Pests & Beneficials in Australian Cotton Landscapes

1st Edition 2011
Reprinted 2016

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Foreword…

This guide takes us to a new era in that it introduces the role that native vegetation can play in Integrated Pest Management (IPM). It outlines some simple management principles that we can use to make areas of native vegetation more effective as habitats for beneficials. For instance, putting bat houses in some trees will encourage bats that consume a considerable amount of insect pests.

This guide also provides photos and information so that you can identify the pests and beneficials in the crop and the natural environment. Good IPM starts with being able to correctly identify what's in your crop.

On our farm we have found that our increased understanding of beneficials has decreased the need to spray. We looked at ways to manage and promote those non-crop area's of our property. Drawing on industry research of beneficials and their behaviour and whole farm management learned from a grazing for profit program, we studied farm layout and the distance from cotton to tree corridors and vegetation, and how this related to spraying in cotton. We have found from first hand experience that looking and measuring numbers of pests and beneficials across our cotton and natural areas helps in making better IPM decisions.

I welcome this new resource in its format as a handy ute guide for the Australian cotton industry and commend it for your use.

Andrew Watson
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Introduction…

Welcome to the First Edition of *"Pests and Beneficials in Australian Cotton Landscapes"*, brought to you by the then Development and Delivery team (now CottonInfo), the then Cotton Catchment Communities CRC, Cotton Grower Services and the IHD Group. This edition was reprinted in 2016 for the CottonInfo IPM workshop series.

This ute guide can assist consultants and growers correctly identify their pest and beneficial insects and creates awareness of the role that native vegetation can play in IPM. Ultimately this information supports responsible pest management decision making.

This guide has been developed to replace 'The Cotton Pest and Beneficial Guide (Pyke and Brown)' which was published in 1996 and has been a popular reference within the Australian cotton industry.

The development of this guide has been a group effort, and we, along with the Australian Cotton Industry, thank the many people and organisations that willingly and generously provided images or technical input and this is acknowledged in detail on the inside back cover.

The new compact format is easy to use providing key information for the identification of pests or beneficials with high quality images.

This new guide contains a considerable amount of new information about beneficial and pests which has significantly changed since the introduction of Bt cotton crops. It also incorporates outcomes from biodiversity research which can be used as a framework for improving native vegetation landscapes as alternate habitat for beneficials. This framework is located in the middle of the guide and is based on 6 management principles;

1. Think beyond the crop.
2. Encourage beneficials with diverse, messy vegetation.
3. Do not disturb, conserve your beneficials.
4. Consider birds and bats as beneficials.
5. Control weeds in and around the farm.
6. Consider water availability.

This publication is not only an important tool for consultants and growers but supports researchers, extension staff, students and anyone new to the Australian cotton industry. The guide is also a valuable resource for those completing the IPM and natural assets modules in *my*BMP.

A more detailed web version will also be maintained, which serves to provide additional information about individual pest and beneficials.

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Cotton aphids vary between yellow, dark green, brown and dull black. 1–2mm (Photo: L. Wilson)

The sticky 'honeydew' excreted by aphids can contaminate lint. (Photo: L. Wilson)

Plants affected with cotton bunchy top have small leaves, often with angular mottling on the margins as shown on this leaf. (Photo: L. Wilson)

Aphids – Cotton aphid

Aphis gossypii Glover

Identification: Cotton aphids are small insects (1–2mm in length). They are rounded with long antenna and two distinctive siphunculi at their tail end. Cotton aphids vary between yellow, dark green, brown and dull black.

May be confused with: Green peach aphid (*Myzus persicae* Sulzer) and cowpea aphid (*Aphis craccivora* Koch) both of which can be found on cotton but rarely develop into damaging levels. Seen with a hand lens or microscope, the green peach aphid has small tubercles at the junction of the antenna and head, which creates a deep 'U' shape between the antenna, absent in the cotton aphid or cowpea aphid. Wingless stages (apterae) of cotton aphid are always matt or dull whereas wingless adults of the cowpea aphid are shiny black.

Lifecycle: Cotton aphids have winged and non-winged forms. The winged aphids (alates) are all adult females and this stage is highly mobile between crops. Alates are produced if the colony is stressed due to crowding or poor food quality. Alates search for a suitable food source, settle and promptly start producing live young without the need to mate. These young will develop into wingless adults. Female aphids give birth to live female young which are clones of themselves, inheriting all of their characteristics including any insecticide resistance. An aphid can give birth to as many as 6 young per day, which mature into adults in 4–7 days leading to many generations per season. Multiplication can continue until the colony becomes crowded or until suitable plant growth is no longer available which induces production of winged forms able to move and locate new hosts.

Damage: Severe aphid damage results in wrinkling, stunting and cupping of leaves. Younger leaves may show a yellow margin and reddened patches.

Aphids cause damage to cotton in 4 ways:

1. They compete with young growth and developing fruit and reduce photosynthesis – resulting in yield loss if damage occurs early – mid season.
2. They secrete honeydew, a sticky, sugary substance which settles on leaves and bolls. Honeydew promotes growth of sooty moulds on bolls and on leaves, where it reduces light penetration and reduces photosynthesis. Honeydew is also a direct contaminant of lint, creating problems in processing. The presence of aphids and honeydew when there are open bolls creates a high risk of penalty from processor or spinners.
3. They spread cotton bunchy top (CBT) disease. Plants affected with CBT have small leaves, often with angular mottling on the margins, shortened internodes, small squares and bolls. Lint yield can be significantly reduced by CBT.

Natural enemies: These include predators such as ladybirds, larvae of lacewings, silverfly and hoverflies. Wasp parasites (*Aphidius colemani* and *Lysiphlebus testaceipes*) can mummify and kill aphids. Mummified aphids are easily identified due to their distinctive, bloated shape and pale brown colouring. Preferential use of more selective insecticides will help to maintain these beneficial populations that will reduce the need to control aphids.

Other control options: Aphids need hosts, often broad leafed weeds, on which to survive through winter. They also use volunteer and ratoon cotton plants – which are also often infected with CBT. Good management of weeds and cotton volunteers and ratoons will reduce aphid survival, especially of insecticide resistance clones, and carry over of CBT disease on farm.

Wasp parasites can mummify and kill aphids. Mummified aphids are easily identified due to their distinctive, bloated shape and pale brown colouring. (Photo: L. Wilson)

Cotton aphids have two distinctive siphunculi at their tail end.1–2mm (Photo: C. Mares)

Unlike cotton aphid the green peach aphid is not favoured by hot conditions and though populations often may develop earlier in the cotton season, they usually die out during the hot period of peak summer. 1–2mm
(Photo: T. Smith)

Aphids – Green peach aphid

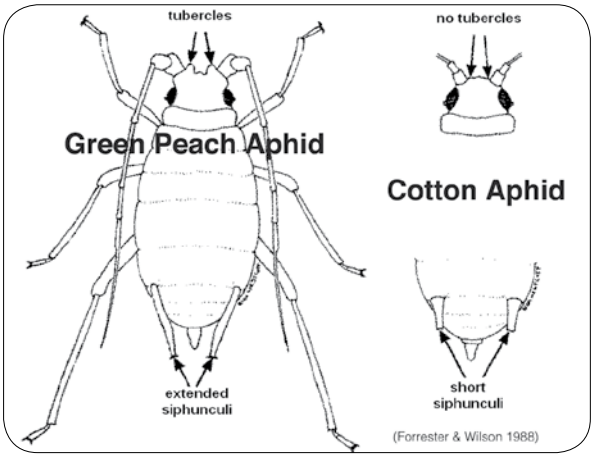
Myzus persicae (Sulze)

Identification: The green peach aphid is pale yellow-green and more oval shaped than the cotton aphid. Seen with a hand lens or microscope, *Myzus persicae* has a small tubercle at the junction of the antenna and head, which is absent in *A. gossypii*. See Figure 1.

