thorax are reddish brown. The females are usually larger than the males. Size: 5-7 mm in length.

Life cycle and biology:

The female lays single eggs into cavities in the stems of vines or in the storage root. The egg cavity is sealed with a faecal plug. The developing larvae tunnel and feed in the vine stem and storage root. Pupation occurs in the larval tunnels. After pupation, the adult emerges from the vine stem or storage root. Adult females cannot dig so they have to travel through cracks in the soil to reach the storage roots to lay their eggs.

Hot dry weather is ideal for larval development and a complete cycle from egg to adult takes about 33 days. Adults can live for 75-105 days and females can lay up to 250 eggs in a lifetime.

Damage:

Sweet potato weevil is considered to be the most important pest of sweet potato with higher infestation levels in the dry season. Immature larvae cause the most destructive damage feeding on the mature stems and storage roots. The adults feed on young leaf buds, leaves, vines and storage roots. Damage to the foliage leads to thickening, drying and cracking of the stems which makes the plant susceptible to infection by fungi and bacteria. Storage roots end up with a network of tunnels which contain faecal matter.

Monitoring and pest management:

Adults may be difficult to find as they are active at night. Look for feeding punctures and exit holes at the base of the stem. If above-ground damage is detected, roots should also be inspected for damage. Damaged storage roots produce terpines which have an unpleasant odour giving the harvested root a bitter taste and making it unfit for consumption.

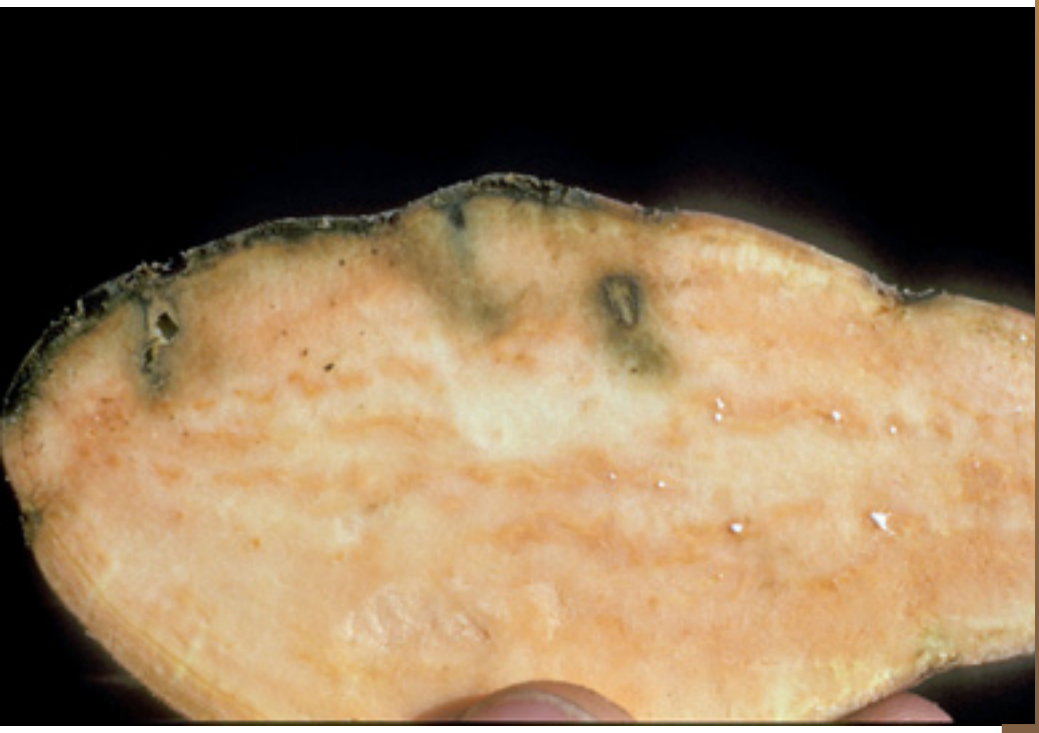
The most effective method of control involves various cultural techniques including: mounding up of soil around the base of the plants, filling soil cracks, reducing the development of soil cracks by using irrigation, crop rotation, removing infested material from previous plantings and using uninfested vines for planting.

Natural enemies:

The fungi, *Beauveria bassiana* and *Metarhizium anisopliae* attack the adults and entomopathogenic bacterium, *Bacillus thuringiensis* (Bt) and the nematodes *Heterorhabditis* spp. and *Steinernema* spp. attack the larvae.

Generalist predators include ants, spiders, ground beetles and earwigs.

Sweet potato weevils, *Cylas formicarius* on a sweet potato storage root.



Cross section of damage to storage root.

Twentyeight-spotted potato ladybird

Epilachna vigintioctopunctata (Family Coccinellidae) (previously known as *Henosepilachna vigintioctopunctata)*

Host plants:

Cucumber, watermelon, rockmelon, pumpkin, luffa, eggplant and potato.

Description:

Eggs: Eggs are yellow, oval in shape with one pointed end and are laid in upright clusters on the underside of leaves. Size: About 2 mm in length.

Immatures: Larvae are creamy-yellow and covered in black branched spines. Size: 5-9 mm in length.

Adults: Oval-shaped, pale brown or reddish brown in colour with 28 black spots (the spots are variable in size). Size: About 6-10 mm in length.

Life cycle and biology:

Eggs usually hatch within 3-4 days. The larval period is about 11-16 days and the pupal stage lasts for about 5-8 days. Adults generally live for a few weeks or longer depending on climatic conditions and their food source.

Damage:

Adults and larvae mainly feed by chewing on the leaves but can damage flowers or developing fruit. The adults feed on the upper surface of the leaves and the larvae feed on the underside of leaves. Leaves become skeletonised where it has been eaten leaving a network of veins joined by a clear film or window which is generally all that remains of the leaf. In heavy infestations, affected leaves drop prematurely and the yield may be affected.

Monitoring and pest management:

Monitor the crop regularly, at least every few days and look for larvae and adults. Remove crop residues after harvest to reduce the chance of populations carrying over onto new crops.

Natural enemies:

Natural enemies include wasp parasitoids (Family Eulophidae) of eggs, larvae and pupae.

Twentyeight-spotted potato ladybird, *Epilachna vigintioctopunctata* eggs and larva.

Twentyeight-spotted potato ladybird, *Epilachna vigintioctopunctata.*

Twentyeight-spotted potato ladybird, *Epilachna vigintioctopunctata* larvae feeding on a cucumber leaf.

Green vegetable bug

Nezara viridula (Family Pentatomidae)

Host plants:

Tomato, cucumber, asparagus, sweet corn, eggplant, other vegetables and field crops such as soybean.

Description:

Eggs: Newly laid eggs are cylindrical in shape, creamy-white and change to pinkish and then orange. Parasitised eggs are black. Size: About 1 mm in length.

Immatures: Nymphs vary in colour, newly hatched nymphs are orange and brown or black. Older nymphs are green or black (or green and black) with white, cream, orange and pink markings. Younger nymphs are more rounded or oval and the older nymphs and adults are shield-shaped. Younger nymphs aggregate in large clusters and older nymphs tend to disperse. Size: 1.5-15 mm in length.

Adults: Shield-shaped and bright green in colour, with three small white spots between the shoulders, yellow or orange coloured adults are occasionally seen. In colder weather the adults may be purple-brown. Size: 13-15 mm in length.

Life cycle and biology:

Females lay 20-150 individual eggs in a large raft on the underside of leaves. Eggs hatch in 5-7 days and the nymphs go through five stages which takes up to 35 days before maturing as adults. Adults live for 10-15 weeks.

The bugs produce a foul smelling odour when they are disturbed to deter predators.

Damage:

The green vegetable bug is an occasional pest that feeds on a range of vegetables. They feed by piercing and sucking sap from stems, leaves and fruit. Damage is seen as wilted shoots and distorted or shrivelled fruit. Although the green vegetable bug feeds on a range of vegetables and other horticultural crops, it prefers to feed on pods with well developed seeds.

Monitoring and pest management:

Inspect crops from early to mid morning. Look for bugs or damage which is usually seen at the top of the canopy.

Natural enemies:

The wasp, *Trissolcus basalis* (Scelionidae) parasitises the eggs. Tachinid flies, attack the fourth and fifth instar nymphs and adults.

Green vegetable bug, *Nezara viridula* nymph.

Green vegetable bug, *Nezara viridula* egg raft and newly hatched nymphs.

Green vegetable bug, *Nezara viridula*.

Migrating seed bug

Graptostethus servus (Family Lygaeidae)

Host plants:

Vegetables are not host plants for food, however swarming bugs may aggregate on vegetables as well as many other plants.

Description:

Eggs: Oval and when newly laid are shiny white with a slight yellow tinge, when they are ready to hatch they become pinkish in colour. Size: 1 mm in length (not normally seen).

Immatures: Similar to adults but smaller and without wings (not normally seen).

Adults: Orange-red with black markings and a cross pattern made by the folded wings. Size: 7-10 mm in length.

Life cycle and biology:

Eggs take 14-21 days to hatch, nymphs develop through four or five instars in about 30 days, adults live for about 80 days.

Four species are recorded from the Northern Territory and the most commonly seen species is *Graptostethus servus.* These bugs feed on seed pods of some field crops, native plants and weeds.

Damage:

Migrating seed bugs may aggregate in large numbers on flowers, fruit and shoots. They are attracted to moisture from irrigation, dew or rain. Although these bugs do not feed on vegetable or fruit crops, they occasionally cause indirect damage (seen as pin-prick spots), possibly caused by feeding on moisture found on fruit, shoots or flowers. Movement of large aggregations may disturb, blemish or produce scratch marks on fruit, flowers and shoots and can cause dessication of the leaves.

Monitoring and pest management:

Look for swarms on crops in the early morning. These bugs tend to aggregate on rural properties in the dry season, starting from early May. The swarms may stay on crops for 2-8 weeks or longer.

Natural enemies:

General predators may include praying mantises and spiders.

Migrating seed bug, *Graptostethus servus*.

Migrating seed bugs, *Graptostethus servus* aggregating on a shoot.

Passionvine bug

Fabrictilis gonagra (Family Coreidae) (previously known as *Leptoglossus australis)*

Host plants:

Cucumber, bitter melon and rockmelon as well as other cucurbits. Other hosts include passionfruit (and other plants in the family Passifloraceae) and citrus (and other plants in the family Rutaceae).

Description:

Eggs: Pale brown, round and laid in rows of up to 32. Size: 1.6 mm in length.

Immatures: The young nymphs are reddish with spines along the sides of the abdomen, similar in shape to the adult but without wings. Older nymphs have yellow and black markings. The final nymph stage is dark brown to black.

Adults: Black or dark brown with a reddish-orange or yellow curved band behind the head. The underside of the body has many red spots and the antenna segments are alternatively coloured black and red. The hind legs are wide and flat with many spines. Size: 18-24 mm in length.

Life cycle and biology:

Eggs are laid on the young tendrils and take 6-10 days to hatch. After hatching the nymphs which are gregarious move out across the plant to feed. They go through five instars and take about 52 days to develop into an adult. Adults can live for up to 14 days.

Damage:

Passionvine nymphs and adults are sap-suckers. Nymphs feed on the young tender shoots of the vine while the adults feed on developing and mature fruit penetrating to the seed. Damaged stems turn yellowish-brown and wilt. Damage to fruit may result in sunken spots, dimples or blemishes which change from green to orange-red. The pulp and seeds may also be damaged. Heavy feeding damage to mature fruit may lead to cracking.

Monitoring and pest management:

Monitor the flowers and developing fruit for damage or bugs. Passionvine bugs are not often reported as a pest in cucurbits although infestations when they do occur can downgrade the quality of fruit or make them unmarketable.

Natural enemies:

Assassin bugs prey on the nymphs and eggs. Generalist predators such as spiders and mantids prey on the nymphs. Wasps in the family Scelionidae are parasites of the eggs. Ants may also predate on the eggs.

Passionvine bug, *Fabrictilis gonagra*.

Feeding damage to cucumber.

Pod sucking bug

Riptortus serripes (Family Alydidae)

(Also known as large brown bean bug)

Host plants:

Snake bean.

Description:

Eggs: Dark purple-brown, ovoid in shape with a flat top and rounded base. They are laid singly. Size: 1.5 mm in length.

Immatures: Nymphs are brown with a green abdomen and are mimics of the green tree ant.

Adults: Dark brown, elongated body with a bright yellow stripe along each side and long antennae. They have a narrow body which is tapered in the middle with a spine on each side of the thorax and strong, spiny hind legs. The top of the abdomen is bright orange which can be seen when the bug is in flight. Size: 14-18 mm in length.

Life cycle and biology:

Pod sucking bugs move onto legume crops at flowering and start feeding and laying single eggs throughout the crop. Nymphs go through five growth stages and reach damaging size by the time pods are filling with developing seeds. Eggs take about 5-7 days to hatch and nymphs complete their development in about 15 days. There are about four generations per year.

Damage:

Pod sucking bugs feed by sucking sap from bean pods. Feeding damage is seen as puncture marks or spots, growth becomes distorted and seeds dry out.

Monitoring and pest management:

Monitoring is best carried out weekly and in the early morning. Look for pod sucking bugs on plants or flying off the crop. It is important to commence monitoring from flowering onwards and during pod development.

Natural enemies:

Predators of the egg and nymph stage include spiders, ants and predatory bugs.

Pod sucking bug, *Riptortus serripes*.

Pod sucking bugs, *Riptortus serripes* on a bean pod.

Shield bug

Oncocoris spp. (Family Pentatomidae)

Host plants:

Snake bean, eggplant, sweet corn, cucumber, field crops, citrus and various other crops and native plants.

Description:

Immatures: Newly hatched nymphs are red and black. As they mature they become mottled grey-brown with banded legs and resemble adults, but are smaller and do not have wings.

Adults: Greyish-brown or mottled dark brown on the upper surface and yellowish-brown underneath the body. Size: 7-10 mm in length.

Life cycle and biology:

These bugs have a similar life cycle to that of the green vegetable bug (refer to page 44). The bugs aggregate in large swarms generally from August through to April.

Damage:

Shield bug is a minor pest of vegetables in the Northern Territory. They are sap suckers preferring to feed on the seeds of mung beans, cowpeas and soybeans. Damaged seeds are deformed, stained or shrivelled around the feeding area. Occasionally large aggregations feed on new shoots of snake bean, eggplant, cucumber, citrus and native plants.

Monitoring and pest management:

Inspect the crop twice a week from flowering to harvest. Bugs are more likely to be seen at the top of the canopy in the early morning.

Natural enemies:

General predators include spiders, ants and predatory bugs. The eggs and young nymphs are more vulnerable to predation. Eggs may also be parasitised by parasitic wasps and tachinid flies.

Shield bugs, *Oncocoris* sp.

Shield bug, *Oncocoris* sp. feeding on sesame.

Bean podborer

Maruca vitrata (Family Pyralidae)

Host plants:

Snake bean, mung bean and cowpea. Occasionally in soybeans and peanuts.

Description:

Eggs: Pale cream and flattened.

Immatures: The larvae are creamy-yellow with a brown head and paired brown spots that run along their back. Mature larvae are up to 25 mm in length.

Adults: Moths have a wingspan of 20-25 mm and a slender body. The forewings are brown with a few translucent markings. The hindwings are translucent white with an irregular brown band along the margin. At rest, the moths have a characteristic pose with the front of the body raised and outspread wings.

Life cycle and biology:

The eggs are laid on the terminal buds, flowers and bean pods. Two days after hatching, larvae bore into the flowers, stems and bean pods. Entry points are often where flowers and pods are touching. The larval period is 10-12 days. When mature the larvae leave the pods and pupate in the soil for 5-8 days. Adults live for up to eight days.

Damage:

Feeding damage occurs in the flowers, stems and pods. Sometimes the flowers are eaten before the pods are formed. Once the larvae enter the pods, they eat the seeds. Entrance holes in the bean pod are often plugged with frass and webbing. Webbing produced by larvae may also be present where pods or flowers join stalks or touch leaves.

Monitoring and pest management:

Inspect flowers and leaves for webbing or larvae. Look for pods with entry holes plugged with frass and webbing. Moths shelter amongst the foliage during the day and may be seen flying off the host plant when disturbed.

Control with pesticides is difficult as larvae are protected when feeding in flowers or pods. Therefore, pesticides are more effective when applied before the larvae enter the pods.

Natural enemies:

Parasitic wasps, parasitic flies, predatory wasps, spiders and ants.

Bean podborer, *Maruca vitrata* larva feeding inside a bean pod.

Bean podborer, *Maruca vitrata.*

Bean podborer, *Maruca vitrata* larvae on stems and bean pod with webbing and frass.

Cluster caterpillar

Spodoptera litura (Family Noctuidae)

Host plants: Broccoli, cabbage, maize, taro, tomato, sweet corn and many other vegetables and field crops.

Description:

Eggs: Laid in clusters of up to 300 eggs and covered in a layer of pale-brown 'furry or cottony' hair-like scales.

Immatures: Young larvae cluster together and have a partly translucent green body with a dark thorax and head. Half-grown larvae are variable in colour and have a red and yellow pattern with green lines and black spots running along each side of the body. There is a dark patch on the 'hump' behind the head. Mature larvae are brown with three thin pale yellow/orange lines running down the length of the body. Along each side there is a row of black dots as well as a row of half moon-shapes along the back. The last larval stage is darker. Size: 50 mm (or longer) in length.

Adults: Moths have brown forewings with brown and cream coloured markings. The hindwings are white and partly translucent with a brown edge. Size: Wingspan 35-40 mm.

Life cycle and biology:

Clusters of eggs are usually laid on the underside of leaves. Eggs hatch within 3-4 days. The larvae go through six larval stages and reach maturity in about 2-3 weeks, then they move off the plant and pupation takes place in the soil over approximately 10 days.

Damage:

After hatching the small larvae chew on the surface of the leaves, creating a 'window effect' ('see-through' leaf with an unbroken upper leaf layer). The older larvae move out across the plant and chew holes in the leaves. Larvae will also feed on the stems, flowers and developing fruit. Seedlings may also be chewed off at ground level.

Monitoring and pest management:

It is important to start monitoring just before flowering and onwards. The high risk period is at flowering and fruit development. Inspect plants for egg masses and clusters of young larvae.

Cluster caterpillar is controlled by most pesticides targeted at *Helicoverpa,* but they are not controlled by nucleopolyhedrovirus (NPV) and are difficult to control with *Bacillus thuringiensis* unless they are very young or recently emerged from eggs.

Natural enemies:

Predatory bugs such as the spined predatory bug, big-eyed bug and assassin bugs attack the eggs and larvae. Other predators that attack the immature stages are ants and lacewing larvae.

Parasitic wasps attack the eggs, larvae and pupae. Parasitic flies (Tachinidae) attack the larvae.

Cluster caterpillar, *Spodoptera litura* egg mass.

Cluster caterpillar, *Spodoptera litura*, larva feeding inside a capsicum fruit.

Cluster caterpillar moth, *Spodoptera litura.*

Cluster caterpillar damage to an eggplant fruit.

Corn earworm and native budworm

Corn earworm, *Helicoverpa armigera* (Family Noctuidae)

Native budworm, *Helicoverpa punctigera* (Family Noctuidae)

Host plants:

Both species are polyphagous.

Corn earworm: Cabbage, tomato, sweet corn/maize, pumpkin, zucchini, other vegetables, field crops, ornamentals, weeds and a wide range of other plants (hosts include dicotyledonous and monocotyledonous plants).

Native budworm: Tomato, field crops and a wide range of cultivated and native plants (hosts are mainly dicotyledonous plants although cereals are occasionally attacked).

Description:

Eggs: Round, ribbed and pearlescent white in colour when first laid, turning light brown as they mature and finally black just before hatching. Size: 0.5 mm in diameter.

Immatures: Newly emerged larvae are hairy, cream-coloured and have a dark brown head. Older larvae vary in colour, they are generally green, pink, light brown or dark brown with markings. There are sparse hairs on the body. To distinguish between species, check mature larvae for the colour of the setae behind the head and the colour of the legs. Corn earworm has light coloured setae with dark coloured legs and native budworm has black setae with light coloured legs. Size: About 40 mm in length when mature.

Adults: Both species have light brown wings with dark brown markings and the hind wings have a broad dark brown band around the edge. On the hindwing of the corn earworm, this band has a pale marking whereas on the native budworm the band is uniformly dark brown. Size: Wingspan up to 41 mm.

Life cycle and biology:

Eggs are laid singly or in groups of 2-3 on leaves, flowers, fruit and growing tips. These eggs usually hatch within 1-2 days. In the Top End, larval development takes about 10-14 days and there are five or six instars. When mature the larvae move into the soil and pupate. Pupal development takes about 10 days. Adults live for up to 10 days and females can produce about 1000 eggs in a lifetime.

Damage:

Larvae feed by chewing on leaves, flowers and developing fruit. Damage to the crop especially during flowering and fruiting can be extensive and this may result in a decreased yield.

Monitoring and pest management:

Monitor the crop once a week during early establishment and then twice a week from flowering to harvest. Inspect the growing tips and flowers for eggs or larvae. A small amount of damage to the vegetative shoots can be tolerated but if the flowers and developing fruit are being attacked, control should be considered.

Corn earworm has been more consistently associated with agricultural crops and therefore has had exposure to pesticide selection (and has developed resistance to many chemical pesticides).The native budworm is not known to have resistance to pesticides. Therefore it is important to identify the species on the crop.

Since pupae are found within the top 10 cm of the soil, ploughing the soil within this region will generally destroy the pupae.

Biopesticides such as nucleopolyhedrovirus (NPV) and *Bacillus thuringiensis* may be useful in controlling infestations.

Natural enemies:

Predatory bugs such as the spined predatory bug, big-eyed bug and assassin bugs attack the eggs and larvae. Other predators that attack the immature stages are ants and lacewing larvae.

Parasitic wasps attack the eggs, larvae and pupae. Parasitic flies (Tachinidae) attack the larvae.

Corn earworm, *Helicoverpa armigera* with a pale marking on the brown band of the hind wing.

Native budworm, *Helicoverpa punctigera* without a pale marking on the brown band of the hind wing.

Corn earworm, *Helicoverpa armigera* larva feeding on sweet corn.

Cucumber moth

Diaphania indica (Family Pyralidae)

Host plants:

Cucumber, rockmelon, watermelon, zucchini and bitter melon.

Description:

Eggs: The eggs are creamy white in colour. Size: 1-2 mm long.

Immatures: The larvae are pale to dark green with a white stripe running along both sides of the body. Size: Up to 15 mm in length.

Adults: The moths are white with a dark brown band around the wing margins. The abdomen has a dark brown band and at the tip there is a tuft of brown hairs which is thicker on the females. Size: Wingspan 20-25 mm.

Life cycle and biology:

The female lays eggs on the underside of leaves and soft stems. Eggs take 1-7 days to hatch. Larvae take about three weeks to mature and then pupate. Pupae are generally found in the soil, under fruit or debris and sometimes in a silken canopy in the leaves. The pupal period takes about two weeks. The lifespan of the adult is 1-2 weeks and they are most active at night.

Damage:

Although the larvae feed on leaves and stems, young leaves and growing tips are preferred. Occasionally the larvae feed on the flowers. Large sections of plants can be damaged and parts of the leaves can be joined together with silk and faeces. Larvae will attack the developing fruit especially if they are in contact with the ground. Chewing damage can be seen as shallow holes in the surface of the fruit and sometimes mature larvae will pupate in these areas. Feeding damage to fruit will downgrade the quality or the crop may become unmarketable.

Monitoring and pest management:

Crops should be inspected twice a week to look for larvae on the underside of leaves, soft stems, growing tips and developing fruit.

If a pesticide is required, a biopesticide such as *Bacillus thuringiensis* should be used as a first option as it does not affect beneficials. This product is only effective if applied to very young recently emerged larvae. Thorough spray coverage is also required.

Natural enemies:

Predatory bugs attack the eggs and larvae. Ants and lacewing larvae may also assist in the control of immature stages.

Cucumber moth, *Diaphania indica* larvae feeding on bitter melon

Cucumber moth, *Diaphania indica.*

Diamondback moth

Plutella xylostella (Family Yponomeutidae)

Host plants:

Buk choy, cabbage and other cruciferous vegetables.

Description:

Eggs: Pale yellow, flattened and oval-shaped. Size: 0.5 mm in length.