May be confused with: The green peach aphid is often confused with the cotton aphid. Unlike cotton aphid it is not favoured by hot conditions. Populations often may develop earlier in the cotton season, but they usually die out during the hot period of peak summer. It is occasionally a pest in late season cotton and as it is widely resistant to a range of organophosphates and carbamate insecticides can be difficult to control.

The life cycle, damage and natural enemies for the green peach aphid in cotton are similar to that of the cotton aphid. It has a wide host range including a number of weed hosts common in cotton or nearby fields. These include peach vine, turnip weed, marshmallow and thornapple. The green peach aphid causes more severe stunting of cotton plants than the cotton aphid. Regular monitoring will help determine the need for control.

Figure 1 (below): *Diagram of the distinguishing features of the green peach aphid (left) and the cotton aphid (right).* *(Extracted from Forrester & Wilson 1988).*



Aphids – Cowpea aphid

Aphis craccivora (Koch)

The cowpea aphid looks very similar to the cotton aphid with the exception that the wingless cowpea aphid adults are a shiny black colour, in contrast to the dull coloration of the cotton aphid. Cowpea aphid feed on a wide range of leguminous hosts and often build up numbers in spring on medics and other legume hosts. Cowpea aphid will settle on cotton and will occasionally reproduce, however the population will normally decline after 3–4 weeks and rarely justifies control.

The cowpea aphid is often found on cotton early in the season but seldom establishes, though it may sometimes produce a small number of offspring. 1–2mm (Photo: J. Wessels)

Aphids – Bean root aphid

Smynthurodes betae (Westwood)

The bean root aphid can affect seedling cotton plants, but is rare. When infestations do occur, they can cause seedling death and can be confused with seedling disease. Careful uprooting of aphid-affected seedlings will reveal colonies of small, globular, wingless aphids at a depth of 10cm or so. They are tended by ants which construct small chambers to allow aphid movement around the roots. These chambers are covered with a white, waxy dust from the aphids. No effective chemical control is known, although irrigation may have some beneficial effect. In most cases identified so far, infestations have occurred in seedbeds previously heavily infested with burr medic.

Bean root aphid is a rare aphid pest that feeds on the roots of cotton seedlings. 1mm (Photo: M. Cahill)

ADB's can act as both a beneficial and a pest. Adults and nymphs will consume eggs and early instar larvae of Helicoverpa spp., but they also damage growing tips and small squares. 3mm (Photo: C. Mares)

The small ADB nymph is often mistaken for the green mirid nymph, although the ADB has much shorter antennae and legs. 1mm (Photo: C. Mares)

Apple dimpling bug (yellow mirid)

Campylomma liebknechti (Girault)

Identification: The apple dimpling bug (ADB) is about one third the size of the green mirid. Adults vary from yellow to pale mottled green and the nymphs are small and yellow. Both adults and nymphs have dark spines on their legs. The colour of nymphs makes them difficult to see when using a yellow beat sheet. A squashed ADB will smell like apples.

May be confused with: The adult ADB, although much smaller and paler can sometimes be confused with the broken back bug and the brown smudge bug. The ADB nymphs however, are frequently confused with a number of other nymphs including green mirids, jassids and aphids. Apart from being yellow, ADB nymphs have shorter legs and antenna than green mirid nymphs. Jassid nymphs have a more tapered shape and are wider at the head and young aphids can be distinguished by the presence of the two tubular siphunculi at the tail end.

Lifecycle: Tiny ovate white eggs are hidden in terminal buds of cotton and hatch in 4 to 6 days to give yellow nymphs with red eyes. These mature in about 4 weeks.

Host range: Apart from being very common in cotton, the ADB is an important pest of apples and can develop on other host plants including linseed, lucerne, sunflower, medics and turnip weed.

Damage: The ADB is known to damage small squares early in squaring cotton but it is also a predator of *Helicoverpa* eggs and spider mites, especially their eggs.

Monitoring: If the ADB is in high numbers it is worthwhile to monitor the plant's fruit set by checking fruit retention. This will indicate if damage is occurring which may require control.

Armyworm – Lesser

Spodoptera exigua (Hübner)

Lesser armyworm is often present in low numbers on young cotton, but prefers various weed hosts.

This species is often incidentally controlled by sprays applied against other pests. Bt cotton is not registered to control this pest but observations in the Australian environment as well as global Monsanto data suggests that it provides moderate control[1].

Identification: The moth is about 10mm in length with grey/brown, mottled forewings. The hindwing is pearly-white. Eggs are laid in 'rafts' of 10 to 30 and are covered with creamy brown webbing-like scales by the female moth. All armyworm larvae are smooth bodied and have white stripes running down their back and sides. Late instar larvae are 30–40mm long.

Lifecycle: The egg stage lasts for 3 days. The larval stage lasts for about 9–14 days and usually has six instars. Pupation occurs in the soil and lasts for about 10 days.

May be confused with: Mature larvae are often mistaken for *Helicoverpa* larvae but are green to brown, about half the length of a mature *Helicoverpa* larva, with a white stripe along each side of the back.

Damage: Larvae may occasionally infest seedlings heavily enough to cause defoliation, and re-sowing may be necessary. The young larvae remain near the egg raft and skeletonise the leaf.

Mature larvae are often mistaken for Helicoverpa larvae but are green to brown, about half the length of a mature Helicoverpa larva, with a white stripe along each side of the back. 25mm
(Photo: PLos Biol 2/8/2004:E250.http://dx.doi.org/10.1371/journal.pbio.0020250)

The armyworm moth has grey/brown mottled forewings and lays her eggs in 'rafts' of 10 to 20 covered in webbing –like scales. 10mm
(Photo: R. Goff)

Armyworm eggs are covered in web-like scales.
(Photo: C. Mares)

Broken backed bugs are shorter than green or brown mirids, about 4mm, and have a defined kink in the back. 5mm (Photo: P. Room)

Brokenbacked bug

Taylorilygus pallidulus (Blanchard)

The brokenbacked bug is not often found in large numbers on cotton and does not seem to be capable of significant damage. Brokenbacked bugs can be a pest of mung beans and are common on sunflowers.

Identification: This bug is 4–5mm, light green in colour with brown flecks on the inner wings. The outer wings are predominantly brown. Wing tips are bent down at 45° giving the 'broken-back' appearance. Nymphs have short pale yellow-green antennae.

May be confused with: Similar species are brown and green mirids and the apple dimpling bug. However the brokenbacked bug is smaller than a mirid and the inner wings have distinct brown flecks. Nymphs have much shorter antennae than those of the mirid.

The brown bean bug is a minor pest in cotton and should not be confused with the assassin bug – a benefical insect. 16–18mm (Photo: K. Power)

Brown bean bug (large)

Riptortus serripes (Fabricius)

The brown bean bug is an uncommon pest in cotton. Soybeans in particular are a favoured host.

Identification: This long dark brown bug is 16–18mm with long antennae, a bright yellow stripe along each side, spines on each ´shoulder´ and robust spiny hindlegs. When it is flying, the bright orange top of the abdomen is revealed. Nymphs are dark brown and are similar in outline to ants. Eggs are a dark purple-brown and are laid singly or in small clusters.

May be confused with: The assassin bug. However it has thicker spiny hind legs and a distinct yellow stripe, whereas the assassin bug has thicker front legs, slender hind legs and a long narrow head with a long curved proboscis.

Lifecycle: Eggs hatch and develop through 5 nymphal stages over about 25 days.

Damage: Similar to the green vegetable bug and should be assessed from boll set to boll maturity.

Brown mirid

Creontiades pacificus (Stal)

The brown mirid is found in a range of crops and is often confused with the green mirid. They move into cotton later in the growing season than green mirid, usually during the boll setting stage.