Immatures: Larvae are pale-green or grey-green with a dark head and a darker green stripe running down the body. Size: Up to 12 mm in length.

Adults: Grey-brown with a white diamond-like pattern along the back where the folded wings meet (viewed when the adult is at rest). Size: 10-12 mm in length.

Life cycle and biology:

Eggs are laid either in clusters of two or three, or singly on leaves and stems. More than 150 eggs can be produced by the female moth in a lifetime. There are four larval stages, the first two stages tunnel inside the leaf. While feeding in the 'leaf mines', the young larvae are protected from natural enemies and some pesticides. As they mature they feed on the undersides of the leaves. When disturbed the larva will wriggle backwards and sometimes drop off the leaf, as it falls, it spins a silken thread from which it becomes suspended.

Larvae are favoured by warm and dry conditions. In the wet season mortality will be higher due to larvae being washed off the leaves as well as being affected by diseases associated with wet or humid weather.

At maturity the larva pupates in a green cocoon which eventually turns brown and is surrounded by lacy white silk. Development from egg to adult usually takes 14-21 days. Adults have the ability to migrate and disperse over long distances.

Damage:

Larvae feed on the leaves, stems, flowers and seed pods. Damage is seen as holes in the leaves, or 'windows' ('see-through' leaf with an unbroken upper leaf layer) where larvae have tunnelled into the leaf. When infestations are high, leaves may be skeletonised.

Monitoring and pest management:

Check the upper and lower leaf surfaces of young leaves and growing tips for larvae, frass and damage. Adults are not usually seen as they are nocturnal.

Diamondback moth has developed resistance to many insecticides including synthetic pyrethroids and organophosphates. Interstate studies have reported that biopesticides such as *Bacillus thuringiensis* and spinosad may assist with control.

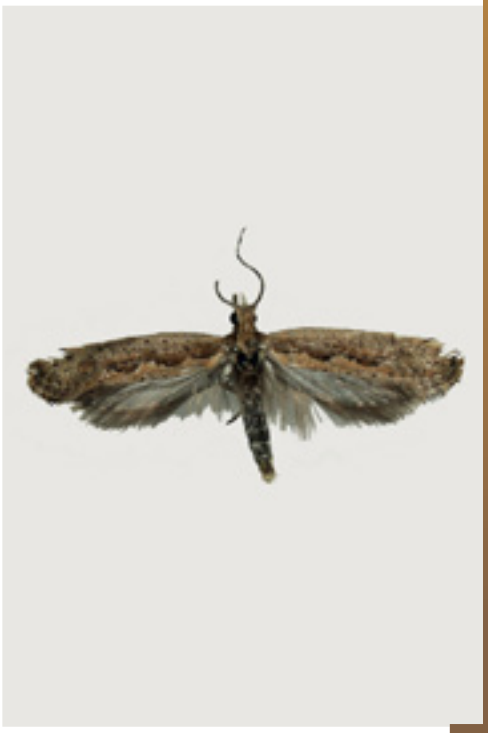
Natural enemies:

Natural enemies include wasp parasitoids which lay eggs into the larvae or pupae (egg parasitoids have been recorded interstate). Lacewing larvae, predatory bugs and spiders feed on the eggs, larvae and pupae. In warm weather with rain and high humidity, the larvae are generally affected by fungal disease and become slow-moving, turn yellow and die.

Diamondback moth, *Plutella xylostella* larva.

Diamondback moth, *Plutella xylostella* pupa.

Diamondback moth damage to buk choy leaf.



Diamondback moth, *Plutella xylostella.*

Eggfruit caterpillar

Sceliodes cordalis (Family Pyralidae)

Host plants:

Eggplant is the preferred host although tomato and capsicum are occasionally attacked. Solanaceous weeds may also be a host.

Description:

Eggs: Oval and creamy-white in colour with a flattened ridge running along the length. As they mature they turn red.

Immatures: The newly hatched larvae have a brown head and are almost opaque turning cream in colour as they develop. Fully grown larvae are pink with a brown head.
Size: Up to 20 mm in length.

Adults: Moths have brown and white wings. The tips of the forewings are dark brown with a black margin. The hindwings are predominately white with a brown margin and a few brown markings. These moths carry their abdomen in a distinctive up-turned manner.
Size: Wingspan up to 27 mm.

Life cycle and biology:

The female moth lays one or two eggs per fruit on the calyx and can lay up to 100 eggs per night. Larvae hatch in about three days and tunnel into the fruit. Larval development takes about 10 days and pupal development takes about seven days at 30°C. The complete life cycle takes about three weeks. In warm temperatures the eggfruit caterpillar is active all year.

Damage:

Once the newly hatched larvae have tunnelled into the fruit they feed inside the fruit making a network of tunnels which are filled with faecal matter. Larvae may also tunnel into the stems which causes the plant to wilt. Larvae that feed inside fruit continue to feed until they mature and exit the fruit to pupate in a white silken cocoon.

Exit holes on the skin of fruit at harvest make the fruit unsaleable. If the larvae are still in the fruit at the time of harvest, fruit may be picked and processed without the damage being detected until the larvae emerge or the fruit is cut.

Monitoring and pest management:

Monitoring should be carried out at regular intervals. The most effective time to control the infestation is the period just after the eggs hatch and before the larvae tunnel into the fruit or stems. The caterpillars are difficult to control once they have tunnelled into the fruit or stems as they are protected from chemical sprays. Look for eggs and young larvae on the fruit and around the calyx.

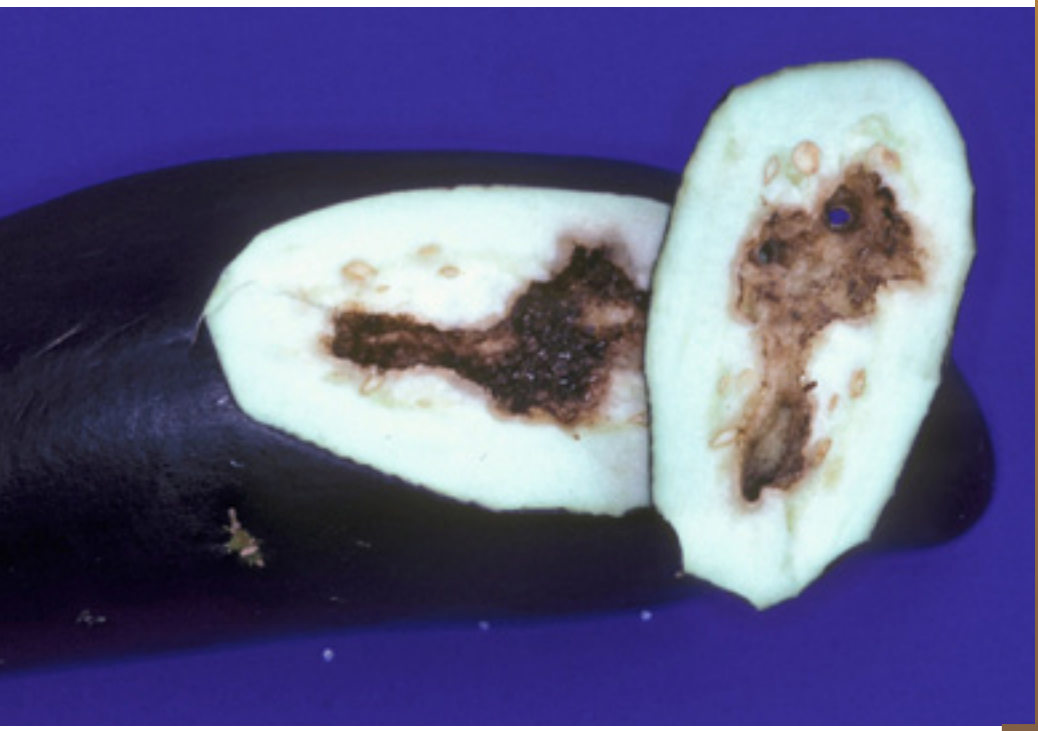
Practising good farm hygiene and removing old crop residue at the end of harvest will help to reduce the infestation level in the field.

Natural enemies:

Trichogrammatid wasps parasitise the eggs.

Eggfruit caterpillar, *Sceliodes cordalis* larva. Image courtesy of S. Subramaniam (DAFF Qld).

Eggfruit caterpillar, *Sceliodes cordalis,* adult moth.



Larval damage to eggplant fruit.

Bean fly

Ophiomyia phaseoli (Family Agromyzidae)

Host plants:

Snake bean, French bean, round bean, flat bean, soya bean and other beans.

Description:

Eggs: Oval and cream coloured. Size: About 1 mm in length.

Immatures: Cream coloured maggots. Size: Up to 3 mm in length.

Adults: Shiny black body with clear wings. Size: Up to 3 mm in length.

Life cycle and biology:

Females lay eggs singly into the upper leaf surface of seedlings as well as young leaves of mature plants. After about two days, the eggs hatch into larvae and feed in the stem for a week before pupating in the lower stem for another week. The entire life cycle takes 2-3 weeks. Females can lay 100 to 300 eggs during a lifetime.

Damage:

Bean fly is the most serious pest of snake bean in the Northern Territory during the dry season. Egg laying is seen as white or yellow puncture marks on the upper leaf surface. Once hatched, larvae tunnel into the leaf tissue through the petiole and then into the stem. Seedlings that are attacked in the first ten days after germination usually show wilting of the first two leaves and die as a result of larvae destroying the internal stem tissue. In older plants, the larvae tunnel into the leaf and stems and feed on the internal tissues. Damage to older plants is seen as wilting, yellowing and stunting. Affected stems become thickened, cracked and have brown scarring. Older plants may survive but branches will readily break off.

Monitoring and pest management:

Monitor seedling crops twice a week. Inspect leaves for small yellow spots caused by egg-laying or feeding punctures. Also look for larval tunnelling at petioles and in the stems, which are swollen and usually cracked.

The critical control period is the week after germination. Control sprays should be applied if there is more than one larval tunnel per plant. Crop rotation by alternating between different non-bean crops will reduce the level of bean fly populations. Systemic pesticides will assist with control.

Natural enemies:

Six species of parasitic wasps have been bred from bean fly pupae in the Darwin area.

Bean fly, *Ophiomyia phaseoli* on leaf with yellow puncture marks from egg laying.

Bean fly, *Ophiomyia phaseoli.*

Cracked and thickened leaf petiole and stem with brown scarring.

Cucumber fly

Bactrocera sp. nr. *cucumis*
(Family Tephritidae)

Host plants:

Damaged, ripe or over-ripe fruit such as angled loofah, cucumber and tomato.

Description:

Eggs: Pale cream-coloured and elongate. Size: About 1 mm in length.

Immatures: The larvae are white or cream coloured maggots with a black tooth-like feeding mouth part. Size: Up to 7 mm in length when mature.

Adults: Golden brown with yellow markings on each side of the thorax with a central stripe on the middle of the thorax and a narrow waist. Size: About 8 mm in length.

Life cycle and biology:

Females 'sting' (pierce) ripe or damaged fruit with the ovipositor and lay clumps of eggs under the skin. In Queensland, a closely related species, *Bactrocera cucumis* lays eggs into the fleshy green fruit stalk of some cucurbits.

Eggs hatch within 1-2 days and larvae feed on the flesh of the fruit and take 6-8 days to mature. When mature the larvae 'flick' out of the fruit and pupate in the soil. After 10-12 days in the pupal stage, the adult emerges.

Damage:

Damage is occasionally seen as sting marks on over-ripe or damaged (but not rotten) fruit. Larvae tunnel into the fruit and feed on the flesh, introducing bacteria which leads to fruit decay.

Monitoring and pest management:

Inspect fruit for sting marks. If tomatoes are 'stung' the damage is most likely caused by the Queensland fruit fly as the cucumber fly only occasionally stings tomatoes. In the Northern Territory it is uncommon to find commercial fruit being affected by cucumber fly, however, occasionally home garden cucurbits or tomatoes that are ripe, over-ripe or damaged are infested.

To reduce populations, practice good farm hygiene by removing fallen fruit and do not let ripe or over-ripe fruit stay on the crop as this allows fruit flies to breed and build up populations on the property.

Refer to the Department's Interstate Certification Assurance (ICA) conditions for pest management advice.

Natural Enemies:

Although the parasitoid opiine wasps (family Braconidae), are known to attack Queensland fruit fly larvae within the fruit, these wasps are not effective in parasitising cucumber fly.

Further information on pest status:

Although this species is similar in appearance to *Bactrocera cucumis* which is found in Queensland and New South Wales, and a major pest of cucurbits and pawpaw, the local species is not a serious pest.

Cucumber fly, *Bactrocera* sp. nr. *cucumis* female and male in copulation.

Numerous larvae in laboratory infested cucumber.

Queensland fruit fly

Bactrocera tryoni (Family Tephritidae)

Host plants:

Tomato, capsicum, chilli and many other commercial and native fruits.

Description:

Eggs: Cream to white in colour and elongated. Size: About 1 mm in length.

Immatures: White or cream-coloured maggots with a black tooth-like feeding mouth part. Size: Up to 8 mm in length.

Adults: The fly is red-brown or yellow-brown with yellow markings on each side of the thorax with a narrow waist. They have clear wings with two dark bands which form a rough 'v-shape'. Female flies have an ovipositor at the rear end which gives them a 'wasp-like' appearance. Size: 9-10 mm in length.

Life cycle and biology:

Females lay clumps of 6-10 eggs just under the skin of the fruit. Larvae hatch within 1-2 days and feed on the flesh of the fruit and take 6-8 days to mature. When mature, the larvae 'flick' out of the fruit and pupate in the soil. After 10-12 days in the pupal stage, the adult emerges.

Damage:

Females will infest immature hard green or ripening tomatoes, however, capsicums and chillies are more likely to be 'stung' when they start to ripen. The sting mark on the fruit where the female fly has laid eggs appears as a pin-pricked mark that is sometimes surrounded by a softened or bruised area. As the larvae feed, they tunnel through the fruit which causes the flesh to decay. If an infested fruit with advanced symptoms is cut or opened to expose the flesh, maggots can be seen and if these are mature they will be ready to flick out of the fruit to pupate in the soil.

Monitoring and pest management:

Inspect fruit for sting marks, adult females may be seen on mature fruit. If tomatoes are 'stung' the damage is most likely caused by the Queensland fruit fly, although the cucumber fly occasionally stings tomatoes.

Refer to the Department's Interstate Certification Assurance (ICA) conditions for pest management advice.

Natural Enemies:

Parasitoid opiine wasps (family Braconidae), are known to attack Queensland fruit fly larvae within the fruit.

Queensland fruit fly, *Bactrocera tryoni* larvae.

Queensland fruit fly, *Bactrocera tryoni* female.

Sting marks from egg laying on tomato fruit.

Broad mite

Polyphagotarsonemus latus
(Family Tarsonemidae)

Host plants:

Eggplant, capsicum, tomato, chilli, silverbeet and a wide range of other vegetables. Other hosts include ornamentals.

Description:

Eggs: Oval and elongate with a flat base, translucent and covered with a spotted pattern of white tubercles. Size: Less than 0.1 mm long.

Immatures: Similar to the adult but smaller, yellowish to transparent in colour. Size: Up to 0.2-0.3 mm in length when mature.

Adults: The female mite is transparent to pale brown and broadly oval-shaped. The male is broadly short, tapered towards the rear end and has long legs. Size: The female is 0.2-0.3 mm in length while the male is much smaller.

Life cycle and biology:

Females lay up to five eggs per day on the underside of new leaves and may produce up to 75 eggs in a lifetime. Larvae hatch after 2-3 days and start to feed. The larvae are slow moving and develop into a non-feeding and inactive quiescent stage. Quiescent female larvae become attractive to the males which pick them up and carry them to new leaves for mating later. Broad mites only take 4-5 days to complete a generation in the dry season. Adults can live for up to 13 days.

Damage:

Broad mites are usually found in the growing tips on the underside of new leaves and under the calyx of flowers and fruit. A small number of mites can produce visible damage symptoms which is seen as thickening, bronzing/greying and curling. Young terminal buds on new shoots may become distorted due to heavy infestations and these can die and drop off. In severe infestations entire plants may die.

Monitoring and pest management:

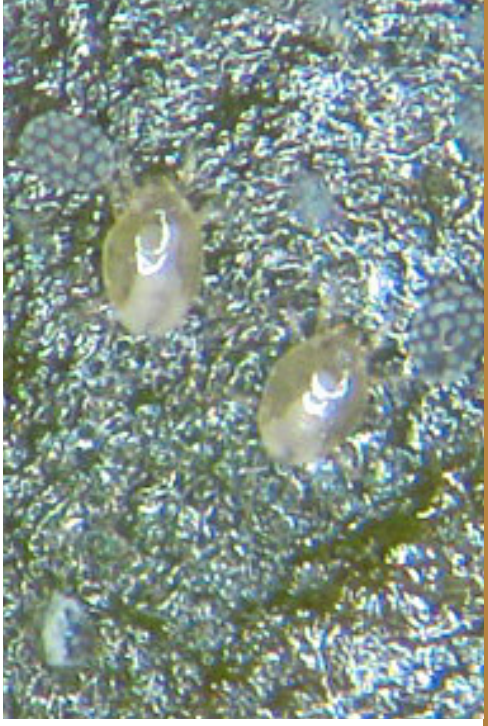
Early detection is necessary for effective management of the mite. It is important to provide close inspection of the new growth at weekly intervals. Look for adults and eggs on the underside of young apical leaves and within flowers. These mites may also be seen in crevices and buds. Avoid introducing infested plant material onto the property. Use seedlings that have been grown away from infested areas.

Most registered chemicals do not kill the egg stage or have enough residual activity to kill hatching larvae. The most effective method of management is to encourage natural enemies or introduce commercially supplied predatory mites.

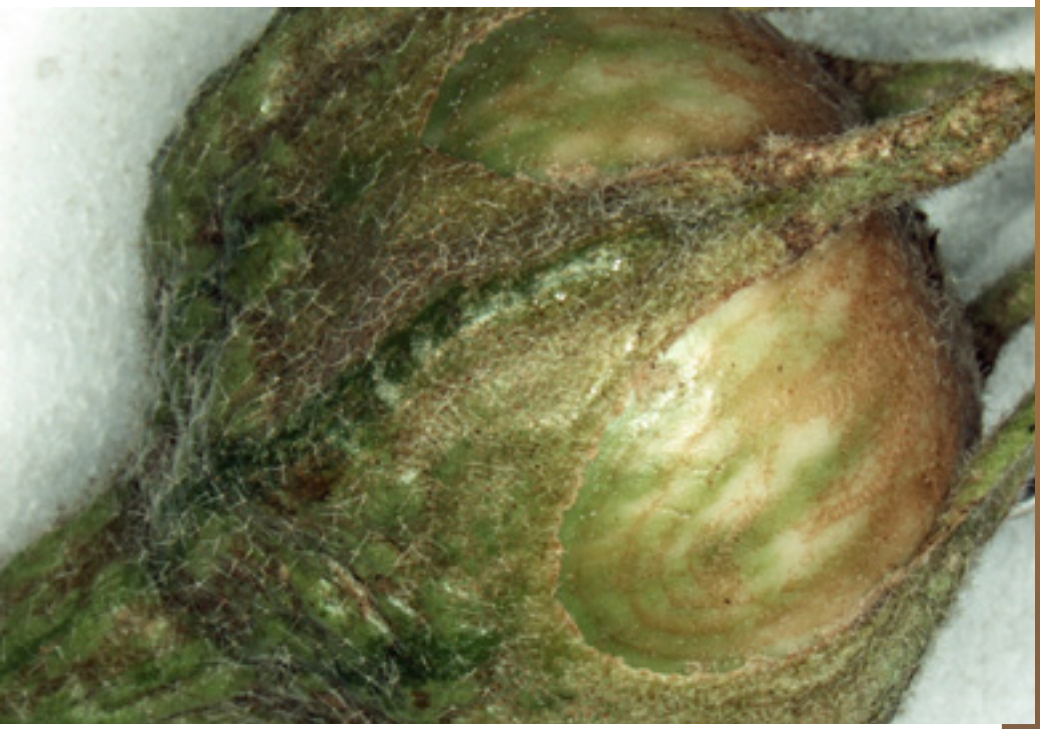
Natural enemies:

Lacewing larvae, other general predators and the commercially supplied predatory mite, *Neoseiulus cucumeris.*

Broad mites, *Polyphagotarsonemus latus* on Thai round eggplant.



Broad mites, *Polyphagotarsonemus latus,* adults and eggs.



Bronzing and scarring on young developing Thai round eggplant.

False spider mites

Brevipalpus phoenicus and *B. californicus* (Family Tenuipalpidae)

Host plants:

Eggplant, tomato, loofah, pumpkin, snake bean and a wide range of other vegetables, fruit trees, other crops and ornamentals.

Description:

Eggs: The eggs are oval-shaped and orange to bright red in colour. Size: 0.1 mm in length.

Immatures: Six-legged larvae and eight-legged nymphs are bright orange-red, oval and flattened. Size: Up to 0.3 mm in length when mature.

Adults: Flattened, oval-shaped body which narrows at the end of the abdomen. They are bright red to reddish-brown in colour with two pairs of legs spread out at the front of the body and two pairs at the back. Size: 0.2-0.3 mm in length.

Life cycle and biology:

The slow moving female mites lay single eggs near the main veins on the underside of leaves. They can lay a few eggs per day for about 25 days. Under dry season conditions, the eggs will hatch in about seven days and development from larvae to adults is about 20 days.

Damage:

False spider mites are more common during hot dry weather. Mites feed on the underside of leaves and also on stems and petioles. Feeding damage varies, symptoms include brown or red leaf discoloration, chlorosis, blistering, curling and defoliation. False spider mites do not produce webbing.

Monitoring and pest management:

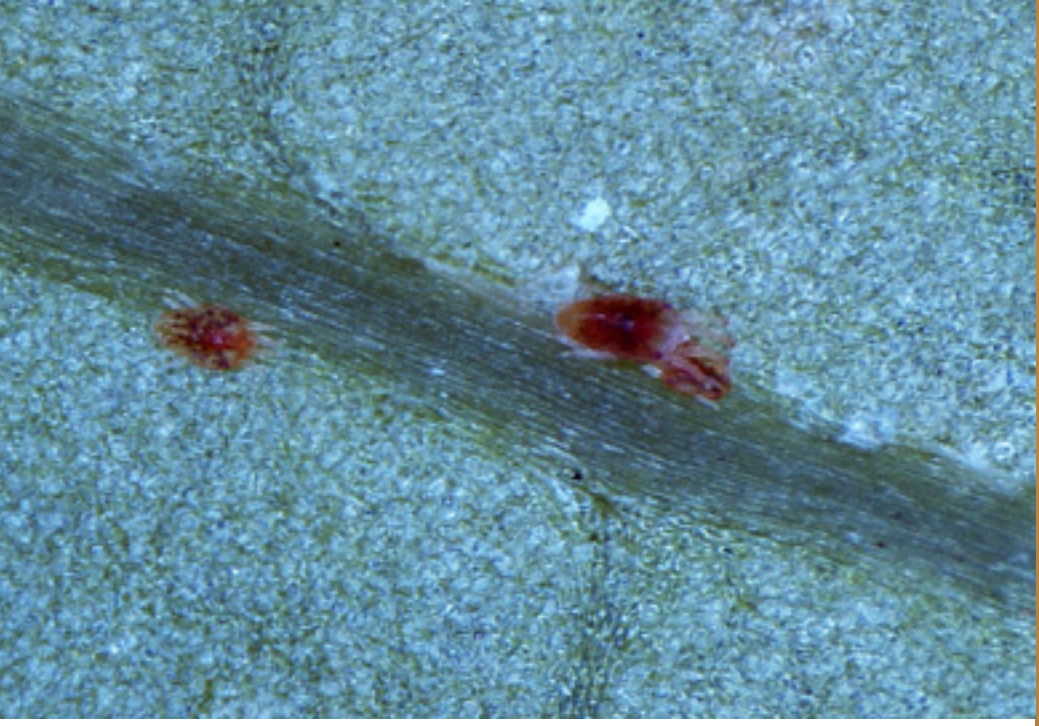
Monitoring should include close inspection of the plants at fortnightly intervals during the growing season. Look for bright red eggs (which are easier to see with the naked eye than the other life stages) and for white cast skins.