Identification: Adult brown mirids are about 7–9mm long, similar in shape to green mirids but have more dark pigments on the head region and on the hind legs than green mirid. Nymphs are green with distinctive long red and white striped antennae and two distinct red bands on the hind legs.

May be confused with: The brown mirid nymph is often confused with the green mirid nymph, but the striped antennae of brown mirids is a distinguishing feature. Brown mirid nymphs may also be mistakenly identified as brown smudge bug nymphs but these are totally dark brown or deep red. Another similar species is the crop mirid whose green nymphs are smaller and have a black spot on the middle of their back.

Damage: Brown mirids do similar damage to green mirids but are usually much less common.

Monitoring: Sample regularly as you would for the green mirid, using visual, sweep net or beat sheet methods. If the brown mirid is in high numbers assess the crops fruit set by monitoring fruit retention or fruiting factor and boll damage. This will indicate if damage is occurring which may require control.

A distinguishing feature of the brown mirid is the dark brown hind legs. 7–9mm (Photo: C. Mares)

This 2nd instar brown mirid nymph shows the distinct striped antennae and two red bands on the hind legs. 2.1–2.4mm (Photo: M. Khan)

Egg raft of the brown shield bug. Eggs are initially cream coloured and are laid in double rows. 5mm long (Photo: H. Brier)

A large brown shield bug nymph with a dark head and thorax, and a pale brown abdomen with transverse dark brown and pale markings at its centre. 4–5mm (Photo: C. Mares)

There has been no significant yield reductions reported from brown shield bug infestations. 8mm (Photo: J. Wessels)

Brown shield bug

Dictyotus caenosus (Westwood)

The brown shield bug or brown stink bug is not commonly found in cotton. The habits of this bug are not well known but they mainly feed on a range of grasses, bean crops and lucerne.

Identification: Adult bugs are shield shaped, matt brown and 7–8mm long. Newly hatched nymphs are orange with dark markings and a black head. As they grow they change colour to have a pale brown abdomen with transverse dark and pale markings at its centre.

May be confused with: The pest may be easily confused with the glossy shield bug, a beneficial insect. The main distinguishing features of the brown shield bug are the matt brown surface, shorter head and smaller eyes. Young nymphs are very similar in appearance to other shield bug nymphs until they grow and change colour.

Lifecycle: Pale cream eggs are laid in twin-row rafts. There are 5 nymphal stages. Usually one generation will develop per summer legume crop.

Damage: It has been shown that the brown shield bug causes the least amount of damage of all shield bugs, causing just one quarter of the damage caused by the green vegetable bug.

Monitoring: The most effective way to check for the brown shield bug is with a beat sheet. Their distribution in the field is very patchy, so it is important that samples are taken from as many sites as possible.

Cluster caterpillar

Spodoptera litura (Fabricius)

Early instars of this pest feed together in a cluster, hence the common name 'cluster caterpillar'. It is an occasional pest of cotton and other broadacre crops.

It is generally well controlled by sprays applied against other pests. Bt cotton is not registered to control this pest but observations in the Australian environment as well as global Monsanto data suggests that it provides poor control[1].

Identification: The pearly-white eggs are laid in clusters of 5–50 under leaves and are covered with fine, brown hairs. Young larvae are smooth and grey/brown while larger larvae are patterned with red, yellow, and greenish-yellow lines. A row of black dots run along each side, and a conspicuous row of dark triangles decorate each side of the back. The adult moth is brown with a complex pattern of cream streaks criss-crossing the fore wings. The hind wings are silvery white.

May be confused with: Larvae are often mistaken for *Helicoverpa armigera* due to the dark pigmentation on the mesothorax (area behind the head). They can also be confused with cutworm because of their plump, smooth skin.

Lifecycle: Egg to adult, takes about 30 days in warm weather, with pupation occurring in the soil.

Damage: Young larvae skeletonise leaves at night, while large larvae consume whole leaves causing partial defoliation. Cotton yield can be reduced if leaf tissue loss is excessive. Generally plants are more sensitive earlier and increasingly less sensitive later. As a rough guide, leaf area loss of greater than 10–15% could result in yield loss if it occurred before crop cutout. After cutout losses of up to 15–20% could be tolerated with low risk. Heavy infestations at any stage can defoliate large areas, destroying squares and flowers and may require control.

A female cluster caterpillar moth beside an egg cluster covered with fine, brown hairs. 25mm (Photo: D. Ironside)

Young cluster caterpillar larvae are smooth-skinned and grey/brown. 10mm (Photo: S. Williams)

Older cluster caterpillar larvae are brightly patterned with dark triangles decorating each side of their back. 35mm (Photo: S. Williams)

Cottonseed bug adults are small with a triangular-pattern in black and white on their back. 5mm (Photo: T. Smith)

Cottonseed nymphs are bright red and often found in clusters in open bolls. 1–2mm (Photo: C. Mares)

Cottonseed bug

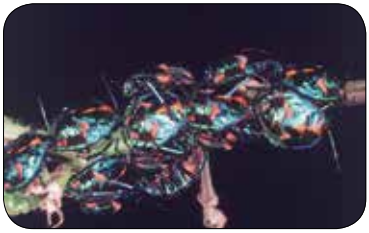
Oxycarenus luctuosus (Montrouzier)

Adult cottonseed bugs, can be found sheltering on cotton plants from the late seedling stage onwards but do not feed or reproduce until cotton bolls open and ripe seeds are available.

Identification: Adults are 3–5mm long and their forewings are transparent with a black spot in the centre. Their bodies are dark brown/ black and are visible through the wings. The eggs are 1mm long, oval shaped, creamy white and laid in open bolls. The nymphs are bright red and can be found in clusters among the lint.

Damage: Adults and nymphs feed on ripe cotton seeds. The only economic damage is from reduction of seed weight in late bolls and also reduction of seed viability. It is not normally considered a pest requiring control measures.

This brightly coloured cotton harlequin bug adult guards her egg cluster. Although rarely a pest, these bugs can feed on the seeds of open or green bolls. 20mm (Photo: J. Wark)



Cotton harlequin bug nymphs are often found in groups. 12mm (Photo: C. Mares)

Cotton harlequin bug

Tectocoris diophthalmus (Thunberg)

Identification: Adults are 20mm long and are brightly patterned in yellow, orange, red, metallic green or metallic blue. Nymphs are mostly metallic blue or metallic green and are found in groups feeding on open bolls or very small bolls where they can reach the seeds with their short stylets. Eggs are laid in a cluster, generally encircling a branch and are guarded by an adult.

Damage: Bugs feeding on the seeds in mature bolls allows the entry of a boll-rotting fungi that stains the lint. Although it is rarely a pest, damage should be assessed regularly from boll set to boll maturity by randomly selecting 14-day-old bolls and squashing them in the palm of the hand. Look for the presence of warts on the inside of the boll wall or stained lint.

Cotton leafperforator

Bucculatrix gossypii (Turner)

The cotton leafperforator occurs mainly in Queensland but has been recorded on occasions in New South Wales.

Larvae of this pest are occasionally noticed surviving early season sprays and are often mistaken for resistant *Helicoverpa armigera*. They are, however, not resistant to pesticides but merely protected from the spray within their silk shelters.

Bt cotton is not registered to control this pest and it is not known what level of control it provides[1].

Identification: Eggs are small and brownish-white and take about 4 days to hatch. Larvae are 6–7mm long and are initially pale green turning pale grey when mature with four black spots just behind the head. Pupae are formed in white, ribbed cocoons attached to the leaf. Adults are silvery white with brownish wing tips. Their hindwings are densely fringed with hairs.

Lifecycle: Eggs take about 4 days to hatch, there are 5 larval instars and the pupal stage requires 6 to 7 days.

Damage: Damage is rarely important. The young larvae, instars 1–3, mine between the upper and lower surfaces of leaves emerging in the fourth instar to feed directly on the leaf. The fourth instar larva forms a thin, silk shelter in which it moults into the final instar. It is this fifth instar which causes the most obvious damage, skeletonising the leaf by feeding on the lower leaf surface leaving numerous windows and small holes.

Although cotton leafperforator damage is rare, large larvae can skeletonise cotton leaves by feeding on the lower leaf surface leaving numerous windows and small holes. 5mm (Photo: C. Mares)

Pupa of cotton leafperforator are formed in white, ribbed cocoons attached to the leaf. 8mm (Photo: C. Mares)

Eggs are small, bluish-green and have a flattened appearance. They are often found on the underside of leaves. <1mm (Photo: C. Mares)

Cotton looper larvae are rarely a pest and feed mainly on leaves. 40mm (Photo: L. Wilson)

Cotton lopper moths are brown with patterned wings. 10–12mm (Photo: R. Goff)

Cotton looper

Anomis flava (Fabricius)

The cotton looper is so named because of the distinctive looping movement of its larvae.

This species is often incidentally controlled by sprays applied against other pests. Bt cotton is not registered to control this pest but observations in the Australian environment as well as global Monsanto data suggests that it provides good control[1].

Identification: The small, singly laid bluish-green eggs can be found on young leaves and squares. The larvae are green and usually have white stripes running along the body. Larvae are up to 40mm long. They have a group of three pairs of legs towards the rear of the body whereas the other loopers have a group of two or four pairs of legs. The larvae travel with a characteristic looping action. The pupae can be found in rolled up leaves and emerge as brown moths with patterned wings.

Damage: Larvae feed mainly on leaves and occasionally on squares and boll surfaces. They prefer older leaves and therefore their damage will progress upwards on the plant. Cotton yield can be reduced if leaf tissue loss is excessive. Generally plants are more sensitive earlier and increasingly less sensitive later. As a rough guide, leaf area loss of greater than 10 –15% could result in yield loss if it occurred before crop cutout. After cutout losses of up to 15–20% could be tolerated with low risk.

Cotton tipworm

Crocidosema plebejana (Zeller)

The cotton tipworm is a common pest of a range of malvaceous plants including cotton.

Outbreaks are associated with the growth of the tipworm's main host, marshmallow (*Malva parviflora*). As marshmallow dies off in the early summer the pest transfers to cotton.

Bt cotton is not registered to control this pest but observations in the Australian environment as well as global Monsanto data suggests that it provides good control[1].

Identification: The small moth singly lays oval-shaped, flattened, transparent blue eggs often next to a leaf vein on the underside of a leaf or on plant terminals. As the egg develops it becomes whiter and a 'red ring' develops just before hatching. Newly hatched larvae are pigment-free cream-coloured with a dark head capsule. As the larvae develop they grow larger (up to 15mm in length) but their colour remains the same. Pupation occurs inside damaged squares that fall to the ground.

May be confused with: It is very common to confuse the newly hatched tipworm larvae with newly hatched *Helicoverpa* larvae. Even with a hand lens they are difficult to distinguish.

Damage: The young larvae graze in the terminals, then later tunnel down into the growing tip and stem. If this damage occurs in the early stages of crop growth, it may result in multiple branching (tipping out) and a delayed crop. Occasionally in high numbers tipworm can also damage squares and bolls. Once larvae begin to tunnel in the stem, insecticides cannot give adequate control. Cotton can recover from a degree of tipworm damage, often without yield loss or delay in maturity.

Control: Tipworms normally disappear from cotton in January-February.

As the cotton tipworm egg develops its colour becomes whiter and a 'red ring' develops just before hatching. 0.5mm (Photo: C. Mares)

Cotton tipworm larvae have a plain pigment-free cream-coloured body with a dark head capsule. 5mm (Photo: C. Mares)

The adult cotton tipworm moth is pale brown and white with a marbled pattern. The ends of the wings have a corrugated look with two small thin yellow stripes near the tips of the forewings. 7mm (Photo: C. Mares)

Field crickets may damage cotton occasionally when present in plague numbers. 30mm
(Photo: K. Power)

The common name of cutworm is derived from the larval habit of severing the stems of young seedlings at or near ground level. 40mm
(Photo: P. Room)

Cutworms are the larvae of the bogong moth, Agrotis infusa (Boisduval) and related species.
(Photo: CSIRO)

Crickets – Black field cricket

Teleogryllus commodus (Walker)

Identification: Adult crickets are up to 30mm, black or brown with long antennae and grasshopper like hind legs. Females have a long pin at the end of the abdomen which is its ovipositor. The 3mm eggs are white and sausage-shaped. The nymphs are like small adults, but their wings and ovipositors are undeveloped.

Lifecycle: Eggs are laid singly, but loosely clustered, about 1 cm deep in damp soil. From hatching the nymphs take 2–4 months to grow into adults, which then live for 2–3 months. The females lay throughout almost their entire life-span, producing some 500–2000 eggs.

Damage: They may damage cotton occasionally in large numbers. The adults and late stage nymphs feed on the leaves and stems of seedlings and may reduce a stand to the extent that replanting is necessary.

Cutworm

Agrotis spp.

Identification: The moths are brown to black and slightly larger than a *Helicoverpa* moth. They lay pearly-white eggs in the soil or on seedlings. The larvae are dark-grey to brown, smooth bodied, and 25 to 50mm in length when fully grown.

Lifecycle: The female moths are highly prolific and can lay up to 2400 eggs. The life cycle from egg to adult takes about 2 months and consists of five larval instars.

Damage: Cutworm larvae attack cotton seedlings at or above soil level and may destroy seedlings by either chewing through the stem or eating entire leaves. They feed late afternoon and at night, spending the days hidden in the soil, except under very overcast conditions.

Flea beetles

Halticinae

They are small, shiny, metallic beetles noted for their jumping ability. At least two species have been observed in seedling cotton, the redheaded flea beetle, *Nisotra sp.* and the brown flea beetle, *Chaetocnema sp.*

Identification: Brown flea beetle adults are 2mm long and shiny brown. The redheaded flea beetle adult is 6mm long, shiny and has an orange-red head with a black body.

Damage: The redheaded flea beetle causes characteristic shothole perforations to leaves but rarely causes economic damage.

The brown flea beetle causes linear surface feeding patterns particularly on the cotyledons. Occasionally infestations are so large that control measures are needed to prevent desiccation of the seedlings.

Monitoring: The brown flea beetle should be monitored in seedling cotton, where the redheaded flea beetle should be monitored throughout the entire season.

This redheaded flea beetle can cause 'shothole' perforations to leaves. 4mm (Photo: C. Mares)

This brown flea beetle is about 2mm long and shiny brown. (Photo: L. Wilson)

Flower beetle

Carpophilus spp.

Flower beetles are small groups of black beetles that are a very common sight in cotton flowers.

Identification: Adults are 4mm long, black and rounded. Larvae are up to 3mm long and are white with a pale brown head.

Lifecycle: Adults live for an average of 3 months. A female lays an average 1000 eggs, which hatch in 2–3 days. The larval stage lasts 6–8 days and pupation 5–7 days.

Damage: Adults and larvae appear to feed on pollen but do not cause any damage in the process. Flower beetles are a pest in stored grain.

Groups of flower beetles are commonly found in cotton flowers. 3.5mm (Photo: T. Smith)

Newly laid green mirid eggs are a light blue colour, changing to a pale yellow prior to hatching. 1.5mm (Photo: M. Khan)

Newly hatched green mirid nymphs are approximately 1.5–2mm in length, with red tipped antennae that are much longer than their body. 2mm (Photo: M. Khan)

Green mirid

Creontiades dilutus (Stal)

The green and brown mirid are both pests of cotton in Australia. Green mirid is the most abundant of the two and can be present right through the season. Green mirid is also a pest of a range of legume crops.