Avoid introducing infested plant material into the crop or clean area. Use seedlings that have been grown away from infested areas.

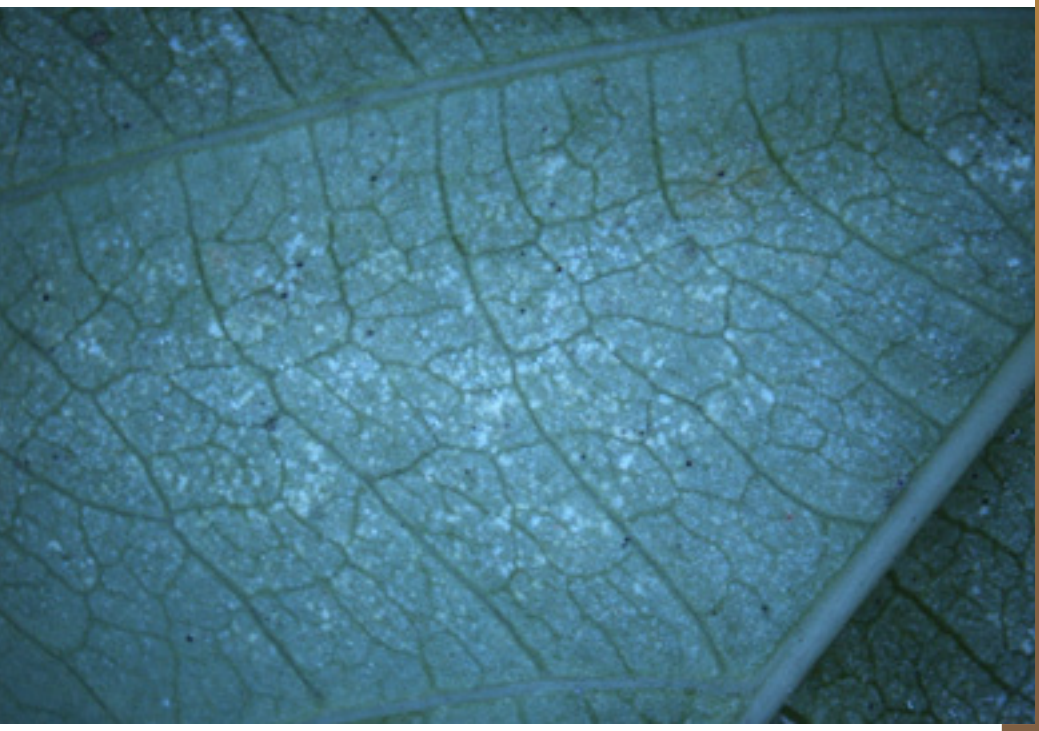
Miticides may assist with control although it is important to be aware of chemical resistance.

Natural enemies:

Various species of native predatory phytoseiid mites are found naturally in vegetable crops and these assist in the biocontrol of false spider mites.



False spider mites, *Brevipalpus* sp.



False spider mite damage on a leaf.

Rust mite

Calacarus sp. (Family Eriophyidae)

Host plants:

Capsicum, chilli and tomato

Description:

Eggs: The eggs are round and colourless to whitish. (Eggs are too small to be seen with the naked eye).

Immatures: Similar to adults but are smaller.

Adults: Torpedo-shaped with two pairs of legs at the front of the body. They are deep-purple in colour and covered with longitudinal white waxy ridges. Depending on the amount of wax present, the adults may appear pale purple. Size: The females are less than 0.25 mm in length and the male is smaller.

Life cycle and biology:

The eggs are laid on leaves and stems. The mites prefer exposed areas on the foliage. In ideal conditions of 27°C and 30% relative humidity, the eggs hatch within two days and the total life cycle from egg to adult is completed in about seven days.

Damage:

The mite has similar habits to those of the tomato russet mite and occurs on vegetable crops during the dry season. Both old and young plants are attacked and although tender parts including young leaves are attacked, the upper surface of older leaves is the preferred feeding site. Feeding damage on chilli plants causes bronzing and distortion of the leaves. On tomato plants, the surface feeding produces a bronzing or rusted appearance on both the stems and leaves. Infested leaves first curl at the leaf edges and become distorted, turn coppery-brown, dry out and drop prematurely.

Monitoring and pest management:

Weekly monitoring for these mites is essential and early detection of the first symptoms should commence when chilli and tomato plants are young.

To reduce the incidence of these mites, it is recommended that growers practice crop rotation since mites can move from old leaves on the ground onto new plants. Efficient removal of plant residues from the old crop will reduce the chance of infestation onto the new crop.

Various miticides may assist in the management of pest populations.

Natural enemies:

Native phytoseiid, tydeid and stigmaeid mites are predators of rust mites.

Rust mites, *Calacarus* sp. and their cast skins.

Underside of tomato leaves with curled margins and leaves becoming distorted.

Tomato russet mite

Aculops lycopersici (Family Eriophyidae)

Host plants:

Tomato, eggplant, capsicum, potato and various other plants.

Description:

Eggs: Round and transparent to white. They are too small to be seen with the naked eye.

Immatures: There are two nymphal stages which are torpedo-shaped, yellowish in colour with two pairs of legs and look similar to the adult. Size: Less than 0.2 mm in length when mature.

Adults: Cream to light grey-brown in colour, torpedo shaped with two pairs of legs at the front of the body. They are not visible to the naked eye. Size: Up to 0.2 mm in length.

Life cycle and biology:

Eggs are laid on leaves and stems of plants. They are often deposited among the leaf hairs or in small crevices. Under optimum conditions at 27°C and 30% relative humidity, the eggs will hatch in two days, and the total life cycle from egg to adult is completed in about seven days. Female mites live for several weeks and may produce up to 50 eggs during a lifetime.

Damage:

Tomato russet mites are serious pests of tomatoes. They live and feed on all green surfaces, and are spread easily at harvest by humans. Mites feed on the plant by puncturing and scraping the surface of the cells and sucking the sap. Damage usually starts at the base of the plant and spreads upwards over the stems and leaves. Feeding causes stem and leaf surfaces to have a bronzed appearance. Damage on fruit causes uneven ripening and immature or mature fruit may have pale green, yellow or white skin blemishes. Infested leaves curl up at the edges, become dry and drop-off. If leaf drop occurs, fruit may be exposed and become sunburnt.

Monitoring and pest management:

The warm, dry conditions of the dry season are favourable to the development and reproduction of the mites. It is important that any infestation is detected early. Plants should be inspected closely for damage symptoms during the growing season, especially at early fruiting. Mites may be seen when inspecting the bronzing damage on the lower leaves and stems.

Russet mites are readily spread by people and equipment, so care should be taken to minimise movement within infested fields. Avoid introducing infested plant material into the crop or property. Use seedlings that have been grown away from infested areas.

Miticides may assist with control although it is important to be aware of chemical resistance.

Natural enemies:

Predatory thrips *Scolothrips sexmaculatus* and some native phytoseiids, tydeid and stigmaeid mite species feed on russet mites.

Tomato russet mites, *Aculops lycopersici* on a tomato leaf.

Early damage is seen as curling at the leaf margins.

Two spotted mite

Tetranychus urticae (Family Tetranychidae)

Host plants:

Watermelon, pumpkin, eggplant, snake bean, taro as well as a large range of other crops, native plants, ornamentals and weeds.

Description:

Eggs: Round and translucent white, pale yellow or green in colour with red eye-spots before hatching. Size: About 0.1 mm in diameter.

Immatures: Newly hatched six-legged larvae are pale. Eight-legged nymphs are yellow-green with dark spots. Size: Up to 0.4 mm in length when mature.

Adults: The adults are oval-shaped with four pairs of legs. Mites vary in colour depending on the host plants that they feed on. The mites are usually greenish-yellow with two large dark spots on the shoulders. In cooler dry weather, they may be orange-red in colour. Size: The females are 0.4-0.5 mm in length while the male is smaller.

Life cycle and biology:

The female lays single eggs near the veins on the underside of leaves. At 30-32°C, the larva hatches within 3-7 days and goes through two nymphal stages before becoming an adult. The development time from egg to adult is usually about a week but can take up to three weeks depending on climatic conditions. Mature females can lay up to 20 eggs per day and more than 100 eggs in a lifetime. Adults can live for up to 30 days.

Damage:

Two-spotted mites feed by piercing leaf cells and sucking out the contents, which causes the cells to collapse and die. This damage is seen as pale-coloured spotting on the upper surface of the leaves. The mites prefer the young leaves and produce very fine, silk-like webbing. When large populations have been present for a few weeks, webbing may cover the whole plant and mites are found on both sides of the leaves. A high infestation of mites may cause leaves to dry and drop-off and plants may die prematurely.

Monitoring and pest management:

Monitoring should start in the early dry season and then at weekly intervals prior to flowering and throughout fruit development. Inspect the upper surface of leaves for whitish or yellowish patches or spots and examine the underside of leaves for mites using a hand lens.

Avoid introducing infested plant material into the crop. Use seedlings that have been grown away from infested areas.

The most effective method of control is releasing predatory mites (see below) and with spot spraying of potassium soap with added spray oil. Note that spraying may cause leaf burn to sensitive plants.

Natural enemies:

Natural enemies of two spotted mite are native phytoseiid mites, predatory thrips (*Scolothrips sexmaculatus*), green lacewing larvae (*Mallada basalis*) and predatory midge (*Feltiella acarivora*).

Commercially supplied predatory mites *Phytoseiulus persimilis* and *Typhlodromus occidentalis* are ideal for control in some crop situations when natural enemies are in low numbers.

Two spotted mite, *Tetranychus urticae* adult and egg.

Two spotted mites, *Tetranychus urticae* on watermelon leaf showing feeding damage.

Giant northern termite

Mastotermes darwiniensis
(Family Mastotermitidae)

Host plants:

Sweet potato, cassava, eggplant, chilli and many horticultural crops.

Description:

Eggs: Eggs are small, elongated, cream coloured and laid in rafts.

Immatures: Similar to workers but smaller.

Adults: There are several different castes:

Workers - soft bodied, off-white in colour and often the gut contents can be seen through the body wall. Size: 10-11.5 mm in length.

Soldiers - soft bodied with an off-white coloured body and an orange/brown head with large mandibles. Size: 11-13 mm in length.

Winged reproductives - dark brown with wings. Size: 35 mm in length including wings.

Primary reproductives - dark brown with severed wings. Size: 15 mm in length.

Secondary reproductives - these are slightly larger than workers and are dark brown all over and without severed wings.

Workers, soldiers and secondary reproductives are completely blind, while nymphs and primary reproductives have distinct eyes.

Life cycle and biology:

The eggs hatch into nymphs or larvae. Nymphs develop into winged reproductives and larvae develop into workers or soldiers. After a mating flight, the winged reproductives lose their wings and become kings and queens (primary reproductives) but are rarely seen. Workers can also change into secondary reproductives which are more common. The soldiers and workers can live for 1-2 years.

Damage:

The giant northern termite has subterranean colonies and bores into plants from underground, sometimes there are no signs of attack until the damage is advanced. Symptoms include wilting and drying of leaves followed by the death of shoot tips or whole stems.

Damage to sweet potato often goes unnoticed until the crop is dug up and the storage root is inspected for holes, tunnels or rotting tissue.

Other species of termites may also attack vegetables but it is uncommon.

Monitoring and pest management:

Inspect the crop regularly for damage symptoms. Often termites can be detected and controlled in trees near the vegetable patch by drilling a hole approximately 12 mm (in diameter) into the centre of the trunk at waist height. If termites are active they will seal this hole with mud on the outside after 24 hours.

A recommended treatment should be carried out as soon as an infestation is detected. Treating trees with confirmed infestations will often stop damage to nearby crops or plants in which symptoms are not yet evident.

Natural enemies:

Although these termites may be attacked by other invertebrates or pathogens, they are usually not effective in controlling entire colonies.

Giant northern termite, *Mastotermes darwiniensis* workers, soldier and egg raft (upper right corner).

Damage inside storage root.

External damage to storage root.

Melon thrips

Thrips palmi (Family Thripidae)

Host plants:

A wide range of vegetable crops including beans, cucumbers, hairy melon (and other melons and gourds), watermelon, bitter melon, angled loofah, capsicum, chilli, eggplant, tomato, pumpkin, squash, zucchini, amaranthus and okra. Other hosts include field crops, ornamentals, native plants and weeds.

Description:

Eggs: Yellowish-white in colour and kidney shaped.

Immatures: Two nymphal stages which are pale yellow and similar in appearance to the adults but without wings. Pre-pupae (which are mobile) are pale yellow and have two short wing buds. Pupae are pale yellow and have long wing buds. Size: Up to 0.8 mm in length.

Adults: Pale orange or yellow in colour with two pairs of narrow feather-like wings with dark setae. When folded, the setae on the wings give the appearance of a central line down the back. Size: About 1 mm in length.

Life cycle and biology:

The female inserts eggs into leaf tissue, developing flower buds and fruit; and can lay up to 100 eggs in a lifetime. In Top End conditions, the eggs hatch in about 3-4 days to produce the first stage nymph. The first two nymphal stages take 3-5 days to develop. When the second nymphal stage is fully fed, it crawls to the ground and burrows a few millimetres into the soil. Two resting stages (pre-pupa and pupa) take place in the soil over 2-3 days. At the end of the second resting stage, the adult emerges and burrows onto the soil surface where it either climbs or flies onto a host plant. The period from egg laying to adult emergence is 10-12 days at 30°C and 14-16 days at 25°C.

Female thrips do not have to copulate with a male to produce young, although all young produced without copulation will be females. This feature of thrips reproduction allows populations to increase rapidly.

Damage:

Melon thrips have piercing and rasping mouthparts and feed by thrusting their mouthparts deep into the leaf tissue to suck out the cell contents. The surface of the leaf develops a crinkled silvery appearance especially along the midrib and veins of the leaf.

Heavily-infested plants show silvering, yellowing or browning of leaves. The growing tips become stunted, deformed and discoloured. Developing fruit may abort or become deformed and scarred.

Monitoring and pest management:

Crops should be monitored for melon thrips, soon after transplanting in the dry season. Monitor weekly by walking through the crop and randomly sampling the underside of new and medium-aged leaves.

Overhead irrigation reduces the population of melon thrips by making the soil too damp for the pupal stages. Although this management technique discourages thrips, growers should be aware that overhead irrigation will increase the occurrence and spread of fungal diseases in the crop.

Natural enemies:

The fungus *Verticillium lecani* attacks and kills recently emerged adults. Lacewing larvae, predatory mites and predatory thrips all feed on nymphs and adults. Predatory bugs that feed on melon thrips include *Orius armatus* and *Geocoris rubra.* However, the most important predator is a small bug (*Deraeocoris* sp.), which consumes up to seven nymphs and adults per day.

Melon thrips, *Thrips palmi*.

Melon thrips, *Thrips palmi* nymph.

Scarring on eggplant.

Feeding damage seen as 'yellowing' along the main veins of a cucumber leaf.

Silverleaf whitefly (Poinsettia whitefly)

Bemisia tabaci biotype B
(Family Aleyrodidae)

Host plants:

A wide host range including vegetables such as cucumber, pumpkin, rockmelon, squash, watermelon, zucchini (as well as other cucurbits), okra, taro, lettuce, cabbage (and other brassicas), beans, eggplant, tomato, capsicum, chilli and sweet potato. Other hosts include fruit trees, ornamentals, field crops and weeds.

Description:

Eggs: Oval in shape and initially whitish or yellow-green turning brown in colour before hatching. Size: About 0.25 mm in length.

Immatures: The larvae are greenish-white, oval and scale-like in appearance. The pupae are yellow and slightly pointed at one end. Size: 1-2 mm in length.

Adults: Tiny 'moth-like' insects with four white powdery wings and a yellow body. Size: About 1.5 mm in length.

Life cycle and biology:

Females lay their eggs in an upright position on the underside of young leaves. Up to 160 eggs can be produced in the 60 day lifetime of the females. After hatching there are four nymphal stages before developing into an adult. In Top End conditions, the complete life cycle takes 18 days from egg to winged adult.

Damage:

Silverleaf whiteflies feed by sucking sap from the new growth. Feeding damage can be seen as pale areas along the leaf veins (in cucurbits the leaf stalks and stems may be whitened), silvering on the upper surface of leaves as well as distorted growth and in heavy infestations, the plants may wilt and collapse or die. On fruit such as tomatoes, feeding damage can cause blotchiness or irregular ripening. The whiteflies also excrete copious amounts of honeydew onto the foliage and this generally leads to growth of black sooty mould which reduces photosynthesis of the plant.

Monitoring and pest management:

If the property is free of the whitefly, every effort should be made to prevent introducing the pest onto the property via infested plants. Silverleaf whitefly can build up into high numbers in a short time, therefore it is important to monitor the crop regularly, at least once or twice a week. B biotype is resistant to a large range of pesticides. In some crop situations, when detected early, infestations can be managed with potassium soap sprays or insect growth regulators. It is also important to remove any weeds near the crop that may be alternate hosts.

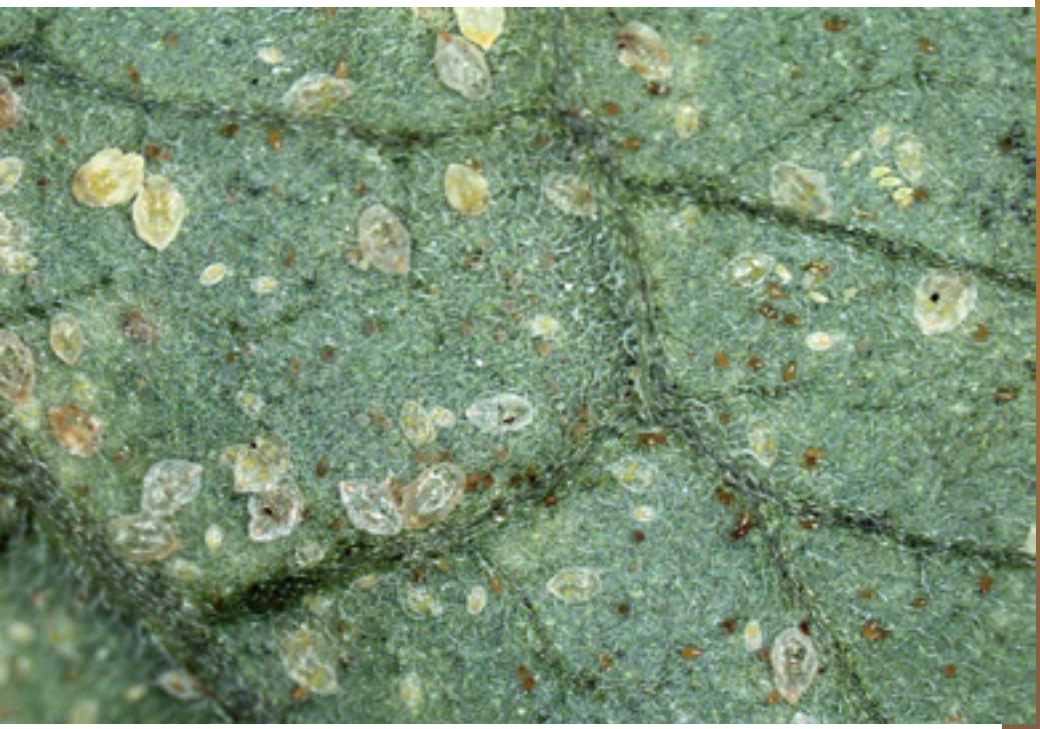
Natural enemies:

There are many native parasites and predators that will control silverleaf whitefly including parasitic wasps and predatory beetles. In low pest populations these beneficial insects may keep the whitefly numbers under control, however, in pest outbreaks when natural enemies are not found in the crop or occur in low numbers, this natural control may not be effective.

A tiny parasitoid wasp, *Eretmocerus hayati* has been introduced to control silverleaf whitefly in the Northern Territory (as well as on properties in Queensland and New South Wales).

Damage and sooty mould on tomato leaves.

Silverleaf whitefly, *Bemisia tabaci* biotype B adult and nymphs on a tomato leaf.



Silverleaf whitefly, *Bemisia tabaci* biotype B nymphs and eggs on the underside of a tomato leaf.

Spiralling whitefly

Aleurodicus dispersus (Family Aleyrodidae)

Host plants:

Chilli, capsicum, tomato and eggplant. Other hosts include many other vegetables (such as sweet potato), fruit trees, ornamentals, native plants and weeds.

Description:

Eggs: Oval in shape and yellow to tan in colour. Size: 0.3 mm in length.

Immatures: The first larval instar is mobile. The later instars are sedentary, light green, oval and scale-like in appearance, with waxy tufts. The pupae (final larval stage) has glass-like rods of wax along the sides of the body. Size: Up to 1 mm in length.

Adults: Tiny 'moth-like' insects with white powdery wings and a yellow body. Size: About 2 mm in length.

Life cycle and biology:

Eggs are laid singly on stalks which are inserted into the leaf at right angles to the leaf veins and are associated with irregular spiralling deposits of white flocculent wax. The eggs hatch into first instar larvae or crawlers which move out across the leaf until they settle, become sedentary and begin to feed. They go through another two larval instars producing more wax and honeydew as they develop. The development period at 20-39˚C is as follows: eggs 9-11 days, first instar (crawler) larva 6-7 days, second instar larva 4-5 days, third instar larva 5-7 days and fourth instar (pupa) 10-11 days. Under laboratory conditions, the adult can live for up to 39 days.

Damage:

Spiralling whiteflies feed by sucking sap from the undersides of leaves and sometimes the fruit calyx and stems. They excrete honeydew and this can form a substrate for the growth of sooty mould which covers the leaf surfaces and may interfere with photosynthesis. In heavy infestations, feeding damage may cause leaf drop or reduced yield in crops and the plant may have a 'snow-like' appearance.

In the wet season, conditions are less favourable and the whiteflies will generally occur in lower numbers. Higher populations are more common during the dry season with cooler temperatures and lower humidity.

Monitoring and pest management:

Monitor on a weekly basis looking for 'clouds' of whiteflies when plants are disturbed and for eggs and larvae on the leaves. Spiralling whitefly is capable of developing resistance to most chemical pesticides and many of these are already ineffective in controlling this species. Spraying with chemical pesticides also destroys natural enemies or biological control agents.

In small crops or in situations where the whitefly is in low numbers and restricted to a small area, the application of potassium soap spray with added spray oil may assist in managing populations. This spray solution may cause leaf burn to sensitive plants.

Natural enemies:

There are many native parasites and predators that are effective in controlling spiralling whitefly including parasitic wasps (family Eulophidae), and a range of predators including the predatory fly larva, *Acletoxenus quadristriatus* (family Drosophilidae), predatory midge (family Cecidomyiidae), hoverfly larvae, *Baccha* (family Syrphidae), lacewing larvae *Micromus, Notiobella* sp. (family Hemerobiidae), *Spermophorella* (family Berothidae) and the mealybug ladybird, *Cryptolaemus montrouzeri* (family Coccinellidae) and predatory mite (parasite of eggs) (family Phytoseiidae).

Naturally occurring beneficials are generally effective in controlling the spiralling whitefly. However, if the spiralling whitefly has recently established in a new area, its natural enemies may not yet be present and the population may increase rapidly and be a major pest.

A tiny parasitoid wasp, *Encarsia* sp. (family Aphelinidae) has been introduced into Queensland and the Northern Territory to control spiralling whitefly. In the Northern Territory, the wasp parasitoid is now well established in most areas where spiralling whitefly occurs. If spiralling whitefly has only recently been introduced onto a property it may take the wasp parasitoid a few weeks or up to a few months (depending on the local conditions, such as population levels of spiralling whitefly, availability of moisture, wind protection etc.) to establish and manage the population.

Spiralling whitefly, *Aleurodicus dispersus*.

Spiralling whitefly, *Aleurodicus dispersus* larvae on the underside of a chilli leaf.

Beneficials of Vegetables

(Beneficials include natural enemies and pollinators)

Beneficials

Bees

European honey bee, *Apis mellifera* (Family Apidae)

Bush bee, *Tetragonula* spp. (previously known as *Trigona*) (Family Apidae)

Many vegetable crops are pollinated by insects. European honey bees are particularly important in the pollination of cucurbit crops (such as melons, zucchini, cucumbers, pumpkins etc.). Bush bees have also been observed as regular visitors to cucurbit flowers. Two commonly seen species are the introduced European honeybee and the native stingless 'bush bee', *Tetragonula* (also known as 'stingless bees' or 'sugar bag bees'). Various other native bees as well as flies, wasps and beetles may also be seen as pollinators of vegetable crops.