Identification: Adults are about 7mm long, and both adults and nymphs are pale green with long antennae. Eggs are 1.5mm long, banana shaped and laid singly within the plant tissue with only an oval egg cap showing above the leaf or petiole surface. Newly hatched nymphs are about 1.4–1.5mm long and larger nymphs (4th and 5th stage) can be up to 7mm long. They are characterised by their distinctive red tipped antennae.

May be confused with: The brown mirid is sometimes found in cotton and is similar in appearance to the green mirid although slightly larger, darker and with antennae that are striped with red and white. Green mirid nymphs may also be confused with broken-backed bug and predatory black mirid nymphs. Nymphs of these insects are much smaller (eg 5th instar broken-backed bug and black mirids are about 3mm long). Broken-backed bugs nymphs have shorter light green antennae while black mirid nymphs have dark red eyes and black and white striped antennae.

Lifecycle: The green mirid has an egg and five nymphal stages. At optimum temperatures (30–32°C) eggs hatch after 4 to 5 days and each nymphal stage takes 1.5–3 days to develop. Adults can live for three to five weeks and females can lay up to 80 eggs in this time.

Host range: Green mirids have a wide range of hosts, including sunflower, safflower, lucerne and other legume and weed species. Safflower in particular builds up large mirid populations which can move into adjacent cotton as the safflower dries out.

Damage: During feeding green mirids pierce the plant tissues with their sharp mouthparts or stylet and release a chemical (pectinase) which destroys cells in the feeding zone. The affected tissue rapidly dulls in colour, then blackens, desiccates and dies. Favoured feeding sites include plant terminals (particularly on seedlings) which often results in death of the growing tip (tipping out), small squares and young leaves. If seedling tipping out and early square loss caused by green mirids is excessive, crop maturity can be delayed and yield reduced. Damage at early crop stage (up to first flowering) can be compensated for under ideal growing conditions (no stress from water or nutrient).

Green mirids can also feed on large squares and small bolls, causing shedding if the bolls are young (< 10 days old) or if the bolls are larger, individual locks may be damaged. This damage is characterized by shiny black spots on the boll wall and brown staining of the developing lint. Bolls over 20 days old are protected by their thick boll coat.

Adult green mirids can cause more damage than nymphal instars 1–3 and similar to or slightly more damage than the final instars 4 and 5.

Monitoring: Mirids are extremely mobile and populations can fluctuate rapidly, so regular sampling is important. Sampling is more effective if carried out using a beat sheet or a sweep net. The beat sheet method has proven to be the best at finding nymphs, while the sweep nets are best for finding adults. It is also important to monitor plant damage, as mirids can be present yet there may be little damage.

Natural enemies: A number of generalist predators are known to feed on mirids. These include spiders (especially the lynx spiders), ants, damsel bugs, big-eyed bugs, assassin bugs and predatory shield bugs. Green mirids are also predators and will eat spider mites and eggs of *Helicoverpa* species.

Adult green mirids are approximately 7–9mm in length with an elongated body, long antennae and long legs (especially the hind legs). 7mm. (Photo: C. Mares)

Green mirid damage is characterized by shiny black spots on the boll wall. (Photo: L. Wilson)

Adults of green stink bug are similar to green vegetable bug, but smaller with brown patches on the back. 4-5mm (Photo: L Wilson)

Eggs of green stink bug are pearly white. 1mm (Photo: L Wilson)

Green stink bug

Plautia affinis (Dallas)

Green stink bug is smaller than green vegetable bug. It is rarely a pest of cotton but has caused damage in crops close to native vegetation contaminated with weeds especially castor oil plant. Adults migrate from weeds into nearby cotton. Sample using beat sheets and assess damage regularly from boll set to boll maturity, by randomly selecting 14 day old bolls, and squashing them into the palm of the hand to look for the presence of warts or stained lint. Currently the threshold for the green stink bug is 3 per metre in a beat sheet sample with 20% damage to small bolls (14 day old).

Green vegetable bug

Nezara viridula (L.)

Green vegetable bug (GVB) is a sporadic pest of cotton. Populations typically build in the mid to late season. They are often found low in the crop canopy, but in mid-morning can sometimes be found feeding on fruit in the upper canopy. GVB is also an important pest in many legume crops, especially soybean, and uses non-cultivated hosts such as turnip weed, castor oil plant and blackberry nightshade.

An adult GVB with a Trichopoda egg attached. 12mm (Photo: L. Wilson)

Identification: The GVB adult is a shield shaped plain green bug about 15mm in length. The 5 nymphal instar stages are patterned and very colourful. The 1st instar is 1mm in length and orange with small black spots. The next three nymphal stages have predominantly black thorax's with lighter spots over their abdomen. The last instar is 10mm in length and has a green thorax and obvious wing buds.

Lifecycle: Females lay between 20–150 eggs in large rafts, usually on the underside of the leaf. The eggs take 5–7 days to hatch. Complete development from egg to adult takes about 5 to 6

weeks in summer. In winter most adult bugs enter diapause and change to a bronze colouration. These 'bronze' forms hide in sheltered locations especially under bark of eucalypts.

Damage: Adults and nymphs can damage bolls. Damage is visible by external feeding marks (black spots), internal wart like growths or lint staining. However, internal inspections can be a better guide according to the age of a boll. Damage to bolls older than 20 days old is uncommon, as the preferred age is about 15 days or less. Instars 4, 5 and adults do the same amount of damage. Instar 3 does half the damage of an adult. A cluster (more than 10) of 1st and 2nd instars does as much damage as one adult.

Monitoring: GVB abundance should be checked regularly (at least weekly) from flowering to boll maturity. Thorough inspections are important as GVB infestations tend to be patchy and bugs may be in the lower canopy and hard to see. Like many insects, the GVB is most visible in the mornings. The best method to sample for the GVB is the 'beat sheet'. Damage should also be assessed regularly from boll set to boll maturity, by randomly selecting 14 day old bolls, and squashing them into the palm of the hand to look for the presence of warts or stained lint on the inside.

Natural enemies: The parasitic wasp *Trissolcus baslais*, parasitises GVB eggs. The parasitised eggs appear black and not the usual orange colour. Parasitised eggs will hatch into more parasites.

Trichopoda giacomellii (Blanchard) is another important parasite of the GVB. This small fly lays eggs on adult and final instar bugs. The fly larvae hatch and bore into the host bug and two weeks later emerge and pupate in the soil. Parasitised GVB's slows feeding soon after being attacked. Male GVB's die soon after the larvae emerge, while females can live up to two weeks, though generally with dramatically reduced egg production.

The female GVB lay between 20–150 eggs in a large raft, usually on the underside of the leaf. *(Photo: T. Smith)*

The 3rd instar GVB has a black thorax with lighter coloured spots over the abdomen. This instar does half the damage of an adult. 7mm *(Photo: T. Smith)*

Brown Helicoverpa eggs. 0.5mm (Photo: C. Mares)

Helicoverpa eggs take between 3-4 days to hatch. 0.5mm (Photo: C. Mares)

This large Helicoverpa feeds on a small boll which will be shed from the plant. 35mm (Photo: C. Mares)

Helicoverpa armigera and *punctigera*

Helicoverpa armigera (Hübner) and *Helicoverpa punctigera* (Wallengren)

Larvae of these two moth species are major pests of cotton, capable of dramatically reducing yield. They are the main target of Bt cotton that contains Cry proteins that are toxic to the *Helicoverpa* larvae, dramatically reducing the need to control them with insecticide[1].

Identification: The two species of *Helicoverpa* are very similar in appearance; however correct identification is important because *H. armigera* has developed resistance to many insecticides. The two species can be separated visually only for some stages of their life cycle (eg medium and large larvae, pupae and adults).

Medium or fourth instar *H. armigera* larvae have a 'saddle' of darker pigments on the fourth segment back from the head (as shown in the picture). Large or final instar larvae can be separated on the basis of colour of the large hairs on the first segment behind the head, white in *H. armigera*, black in *H. punctigera*. *H. armigera* pupae have two small 'tail' spines which are apart and slightly smaller while they are close together and longer in *H. punctigera*. Adults can be identified using the hind wings; *H. armigera* has a small light or pale patch in the dark section of the wing while the dark section is uniform in *H. punctigera*.

May be confused with: Newly hatched *Helicoverpa* larvae may be confused with newly hatched tipworm larvae. Even with a hand lens it is difficult to distinguish among the two species at this early life stage.

Lifecycle: At 25°C, *Helicoverpa* eggs take 3–4 days to hatch. During this time eggs turn from white to brown and close to hatching the black head capsule of the larvae is visible through the

eggshell. Larvae develop through five or six growth stages (instars) and become fully grown in 2–3 weeks. With the inclusion of the time from moth emergence to fertile egg production of around 5 days, a generation is estimated to be completed in about 42 days during summer. Four to five generations occur per growing season. Final instar larvae move to the soil to pupate, usually not far from the base of the plant where they complete development. These larvae dig a tunnel leading to a chamber in which they change to the pupal or 'chrysalis' stage. During summer pupal maturation takes about 16 days. As day length shortens and temperatures fall an increasing proportion of these pupae will enter diapause and will spend the winter as pupae. Cultivation of the soil to a depth of 10cm during winter destroys the emergence tunnels and directly kills many pupae. This is an important tactic to control pupae carrying insecticide resistance.

Damage: In conventional cotton varieties, all stages of growth may be attacked, but reproductive tissue is preferred. Seedlings may be 'tipped out' (ie terminal buds eaten), squares and small bolls damaged then shed, and maturing bolls lost due to direct larval feeding or secondary fungal attack which enters through the feeding holes.

Large larvae (longer than 24mm) are the most damaging stage, since larvae consume about 50% of their overall diet as fifth and sixth instars.

Monitoring: *Helicoverpa* eggs and larvae should be monitored from seedling emergence through to 30–40% open bolls at least twice per week in both conventional and Bt cotton crops.

Natural enemies: The most common predators are predatory bugs, predatory beetles, spiders, lacewings and ants.

Some wasps and flies attack *Helicoverpa* eggs, larvae and pupae. Parasitoids kill their *Helicoverpa* host to complete their development.

Large Helicoverpa armigera larvae – note the presence of a 'saddle' of darker pigments on the fourth segment back from the head. 35mm (Photo: CSIRO)

Destroying overwintering Helicoverpa pupae through cultivation is an important component of the industry's Insecticide Resistance Management Strategy (IRMS).

Adult moths of H. punctigera (left) and H. armigera (right) – note pale patch on hind wing. (Photo: P. Room)

Jassids prefer to feed on the upper surface of mature leaves from flowering onwards. 3mm *(Photo:T. Smith)*

Jassid damage appears as a pale silvery stippled effect. There has been no significant yield reductions reported from this damage. *(Photo: L. Wilson)*

Leafhoppers range in colour from green to yellow-green and brown. 3mm *(Photo: C. Mares)*

Leafhoppers (jassids)

There are at least two species of leafhoppers found in cotton, the vegetable leafhopper, *Austroasca viridigrisea* (Paoli) and the cotton leafhopper, *Amrasca terraereginae* (Paoli). The vegetable leafhopper is the most common of these pests found on cotton in New South Wales. The cotton leafhopper also occurs in New South Wales but is more abundant in Queensland. Other species such as the common brown leafhopper, *Orosius argentus*, and the spotted leafhopper, *Austroagilla torrida*, are also occasionally found.

Identification: Adults are small, elongate, wedge-shaped insects about 3mm long, ranging from green to yellow-green and brown. Leafhoppers are quick to hop and fly off when disturbed. Nymphs resemble adults but are smaller, paler, wingless and generally slower moving.

Lifecycle: Eggs are laid in slits made in soft plant tissue. During the summer, a lifecycle can be completed in less than two weeks.

Damage: Leafhoppers occasionally damage seedlings and new growth but prefer to feed on the upper surface of mature leaves from flowering onwards. Damage appears as a pale silvery stippled effect. The stipples often occur in wiggly lines. Leafhoppers are unlikely to reduce yield unless in very high numbers before crop cut-out (when production of new growth ceases). This would be indicated by damage to >50% of the upper leaf surface.

Natural enemies: Predatory bugs and spiders will attack leafhoppers. Unnecessary sprays for leafhoppers may adversely affect these and other beneficial insects and may flare other pests.

Lightbrown apple moth (Tortrix)

Epiphyas postvittana (Walker)

The lightbrown apple moth is a leafroller moth belonging to the Lepidopteran family Tortricidae. It is rarely a problem in cotton.

Bt cotton is not registered to control this pest and it is not known what level of control it provides[1].

Identification: The 12mm long pale brown moth lays flat masses (20–30) of pale greenish/yellow translucent oval shaped eggs. Young larvae resemble small tipworm larvae, having a black head and pale body. Older larvae vary from light to dark green with a light brown head and can grow up to 20mm long.

May be confused with: Hatchlings may be confused with *Helicoverpa* or tipworm hatchlings, as they are pale with dark head capsules. However, they have webbing and a fast, twisting movement when prodded.

Lifecycle: Eggs will hatch in approximately 8–9 days at 20°C. Larvae pass through five to six instars during their development. Pupation occurs within the feeding shelter. Complete pupal development takes approximately 10 days at 20°C.

Damage: Damage from the larvae is very rare. Early instar larvae feed on the underside of leaves within a silk chamber. Later instar larvae may fold single leaves or create a nest of several terminal leaves webbed together.

Natural enemies: The moth is native to Australia, and its natural predators keep the population in check. The most common natural enemy is the Tachinid fly. They deposit their eggs on the light brown apple moth larvae and these eggs hatch into a fly larva that eventually kills the pest larva.

Tortrix larvae (18mm) can be easily distinguished from other larvae by the presence of webbing and the fast, twisting movement of the larvae when prodded. Pupation occurs within the larval nest. 10mm (Photo: D. Ironside)

Tortrix moth male and female (right). 12mm (Photo: D. Ironside)

The underside of a spur-throated locust showing the characteristic spur on the throat. 65mm (Photo: L. Wilson)

This swarm of spur-throated locust were seen destroying leaves and branches on an established cotton crop. (Photo: S. Logan)

Locusts – Spur-throated

Nomadacris guttulosa (Walker)

Some seasons favour the build up of large populations of locusts. One species, the spur-throated locust occasionally infests cotton, sometime in huge numbers and can cause considerable damage.

Identification: Adult spur-throated locusts are 50–80mm long, with white spines on the hind legs. All stages have a spur between the front legs. The nymphs are pale green turning brown as they develop.

May be confused with: Some species of grasshoppers also have a spur between the front legs. Pale green mid-instar locusts are often confused with green grasshoppers, although the mid-instar locusts have the throat spur and do not have wing buds. Adult spur-throated locusts can also be confused with the bigger migratory locusts.

Damage: Occasional migratory swarms of the spur-throated locust can destroy large areas of young plants and prompt control may be necessary. Populations can persist in cotton crops right through the growing season and may slowly build, initially only causing damage to leaves (holes and edges chewed away). Cotton yield can be reduced if leaf tissue loss is excessive. Generally plants are more sensitive earlier and increasingly less sensitive later. As a rough guide, leaf area loss of greater than 10–15% could result in yield loss if it occurred before crop cutout. After cutout losses of up to 15–20% could be tolerated with low risk. However, higher numbers of locusts will cause greater damage and will strip leaves and also damage terminals and fruiting branches and may need control. The smaller Australian plague locust *Chortoicetes terminifera* (Walker) does not damage cotton.