Description:

European honey bee

Adult workers: Brown body with a pattern of golden brown and black bands on the upper side of the abdomen, body covered in short dense hair, legs are black. These bees have a barbed sting. Size: 13-15 mm in length.

Bush bees

Adult workers: Shiny black or blackish-brown and with hairy legs. These bees are stingless. Size: 3.5-5 mm in length.

Other native bees

There are many other species of native bees that may also be seen in vegetable crops and nearby vegetation. Most of the native bees are solitary and vary in size (4-25 mm) and colour from black and yellow to blue banded.

Biology and pollinator activity:

Bees are attracted to flowers for pollen and nectar on which they feed. By flying from plant to plant visiting flowers of the same species, bees assist in cross pollination of plants and increase the chance of fruit set. When foraging, bees locate a source of pollen then return to the nest to communicate to the rest of the colony on the location of the food source.

European honey bee

European honey bees were originally introduced into Australia by the early European settlers to produce honey. These bees are efficient pollinators of a large range of crops and other plants. They live in colonies which consist of a queen bee, thousands of workers (females), brood (eggs, larvae and pupae) and during the reproductive season there are also drones (males). The life cycle from egg to adult takes between 25-56 days depending on the time of year. The queen can live for 6-7 years.

These bees are usually managed on properties in hives (although feral bees can be found in other areas such as hollow limbs of trees or cavities in walls of buildings). Commercial hives are 'movable frame hives' consisting of a bottom board, a brood box (containing the queen), with a queen excluder frame, a 'super' (box with comb containing honey and no brood) and a lid.

Bush bees

Bush bees are native and live in colonies containing workers (females), drones (males) and usually one queen. They are stingless and not aggressive. However, opening or splitting the nest will cause disturbance and this may agitate the bees. Nests are usually built in tree cavities although in the Darwin area, nests have commonly been recorded from retaining walls, wall cavities and door frames. The nest consists of brood cells (containing eggs and larvae) which may be in a cluster, comb or semi-comb arrangement. The brood cells are made of brown cerumen (a mixture of secreted wax and field collected resins and waxes).

The honey and pollen pots are also made of cerumen and these are usually constructed in groups. The whole nest is surrounded by a hard layer of cerumen and other field-collected material. The bees enter the nest through an external hole made of cerumen or through an entrance tunnel (occasionally there is more than one entrance). Usually the only indication of a nest within a hollow tree trunk is the external appearance of a black waxy resin entrance hole or tunnel. In commercial hives the colonies have been removed from their original natural nest sites into a wooden box or a PVC-constructed cylindrical hive.

Most observations of bush bees in crops are from naturally occurring hives which are not managed. It has been observed by growers and some researchers that bush bees are more efficient in pollinating small flowers since they have small bodies and are able to make more direct contact with the stigmata while collecting and transferring pollen. Flowers with deep corollas (wide enough for the bees to enter), dense inflorescences and white or yellow flowers may also be preferred.

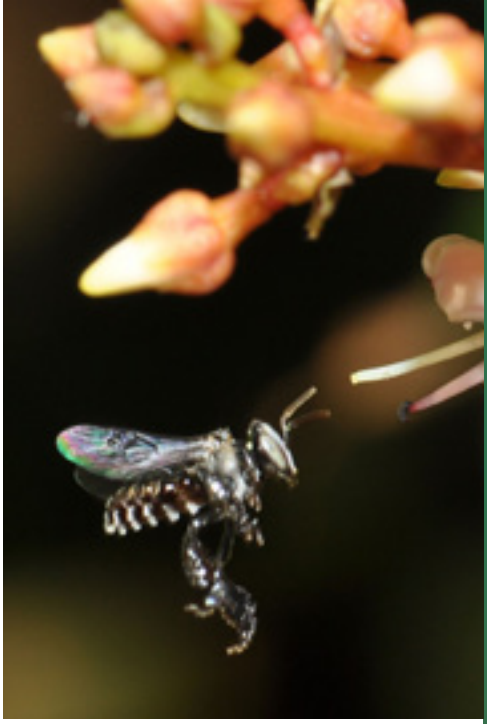
Monitoring:

Bees are active during the day and usually in the morning.

Other comments:

Care should be taken when approaching the European honey bee as they may sting. The venom injected from the sting can cause allergic reactions with intense local pain and swelling (or more severe symptoms). When these bees sting they dislodge their barbed sting (which continues to pump venom from the gland) and this needs to be removed from the victim.

Bees are very sensitive to most insecticides, particularly carbaryl and fipronil.



Bush bee, *Tetragonula* sp.

European honey bee, *Apis mellifera.*

Ground beetles

(Family Carabidae)

Targeted prey:

Aphids, caterpillars, beetle larvae, immature stages of flies (eggs, larvae and pupae), slugs and a large range of other invertebrates.

Description:

Adults: Sturdy, usually flattened beetles, often with ridged wing covers, long strong legs, large mandibles and large eyes. Most of the nocturnal species are brown or black in colour whereas the diurnal species are patterned, brightly coloured or iridescent. Size: 1-60 mm in length.

Biology and predatory activity:

Ground beetles live on the soil, sheltering under rocks and logs, they usually hunt for prey that fall off plants or feed on ground dwelling invertebrates. Some species forage on vegetation for prey. Those that forage on the ground usually do not fly but are generally fast runners. A few species are prey specific but most are opportunists and feed on whatever is available including plant matter as well as scavenged material.

Eggs are laid singly in the soil, leaf litter or rotten wood, the larva which lives exclusively under the surface of the soil passes through three stages before pupation which occurs in the soil. Adult ground beetles can live for 1-4 years.

Both the larvae and adults are predatory. Larvae either stay in burrows or protected areas and lie in wait for prey to come along or hunt within the soil or leaf litter for insect larvae. Some adults shelter during the day and hunt at night by using 'chemical and tactile stimuli' (senses for smelling and touching).

The species that are active during the day hunt by sight and have well developed large eyes for detecting movement and use their large mandibles to capture prey.

Most adult ground beetles move on foot but some species can fly. Some fast-runners such as the tiger beetles (sub family Cicindelinae) are capable of out-running and capturing flying prey. Prey are captured and eaten with their large and powerful mandibles.

Natural or cultivated vegetation along the borders of crops and grass strips between rows provide refuges for these beetles. The use of mulch increases the number of non-pest prey which provides an extra food source for ground beetles.

Ground beetles are attracted to lights at night and if disturbed, some species may produce an unpleasant odour or strong smelling liquid which is used as a defence mechanism.

Monitoring:

Ground beetles may be found actively foraging within the crop or in surrounding weeds and other vegetation. There are many species that are found on the ground amongst mulch, stones and other debris.

Tiger beetle, *Cicindela* sp.

Ground beetle, *Megacephala marginicollis.*

Ground beetle, *Chlaenius flaviguttatus.*

Ground beetle, *Gnathaphanus pulcher.*

Mealybug ladybird

Cryptolaemus montrouzieri
(Family Coccinellidae)

Targeted prey:

Adults and larvae feed on mealybugs, fluted scales, pulvinaria scales and soft scales. Eggs and small immature stages are preferred.

Description:

Eggs: Yellow in colour and laid into the egg masses of mealybugs or scales.

Immatures: Larvae are grey on the underside with six black legs and have white waxy filaments on the dorsal side of their body. Size: Up to 13 mm in length.

Adults: Oval-shaped beetles with black wing covers and an orange-brown head and rear end. Adults can crawl rapidly and also disperse by flying. Size: 4-5 mm in length.

Biology and predatory activity:

Adult *Cryptolaemus* beetles lay up to 10 eggs per day into the egg masses of mealybugs or other prey. The adult beetles and larvae feed on mealybug eggs and nymphs. When mature, the beetle larvae move to protected areas of the crop such as the underside of leaves to pupate. The complete life cycle from egg to adult takes about four weeks. Adults can live for a few months.

Cryptolaemus has a better chance of establishing when host prey are in high numbers within the crop. Crops that are protected from the wind or have dense foliage to provide shelter, are usually more suitable for the establishment of the beetles. When releasing *Cryptolaemus* they perform best when they can be contained close to the host within the infested crop. They do best at 28˚C but will readily survive at temperatures between 16-33˚C. In the Top End, naturally occurring populations have also been observed in the field at temperatures higher than 33˚C.

Monitoring:

Look for crawling, fast moving larvae and adults especially amongst plants infested with mealybugs and fluted scales. Mealybugs and fluted scales can be distinguished from *Cryptolaemus* larvae by the orange or yellow on the underside of their bodies. Also, they generally do not crawl around after they settle and insert their mouth parts into the plant tissue to feed. *Cryptolaemus* larvae are grey on the underside and they have well developed legs and are usually active.

Cryptolaemus is a native predator but can also be purchased from a commercial supplier. Crops should not be sprayed with pesticides for at least two weeks before and after releasing this predator.

Mealybug ladybirds, *Cryptolaemus montrouzieri*

Mealybug ladybird, *Cryptolaemus montrouzieri* larva.

Predatory ladybirds

Coccinella, Cryptolaemus, Harmonia, Menochilus, Micraspis, Scymnus, Stethorus (Family Coccinellidae)

Targeted prey:

Listed below are some of the predatory ladybirds that occur in vegetable crops from the Top End. Both adults and larvae feed on prey. Many others may also occur and assist with biological control.

Coccinella: Aphids, small invertebrates, nectar and pollen.

Harmonia: Aphids as well as leafhoppers, psyllids, and eggs of chrysomelid beetles.

Menochilus: Aphids, scale insects, whiteflies and psyllids.

Micraspis: Aphids, other insects (polyphagous) as well as pollen.

Scymnus: Aphids, spider mites and insect eggs.

Stethorus: Spider mites.

Description:

Eggs: Red, yellow or white and oval or rod-shaped. Laid singly or in batches. When first laid, the eggs are usually white or creamy-white but then darken before hatching. Size: 0.2-2.0 mm in length.

Immatures: Various colours, elongate and some species with spines or waxy filaments. Size: 1-8 mm in length.

Adults: Various colours including: brown, orange, red, black or yellow with different coloured patterns or spots, usually oval or elongate-oval and dome-shaped and may be covered in short fine hairs or glossy and hairless. Size: 1-10 mm in length.

Coccinella: Orange with black spots, body elongate-oval, dome-shaped, hairless. Size: 4-8.5 mm in length.

Harmonia: Yellow/orange with black spots, body broadly oval, dome-shaped, hairless. Size: 7-9 mm in length.

Menochilus: Yellow/orange with black pattern, body broadly oval, dome-shaped, hairless. Size: 3-6.5 mm in length.

Micraspis: Yellow with dark (black) stripes, body elongate-oval, dome-shaped, hairless. Size: 3-6 mm in length.

Scymnus: Brown with black pattern, elongate-oval, moderately dome-shaped, densely hairy (hairs are difficult to see with the naked eye). The larvae are covered in waxy secretions, allowing them to move around aphids in disguise. Size: 1-3 mm in length.

Stethorus: Elongate-oval, moderately dome-shaped, black and densely hairy (hairs difficult to see with naked eye). Size: 1-2 mm in length.

Biology and predatory activity:

Coccinellids that feed on scale insects lay their eggs either near the scales, underneath or on top of the scale. Those that feed on aphids will also deposit eggs close to the colony. The larvae have mandibles that allow them to bite and chew prey. Some species inject digestive juices into the prey and suck out their body fluids and then discard their exoskeleton. Cannibalism occurs in coccinellids; older larvae or adults may feed on some of the immature stages within the same species or different species.

Eggs usually hatch within 2-18 days, the pupal period is 7-14 days. Development from egg to adult usually takes 30-40 days. Adults can live for up to a few months or longer. Both adults and larvae feed on prey but will also supplement their diet with nectar, honeydew (from sap-sucking insects), pollen and water.

Monitoring:

Ladybird larvae and adults are generally easier to find when they are in larger numbers feeding amongst a heavy infestation of aphids, scales or other pests.

Zig zag beetle, *Menochilus sexmaculatus.*

Scymnus sp.

Transverse ladybird, *Coccinella transversalis* feeding on aphids.

Rove beetles

(Family Staphylinidae)

Targeted prey:

Aphids, dried fruit beetle, mites, springtails, small spiders, immature stages of flies (eggs, larvae and pupae), fungus gnats and other small invertebrates.

Description:

Eggs: Usually white and circular or pear-shaped.

Immatures: Flexible, elongate and flattened with well developed legs, various colours including white, grey and brown. Size: up to 20 mm.

Adults: Most species are black or brown. Some are yellow or reddish brown with a black pattern. They are usually elongate with shortened elytra so that the flexible abdomen is mostly exposed. Size: 1-22 mm in length.

Biology and predatory activity:

Staphylinids live (often hidden) in soil, moist humus or plant debris. When pursuing prey, they may be found running on bare ground, or on vegetation. Although they run to capture prey, they can also fly. Some species are associated with dung, carrion or fungi.

The shortened elytra and freely moveable abdomen is an adaptation for foraging efficiently in dense vegetation. The large well developed and protruding eyes on the sides of the head provide a clear and wide view around the beetle. Those that live on the ground have good eyesight which they use to pursue and capture moving prey with precision. Rove beetles that live in dense vegetation stalk their prey cautiously.

The rove beetle, *Dalotia coriaria* is used for biological control and is available commercially. Both the adult and larval stages are predatory. *Dalotia* prefers a warm humid environment and are particularly useful in vegetable propagation shade houses where they feed on immature stages of fungus gnats, moth-flies and other nuisance flies that breed in the growing media.

Monitoring:

Although rove beetles may occur in reasonable numbers within or nearby the crop they are often difficult to find as they are quite small, dark-coloured and tend to crawl (or fly) away quickly. They may be easier to sample when looking in moist mulch or leaf litter or when they are attracted to lights at night.

Other comments:

The species, *Paederus australis,* contains a toxin and if the beetle is rubbed against the skin it can cause painful and itchy skin irritations which lead to pustules and blistering.

Rove beetle, *Xantholinus* sp.

Rove beetle, *Paederus* sp.

Assassin bugs

Pristhesancus, Peirates, Oncocephalus
(Family Reduviidae)

Targeted prey:

Generalist predators that consume bugs and caterpillars as well as a large range of other insects.

The Australian assassin bug, *Pristhesancus plagipennis* is useful in controlling *Helicoverpa* and green vegetable bug.

Description:

Eggs: Pristhesancus: clusters of elongate orange eggs which turn red before hatching.

Immatures: Pristhesancus: Nymphs are wingless, black with bright orange markings and pass through five growth stages before they become adults.

Oncocephalus: Similar to adult but without wings.

Adults: Pristhesancus: Brown body with membranous wings which are folded along the back. Size: 25-30 mm in length.

Peirates: Black body with brown or black legs and yellow-brown markings on the wings. Size: The species recorded in the Northern Territory are up to 22 mm in length.

Oncocephalus: Light brown body with dark brown markings. Size: 14–20 mm in length.

Biology and predatory activity:

Assassin bugs have a large strong segmented feeding tube known as the rostrum. The rostrum is modified to capture prey and is curved outwards from the head, unlike plant sucking bugs which have a rostrum that is tucked flat under the head. They have a distinct 'neck' and prominent eyes and also have a prosternum groove in which they can insert the rostrum to make a sound to frighten away predators. The fore and mid legs are generally modified to capture or hold prey. While the prey is held and pierced, a salivary secretion is pumped into the body which paralyses the prey and dissolves its internal tissues into a liquid that the bug can suck up.

Studies of assassin bugs have been carried out on field crops such as soybeans and cotton where corn earworm and native budworm have been the main pests. The results indicate that assassin bugs are generalist predators and have a survival advantage over host-specific parasitoid wasps in that they are able to feed on a range of prey during periods when food is scarce.

Pristhesancus plagipennis is currently being trialled for commercial development.

Monitoring:

Assassin bugs are occasionally seen during routine monitoring. They may be difficult to detect especially if the vegetation is dense and they are hiding behind leaves. Inspect parts of the crops that are infested with targeted prey. The best times to monitor are in the early morning or evening.

Other comments:

Most species of assassin bugs only attack insects or other arthropods, however, if these bugs are threatened or captured by humans they can inflict a painful 'bite' with their rostrum. There is one species in Australia (sub family Triatominae) that feeds on the blood of mammals and birds.

Assassin bug, *Pristhesancus* sp.

Assassin bug, *Pristhesancus* sp. side view showing the rostrum.

Assassin bug, *Peirates* sp.

Assassin bug, *Oncocephalus* sp.

Big-eyed bug

Geocoris spp. (Family Lygaeidae)

Targeted prey:

Spider mites, thrips, aphids, whiteflies, small caterpillars, other small insects and insect eggs.

Description:

Eggs: Greyish-white with two red eye-spots (which develop after a few days), elongate and laid singly or in clusters on stems and under leaves close to potential prey.

Immatures: Nymphs look like adults but are smaller, may be paler in colour and do not have wings.

Adults: Black, grey or tan with prominent large eyes and a triangle-shaped mark on the thorax. The adults have folded membranous wings. Size: 3-5 mm in length.

Biology and predatory activity:

The nymphs and adults are predatory but are also known to feed on seeds as well as nectar or honeydew. As with other predatory bugs, big-eyed bugs have long piercing mouth parts which they use to puncture, kill and suck out the liquid contents of their prey. The complete life cycle from egg to adult takes about 30 days.

In the Northern Territory, big-eyed bugs have been observed as efficient predators of melon thrips, spider mites and aphids in cucurbit crops such as cucumber and zucchini.

Monitoring:

Big-eyed bugs are commonly seen amongst infestations of melon thrips, aphids and spider mites. Inspect parts of the crop that are infested with targeted prey. The best times to monitor are in the early morning or evening.

Big-eyed bug, *Geocoris* sp. on an eggplant leaf.

Big-eyed bug, *Geocoris* sp. capturing an aphid.

Minute pirate bugs

Orius armatus, Orius tantillus and *Orius* spp. (Family Anthocoridae)

Targeted prey:

Thrips, mites, aphids, whiteflies, insect eggs, small caterpillars and various small immature insects.

Description:

Eggs: Small, white or colourless and not easily seen as they are almost completely inserted into plant tissue with only the upper cap-like part visible. Size: 0.4 mm.

Immatures: Colourless when they hatch, then darken to yellow and later, dark reddish-brown as they develop.

Adults: Dark brown or black oval-shaped bugs with lighter markings on the wings. Size: 2-5 mm in length.

Biology and predatory activity:

Minute pirate bugs are generalist predators occurring in vegetables as well as other flowering crops. Although *Orius armatus* occurs naturally in the Top End it is also available from a commercial supplier. Both the nymphs and adults of minute pirate bugs are able to move quickly to capture prey. After catching the prey, they pierce the body with their sharp needle-like proboscis, inject digestive enzymes and suck out the contents of the body.

Adults are attracted to flowers and are particularly useful in controlling pests such as flower thrips. They are also effective predators of melon thrips and are often observed in bitter melon, cucumber and eggplant crops.

Different species will have a preference for a particular host range and some feed on plant sap as well as pollen (but usually cause no significant damage to the plant). The ability for these predators to feed on an alternative plant food source allows them to persist in agricultural crops when prey are scarce.

Eggs hatch in 3-5 days, there are five nymphal stages and the development period from egg to adult takes about 12-14 days. Adults live for about 28 days.

Monitoring:

Minute pirate bugs may be occasionally seen when monitoring for their targeted prey especially amongst flowers. The best times to monitor are either in the early morning or late afternoon when they are the most active. On cooler days they may be more active in the middle of the day.

Minute pirate bug, *Orius* sp. on a cucumber leaf.

Minute pirate bug, *Orius* sp. nymph in pursuit of thrips nymphs.

Spined predatory shield bug

Oechalia schellenbergii
(Family Pentatomidae)

Targeted prey:

Caterpillars, sawfly larvae, beetle larvae and various other insect larvae and eggs. For example they are effective predators of *Helicoverpa* eggs and larvae.

Description:

Eggs: Black in colour with short white spines around the top fringe.

Immatures: Nymphs are black and red, and do not have spines or wings.

Adults: Shield-shaped and mottled brown or grey in colour. There are sharp spines on either side of the thorax and a triangular patch of black on the end of the abdomen where the folded wings overlap. Size: 8-12 mm in length. (Females are slightly larger than males).

Biology and predatory activity:

The spined predatory shield bug is an effective predator found in field crops, vegetables, tree crops and native vegetation such as *Eucalyptus, Acacia* and *Melaleuca.* They are also found on weeds infested with caterpillars.

Eggs are laid in clusters (of up to 50), on or under leaves. Newly hatched nymphs may be seen near the egg cluster for 2-3 days before dispersing. There are five nymphal stages and development from egg to adult takes about three weeks. Adults can live for up to eight weeks.

Young nymphs feed on plant sap. Older nymphs and adults capture prey and feed by injecting their piercing proboscis into the larva to suck out the liquid body contents. These bugs are voracious feeders and older nymphs or adults are able to capture large larvae. The predators are capable of consuming up to 20 larvae in a lifetime.

Monitoring:

When monitoring a crop, spined predatory shield bugs may be seen with a caterpillar impaled on their proboscis. Adults tend to move or fly away when disturbed.

Spined predatory shield bug, *Oechalia schellenbergii* nymph attacking a caterpillar.

Spined predatory shield bug, *Oechalia schellenbergii* attacking a cluster caterpillar.

Hover fly larvae

(Family Syrphidae)

Targeted prey:

Aphids, small caterpillars, mealybugs and whiteflies.

Description:

Eggs: Small white and oval-shaped, usually laid on, or near the host insect.

Immatures: The larvae (maggots) are blind and are generally white, brown or green with two white stripes along the length of the body.

Adults: Stout or slender bodied with a large head, large eyes and short antennae. They have one pair of clear wings, and the body is brightly coloured with yellow and black bands (or pattern). The body is covered in dense fine (usually yellow) hairs. Size: 3-10 mm in length.

Biology and predatory activity:

Hoverfly adults mimic wasps and bees. They are fast flyers that move in alternating bursts and are often seen hovering in one spot over flowers.

The larvae are predatory and the adults are pollinators (feeding on nectar and pollen). Adults will also feed on honeydew excreted from aphids and other sap-sucking insects.

Female hoverflies lay their eggs singly or in small batches on or near their targeted prey. After hatching the larvae immediately seek out prey to feed on and go through three larval stages before pupating in a brown cocoon and emerging as an adult. Development from egg to adult takes 2-6 weeks.

Studies have indicated that companion planting of in-between-rows or border strips of suitable flowering plants such as coriander or chrysanthemum provides extra nectar and pollen which may attract a larger number of hoverflies into the crop. When choosing companion plants it is important to consider those that have a flowering cycle timed in with the crucial period when hoverflies are needed in the crop cycle (companion planting may also increase the diversity of other beneficials). Flowers that have open corollas which allow easy access to nectar and pollen are generally preferred by hoverflies.

Monitoring:

Hoverfly larvae are often found on vegetables that are infested with aphids, mealybugs or whiteflies. They are usually easier to find on foliage that are heavily infested with targeted prey such as on cucurbit or bean leaves heavily infested with aphids. Other species of hover fly larvae live in rotting vegetation. Some larvae are aquatic such as the rat-tailed maggots and may occasionally be seen in undisturbed open containers of water or ponds in home gardens or rural blocks.

Hover fly (Family Syrphidae).

Hover fly (Family Syrphidae) larva preying on aphids.

Parasitic flies

(Family Tachinidae)

Targeted prey:

Caterpillars such as cucumber moth larvae, *Spodoptera* larvae, *Helicoverpa* larvae, various beetle larvae, grasshoppers, wasps and true bugs.

Examples of parasitic flies reared from caterpillars:

Peribaea sp., *Carcelia* sp. reared from *Spodoptera litura* larvae

Palexorista sp., *Goniophthalmus australis, Exorista* sp., *Carcelia* sp. reared from *Helicoverpa* larvae

Description:

Eggs: Small white, oval-shaped soft eggs.

Immatures: Larvae (also referred to as maggots) do not have legs.

Adults: Stout bodied, usually with bristles and most are grey with black markings. Some species are metallic coloured. Size: Up to 20 mm.