Mealybug (solenopsis)

Phenacoccus solenopsis

Solenopsis mealybugs are small, sucking insects, related to aphids. These pests are known to affect a wide range of cultivated plants and weeds; occasionally, however, populations increase and damaging infestations or 'hotspots' can occur.

Several mealybug species are recorded from field crops with no, or minor effects on the crop. Solenopsis mealybug has recently been recorded as a serious pest of cotton, and is found in most cotton-growing regions of the world.

Identification: The female mealybug is wingless with a 3–4mm long oval shaped body which is covered with white hydrophobic (water repellent) mealy wax. There are dark bare spots on the thorax and abdomen, which appear as dark longitudinal lines.

The adult male is about 1mm long, with a grey body and a single pair of transparent wings. Two filaments of white wax project from the end of its abdomen. The adult male has no feeding mouthparts and causes no damage.

May be confused with: There are a number of native species of mealybug found in cotton landscapes. For example, the hibiscus mealybug is pinkish and the long-tail mealybug has a distinct projection from the tail end. However, there are many species that cannot be distinguished in the field from solenopsis mealybug, even with the help of a hand lens. Formal identification of mealybugs is done by examination of characters on the 'skin' of slide mounted, prepared specimens.

Lifecycle: Mealybugs have a high reproductive rate, with adult females capable of producing hundreds of eggs. Egg development takes 3–9 days and the nymphal stage can last 22–25 days. Development from egg to adult takes an average of 26 days. Adult mealybugs can live for about three

The oval shaped mealybug adult is covered in a white wax. 4mm (Photo: C. Mares)

Remove affected plants early to reduce mealybug numbers in the rest of the crop. (Photo: S. Mass)

The Crytpolaemus ladybeetle larvae look like oversized mealybugs but are one of their main predators. 7–8mm (Photo: R. Whyte)

The long-tail mealybug has a distinct projection from the tail end. 3–4mm (Photo: Bugs for Bugs)

Mealybugs can cause crinkled and twisted leaves, reduced flower and boll development, smaller bolls, and distorted and stunted plants with a bushy appearance. (Photo: S. Addison)

months. Research has found that the crawler stage can live for up to 6 days, and the 3rd instar stage for up to 50 days without food or water. During winter mealybugs can be found up to 5cm below the soil on the tap root of host plants.

Methods of spreading: Mealybugs have limited mobility but are readily spread from infested plants and weeds by wind, water (they float), birds and animals (including ants), and on equipment, vehicles and clothing. They will also crawl to neighbouring plants.

Damage: Adults and nymphs suck the sap from plant tissue. This can occur at all stages of crop development. Infestations cause crinkled and twisted leaves, reduced flower and boll development, smaller bolls, and distorted and stunted plants with a bushy appearance. Boll opening may also be affected, resulting in significant yield losses. Heavy, prolonged infestations can lead to plant death. In the field, mealybug damage often appears in patches, especially in areas where plants are suffering stress.

Heavy infestations excrete honeydew, which can contaminate lint and promote the development of black sooty mould on leaves, which can inhibit plant photosynthesis and growth. Ants feed on the honeydew and spread the mealybugs. Ants also clean the colonies and protect the mealybugs from predatory insects (such as ladybird beetles).

Control: The removal of weeds and volunteer cotton, good farm hygiene and conserving natural enemies are the key management principles for the control of mealybugs in cotton.

Natural enemies: Ladybeetles and lacewings have been identified as key predators of mealybug. In particular the mealybug specialist ladybeetle, *Cryptolaemus montrouzieri* whose larvae look like an oversize mealybug.

Mites

Spider mites

Tetranychus urticae (Koch), *T. ludeni* and *T. lambi*

Three spider mite species are found in cotton, the two-spotted spider mite (*Tetranychus urticae* Koch), the bean spider mite (*T. ludeni*) and the strawberry spider mite (*T. lambi*). Mites are secondary pests – they are controlled by natural enemies but when broad spectrum insecticides are applied for other pests, the reduction in natural enemies allows mites to increase unchecked.

Identification: Adult two-spotted spider mite and bean spider mites are 0.5mm long and have 8 legs. Two-spotted spider mites are usually yellow-green with darker green spots on either side of the body. This species also has an orange-red overwintering form, but in cotton regions this is rarely seen. Adults of bean spider mite are deep red. Adults of the strawberry spider mite are smaller, about 0.3mm long, yellow-green and have six spots around the tail end of the body. Accurate identification of species is important as strawberry spider mites have a very low risk of causing loss.

Lifecycle: At 30°C mites will complete development from egg to adult in about 7 days. This means there are many and overlapping generations. A single mite spray may select for resistance in several generations at once. Adult female mites lay about 70 eggs over about a 2 week period. The spherical, semitranslucent eggs are laid singly on the underside of the leaf and give rise to a 6-legged larval stage which is followed by two 8-legged nymphal stages.

Host Range: Spider mites have a wide host range and can survive through the year on many broad-leafed weeds. In summer, two-spotted spider mite attacks cotton, sorghum, maize, soybean, adzuki bean, mung bean and sunflowers. Winters are generally not cold enough to induce mites to enter diapause so they continue feeding on hosts such as marshmallow, deadnettle, medics, wireweed,

Of the three spider mite species found in cotton, the two-spotted spider mite is the most numerous and important pest. 0.5mm (Photo: L. Wilson)

Spider mites have a large host range including safflower. (Photo: L. Wilson)

In cold climates two-spotted spider mite changes to a bright orange diapause form. This is rare in cotton regions. 0.5mm (Photo: C. Bower)

The first sign of two-spotted spider mite damage is bronzing of the upper leaf surface near the petiole or leaf folds. (Photo: L. Wilson)

Strawberry spider mites rarely require control. 0.3mm (Photo: C. Mares)

Bean spider mite damage is less intense and rarely results in bronzing of leaves. However, high populations may result in leaf loss and may need to be controlled. 0.5mm (Photo: M. Hill)

sowthistle and volunteer/ratoon cotton plants as well as winter crops such as faba bean, fieldpeas and safflower.

Damage: Spider mites live on the underside of leaves. All stages use piercing mouthparts to puncture cells and remove the contents. Spider mites prefer younger leaves and highest populations are found on main stem nodes 3 to 5 below the terminal.

The species vary in damage symptoms and potential to reduce yield. Two-spotted spider mite is the most common species found in cotton. It causes bronzing of the upper leaf surface usually beginning near the petiole or leaf folds. These bronzed areas are matched by brown damaged areas on the underside of the leaf. Heavy mite damage will cause leaves to desiccate and fall off. The earlier in the season that infestations develop, the greater the potential loss of cotton yield and quality.

Bean spider mite damage is less intense and rarely results in bronzing of leaves. However, sustained high populations may result in leaf loss and may need to be controlled.

In contrast, the strawberry spider mite causes characteristic sparsely stippled feeding damage and will rarely, if ever, require control.

Monitoring: On seedling cotton check the underside of all leaves including the cotyledons. As plants grow, spider mites progress up the plant and the lower surface of upper leaves (nodes 3–5 below the terminal) should be checked with a hand lens. Sample at least weekly to gain an understanding of trends in mite population developed. Spider mites are too numerous to count. Instead the presence of an infestation, either adults, immatures or eggs is rated on a presence/ absence assessment system (described in the Cotton Pest Management Guide).

Natural enemies: Thrips, big-eyed bugs, minute two-spotted ladybeetles and other ladybeetles, tangle web spiders, apple dimpling bugs, brown smudge bugs, pirate bugs and damsel bugs.

Control: Control of spider mites is warranted if the value of potential yield loss is double the cost of control (ie make money, not just recover costs). To estimate this, mite yield loss tables can be found in the Cotton Pest Management Guide. The impact of predators is built into these tables as effective predation will lower rates of increase, leading to low yield loss predictions.