Biology and parasitic activity:

Adults of most species are diurnal, very active and are often seen feeding on nectar of flowers and may help with pollination, they also feed on honeydew from scale insects and aphids. Since most tachinids do not have a piercing ovipositor (although there are exceptions), the eggs or live young are deposited externally on or near the host. When the eggs hatch, the larvae burrow into the larval stage of the host, although some will attack the adult stage. Other ways of parasitising the host is when eggs are ingested and hatch within the body (of the host).

Parasitoid eggs may be seen attached to the external body of caterpillars. The larvae which go through three instars burrow into the host and eat the insides which usually kills the host, although there are exceptions where the host is not killed. When mature, the third instar larva will either pupate inside the host or in the soil or leaf litter. Larval development is usually completed in 1-3 weeks.

Monitoring:

Adult tachinid flies are sometimes seen as pollinators. Since the immature stages usually develop inside their hosts, they are difficult to observe. When trying to determine if tachinids are parasitising pests in the crop such as caterpillars, these caterpillars can be collected into a 'rearing container' and reared through to their adult stage. If the caterpillars were parasitised, the adult flies will emerge generally after the caterpillar has died or pupated.

Parasitic fly (Family Tachinidae).

A parasitic fly (Family Tachinidae) approaching a caterpillar to lay eggs onto its body.

Robber flies

Laphria, Leptogaster, Ommatius
(Family Asilidae)

Targeted prey:

A wide range of prey in various sizes including: flies, wasps, grasshoppers, butterflies, moths, true bugs and various other insects and spiders.

Description:

Eggs: Cream-coloured eggs which are usually laid in masses and covered in a chalky protective coating.

Immatures: The larvae are cylindrical, elongate and tapered towards the head.

Adults: Small to large flies that are usually grey, brown or black with some species being brightly coloured with yellow or red markings. They have a distinct neck, prominent and well separated eyes, and a beard of hair around the large pointed proboscis. The thorax and legs are covered in bristles or hair. The abdomen is either 'stout and tapering' or 'narrow and elongate'. They are adapted for hunting and catching prey in mid-flight with strong legs and claws. Size: 5-30 mm in length.

Biology and predatory activity:

Adults lay eggs in masses which are usually covered in a chalky protective coating onto plants, in gaps in soil or into bark or wood. The larvae live in soil or rotting wood and feed on other soft-bodied insects or insect eggs. Some species are also ectoparasitic. Pupation occurs in the soil. Adult robber flies are opportunistic predators and are found in sunny, open and dry habitats such as savannah and open woodland.

When foraging for prey, they weave in and out of vegetation and hover over plant stems and flower heads. Another hunting strategy is to ambush passing prey from a stationary position on a perch. They generally attack prey that are 2-3 times smaller than themselves. Prey are generally captured in mid-flight, although some species such as *Leptogaster* forage close to the ground and strike at resting prey (on soil or vegetation). After the prey are captured and stabbed with their large proboscis the prey are held and injected with toxins and enzymes to liquefy the body contents which are then sucked out, leaving only the exoskeleton. Cannibalism and predation on other species of robber flies also occurs with some species.

Monitoring:

Robber flies are not easily spotted since they are very mobile as they weave in and out of the crop, although they may be occasionally seen hovering over flowers within the crop or in surrounding vegetation.

Robber fly (Family Asilidae).

Robber fly (Family Asilidae) (side view) showing the pointed proboscis and strong legs for catching prey.

Lacewings

Green lacewing, *Mallada signata*
(Family Chrysopidae)

Brown lacewing, (Tasman's lacewing),
Micromus tasmaniae
(Family Hemerobiidae)

Other species of green and brown lacewings also occur naturally and these have a similar life cycle and biology.

Targeted prey:

Larvae are generalist predators and feed on insects such as melon thrips, scales, mites, aphids, immature mealybugs, immature fluted scales, moth eggs, small caterpillars and whiteflies.

Description:

Green lacewings

Eggs: White, oval-shaped and on stalks.

Immatures: Larvae are brown with a wide mid-section body that tapers towards the head and rear end. They have large piercing mandibles for capturing prey and long bristles along the side and back of the body which accumulate the remnants of dead prey to help camouflage them from predators. Size: Up to 8 mm in length.

Adults: Green body with two pairs of delicate transparent lace-like wings. Size: Up to 10 mm in length (not including wings).

Brown lacewings

Eggs: Brown or white, oblong and laid on the underside of leaves (without stalks).

Immatures: Larvae are mottled brown in colour with a long body which is wider in the middle and tapers at each end. They have large piercing mandibles for capturing prey and do not carry debris on their backs. Size: About 7-9 mm in length.

Adults: Brown with two pairs of delicate hairy transparent lace-like wings and long antennae. Size: Up to 12 mm in length (not including wings).

Biology and predatory activity:

Green lacewings:

The green lacewing, *Mallada signata* is a native species and is also available for purchase from commercial suppliers. Their prey generally includes aphids, two spotted mites, scales, mealybugs, moth eggs and small caterpillars. These lacewings are more active in warm weather. Many species of green lacewings are found naturally in vegetable crops, the adults are either predatory or feed on honeydew.

The first instar larva hatches from the egg. As the larva grows, it moults and goes through another two instars taking up to seven days. When mature the last instar larva moves into the leaf litter and spins a cocoon to pupate. When adults emerge from the pupal stage they attempt to find a mate. Adults can live for up to 100 days.

If it is necessary to release green lacewing into vegetable crops, they will be more likely to establish if there is a refuge of trees or shrubs nearby. Residual pesticides should not be applied to the crop for 3-4 weeks before release. Since adults feed on nectar and pollen, flowering crops or flowering vegetation nearby will encourage adults to stay in the area.

Brown lacewings:

Tasman's lacewings, *(Micromus tasmaniae)* are often found in low vegetation and are naturally occurring. Many species move onto vegetable crops to feed on various prey and become efficient biological control agents. Adults are also predatory and have a similar

diet to their larvae. They feed on a wide range of pests including aphids, moth eggs, small larvae, scales and whiteflies as well as nectar from flowers.

The first instar larva hatches from the egg, as the larva grows, it moults and goes through another two instars taking about seven days (or less), when mature the last instar larva moves into the leaf litter and spins a cocoon to pupate. When adults emerge from the pupal stage, they attempt to find a mate. Adults can live for up to 100 days.

They are suitable for establishing in vegetable crops. Brown lacewings are currently being trialled for commercial development.

Monitoring:

When looking for lacewings, check for eggs which are attached to leaves, larvae may be seen foraging. Adults are difficult to monitor but are often seen attracted to lights at night.

Green lacewing (Family Chrysopidae).

Brown lacewing, *Micromus* sp.

Green lacewing (Family Chrysopidae) larva.

Brown lacewing, *Micromus* sp. larva foraging for aphids.

Predatory mites

(Families Phytoseiidae, Cunaxidae, Cheyletidae, Stigmaeidae)

Targeted prey:

Phytoseiidae: mites (especially spider mites and bud mites), small insects, nematodes, fungi and pollen.

Cunaxidae: generalist predators of small insects and nematodes.

Cheyletidae: mites and small insects.

Stigmaeidae: mites (particularly spider mites, false spider mites and bud mites) and small insects.

Description:

Body length of adults: About 0.8 mm or less.

Phytoseiidae: *Phytoseiulus:* orange to reddish-orange, pear-shaped body and long legs.

Cunaxidae: bright red, brown or yellow in colour and tear drop shaped with a prominent piercing mouthpart.

Cheyletidae: white, yellow or orange coloured mites with prominent feeding structures at the front of the body called gnathosoma (mouth parts and thickened palps). The setae on the body may be hair-like or more ornate such as club-shaped, shell-like or staghorn-like.

Stigmaeidae: yellow, orange or red in colour with an ovoid or elongate body. The upper side of the body is often covered in one or more plates.

Biology and predatory activity:

Phytoseiidae: These mites are fast moving predators and live on plants as well as in soil. They mainly feed on mites, small insects, nematodes, fungi and pollen. The development from egg to adult is very short and generally completed in 4-7 days. High humidity is required for eggs to hatch. These mites are able to utilise the webbing made by spider mites to access their prey. They can detect kairomones emitted by the prey and are able to stay within the prey infested areas or move to nearby new infestations.

Crops with dense foliage grown in humid areas are more suitable for the establishment of phytoseiid mites. The Chilean predatory mite, *Phytoseiulus persimilus* is commercially available and has been used successfully to control two spotted mite, *Tetranychus urticae* in vegetables.

Cunaxidae: These mites are fast moving generalist predators that attack a range of small arthropods in many crops. They also occur in the soil and attack the root knot nematode *Meloidogyne* spp. Other species are found in leaf litter and stored products. Some cunaxids hunt their prey and fasten them with silken threads excreted from their mouthparts, and others snare or ambush their prey.

Cheyletidae: Mites in this family are divided into two groups, predators and parasites. These parasitic mites occur on mammals, birds and insects. Predatory cheyletids live on plants and in the soil. They feed on mites and small insects. Other predatory species occur in stored products. They are slow moving and ambush their prey or capture them cautiously.

Stigmaeidae: These mites live on plants and in the soil. They feed on spider mites, false spider mites as well as other mites, the egg and non-active stages are often preferred.

Amblyseius thwaitei (Family Phytoseiidae) preying on two spotted mites.

Predatory mite (Family Cunaxidae) capturing a two spotted mite.

Chilean predatory mite, *Phytoseiulus persimilis* (Family Phytoseiidae) preying on two spotted mites.

Spiders

(Families Araneidae, Lycosidae, Oxyopidae, Salticidae, Thomisidae and many others).

Targeted prey:

A large range of flying and crawling insects including aphids, caterpillars, moths, bugs, grasshoppers, beetles, flies, planthoppers as well as pollinators, other predatory insects (such as wasps), other spiders and members of their own species. Many of the flying insects are captured in webs.

Description:

Eggs: White, yellow, cream, pink, red or brown in colour and oval or spherical in shape.

Immatures: Spiderlings are similar to adults but are generally smaller with variations in colour and markings.

Adults: Spiders have two distinct body parts: the cephalothorax (the head and thorax) which is joined by a 'waist' or pedicel to the abdomen. They have simple eyes (most have eight), chelicerae (with fangs) adapted for biting or piercing prey, a pair of pedipalps, eight legs and silk producing organs (silk comes out through the spinnerets at the rear end of the abdomen). Breathing occurs through 'lungs' on the underside of the body.

There is a large variation in the size and colour of spiders depending on the species. The following examples are provided as a guide:

Orb-web spiders (family Araneidae): Many tropical species are colourful and vary in shape. Size: Species found in vegetable crops are usually up to 25 mm in length.

Wolf spiders (family Lycosidae): Wolf spiders found in vegetable crops are usually brown or greyish-brown with a radiating pattern on the cephalothorax and a ribbed pattern on the abdomen. They are stoutly-built and are agile hunters. Size: Usually up to 25 mm in length.

Lynx spiders (family Oxyopidae): Lynx spiders have spines on their legs and generally have a striped abdomen with alternating light and dark bands running lengthways. Size: About 5-9 mm in length.

Jumping spiders (family Salticidae): These spiders are generally colourful with short stout legs and a square (or rectangular) shaped cephalothorax. The anterior eyes are prominent and are positioned along the front of the carapace. The males are often 'elaborately decorated' and perform courtship displays in front of females. Size: Up to about 15 mm in length.

Crab spiders (family Thomisidae): These spiders are crab-like and have the ability to walk 'sideways'. They are usually grey, brown, white, yellow or green and may be well camouflaged in flowers or vegetation. Size: Up to about 14 mm in length.

Biology and predatory activity:

Spiders occur in diverse habitats including natural environments (such as dry forests, monsoon vine thickets, woodlands, shrublands, grasslands and arid regions), gardens, parks, agricultural systems (within crops as well as nearby natural vegetation and weeds), suburban areas and some live on the banks of creeks and rivers. They live on the ground, in tunnels/burrows, on vegetation, under stones and logs as well as in leaf litter.

Spiders are generalist predators feeding mainly on live prey and are sometimes cannibalistic on other spiders or members of their own species. They are useful biological control agents in vegetable crops as they feed on a wide range of pests, have a high

dispersal ability, are long-lived, can tolerate dry conditions and are able to survive for long periods without food.

Eggs are usually laid with or without a sticky secretion and wrapped in a silken cocoon to protect them from predators and the weather. The appearance of the silken cocoon may be smooth, rough or spiny depending on the species. Spiderlings emerge from eggs and go through a series of moults (with the first moult having occurred inside the egg) before developing into an adult.

Female spiders provide a range of parental care. In many species, the female spider guards the egg sac (from predators) by building a silken shelter and stays with the eggs until they hatch. Other species leave the eggs unattended in rolled leaves, in bark, under stones or other debris. The orb-web spiders wrap the eggs in a protective silk cocoon which is left hanging within the web. Hunting spiders such as wolf spiders carry the egg sac attached to the spinnerets and when the eggs hatch the spiderlings are carried on the abdomen for about a week before dispersing.

Dispersal is usually by a method called 'ballooning'. The spiderling will raise its abdomen up high and produce a thread of silk, when the thread is long enough the spiderling can be lifted into the wind and carried to a new location. Ground dwelling spiders disperse by crawling away from the nest. As a general guide, smaller spiders can take 6-12 months to reach maturity and larger spiders can take 2-3 years.

Prey are captured by building webs or by hunting and ambushing. Web building spiders build snares to capture insects, while non-web builders such as the hunters, chase and stalk their prey. Wolf spiders and jumping spiders pursue their

St. Andrew's cross, *Argiope keyserlingi* (Family Araneidae).

Jumping spider, *Mopsus* sp. (Family Salticidae).

prey and then capture them with a final leap. Lynx spiders are also active hunters and can leap considerable distances to capture prey. Ambushers such as some crab spiders lie in wait on leaves or in flowers catching their prey unawares with their strong front legs. The prey are then bitten and paralysed.

Web builders such as the orb-web spiders are fairly sedentary. Most of these spiders build webs and position themselves in the middle of the web or on the edge of the web. Insects fly into the web and become attached to the sticky threads, the spider rushes over as soon as they are caught and the insects are bitten or wrapped in silk. Jumping spiders do not use silk as a snare but as a safety thread or 'drag-line'. These spiders attach a drag line before they jump and when they are moving around, so if they fall off the foliage, they can climb back to the starting point.

Although most spiders do not have well developed eyesight and rely on their sense of touch, taste and sensing vibration to navigate, capture prey, find mates and recognise enemies, a few spiders such as the wolf spiders, jumping spiders, lynx spiders and crab spiders do have well developed eyesight which is important to their effectiveness in detecting and capturing prey.

Spiders use their mouthparts to crush and hold onto prey while they inject paralysing venom into their bodies to kill them. Some spiders wrap their prey with silk before biting and killing them. Spiders do not eat solid food as the mouth is adapted to only take in liquid. Therefore an 'external pre-digestion' process takes place first by regurgitating enzyme-rich digestive fluids into or onto the prey which break down the internal organs so that they can be sucked out and ingested, leaving behind the crumpled exoskeleton.

Monitoring:

Spiders can be found on vegetation, in webs on or between plants or on the ground amongst leaf litter or stones. Often they are well camouflaged with the background or are hidden in burrows. Caution needs to be taken when approaching spiders as some may bite and cause allergic reactions or more severe symptoms.

Integrated pest management:

Overseas studies have shown that the use of mulching in crops has the potential to increase the population of non-pests such as springtails and other detritus feeders which were an alternate food source for wolf spiders as well as other spiders. Some researchers have suggested that these non-pest arthropods may attract spiders into the cropping area and improve the biological control of plant pests.

Crab spider (Family Thomisidae).

Lynx spider (Family Oxyopidae).

Predatory thrips (six-spotted thrips)

Six-spotted thrips, *Scolothrips sexmaculatus* (Family Thripidae)

Targeted prey:

Two spotted mite, *Tetranychus urticae* and other spider mites (family Tetranychidae).

The six-spotted thrips is a natural predator of spider mites in cucumber and beans as well as other vegetables, weeds and many other non-vegetable crops. Overseas studies have shown that six-spotted thrips is an effective predator of spider mites (in comparison to other common predators of spider mites) in laboratory and field trials and has been collected in the field from a large range of vegetable, tree crops and field crops.

Description:

Eggs: Kidney-shaped, translucent when deposited then become white and opaque, very small and inserted into tender leaf or stem tissue.

Immatures: The nymphs are pale yellow to white and are semi-transparent.

Adults: Pale yellow with three grey markings on each forewing. Size: Females are 2-3 mm in length. (Males are smaller).

Biology and predatory activity:

The six-spotted thrips is not species specific and feeds on a range of spider mites, although their common prey in vegetables is generally the two spotted mite. When foraging, the six-spotted thrips are well adapted to spider mite webbing and are able to penetrate it easily in search of mites and mite eggs.

The females lay about 14-16 eggs per day (and can lay up to 220 in a lifetime). Optimal temperature for reproduction is around 30°C and at this temperature they can double their numbers within 2-3 days. Eggs take up to seven days to hatch. After hatching, the larvae feed and develop to maturity within about five days and then pupate. Pupation occurs on the leaf near the feeding sites. The pre-pupal stage lasts for one day and the pupal stage takes five days. Pupae do not feed but are mobile. Unfertilised eggs develop into male offspring while fertilised eggs develop into male and female offspring. The adults live for about 14-21 days.

Although the first instar larvae mostly feed on eggs and inactive stages of spider mites, they are capable of attacking and feeding on all mite life stages, particularly the second instars and adults. In crowded conditions or when prey are scarce, the thrips nymphs may become cannibalistic, feeding on nymphs (of their own species) that are weak or hatching. Adults rarely show cannibalistic behaviour as they tend to move to new areas once the current foraging space has been depleted of prey.

When searching for mites, the six-spotted thrips requires physical contact with the mite before they initiate a pursuit and capture. They are voracious feeders, capturing spider mites which are held down with their front legs and then pierced to suck out the body contents. Individual females are able to consume on average about 50 mites per day in warm weather (around 30°C).

Monitoring:

Look for symptoms of spider mites such as pale-coloured spotting on leaves and the presence of webbing, as this is where six-spotted thrips are more likely to be found. A hand lens may help with close examination.

Six-spotted thrips, *Scolothrips sexmaculatus* feeding on a two spotted mite.

Six-spotted thrips, *Scolothrips sexmaculatus* nymph capturing a two spotted mite.

Parasitic wasps

(Families Aphelinidae, Braconidae, Encyrtidae, Eulophidae, Ichneumonidae)

Targeted prey:

Family Aphelinidae: Spiralling whitefly, silverleaf whitefly, melon aphid, diaspid scales, mealybugs, and other arthropods.

Family Encyrtidae: Spiralling whitefly, green vegetable bug eggs, various caterpillars, mealybugs, scales and other arthropods.

Family Eulophidae: Spiralling whitefly, bean fly larvae, various caterpillars (including *Helicoverpa* spp., diamondback moth), melon thrips, twentyeight-spotted potato ladybird and other arthropods.

Family Braconidae: Various caterpillars (including cucumber moth, bean podborer, cluster caterpillar, *Helicoverpa* spp.) fruit fly larvae, aphids and other invertebrates.

Family Ichneumonidae: Various caterpillars (including *Helicoverpa* spp.), various beetle and wasp larvae, spiders and other arthropods.

Description and parasitic activity:

Tiny to small wasp parasites

Adults: Family Aphelinidae - Tiny wasps usually yellow or brown in colour with a soft body. These wasps are usually internal parasitoids of scales, whiteflies, aphids and mealybugs although some are ectoparasitoids (develop under scales) and others are internal parasitoids of the eggs of moths and leafhoppers. This family contains the wasp parasitoids *Encarsia* sp. (used in the biological control of spiralling whitefly) and *Eretomcerus hayati* (used in the biocontrol of silverleaf whitefly). Size: Up to 1.5 mm in length.

Adults: Family Eulophidae - Minute wasps which are variable in colour, often with a metallic sheen. Eulophids have large eyes and transparent wings. They are either ectoparasitic, endoparsitic or hyperparasitic on a wide range of hosts, in particular leaf mining caterpillars and fly larvae. They attack all life stages from egg to adult. A few species are plant feeders and some are predatory. Size: 0.5-6 mm in length.

Adults: Family Encyrtidae - The species recorded from vegetables are generally pale to dark brown, often with a metallic sheen. Most species in this family are endoparsitoids of immature scales and occasionally the adults. Some are parsasitoids of mealybugs and fluted scales. In the Darwin area spiralling whitefly nymphs are common hosts and green vegetable bug eggs are occasionally attacked. Size: 0.5-5 mm in length.

Medium to large wasp parasites

Adults: Family Braconidae - Small to medium wasps which vary in colour from orange, red, yellow, black, white and brown. They have long thin bodies with long antennae and some have a prominent long ovipositor. They are usually external parasites of immature insects such as caterpillars and aphids but may also attack eggs and adults. Braconids have also been reared from fruit fly larvae. Size: 1-80 mm in length.

Adults: Family Ichneumonidae - Minute to large wasps, vary in colour from yellow to black (some with bright coloured markings on the body) and antennae with white or yellow mid-segments. Most species have a slender body, long antennae, long abdomen and an elongate projecting ovipositor.

Encyrtid wasp (Family Encyrtidae) parasite of melon thrips.

Aphelinidae wasp (Family Aphelinidae) parasite of whiteflies.

Braconidae wasp (Family Braconidae) parasite of fruit fly larvae.

Encarsia sp. (Family Aphelinidae) spiralling whitefly parasite.

Parasitic wasps

These wasps are usually parasites of caterpillar, beetle and wasp larvae. Other arthropods including spiders are also attacked. Eggs are laid, on or in the host. Ichneumonid larvae either feed in the body of the host or externally. These wasps generally attack larger hosts. Size: Most species up to 22 mm in length (not including the length of the ovipositor).

Biology:

Adult wasps feed on nectar of flowers, dew or are attracted to the honeydew produced by sap-sucking insects. The stages of insects attacked are often the egg or larvae but sometimes the pupae or adults are also attacked. Development from egg to adult usually takes about 30 days.

Integrated pest management:

Vegetable monocultures (of just one type of vegetable such as snake bean) support a limited diversity of wasp parasites. However growing more than one type of vegetable (such as snake beans, cucurbits and a range of Asian vegetables) increases the range of prey species as well as flowers producing nectar. Different flowering plants which may flower at different times offer an extended period of alternate food sources to the adult wasps.

Non-crop vegetation (often these are weeds or native vegetation) growing along the borders or adjacent to the cropping area will also encourage wasp parasites to visit the area and establish populations. Native vegetation and weeds also contribute to the nectar source available for the adult wasps. The access to non-crop vegetation also provides a refuge when the crop is disturbed such as during harvest or pesticide spraying.

Vegetables are usually only grown in the dry season and these crops are mostly annuals. The availability of perennial vegetation will support a continual population of hosts for the wasp parasites to lay eggs as well as providing nectar for a longer duration than the annual crops.

Natural or introduced wasp parasites have a greater chance of establishing and building-up populations if minimal or no pesticides are used.

Monitoring:

Whiteflies (larvae and pupae), mealybugs or scales that appear ‘darker’ or ‘black’ are individuals that may be infested with a wasp parasite. When examined closely with a hand lens or microscope the developing wasp parasite can usually be seen through the body of the host.

Caterpillar infested with braconid wasp eggs (shown in white on both sides of the caterpillar) as well as a larva/ pupa (extruding from the centre of the caterpillar).

Family Braconidae.

Family Ichneumonidae.

Diseases of Vegetables

Diseases

Bacterial leaf spots

Cause:

The four main leaf spot diseases of vegetables in the Northern Territory are caused by the bacteria *Xanthomonas campestris* pv *vesicatoria*, *Xanthomonas campestris* pv *campestris*, *Xanthomonas campestris* pv *vitians* and *Pseudomonas* spp.

Host Plants:

Xanthomonas campestris has been recorded on cabbage, capsicum and lettuce and *Pseudomonas* has been recorded on mint and basil. Many other vegetables are also hosts.

Importance:

Bacterial leaf spot, also known as black rot is considered to be one of the most serious diseases of brassicas especially in warm humid climates.

Symptoms:

On cabbage, initial black rot symptoms appear as small yellow v-shaped areas along the margin of the leaf. The affected areas of the leaf later turn brown, dry out and may coalesce causing the leaf scald symptom. The veins may appear black and will be seen as a black cross section when the stem or leaf petiole is cut. Other pathogens will also invade the affected parts and this can lead to a rapid deterioration and rot.

On lettuce, small (2–5 mm), translucent, irregular or angular water-soaked spots develop on the leaves. These later become dark brown and papery. If a large number of spots occur on a leaf, affected areas become yellow, then brown and die. Older leaves are more susceptible. Lettuce hearts may rot, or may not develop at all if infected when young.

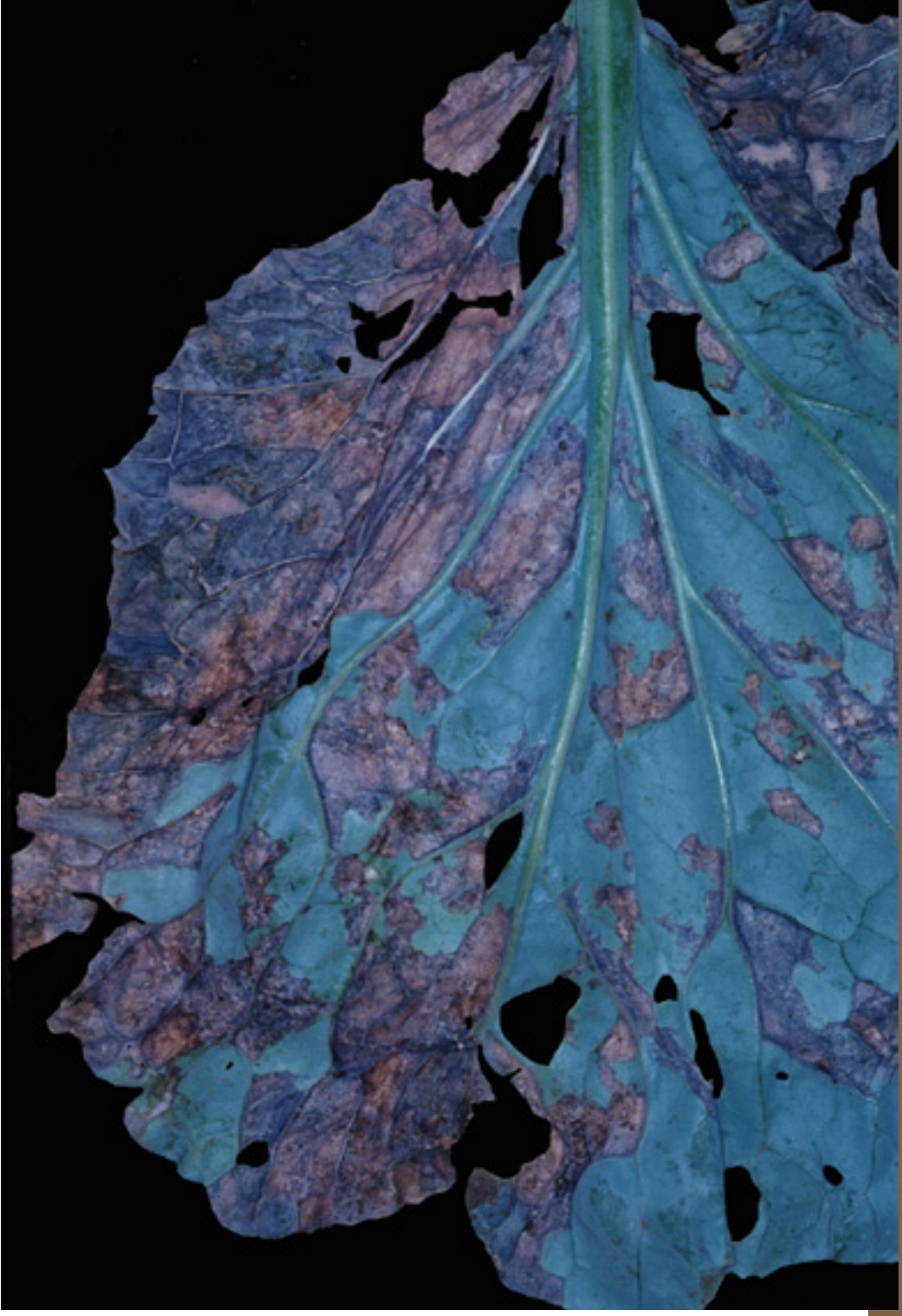
On capsicum leaves, small angular, water-soaked spots develop that later turn brown and seldom exceed 5 mm in diameter. In favourable conditions, the spots often coalesce and cause leaf blight. Severely diseased leaves, particularly lower leaves, fall from the plant.

Source of infection:

The bacteria can be introduced onto a property from seed, transferred by people and equipment as well as being dispersed by insects, wind, rain and windblown irrigation. The disease can survive in crop residues (before it decomposes) as well as brassica weeds and other brassica crops.

Management:

Do not use infected seed. Restrict the movement of infected plant material or crop residue into unaffected areas. Preventative sprays with a copper fungicide may reduce the spread of black rot especially at the seedling stage.



Cabbage leaf showing symptoms of bacterial leaf scald.

Bacterial wilt

Cause:

The bacterium, *Ralstonia solanacearum*.

Host Plants:

Tomato, capsicum, chilli, eggplant, butternut pumpkin, zucchini, Amaranthus, bitter melon, Chinese cabbage, coriander and many other plants.

Importance:

Bacterial wilt is a serious disease and symptoms generally appear suddenly, followed by plant death.

Symptoms:

Affected plants may suddenly wilt, often at the onset of fruit set then after a few days the plant will die. When the lower stem is cut, there is a brown discolouration on the cross section and after a few minutes a slimy milky exudate may appear. This is easier to see if the cut stem is placed in a glass of water. Other symptoms that may be associated with the disease are stunting and yellowing of the leaves.

Source of infection:

The bacterial wilt organism occurs naturally in some local soils. The soil types that seem to be most conducive to bacterial wilt are the red lateritic soils along the coastal strip around Darwin and the light textured levee soils such as those in the Katherine region.

The bacteria enters the plant through wounds in the roots. Plants which have been damaged by insects, transplanting or root knot nematodes are the most susceptible. The bacteria eventually invade the water conducting tissues which become clogged with bacteria and slime, preventing water transport which causes the plant to wilt.

The disease is spread by runoff water as well as by movement of affected soil and seedlings.

Management:

Chemical treatments are not practical. Some resistant varieties of tomatoes are available such as the variety ‘Scorpio’. Resistant rootstocks such as wild Malay eggplant (*Solanum melongena*) and Thai pea eggplant or devil’s fig (*Solanum torvum*) may be used for grafting. Other methods to prevent plants becoming infected are to grow them in clean pots using sterile potting mix or produce seedlings in soil free medium. Growing plants in sterile media using hydroponics is also an option.

Two wilted tomato plants in a row in the field.

Wilted tomato plant in the field.

Capsicum plant affected with bacterial wilt in a pot.

Alternaria leaf blight

Cause:

The fungus, *Alternaria cucumerina*.

Host Plants:

Butternut pumpkin, squash, zucchini and other cucurbits.

Importance:

The disease has a sporadic occurrence of medium significance at the beginning or end of the growing season when it is more humid. Although most cucurbits are affected, cucumbers and pumpkins are more susceptible to the disease.

Symptoms:

Spots or lesions develop on the oldest leaves, first as small water-soaked spots which then become larger circular brown areas that may spread over the entire leaf. As the disease progresses, the symptoms spread to younger leaves. Concentric rings are seen in the older spots giving it a target-like appearance. In affected vines, the leaves curl, dry out and fall prematurely. The vines may be partly or completely defoliated by harvest and the exposed fruit can become sunburnt and ripen prematurely.

Source of infection:

The fungus may be introduced from infected seed. Spores can be transmitted by wind and the disease will also survive on crop residues in the soil.

Management:

Provide optimum growing conditions including adequate soil preparation, nutrition, irrigation, and soil pH. Practice crop rotation so that cucurbits are only planted in the same field every three years. Plough in or remove crop residues. Only use clean, uninfected seed for planting. Apply fungicide as soon as the disease becomes apparent.

Alternaria leaf blight on pumpkin. *Image courtesy of D. Persley (DAFF Qld).*

Alternaria purple blotch

Cause:

The fungus, *Alternaria porri*.

Host Plants:

Shallot, spring onion and onion.

The fungus also occurs on leeks in southern regions of Australia.

Importance:

Purple blotch is fairly common in warm and humid areas.

Symptoms:

Early symptoms appear as water soaked spots on leaves which develop a white centre. The spots grow larger into marked zones that are brown to purple in colour. Leaves may eventually die. Onion bulbs are generally infected at harvest when the shoots are cut (topped) which may lead to post harvest rots.

Source of infection:

The disease is spread by spores carried in the wind. The infection can take place through the stomata or through the epidermis. Thrips feeding on the host plants may increase the chance of infection by the fungus. Leaves need to be wet for a period of eight hours at temperatures of 15–25°C for infection to take place.

Management:

If overhead irrigation is used, the watering time should be reduced so that the leaves are only wet for a short period. Ideally, practice crop rotation every three years. Apply fungicide as soon as the disease becomes apparent.

Leek with symptoms of Alternaria purple blotch. *Image courtesy of B. Hall (SARDI).*

Alternaria spot

Cause:

The fungus, *Alternaria brassicicola* and *Alternaria tenuissima*.

Host Plants:

Broccoli, cabbage and Chinese cabbage.

Importance:

This disease occurs sporadically in the Northern Territory, especially in the dry season when irrigation systems create a moist microclimate.

Symptoms:

Symptoms begin as small dark dots on leaves which then grow into larger circular, dark grey-brown to black spots or lesions. The larger spots have a ringed 'concentric' or 'target' pattern. As the spots age they dry out and tear, producing holes in the leaves. Lesions may also be found on stems as well as leaf stalks, flower stalks and seed heads. Seedlings may also be affected.

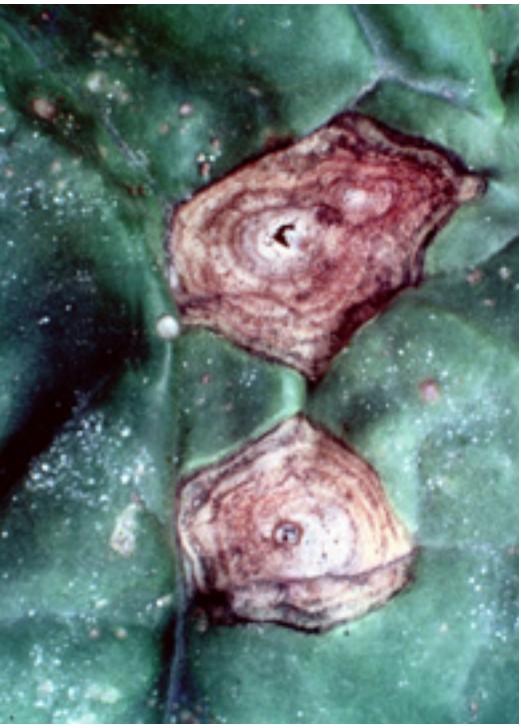
Source of infection:

The pathogen may remain in crop residue and the spores are spread by wind and irrigation splash. For infection to take place, the leaf needs to remain wet for six to eight hours. Warm moist conditions favour the development of the disease.

Management:

Carry out crop rotation with non-hosts and remove infected crop residues. Protective fungicide sprays will assist in managing this disease when it is prevalent.

Cabbage with Alternaria leaf spots.



Close-up of Alternaria leaf spots.

Cabbage leaf with Alternaria leaf spots.

Alternaria target spot

Cause:
The fungus, *Alternaria solani*.

Host Plants:
Tomato and potato.

Importance:
Target spot occurs sporadically in the Northern Territory and can be significant.

Symptoms:
The symptoms start off as small brown to black spots on lower leaves and become larger as the disease progresses forming a marked zone pattern. The spots are initially circular but as they grow larger they extend their shape within the leaf veins which gives them an angular appearance.

This disease generally affects the crop after flowering and as it ages. In the later stages, affected leaves are brown and dried to the extent where the whole plant may become defoliated.

Source of infection:
Transmission is from infected plants and residue of infected plant material. The spores are transferred by wind or irrigation water. To enable the spores to germinate, the leaf surface requires moisture.

Management:
Providing adequate nutrition and irrigation will reduce plant stress and promote a healthier crop. A preventative fungicide spray program will assist when the disease is prevalent.

Tomato affected by Alternaria target spot.
Image courtesy of Hall and Somerville photographic collection, UC Davis.

Tomato Alternaria target spot showing leaf and fruit field symptoms.
Image courtesy of Hall and Somerville photographic collection, UC Davis.

Anthracnose - cucurbits

Cause:

The fungi, *Colletotrichum orbiculare*.

Host Plants:

The only known host in the Northern Territory is long melon. In Queensland, butternut pumpkin, melons, cucumber and other cucurbits are also hosts.

Importance:

Cucurbit anthracnose is occasionally of importance on long melons in the Northern Territory. If clean seed is used for crop establishment, the disease is not usually a problem.

Symptoms:

Symptoms appear on the leaves as small, brown, circular spots surrounded by a yellow halo. As the infection develops, larger circular to elongate dark brown to black spots are usually seen along the network of veins. Infection on the runners is seen as pale brown, slightly depressed elongated spots.

Spots on the fruit are usually on the lower half; they are circular, pale brown and sunken with a raised margin. As the infection progresses the spots enlarge and may join up, covering a large part of the fruit. In humid weather, pink spores are seen on the dark spots. The infection does not penetrate to the fruit flesh, however this pathogen can weaken the fruit and allow other pathogens to cause further decay.

Source of infection:

The fungi can remain in the crop residue or the seed. Spores on infected parts of the plants can be washed off by rain or irrigation water. Farm equipment, clothing and footwear that is contaminated can transfer cucurbit anthracnose to other uninfected areas. Warm, humid weather is required for the disease to establish.

Management:

Preventative fungicide sprays will help with disease management. Seeds used for planting should be disease free.

Anthracnose lesions on long melon leaves.

Close-up of anthracnose lesions on a long melon leaf.

Anthracnose
– Chilli, capsicum, asparagus, eggplant and okra

Cause:
The fungi, *Colletotrichum gloeosporioides* and *Colletotrichum* species.

Host Plants:
Chilli, capsicum, asparagus, eggplant and occasionally on okra.

Importance:
This disease is more common on chillies than on capsicums. Although the pathogen commonly occurs on eggplant foliage, this usually does not lead to any significant damage. Anthracnose has caused major crop losses in asparagus in the Northern Territory.

Symptoms:
On capsicums and chillies the fruit can become infected at any stage, however, the symptoms appear when the fruit starts to ripen. Early symptoms are small, circular, slightly sunken and dark yellow spots. As the disease progresses on the fruit and continues to grow, the spots may join up. Black fruiting bodies may develop within the spots and are arranged in concentric rings. Black hairs may develop on the spots depending on the species of *Colletotrichum*. In humid weather, pink spores may form on the spots. As the rot continues to grow, the infection may spread into the seed cavity and affect the seeds.

On asparagus the dark, water-soaked oval shaped lesions on the stems or 'spears' can have a girdling effect and the plant eventually dies.

Source of infection:
Anthracnose can remain in the crop residue or the seed. Spores on infected fruit can spread to healthy fruit in wet and windy weather.

Management:
Preventative fungicide sprays will help with disease management. Disease free seeds should be used for planting.

Chilli fruit showing a sunken anthracnose lesion.

Capsicum fruit showing a sunken anthracnose lesion.

Bean rust

Cause:

The fungus, *Uromyces vignae*.

Host Plants:

Snake bean and cowpea.

Importance:

The climate in the Northern Territory is favourable to bean rust and the disease can occur throughout the growing season.

Symptoms:

The symptoms first appear as scattered light green spots which then develop into orange to reddish powdery pustules which contain spores. The spots or pustules are up to 2 mm in diameter and occur on the upper and lower leaf surface as well as on the pods. A yellow halo may be seen around larger pustules.

Source of infection:

Bean rust is spread by the transfer of spores by the wind from older infected crops to younger crops. It takes about 7–14 days for infections to develop.

Management:

The brown seeded variety of snake bean is the most susceptible to rust while the black or white seeded varieties are generally resistant. Therefore, growers should obtain a source of white or black seeds and use these to establish their crop.

Remove or plough in remnants of the older crop after harvest so that there is no residue of inoculum. Applications of suitable fungicides will help manage the disease. Fungicides that contain sulphur should be used with caution in warm weather.

Snake bean leaf showing the reddish brown rust pustules.

Brown etch

Cause:

The fungus *Fusarium* spp.

Host Plants:

Butternut pumpkin and occasionally other pumpkin varieties.

Importance:

Warm wet conditions favour the disease and these conditions may occur within the crop foliage in the dry season.

Symptoms:

The symptoms occur on the skin of the fruit which has bronze areas with concentric bands that later turn brown-grey. The brown etch is usually on the lower surface and may become quite enlarged and cracked. Secondary infections may enter through the broken skin and cause rots inside the fruit.

Source of infection:

The fungi causing brown etch are soil inhabitants and invade the fruit where ground contact has occurred.

Management:

Various factors may reduce the incidence of the disease in the crop and these include using less susceptible varieties (such as Kent pumpkin), avoiding the use of overhead irrigation, practising crop rotation with non-cucurbits and providing a calcium supplement to the plants which would help to improve the skin elasticity and reduce skin cracks.

Fruit should be washed with a suitable sanitiser after harvest to reduce the inoculum levels and the spread of the pathogen.

Butternut pumpkin with brown etch symptoms on the skin that was in contact with the soil.

Cercospora leaf spot

Cause:

The fungi, *Cercospora* spp. and *Pseudocercospora* spp.

Host Plants:

Capsicum - *Cercospora capsici*

Bitter melon, long melon and watermelon - *Cercospora apii*

Basil and Thai basil - *Cercospora guatemalensis*

Cabbage, rockmelon and Thai pea eggplant - *Cercospora* spp.

Okra - *Pseudocercospora abelmoschi*

Snake bean - *Pseudocercospora cruenta*

Tomato - *Pseudocercospora fuligena*

Importance:

Cercospora leaf spot is a common disease in tropical and subtropical regions, however, it is usually only a minor disease in a well managed crop.

Symptoms:

The symptoms are first seen as water-soaked lesions on leaves, petioles and stems. As the circular lesions grow, they develop a light brown or grey centre surrounded by dark red-brown margins. In ideal growing conditions, and using a high magnification hand lens, needle-like black spores may be seen in the light brown-grey centre of the spots. Concentric rings are formed as the lesions expand and over time the lesions will become dried and cracked. As the rings expand, they may join up to form blotches where large parts or whole leaves may become affected. The disease usually starts on the older foliage and then progresses onto the younger leaves and stems. In warm, wet or humid weather the disease will cause the leaves to wilt and die, leading to defoliation.

Source of infection:

Infection is transmitted from remnants of the old crop onto new crops. In wet conditions (or heavy dew), spores are able to germinate and the fungal hyphae can penetrate the leaf stomata which leads to infection. The spores are generally spread by wind, rain or irrigation water.

Management:

Cultural practices such as crop rotation will help reduce the inoculum levels in the field. Use clean seeds for planting. Protective fungicides are useful.

Cercospora leaf spot on watermelon leaves.

Basil leaves showing necrotic Cercospora leaf spots.

Choanephora fruit rot
(wet rot, Choanephora blight)

Cause:
The fungus, *Choanephora cucurbitarum*.

Host Plants:
Butternut pumpkin, squash and zucchini.

Importance:
Choanephora fruit rot affects flowers and fruit. It is more prevalent when there is warm weather (above 25°C), high humidity and rain. Fruit that are the closest to the ground are more likely to be infected. Although the pathogen is destructive, it is short lived and does not necessarily carry over to the next fruiting period unless conditions are favourable to disease development.

Symptoms:
The infection starts at the flowers and the blossom end of fruit as a soft wet rot during wet weather. The rotting process is very rapid and an entire fruit can rot completely within 24–48 hours. As the fruit rots, a 'furry' fungal growth can be seen on the fruit with numerous black spores which appear as 'heads' attached to the fruit by a fine hair-like stalk. The spores resemble those of *Rhizopus stolonifer*, however, in *Choanephora*, the spore bearing heads are branched (seen with x20 hand lens).

Source of infection:
During the off-season, the disease is able to carry over on dead plant material in the field as dormant spores. The spores are spread to the flowers by wind, water splash or insects (such as bees and other flower insects). The infection starts in the flowers and then moves to the fruit and fruit stem. Although the crops are grown in the dry season the disease can become a problem during occasional wet weather.

Management:
Some cultural practices will reduce the incidence of the disease in cucurbit crops, these include the use of raised beds (which will reduce soil moisture) and preventing fruit contact with the soil by using plastic mulch or trellising. Fungicides may reduce the incidence of the disease, however, it is difficult to protect blossoms throughout the growing period since new flowers open daily. Use drip irrigation instead of overhead irrigation.

Zucchini leaf showing leaf margin necrosis resulting from Choanephora infection.

Weakened watermelon fruit affected by Choanephora.

Corynespora leaf spot

Cause:

The fungus, *Corynespora cassiicola*.

Host Plants:

Tomatoes, cucumbers, other cucurbits, other crops (including sesame) and weeds.

Importance:

Corynespora leaf spot is a fungal disease that affects the leaves of host plants but not the fruit (with the exception of sesame). Disease development is favoured by warm weather, rainfall and moist conditions. Although many of the vegetable crops including tomatoes and cucumbers are grown in the dry season, high moisture or humidity within the foliage of the crop may be enough for the development of the disease.

Symptoms:

The symptoms first appear as small water-soaked spots or lesions and then enlarge to form large circular zonate spots that are tan to dark brown in colour. As the disease becomes more advanced, the leaf turns yellow and dies.

Source of infection:

The fungus can survive on crop debris, other crops and weeds. Plants become infected when the spores are transmitted by wind and water splash or rain.

Management:

If crops are grown in areas where the climatic conditions favour the development of the disease, fungicide sprays should be applied when the disease occurs.

Corynespora leaf spot on cucumber leaves.

Damping-off diseases of seedlings

Cause:

The fungi, *Pythium* spp., *Rhizoctonia solani, Phytophthora*, *Fusarium* and other species.

Host Plants:

Seedlings of almost all vegetable, fruit, ornamental and field crops.

Importance:

Pythium spp. and *Rhizoctonia solani* affects seeds or seedlings and the two pathogens are extremely common in soils in tropical and temperate regions.

Symptoms:

Pre-emergence damping-off is the infection or rot of seeds or seedlings before emergence.

Post-emergence damping-off occurs after the seedlings emerge from the soil. Affected plants wilt and collapse at or close to ground level and die soon after emergence. This is caused by a soft decay of the roots. Plants that survive are stunted. Older seedlings that have a harder or stronger stem such as cabbage do not fall over but the stem may be thin, discoloured or twisted and is referred to as 'wire stem'. The plant eventually becomes girdled and dies.

Source of infection:

Seedlings or seeds are infected just after they are sown in the field or in potting mix in seedling trays. The pathogens are spread by rain, irrigation water, contaminated equipment, infected plants, and soil or potting mix.

Management:

Grow seedlings in bagged potting mix on elevated benches using clean containers. Prevent contact with infected plants, contaminated soil or equipment. Treat water supplies if suspected that they could be a source of contamination. Thin out seedlings to provide good air circulation and avoid over-watering. Treat seeds with a recommended fungicide before they are sown.

Carrot seedlings killed by post emergence damping off in the field.

Downy mildew

Cause:

The fungi, *Pseudoperonospora cubensis* and *Bremia lactucae*.

Host Plants:

Angled loofah, cucumber, rockmelon, smooth loofah, squash, zucchini (pathogen *Pseudoperonospora cubensis*) and lettuce (pathogen *Bremia lactucae*).

Importance:

Although the disease has been recorded from a large range of cucurbits, it is more common in cucumbers and rockmelons.

Symptoms:

Downy mildew first appears as yellow angular spots on the leaves. The angular spots are more obvious on cucumber, and are more rounded on rockmelon and zucchini. On the underside of the leaves there is a purple-grey downy growth that appears on the spots. Eventually the spots turn brown and die off. If there are many spots on the leaf, the whole leaf may shrivel. Unlike powdery mildew, downy mildew requires moist conditions for development.

Source of infection:

The pathogen survives on cucurbit crops or weeds in the cucurbit family. The infection is spread by the dispersal of spores by wind or rain. Infection is common in the growing season.

Management:

Fungicides need to be applied if the disease is a problem. Where possible, use resistant varieties.

Cucumber downy mildew lesions shown as yellow chlorotic lesions on the upper leaf surface.

Rockmelon downy mildew lesions shown as angular downy lesions on the lower leaf surface.

Fusarium base rot and sudden wilt or vine decline

Cause:

Adverse cultural conditions. *Fusarium solani* and other fungi may be associated with the condition. The disorder is not caused by *Fusarium oxysporum*.

Host Plants:

Most cucurbits including rockmelons, watermelons, zucchini, cucumber and pumpkins.

Importance:

Fusarium base rot, also called Fusarium foot rot is usually only a sporadic problem. Sudden wilt, also known as vine decline often affects a significant amount of a mature crop.

Symptoms:

In seedling plants, leaves become pale and wilt. Bases of affected plants are orange brown to reddish brown in colour and are often swollen. Roots are initially healthy, but in advanced cases turn brown. There is no vascular browning. Symptoms in older plants are similar. A characteristic of the disease is that soft tissue at the base of the plant disintegrates, leaving only the stringy water conducting fibrous tissue which is often darkened in colour. Sudden wilt or vine decline can affect most cucurbits but is most common on rockmelons and honeydew melons. Young plants can be affected but it is usually vines that appear to be developing normally that suddenly turn yellow, wilt, and die prematurely from fruit set onwards. Rapid wilt of plants may result in complete death in less than two weeks, causing total crop loss.

Source of infection:

The problem is associated with plant stress occurring at fruit set. If the high demand for water can not be met during fruit enlargement, the vine wilts. These conditions develop if soil structure is poor and soil compaction is present, especially in the root zone.

Management:

Ensure soil is well managed and plants are not over-watered.

Rockmelon affected with Fusarium base rot disorder, showing the characteristic swollen plant base.

Fusarium wilt and base rot of basil

Cause:

The fungus, *Fusarium oxysporum* f. sp. *basilicum*

Host Plants:

Basil.

Importance:

Fusarium wilt and base rot is a major disease of basil in the Top End, both in the field and in hydroponics.

Symptoms:

The symptoms appear on seedlings as black water-soaked patches on the leaves and stems. When stems and roots are dissected, the vascular tissue is seen as a grey-brown colour. Symptoms on mature plants include stunting, wilting and defoliation. The outer stem tissue is discoloured and lateral shoots may die back from the tips. In a cross section of the dissected stems and roots, the vascular tissue has a dark grey to red brown discolouration. In advanced symptoms, the stem pith breaks down as a base rot.

Source of infection:

The disease was first introduced into Australia in infected seed and is now spread locally through infected soil. Once introduced onto a property, Fusarium wilt can persist in the soil for years. Fungal spores can be spread by air currents, wind and water.

Management:

Use resistant varieties and certified disease free seed for planting. Avoid moving equipment from infected sites to uninfected sites. In hydroponics, all trays and pots should be disinfected using an agricultural sanitiser.

Healthy basil, early stages and final dieback stage of Fusarium wilt.

Fusarium wilt of snake beans

Cause:

The fungus, *Fusarium oxysporum* f.sp. *tracheiphilum*.

Host Plants:

Snake beans.

Importance:

Fusarium wilt is a serious fungal disease of snake beans in the Darwin area. The disease was first reported in 1999 and has now spread to most snake bean growing properties.

Symptoms:

Infected plants wilt straight away and often collapse within one to three days. The symptoms usually appear when the plants flower and set fruit. To diagnose the disease, the stem, branches or tap root can be sliced into the centre length-wise with a knife. Infected plants have a reddish brown discolouration of the water conducting tissues (vascular tissues) towards the centre of the sliced stem or root. In some situations the discolouration is also seen in the branches.

Source of infection:

The fungus is soil-borne and infects plants through the roots, especially when the roots have been damaged by farming implements or infested with root knot nematodes. The fungus can also infect the seed.

Management:

The disease can be managed by taking precautions in adopting hygienic practices to prevent the disease from entering an uninfected property. Using clean seeds and using resistant plants. This is achieved by grafting a snake bean shoot onto a resistant cowpea rootstock. Grafted plants can be grown in Fusarium wilt infected soil. The variety of cowpea that is resistant to Fusarium wilt is 'Iron' cowpea. 'Iron' cowpea is also resistant to root knot nematode and has a strong, vigorous root system.

Snake bean crop in the field showing plants killed by Fusarium wilt.

Fusarium wilt infected snake bean split longitudinally showing internal browning of vascular (water conducting) tissues.

Fusarium wilt of watermelon

Cause:

The fungus, *Fusarium oxysporum* f. sp. *niveum.*

Host Plants:

Watermelon.

Importance:

Watermelon Fusarium wilt was detected in the Northern Territory in seedlings and established plants in 2011. The disease is serious in watermelons but does not affect other cucurbits such as rockmelons and cucumbers. The pathogen is considered to be a cool temperature disease and will thrive in optimum temperatures of 27°C but will develop between 20–30°C. Watermelon Fusarium wilt is present in all states and territories in Australia where the crop is grown. Some seeded watermelon varieties are resistant to the disease, however seedless varieties are not.

Symptoms:

Symptoms of Fusarium wilt in seedlings are similar to those of water stress with leaf burn and dieback starting from the top and going downwards. In field plants, the symptoms first occur with the wilting of older leaves and are often seen on one side of the plant, for example; one or two leaves or a branch of a vine being affected on one side. As the disease progresses, the plants eventually die. Unlike Fusarium wilt in snake beans and bananas, watermelon Fusarium wilt does not have vascular browning.

Source of infection:

The fungus is spread by infested seed, contaminated soil (found on machinery, equipment and plants), infected plants and by water. The disease can remain in the soil for ten years or more since it produces long lasting chlamydospores.

Management:

Grafting watermelon shoots onto resistant rootstocks of long melons or bottle gourds is currently the recommended strategy for managing the disease.

Seedless watermelon seedlings affected by Fusarium wilt showing plants in varying degrees of necrosis.

Watermelon Fusarium wilt showing a young plant wilting on plastic mulch in the field.

Maize downy mildew

Cause:

The fungus, *Peronosclerospora maydis/ Peronosclerospora australiensis.*

Host Plants:

Sweet corn and maize.

Importance:

Maize downy mildew (also referred to as Java downy mildew) was first detected in Australia in 1980 at Katherine then Douglas Daly in the Northern Territory and then in Kununurra in north Western Australia. The disease has also been found at Sunday Creek (south of Katherine). It was later detected in Queensland. The disease can cause severe losses in sweet corn and maize. The areas where the disease has been detected are generally drier regions.

Symptoms:

Damage on leaves appears as light green to pale yellow 'striping' with distinct margins between the healthy and infected areas. The leaf bases of young plants may be chlorotic (appear yellow) when the leaf grows out or unfolds.

Mature plants are often distorted with shortened or lengthened stems, deformed tassels, multiple cobs and deformed cobs. Root lodging may increase because of the disease.

Source of infection:

The disease occurs on plume sorghum and is probably endemic to northern Australia. Maize and sweet corn are usually infected from the disease on plume sorghum growing nearby. The spread of the disease is by transmission of spores which develop at night and are short-lived, therefore the infection can only spread a short distance.

Management:

In regions where sweet corn is vulnerable to the disease, the seeds should be treated with a fungicide before planting.

Diffuse chlorotic striping symptoms of Maize downy mildew on a maize leaf.

Pink disease

Cause:

The fungus, *Erythricium salmonicolor.*

Host Plants:

Chilli and Thai round eggplant as well as many tropical woody crops.

Importance:

This disease affects tropical woody crops that continue to grow throughout the wet season. Non-woody vegetables such as lettuce, kang kong etc. are not affected. The disease is favoured by fog, rain, overhead watering and other conditions which lead to high humidity.

Symptoms:

The symptoms include swollen or sunken areas on the stems and cracking or splitting bark. The plant may die from girdling.

Source of infection:

Pink disease penetrates intact or injured bark and eventually kills the cambium.

Management:

Affected areas of the plants can be pruned, ensuring that the entire infected area is removed. Applications of fungicides may assist control. Thin out dense plantings to increase air circulation and prune excess growth.

Pink coloured fungus on a stem.

Powdery mildew

Cause:

The fungus, *Podosphaera xanthii*.

Host Plants:

Zucchini, marrow, pumpkin, cucumber, rockmelon, watermelon, squash, bitter melon and other cucurbits as well as okra and snake bean.

Importance:

Powdery mildew can affect all cucurbits but seems to be more common in zucchini, marrows and pumpkin. Kent (Jap) pumpkins are more resistant than other pumpkins. In severe outbreaks, plants can become defoliated; this exposes the fruit which may become sunburnt and can lead to secondary rots.

Symptoms:

Symptoms appear as a white powdery growth on stems and leaves. Yellow spots develop and eventually whole leaves may turn yellow and shrivel. Unlike many fungal diseases, powdery mildew can establish readily in dry weather. Moisture from dew is sufficient for the initiation of infections.

Source of infection:

Development of the disease is favoured by warm, dry and cloudy conditions.

Management:

To reduce the chance of infection onto the crop, all old crop residues should be removed. The application of protectant and eradicant fungicides may be useful in managing the disease. Consider planting resistant varieties.

Leaves affected with powdery mildew showing white powdery growth of the fungus.

Close-up of powdery mildew growth on a bean leaf.

Rhizoctonia base rot

Cause:

The fungus, *Rhizoctonia solani*.

Host Plants:

Beans, cabbage, cauliflower, Ceylon spinach, cucumber, lettuce, rockmelon, Thai basil and many other cultivated plants.

Importance:

In the Northern Territory, base rot is particularly important and common in lettuce. *Rhizoctonia solani* is also one of the fungi that causes damping off in seedlings as well as root rots, stem rots, fruit rot and stem cankers.

Symptoms:

In crops such as lettuce, the pathogen affects the older leaves which are in contact with the soil. Brown lesions are seen on affected leaves and leaf stalks. Base rot causes the plant to wilt and die.

In plants that have fleshy stems and storage roots, the pathogen may cause brown rots or sunken cankers which may be covered in mycelium growth.

Fruit such as rockmelon in contact with the soil may become infected. The affected areas have water soaked marks that are sunken and cracked.

Source of infection:

Rhizoctonia diseases are more common in soils which are moderately wet, rather than dry or water-logged soils. The disease can persist in soils for an indefinite period and is generally found in the upper 20 cm of the soil or in organic material. The pathogen is spread by transfer of contaminated soil, water, equipment or plant material.

Management:

Methods of reducing the incidence of the disease include: growing crops such as rockmelon using plastic mulch (so that fruit is not touching the soil), using soil free potting mixes and avoiding injury to plants which allows entry of the fungus. Seeds should be treated with a recommended fungicide before planting.

Rhizoctonia base rot in lettuce.

Rhizoctonia ground rot of cucumber fruit.

Rockmelon fruit rots

Cause:

The fungi, *Fusarium semitectum*, *Geotrichum candidum* and *Rhizopus stolonifer*.

Host Plants:

Rockmelon.

Importance:

These diseases commonly affect the fruit after harvest while the produce is in transit or in storage.

Symptoms:

Fusarium rot, *Fusarium semitectum*

Circular lesions of various sizes develop on the skin of the fruit. The tissue under the lesions is corky or discoloured. The fungal growth is usually white and can also be pink or purple in colour.

Sour rot, *Geotrichum candidum*

Sour rot is a common post harvest rot on rockmelons. The infection starts at the stem end of the fruit. The pathogen causes the flesh of the fruit to rot rather than the skin. Infected tissue is often covered in white fungal growth which looks like camembert cheese.

Rhizopus soft rot, *Rhizopus stolonifer*

The rot appears as a soft water soaked area on the skin of the fruit. Cracks often develop and white fungal strands start to grow on the skin which later form masses of black spore heads (sporangia). The flesh becomes soft and wet.

Management:

Avoid harvesting in wet weather. Care should be taken during harvesting and packing to minimise or avoid damage to the fruit which allows entry of infections through the skin. Fruit should be cooled quickly after harvest. Apply recommended post harvest fungicide treatments.

Rockmelon fruit rot due to Fusarium.

Rockmelons in the field infected with fruit rot caused by *Geotrichum candidum*.
Image courtesy of Hall and Somerville photographic collection, UC Davis.

Sclerotium stem and base rot

Cause:

The fungus, *Sclerotium rolfsii*.

Host Plants:

Capsicum, eggplant, butternut pumpkin, tomato, watermelon, coriander, potato, various other vegetables, field crops and ornamentals.

Importance:

The pathogen is a soil-borne fungus which is common and widespread in tropical and subtropical regions. Plants that are affected develop rots in the lower stem, roots and crown. Fruit that are in contact with the soil may be affected and develop rots. The disease affects the fruit and runners of cucurbits at the soil surface.

Symptoms:

Symptoms appear as brown to black rot at the base of the stem. White cottony thread-like fungal growth (mycelium) with white spherical (sclerotia) bodies which later turn brown, 1–2 mm in diameter, grow in the affected area. Fruit that are in contact with the soil may become infected and rot. The affected stem becomes girdled resulting in sudden yellowing, wilting and death of the plant within days.

Source of infection:

The fungus can survive as sclerotia in the soil or in plant residues for years. The spread of the disease is generally from the transfer of hyphae or sclerotia on equipment, soil or plant material. Crops growing in less favourable conditions are often affected by *Sclerotium*.

Management:

Avoid introducing infected soil, equipment or plant material onto the property. Crop rotation may help in reducing the inoculum levels in the soil by alternating the crop with a resistant vegetable such as sweet potato. The removal or deep ploughing of the infected crop residue will help to reduce the inoculum level that will be in contact with the next crop. Weeds may also be a host for the disease and these should be monitored and removed. Adding lime to the soil to raise the pH to 7 may also help in managing this disease.

Sclerotium base rot on a French bean plant showing white mycelium radiating out from the plant base with white and brown pinhead sized sclerotia.

White blister

Cause:
The fungus, *Albugo ipomoeae-aquaticae*.

Host Plants:
Kang kong.

Importance:
White blister is a common disease in kang kong and there are very few other diseases that affect this crop.

Symptoms:
The symptoms appear as white blisters or 'sori' on the undersides of leaves and on stems. Blisters contain spores and are developed under the epidermis. When the epidermis eventually breaks, white powdery spores are released and dispersed. As the disease progresses, light green to yellow spots are seen on the upper leaf surface and spores may also be produced on the spots. Blisters may expand in size. In advanced infections, leaves become distorted, wilt and die off.

Source of infection:
Spores from infected plants and crop residue can be spread by water or wind.

Management:
It is important to practice appropriate field hygiene and be careful not to introduce the disease onto the property by using contaminated equipment and infected planting material. Apply recommended fungicides when the disease occurs.

White blister symptoms of Albugo infection on the undersides of kang kong leaves.

Root knot nematodes

Cause:

There are three species of root knot nematodes, *Meloidogyne javanica*, *M. incognita* and *M. arenaria* which are widespread in northern Australia. The first two species have been recorded from the Northern Territory.

Host Plants:

Beans (round, flat), bitter melon, cucumber, okra, rockmelon, snake bean, squash, Thai basil, tomato, watermelon, Amaranthus and Ceylon spinach (may also affect other vegetables: capsicum, eggplant, ginger, lettuce, sweet potato), various fruit crops, various field crops and various ornamentals.

Importance:

Root knot nematodes are of particular importance in warm or hot climates. Damage is usually most severe in sandy soils and clay loam soils.

Symptoms:

Plants infected by root knot nematodes often show symptoms of stunting, wilting and yellowing. In most situations, the nematode numbers increase through the season and symptoms are more likely to be seen on plants as they mature, flower and set fruit. At this stage the plants wilt and die back so that the fruit development is delayed or reduced.

The presence of nematodes in roots stimulates the surrounding tissues to divide and enlarge, forming galls which can develop all over the roots. The galls range in size from a slight root thickening to lumps of 5–10 mm in diameter. Heavily infested roots die off and the root system becomes weakened with only a few remaining roots with large galls. The galls produced from nematodes should not be confused with small nodules on the roots of leguminous plants such as beans which are developed by the presence of beneficial nitrogen fixing bacteria.

Source of infection:

Crops grown on new ground are usually not noticeably affected, however when crops are grown in successive years on the same ground, root knot nematodes often build up to cause noticeable disease symptoms.

Biology:

Mature female nematodes lay hundreds of eggs on the surface of the root or within the root tissue. The juveniles emerge from the eggs and work their way to the root tip where they enter the plant. Juvenile nematodes are about 0.5 mm in length. Most nematodes are females, although occasionally males are produced. At maturity the females have a sphere or pear-shaped body while the males remain worm-like. The complete life cycle from egg to adult is about 4–6 weeks in warm weather and 10 weeks or more in cooler weather.

Plants that have been infected by more than one generation of nematodes generally have large galls on the roots which are seen towards the end of the growing season.

Management:

Root knot nematodes can be managed effectively on horticultural plots by incorporating large amounts of organic plant matter into the soil in the form of green manure crops or plant waste prior to growing a crop at the rate of at least 8 tonnes dry matter per hectare. For large areas, it is more efficient to grow a green manure crop and then incorporate (plough) it back into the soil.

In parts of the Philippines, the trap crop plant, *Crotalaria spectabilis* is used commercially for effective management of root knot

nematodes. This was trialled once in Darwin and could be useful in home gardens or small holding situations where the incorporation of bulk organic material is not practical.

Root knot nematode affected snake bean with galls on roots.

Phytoplasmas

Cause:
Phytoplasma.

Host Plants:
Capsicum, chilli, sweet potato, eggplant, snake bean, other beans, tomato, rockmelon, zucchini and many other cultivated plants and weeds.

Importance:
Phytoplasma diseases are not economically important in the Northern Territory.

Symptoms:
Symptoms vary depending on the plant host. The most common phytoplasma symptoms are yellowing of leaves, stunting, dieback, little leaf, proliferation of shoots (witches' broom), leaf-like flowers (phyllody), greening of petals (virescence) and floral gigantism (big bud).

Source of infection:
Phytoplasmas are transmitted by leafhopper vectors. Two common phytoplasma diseases found in the Northern Territory are associated with tomato big bud and sweet potato little leaf phytoplasmas. These are transmitted by a leafhopper, *Orosius argentatus,* which breeds mainly in weeds. These leafhoppers tend to move onto a crop in dry weather when weeds are water stressed and dry out. Once a plant is infected, the disease can spread unevenly throughout the plant. In some cases, several branches may show symptoms while others appear healthy.

Management:
Become familiar with the identification of the leafhopper and learn to monitor the vector in crops. Remove weeds that are growing around crops.

Other phytoplasmas:
'*Candidatus* Phytoplasma australiense' (Papaya dieback): Crops affected include Jarrahdale and butternut pumpkins. This is a rare phytoplasma disease referred to as pumpkin yellow leaf curl disease. This phytoplasma has been found in papaya in the Northern Territory, it is associated with grapevine yellows, strawberry green petal and strawberry lethal yellows diseases in the southern states. The identity of the insect vectors transmitting this Phytoplasma is unknown.

Eggplants infected by Phytoplasma showing numerous small chlorotic leaves compared with healthy leaves on uninfected eggplants.

Pumpkin plant with yellow leaf curl disease symptoms caused by the same phytoplasma that causes Papaya dieback.

Mosaic viruses of cucurbits

Cause:

Two viruses belonging to the potyvirus group, cucurbit strain of papaya ringspot virus (PRSV-W) and zucchini yellow mosaic virus (ZYMV).

Host Plants:

Zucchini, squash, cucumber, long melons, smooth luffa, watermelon, rockmelon, gramma pumpkins, and other pumpkins such as butternut and Kent (Jap).

Importance:

Mosaic viruses of cucurbits can cause severe production losses where entire crops may become infected. In the Northern Territory, the cucurbit strain of papaya ringspot virus was first detected in 1977. The zucchini yellow mosaic virus was first detected in 1989.

Symptoms:

The leaves of infected plants have a mottled or mosaic pattern of light and dark green instead of the normal dark green colour. Leaves may also be distorted, bubbled or very narrow (especially in zucchini). The fruit of green/black zucchini and butternuts that are infected with the virus is often distorted with bubbles and is unmarketable. Infected golden squash and golden zucchini fruit display a colour change where the yellow colour is replaced to some extent by green.

Source of infection:

These viruses are spread only by aphids. Other insects and mites feeding on the plants can not transmit the virus to healthy plants. The virus can be picked up by an aphid on its mouthpart in a matter of a few seconds and then injected into the next healthy plant that it feeds on. The virus is retained in the aphid for only a short time which is usually a few minutes to hours. Aphid transmission of the virus is usually only within short distances of nearby infected crops, however, winged aphids are able to spread the virus further, up to several kilometres if dispersal is assisted by the wind.

In the Top End any species of aphids can transmit the viruses, but the main vector is *Aphis gossypii* which is the most common aphid on cucurbits.

Management:

Since the virus is transmitted by aphids it is important to monitor the crop for aphids as well as for the virus symptoms. The use of sprays to control aphids may help in preventing infestations, however, it only takes one aphid to transmit the virus.

Any plants that are showing virus symptoms should be removed immediately so they do not become new sources of infection. Virus infections usually start with one or a few plants in a crop, so regular monitoring and removal of infected plants is important. Non-sequential plantings should be made to ensure breaks in virus build-up. It is also important to communicate and cooperate with neighbours to inform each other and to ensure that all crops are monitored regularly and are free of the virus.

Jarrahdale pumpkin plant infected with ZYMV showing stunting, yellow mosaic, puckering and distortion of leaves.

Watermelon infected with ZYMV showing bubbling and mottling of the fruit.

Sweet potato feathery mottle virus

Cause:

The potyvirus, sweet potato feathery mottle virus.

Host Plants:

Sweet potato and other *Ipomoea* species.

Importance:

The virus causes reduced yield and a decline in the quality of the storage roots. It is a common and widespread virus and the extent of damage to sweet potatoes will depend on the variety, growing conditions and the age of the plants.

Symptoms:

Symptoms may include mottling of young leaves, irregular scattered yellow spots with a purple margin as well as yellowing along the mid vein. In older leaves, symptoms may be more obvious. During early crop establishment, plant vigour may be reduced. The disease causes the storage roots to become elongate and thinner and is worse if the affected planting material is used for future crops. The outside of the storage roots is generally covered in short shallow brown cracks and the flesh of orange varieties is paler in colour.

Source of infection:

The virus is spread by aphids and the use of infected planting material.

Management:

Planting material should only be sourced from virus free nursery stock. Monitor crops regularly and remove and destroy any infected plants in the field.

Sweet potato showing feathery mottle symptoms on leaves.

Sweet potato storage roots showing feathery mottle cracking symptoms.
Image courtesy of Hall and Somerville photographic collection, UC Davis.

Tomato leaf curl virus
Australian strain (also known as tomato leaf roll)

Cause:
Tomato leaf curl virus (TLCV-Au) – Australian strain, a gemini virus.

Host Plants:
Tomatoes and eggplant.

Importance:
Tomato leaf roll is one of the most serious diseases of tomatoes in the Top End. The disease is of particular importance along coastal areas.

Symptoms:
Plants affected by tomato leaf roll have a much reduced rate of growth and become stunted or dwarfed. New leaves are rolled upwards and inwards, the older leaves are often bent downwards and are stiff. Leaves are thicker than normal, have a leathery texture and often have a purple tinge to the venation on the underside. Affected new leaves are generally paler. If fruit are produced, they are smaller than normal, have a dry texture and are unmarketable. Plants with an advanced infection will not produce fruit.

Source of infection:
The virus can be graft transmitted from one tomato to another as well as between other solanaceous plants. The pathogen can be transmitted to tomato plants by the native sweet potato whitefly, *Bemisia tabaci*. It is suspected that the TLCV-Au is harboured by some wild/native plants and is transmitted from these to tomato plants.

Trials have shown that the incidence of tomato leaf curl was higher earlier in the year and subsided later in the year. For example, crops sown in February had a higher incidence than those sown in March.

When grafting tomatoes onto wild Malay eggplant to control bacterial wilt, it should be noted that the eggplant is a symptomless host of the disease. Infected eggplants will infect tomato scions with TLCV-Au through the graft.

Management:
There are no resistant varieties of tomatoes. If pesticides are used to control whiteflies, this will reduce the incidence of the virus. Cucumbers or squash are more attractive to whiteflies than tomatoes, therefore can be used as bait crops when inter-planted with tomato.

To reduce the prevalence of the disease in tomatoes it is recommended that the crop is sown in late March rather than earlier in the year.

Tomato leaf curl virus (TLCV-Au) affected tomato plant showing a leaf with chlorotic curled leaflets reduced in size.

Stunted plant affected with tomato leaf curl virus (TLCV-Au).

Disorders of Vegetables

Disorders

Blossom end rot

Cause:

Physiological disorder, calcium deficiency and moisture imbalance.

Host Plants:

Tomatoes, watermelons and capsicums.

Importance:

The immediate cause of blossom end rot is an inadequate supply of calcium to the developing fruit. This does not necessarily mean that there is a lack of calcium in the soil but it is more likely that the calcium in the soil is not available to the plant or there is a problem with the calcium uptake by the roots. Also, there may be calcium in the plant that is unavailable to the developing fruit.

Calcium is required for plant growth and is used for cementing cell membranes to hold plant cells together. In plant parts where there is rapid growth, such as the developing fruit, there is a special demand for calcium. Unlike other essential elements, calcium cannot be stored in older plant tissues and then transported to newly developing tissues where it is needed. An inadequate supply of calcium can result in the death of cells and breakdown of plant tissues. This occurs in blossom end rot where the fruit is the furthest from the source of calcium and the weakest 'sink' for calcium.

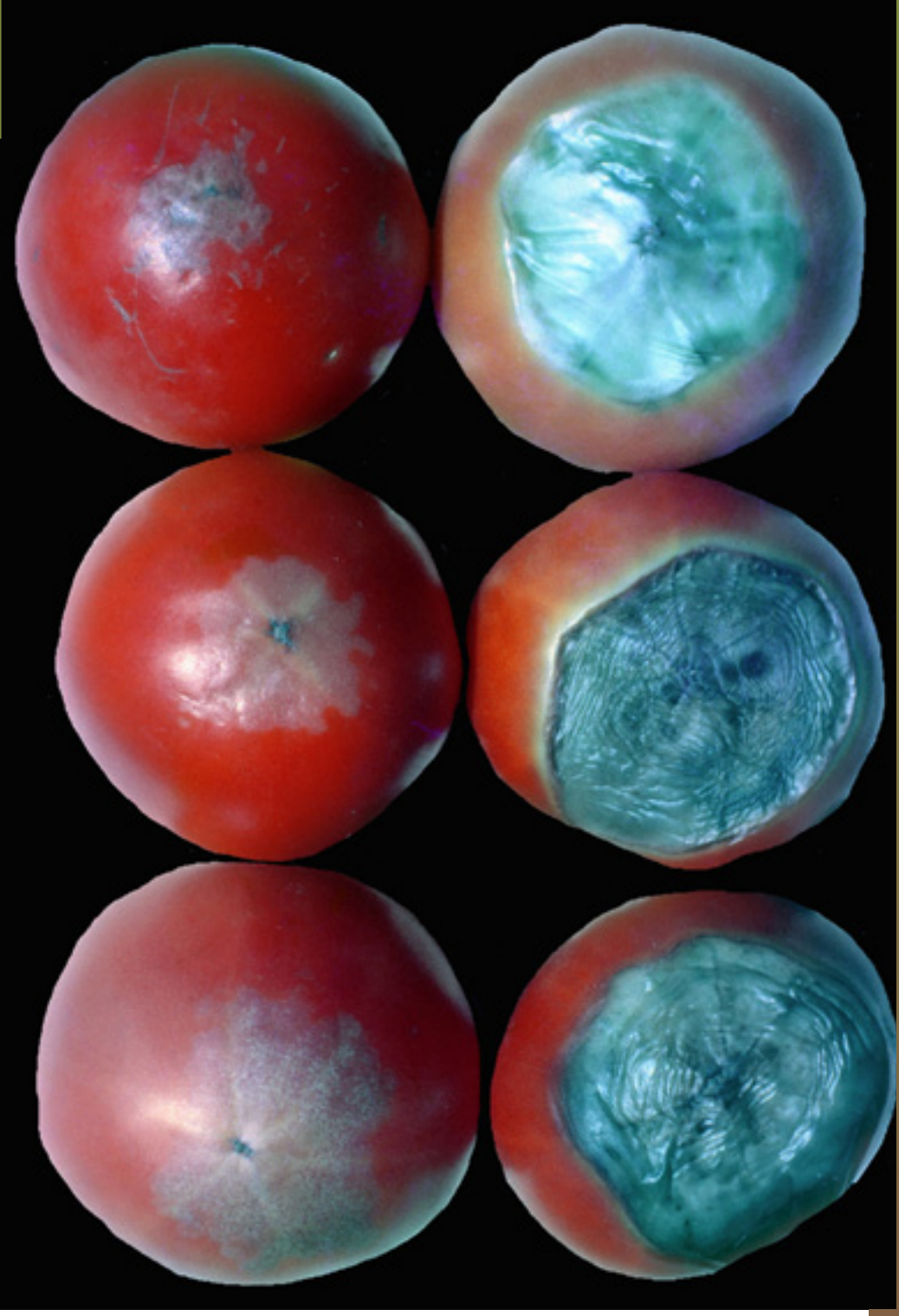
Symptoms:

In tomatoes and capsicums, the first sign of the disease is a water-soaked area at the blossom end which eventually turns brown and becomes dry, sunken and leathery in texture. In watermelons, the blossom end appears dry and then turns brown to black. Secondary mould may grow in the affected areas and are sometimes mistakenly blamed for the condition.

Management:

If blossom end rot is suspected, it is worth checking to see if the plants are suffering from an inadequate supply of calcium and then carry out procedures to correct the imbalance or the condition.

The conditions that may lead to an inadequate calcium supply include: insufficient water, uneven watering, dry hot windy weather, low calcium content in the soil, excessively low soil pH, excessive use of nitrogen fertiliser, excessive amounts of other salts in the soil and water logging.



Tomato fruit affected with blossom end rot.

Cucurbit stunting disorder

Cause:

Adverse soil conditions. It is thought that areas of 'hard pan' in sandy soils are the source of the problem.

Host Plants:

Rockmelons, squash and butternut pumpkins.

Importance:

The disorder affects cucurbit crops on the sandy soils in the Katherine and Mataranka areas of the Northern Territory.

Symptoms:

Affected plants are markedly stunted, with rockmelon and butternut pumpkins having much reduced vines. Plants are not wilted and do not have symptoms of base rot or root rot. The root systems of plants are reduced in size and length, and are often bent over as 'J-shaped' roots. There are no symptoms of root knot nematodes or of other nematode damage.

Source of infection:

This is a cultural disorder rather than a disease.

Management:

It is suggested that deep ripping of the affected areas at the start of the wet season (before planting a deep rooted green manure crop) or at the end of the wet season (while incorporating a green manure crop) can break up any hard pans in the soil and allow better root growth.

Cucurbit stunting disorder showing a patch of stunted plants with chlorotic and necrotic leaves amongst a crop of butternut pumpkins on sandy soil.

Wallaby ear

Cause:

A toxin injected during feeding by the leafhopper, *Cicadulina bimaculata*.

Host Plants:

Sweet corn, maize, sorghum and millet.

Importance:

The symptoms on sweet corn and maize are caused by a toxin injected into the plant by the feeding leafhopper. This disorder was once referred to as a virus but the symptoms are caused by the reaction of the plant to the toxin.

Symptoms:

The affected leaves are short, dark green, and have prominent veins on the underside. Plants may be stunted, especially if they have been affected at an early stage by the leafhoppers. Young plants are more vulnerable to the disorder and have more pronounced symptoms.

Source of infection:

The leafhopper, *Cicadulina bimaculata* is yellow or bright green in colour, wedge shaped and 3 mm in length. The adults have wings and jump readily. The leafhoppers breed in grasses and can move onto corn or maize crops to feed. The amount of spread and extent of damage depends on the density of the leafhopper population.

Management:

Monitoring for leafhoppers and managing their population will help reduce the incidence of the disorder on susceptible crops. Plant less susceptible varieties if wallaby ear is a problem.

Affected sweet corn plant. Leaves have prominent thickened veins and are folded to look like wallaby ears.

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Glossary

A

Abdomen	The rear main body segment of an insect, mite or spider.
Adult	A fully grown and mature arthropod.
Alate	An insect stage or caste that has wings.
Annual	Occurring once a year. A crop that is grown for one season.
Antenna	A jointed, movable, sensory appendage usually occurring in pairs (plural: antennae) on the head of arthropods.
Anther	Male part of the flower.
Arthropod	An invertebrate in the Phylum Arthropoda, having a segmented body, jointed limbs, and usually a chitinous exoskeleton (external body covering or shell) that goes through moultings. Examples include: insects, mites, spider, crustaceans and myriapods.

B

Bacterium	(plural bacteria). One celled organism capable of causing an infection.
Ballooning	(in reference to spiders). Dispersing by catching the breeze with silk strands.
Beneficial	An organism (insect, mite, spider or pathogen) that preys on or parasitises a plant pest. Pollinators (although they do not necessarily prey on or parasitise pests) have also been included as beneficial organisms because they benefit the plant.
Biological control (or biocontrol)	Method of controlling a plant pest by using a beneficial organism.
Biological control agent	An organism that is used to control a plant pest.
Biopesticide	A biological pesticide such as a bacterium or virus that has been mass produced and formulated to treat a plant pest.
Blight	A plant disease causing rapid and widespread death of plant tissue. Symptoms include extensive spotting, discolouration, wilting or deterioration of leaves, flowers and stems.
Brassica	Plants in the genus Brassica (family Brassicaceae). Collectively the members of the family are known as cruciferous vegetables.

C

Calyx	The sepals of a flower. The calyx is also seen at the stem end of some fruits such as tomato and eggplant.

Cambium	(vascular cambium). The meristem tissue between the xylem and phloem that produces secondary vascular tissues which are the secondary xylem (wood) and secondary phloem (inner bark). The cork cambium is a layer of meristem tissue that produces the cork (part of the bark).
Camouflage	The appearance of an organism that helps it to conceal or blend into the background.
Canker	A necrotic and often sunken lesion on a stem or branch of a plant.
Cannibalism	The act of an organism that feeds on members of its own species.
Canopy	The cover formed by the upper branches and foliage of a plant.
Carapace	The chitinous exoskeleton that covers the dorsal anterior part of a spider.
Carrion	Dead and decaying flesh of an animal.
Castes	Different types of individual forms within a species of social insects. Each caste is adapted morphologically to perform different functions.
Cast skins	The skin that is shed through growth and moulting.
Cephalothorax	Fused head and thorax of a spider.
Chelicera	(plural chelicerae). The chelicerae are mouthparts (of spiders and other arachnids) that are used to grasp food.
Chlamydospore	A thick-walled asexual spore formed by the modification a fungal hypha cell.
Chlorosis	Partial or complete absence of normal green colour. Affected organs become pale green, yellow green, yellow or white.
Coalesce	To grow together to form one mass or to blend.
Cocoon	A silk case or covering which forms a protective layer for the insect during the pupal stage.
Colony	Many individuals of the same species living together. Usually refers to social insects such as termites or ants.
Corolla	The petals of a flower referred to collectively.
Cruciferous vegetables	Vegetables in the family Brassicaceae (such as cabbage, buk choy, choy sum, mustard greens).
Cucurbit	Refers to a plant in the family Cucurbitaceae, such as a pumpkin, cucumber, squash or melons.

D

Debris	The remains of anything broken down. Generally refers to remains of plant material or other matter on the soil.

Glossary

Defoliate	To lose or become stripped of leaves.
Desiccate	To remove moisture.
Dicotyledon	A broadleaf plant in the plant class Magnoliopsida.
Dieback	Necrosis of a shoot beginning at the apex (top) and spreading down towards the older tissues. May result in stem death.
Discolour/ discolouration	To change colour; result of a change in colour.
Disease	Any malfunctioning of host cells and tissues that results from continuous irritation by a pathogenic agent or environmental factor and leads to development of symptoms.
Disorder	An abnormal condition of a plant caused by nutritional, physiological or environmental factors.
Disperse	To spread widely.
Diversity	A range of different types.
Dorsal	Situated on the upper side of the body.
Dung	Excrement.

E

Ectoparasitoid	A parasite that lives externally on and at the expense of another organism which it kills.
Egg	The round, oval or elongate body produced by the female that hatches into a larva (insects and mites) or spiderling (spiders).
Elytron	(plural elytra) A pair of hardened forewings of beetles which forms a protective cover for the flight wings.
Endoparasitoid	A parasite that lives internally at the expense of another organism which it kills.
Enzyme	A protein capable of producing chemical changes in organic substances such as in digestion.
Epidermis	The outer layer of the 'skin' of plants, covering leaves, flowers, young stems and roots.
Eukaryotic cells	Cells with a nucleus and other complex membrane bound structures. Eukaryote organisms include fungi, plants, insects and animals.
Exoskeleton	The external hardened skeleton (cuticle, covering or shell) to which muscles are attached internally.
Exudate	A substance that oozes out of a pore or small opening.

F

Flower	The blossom of a plant.
Foliage	The leaves of a plant referred to collectively.
Forage	To search for food.
Frass	Solid excreta of an insect (usually produced by the larval stage).
Fruit	The structure that is formed after the fertilisation of the flower.
Fungal pathogen	A fungus that can cause a disease in a plant.
Fungicide	A product used to destroy or inhibit fungi or fungal spores.
Fungus	(plural fungi). A eukaryotic organism that includes, moulds, mildews, smuts, rusts, mushrooms and yeasts.

G

Generalist predator	An insect, mite or spider that attacks a large range of prey.
Generation (one generation)	One full life cycle.
Germinate	Reference to seeds and spores. Start to grow or develop.
Grub	The larval stage of a beetle.

H

Habitat	The natural environment of an organism.
Halo	A ring or circle (in reference to the marking made by a disease symptom).
Hatch	The emergence of the larva (insects and mites) and spiderling (spiders) from the egg.
Honeydew	The sugary substance secreted by sucking insects such as aphids, scales, mealybugs, and leafhoppers.
Host	A living plant, insect, mite or spider that is parasitised or used as a food source by a pest or disease agent.
Humus	Dark organic material in soil that is produced by the decomposition of plant or animal matter.
Hypha	(plural hyphae). Tubular thread-like filament. A mass of hyphae form mycelium which are the structural components of a fungus.

Glossary

I

ICA	Interstate certification assurance
Immature	Not mature or fully developed.
Inoculum	(plural inocula). A pathogen or a part of a pathogen that can cause infection when transferred in favourable conditions.
Insect	An organism in the class Insecta. An insect is an arthropod that has a chitinous exoskeleton, three body segments (head, thorax and abdomen), three pairs of jointed legs (in the adult stage), compound eyes and a pair of segmented antennae.
Instar	The growth stage between two successive moults.
Invertebrate	Organisms without a vertebral column (backbone).

K

Kairomones	A chemical substance emitted by an organism (such as an insect or mite) that has an adaptive benefit to another species (without benefit to the emitter).

L

Larva	(plural larvae). An immature stage of insects that have complete metamorphosis.
Lateral root	Roots that grow horizontally from the primary root.
Leaf	A plant organ (often green) that is usually attached to the stem.
Life cycle	A series of stages in the growth and development of insects, mites and spiders.

M

Maggot	Soft bodied, legless larva of flies.
Mandible	Mouthpart appendage usually for biting.
Mature	Fully grown or completely developed.
Membrane	A thin layer of animal or plant tissue.
Membranous	Resembling a membrane.
Meristem	The tissue found in areas of the plant where growth can take place.
Midrib (of leaf)	The central vein of a leaf.
Mimic	To imitate.
Miticide	A substance for killing mites.
Monitor	To inspect or examine.

Monocotyledon	A narrow leaf plant in the class Liliopsida.
Monoculture	One type of crop.
Moult	To shed skin or outer layer during growth.
Mulch	A covering of compost, plant material, plastic sheeting or other material around the base of plants to reduce evaporation, add nutrients and reduce the growth of weeds.

N

Native	Indigenous origin.
Natural enemy	A predator or parasite that controls the population of plant pests.
Necrosis	The death and discolouration of plant tissues.
Nectar	The sugary secretion in flowers that attracts pollinators.
Nematode	Generally microscopic worm-like organism that feeds on bacteria, or are parasites of plants and animals.
Nocturnal	Occurring at night.
NPV	Nucleopolyhedrovirus.
Nucleopolyhedrovirus	A virus affecting insects and is used as a pesticide to control caterpillars (the larvae of moths and butterflies).
Nymph	Immature stage of insects that have an incomplete metamorphosis as well as mites.

O

Ootheca	(plural oothecae). A protective casing or capsule containing eggs.
Opportunists	Refers to predators that adapt their feeding to whatever food source is available.
Organism	A form of life such as an insect, plant, bacterium, fungus and others.
Ovipositor	The organ used for laying eggs.
Ovule	The female germ cell which after fertilisation develops into a seed.

P

Parasite	An organism that lives at the expense of its host.
Parasitic	Referring to a characteristic of a parasite.
Parasitoid	A parasite that kills its host.
Pathogen	A fungus, bacterium, virus or other organism that has the potential to cause a disease.
Pearlescent	An iridescent luster that resembles that of a pearl.

Glossary

Pedicel	The stalk of an individual flower.
Pedipalps	In arachnids, a pair of appendages behind the chelicerae, which function to grasp prey and in sexually mature male spiders to transfer sperm to the female.
Perennial	Referring to plants that live for more than two years.
Pesticide	A chemical preparation for destroying pests (insects-insecticide and mites-miticide), fungi (fungicide) or weeds (herbicide). Sometimes used as a collective term to refer to insecticides, fungicides and herbicides.
Petiole	The stalk of a leaf.
Photosynthesis	In plants, using chlorophyll and associated pigments, the formation of complex organic materials such as carbohydrates from carbon dioxide, water and inorganic salts using sunlight as the energy source.
Phytoplasma	Prokaryotic microorganisms that occur in the phloem and are transmitted to other plants by phloem feeding insects.
Pollen	In flowering plants, the (often yellowish) grains or fine powder (which contains the sperm cells) produced in the anther used in fertilisation (transfer of pollen from the anther to the stigma).
Pollination	The transfer of pollen from the anther to the stigma.
Pollinator	A vector that moves pollen from the anther to the stigma for fertilisation.
Polymorphic	Many forms in the caste such as in ginger ants, there are minor and major workers, and reproductives.
Polyphagous	Feeding on many different types of food.
Predator	An insect, mite, or spider that preys on another organism.
Prey	An insect, mite or spider that is pursued or captured by a predator.
Primary root	The first root that develops from the seed.
Proboscis	The mouth part of an insect that is adapted for sucking and piercing.
Prokaryotic	Cells without a nucleus. Prokaryote organisms include bacteria and phytoplasma.
Prosternum groove	A groove on the ventral side of the thorax.
Pupa	(plural pupae). The inactive stage that forms after the larva matures and before the adult stage.
Pupate	To develop into a pupa.
Pupation	Process to become a pupa.

Q

Quiescent	Stage where metabolism and development has slowed down.

R

Refuge	Vegetation where there is shelter, food and protection from the environment.
Reproductives (primary and secondary)	The individuals in a caste that are able to produce offspring.
Resistance (pesticide resistance)	A chemical pesticide may not be 100% effective in killing the targeted pest, therefore some of the individuals survive to reproduce. The offspring of the 'survivors' can inherit the traits of being resistant to the pesticide and then pass it on to future generations, where each generation may develop further resistance to the pesticide.
Rootstock	A plant with roots that have suitable pest or disease resistance or specially selected roots (for certain environmental or climatic conditions) that is used as stock in plant propagation.
Rostrum	Protruding mouthpart.
Runners	Reference to the vine or actively growing stem of a climbing plant such as beans or cucurbits.
Rust	A fungal disease giving a 'rusty' appearance to a plant and caused by one of the Uredinales (rust fungi). The spores produced vary in colour.

S

Sap	The circulating fluid of a plant.
Scavenger	An insect or mite that feeds on dead organic matter.
Sclerotium	(plural sclerotia). A resistant vegetative resting stage of a fungus which consists of a compact mass of hardened hyphae containing food reserves and capable of surviving unfavourable environmental conditions.
Seed	The fertilised matured ovule of a flowering plant containing the embryo.
Seedling	A young plant grown from a seed.
Seta	(plural setae). A hair.
Shoot	A stem with leaves.
Signs	Any indication of disease on a host plant from direct observation of the pathogen or its parts (spores, mycelium, exudate etc.). Also refer to *symptoms*.

Glossary

Silk	A soft fibre that is produced by certain insects and spiders.
Siphunculus	(plural siphunculi). Paired tubular structures on the abdomen of aphids.
Skeletonised	Chewing damage to leaves where the tissue is eaten and only the network of veins are intact.
Soldiers	In termites and ants, the individuals in the caste that defend the colony.
Sooty mould	A black fungus generally found on foliage where there is honeydew.
Sorus	(plural sori). A compact mass of sporangia.
Spiderling	Immature spiders.
Spinnerets	Silk spinning organ of a spider.
Sporadic	Appearing or happening at irregular intervals.
Sporangium	(plural sporangia). The case or sac which produces and contains spores.
Spore	A reproductive cell capable of developing into a new individual by asexual reproduction. Spores are produced by bacteria, fungi and plants.
Stem	The stalk of a plant which supports leaves, flowers or fruit.
Stigma	Female part of the flower.
Sting mark	Produced by fruit flies laying eggs into fruit. The pierced skin of a fruit that looks like a 'pin-pricked' spot.
Stoma	(plural stomata). A pore in the epidermis of leaves or stems that is used for gaseous exchange. The pore is bordered by two specialised cells called guard cells. The stomata is generally referred to as the pore and guard cells.
Symptoms	Indication of a disease or pest by the reaction of the host. The visible external or internal effects produced in or on a plant by the presence of a pathogen or pest. Also refer to *signs*.

T

Tap root	The main central root (usually growing downwards) which develops from the primary root. Lateral roots form along the primary root. In some plants (monocotyledons), the primary root becomes less obvious as lateral roots form a fibrous root system.
Targeted prey	Specific insects or mites that are preferred as a source of food for predators and parasites.
Tendril	A leafless organ that is twine-like and usually forms a spiral around a substrate to support the growth of a climbing plant such as beans.

Thorax	The middle section of the three main body parts of an insects.
Toxin	A 'poison' produced by an animal or plant that is often a defence mechanism to repel or deter the predator.
Translucent	Allows light to pass through but is not clearly visible (such as appearance like frosted glass).
Transparent	Allows light to pass through and is easily seen through.
Tubercles	A small rounded projection seen on the body of certain insects or mites.

V

Vascular plants	Plants with lignified (with lignin which, combined with cellulose is the main part of woody tissue) tissues for conducting water, minerals and photosynthetic products through the plant.
Vascular tissue	The tissue that transports water, minerals and photosynthetic products in vascular plants. Composed of the xylem, phloem and two meristems (the vascular cambium and the cork cambium).
Vigour	Healthy growth, active strength or force.
Virus	An ultramicroscopic infectious agent with a ribonucleic acid (RNA) or deoxyribonucleic acid (DNA) core and a protein coat that replicates only in cells of living hosts.
Voracious	Consuming large quantities of food.

W

Web	Thin strands of silk produced by spiders to build a snare to capture prey.
Webbing	A woven mesh produced by spiders or some insect larvae usually made of silk that is used as a shelter or case to pupate in.
Window effect	Chewing damage on a leaf where the surface has been chewed but not broken through but appears as a 'see-through' leaf with an unbroken upper leaf layer.
Workers	The caste in termites and ants that have the role of foraging for food as well as brood and nest maintenance.

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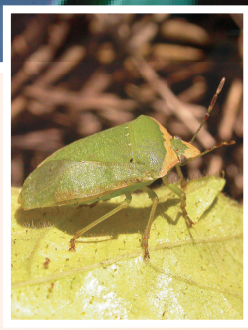

FIELD GUIDE

to Pests, Beneficials, Diseases
and Disorders of Vegetables
in northern Australia

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