Other mites

Blue oat mite, *Penthaleus major*, is occasionally found in seedling cotton crops and can cause leaves to have a mottled whitened appearance and unthrifty plant growth. It is mainly a pest of cereals and grasses and may build on these and migrate into cotton crops. This mite is about 1mm long. It has a small red area on its back that red legged earth mite does not. Check young cotton for the presence of this species if growth is poor.

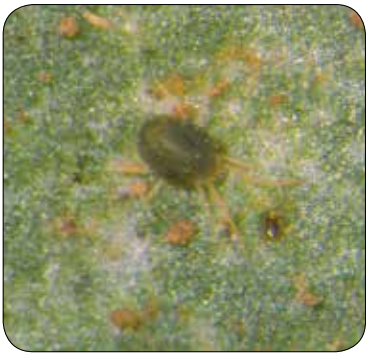
Redlegged earth mite, *Halotydeus destructor*, is also occasionally found in seedling cotton crops. They are about 1mm long with a black body and red legs. Damage results in leaves with a mottled whitened appearance and can be severe, resulting in very slow growth of young seedlings or plant death. This pest attacks most winter crops and is a major pest of legume pastures and canola. Check young cotton for the presence of this species if growth is poor.

Brown wheat mite, *Petrobia lateens*, is a small mite, about 0.6mm long, with long front legs. The adults are brown but when seen against a leaf can appear dark green to almost black. Immature stages are smaller and lighter coloured (orange-red-brown). It sometimes is a problem on seedling cotton that is emerging close to cereal crops. All stages feed on the undersides of leaves and cause them to have a bleached white appearance and plants will look unthrifty. If numbers are very high death of seedlings can occur.

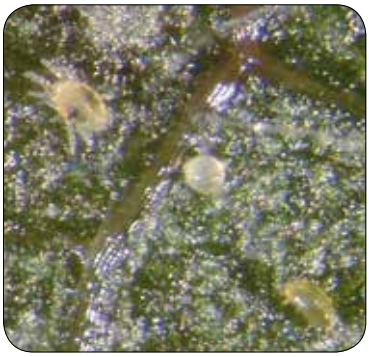
Broad mite, *Polyphagotarsonemus latus*, is rarely a pest in cotton but can be a major pest of

Note the presence of the small red area on the back of this blue oat mite. 1mm (Photo: CSIRO)

The redlegged earth mite attacks winter crops and legume pastures. They are plain black with red legs. 1mm (Photo: NSW DPI)



The brown wheat mite has noticeably longer front legs compared to other mites. <1mm (Photo: L. Wilson)



This broad mite (bottom right) shares a leaf with a two-spotted spider mite (Left). <0.5mm *(Photo: J. Miyazaki)*

Cotton leaves damaged by broad mite are stunted, hard and brittle and the underside has a 'wet' appearance. *(Photo: D. Lea)*

The broad mites in this image have crawled onto the legs of a slilverleaf whitelfy adult (1.5mm) to be transported from plant to plant. *(Photo: D. Lea)*

a wide variety of vegetable crop plants especially capsicums or peppers and many ornamentals.

Broad mites are so small (~0.3mm) that they are difficult to see even with a good hand lens. They are found in groups hidden around the mid-vein on the undersides of the leaves. The adults are white-yellow, about 0.2mm long, and the male is extremely active. Eggs laid on the underside of leaves are oval, translucent and covered with five or six rows of white tubercles.

The life cycle from egg to adult takes between 6 to 9 days and includes 2 nymphal stages. Broad mites can spread from plant to plant by walking but are also 'phoretic' and will crawl onto the legs of adult whitefly and be carried to new plants by the whitefly.

Broad mites have a large host range including citrus trees and other food-crop hosts, including papaya, babaco, capsicum and cocoa. Many ornamental and cut flower plants are susceptible, including African violet, azalea, pittosporum, impatiens, begonia, gerbera, chrysanthemum and gloxinia.

In cotton broad mite feeding damage gives the undersides of leaves a wet appearance, as though covered by a thin layer of water. Damage results in the leaves being stunted, hard and brittle, and cracks can appear in the leaves.

Broad mites are preyed on by a range of predatory bugs such as minute pirate bugs, predatory mites and lacewing larvae.

Pale cotton stainer

Dysdercus sidae

Two species of cotton stainers are occasional pests, the cotton stainer (*Dysdercus cingulatus*) and the pale cotton stainer (*Dysdercus sidae*), which is generally the most common. They tend to be more common late season in crops that have had low spray regimes.

Identification: Adult pale cotton stainers are 12mm long, brown and black or red and have black backs. There is a small black spot near the centre of each forewing. There is a black triangular marking ahead of the centre of the back, and black markings occur across the front of the thorax and on the head. The underside is yellow-green with red and black markings. Small nymphs are yellow, becoming red and black as they mature.

May be confused with: The seed eating bug (*Graptostethus servus*) and the red eyes bug (*Leptocoris mitellata*). However the pale cotton stainer wings are generally dark (rather than being orange) and have a distinct dark spot.

Lifecycle: Batches of about 100 creamy white eggs are laid in shallow depressions in the soil. Young pale cotton stainers moult through five nymphal stages before reaching adulthood. Two days after the final moult, adults will begin to mate.

Damage: Adults and nymphs feed on cotton seeds. Damage to young bolls often results in black spots on bolls and warty growths on the inside of the bolls. Young seeds may be damaged. Pale cotton stainers can damage bolls of all stages, even those almost mature. On older bolls (>20 days old) there are no visible signs of feeding on the boll coat. However, if damaged bolls are opened, small black puncture marks can be seen on the inside of the boll wall. The lint of damaged bolls often becomes yellow or brownish, possibly due to the entry of fungi which stain the lint and

Batches of about 100 creamy white pale cotton stainer eggs are laid in shallow depressions in the soil. 1mm (Photo: L. Wilson)

This 3rd instar pale cotton stainer is able to commence feeding on developing seed within the bolls. 6–8mm (Photo: L. Wilson)

Adult pale cotton stainers can be distributed through the crop at low densities, often in mating pairs but sometimes they can also be found in quite dense clusters of mating pairs. 10mm (Photo: L. Wilson)

Pale cotton stainer damage can allow the entry of fungi which can cause 'tightlock', where the open bolls don't fluff out. (Photo: L. Wilson)

cause 'tightlock' where bolls do not fluff out. Damaged locks of the bolls tend to adhere to the boll coat if the locks are removed rather than coming out freely. The larger end of the seeds, which is closest to the outside of the developing boll often shows dark brown damaged areas if the seeds are cut in half. Damaged seeds are unable to complete the development of fibres. If sufficient bolls are damaged loss of yield, and reduced fibre quality can occur. Even on open bolls, pale cotton stainers will sometimes feed on the exposed seed and will occasionally lay eggs inside open bolls. The germination success of damaged seed can be substantially reduced. Female pale cotton stainers are more damaging than the smaller males or mating pairs.

Monitoring: Pale cotton stainers and boll damage should be checked weekly once bolls are present. The best way to sample is to use a beat sheet, being aware that they are often more abundant lower in the canopy. Boll damage can be assessed by cutting open bolls of varying ages and examining these for browned, dried damage areas. Confirmation that it is pale cotton stainer damage can be achieved by cutting seeds in half and checking for damaged areas.

Control: Several broad spectrum insecticides are registered for control – their use should be considered carefully as they can disrupt natural enemies which may flare populations of other pests. As there is no resting stage in the pale cotton stainer's lifecycle, cultural controls between cotton seasons, especially limiting access to alternate food sources such as volunteer or ratoon cotton and exposed fuzzy seed will assist greatly in delaying population development.

Natural Enemies: A range of natural enemies such as Tachinids (parasitic flies) and predatory bugs (eg assassin bugs) have been recorded in Africa. The role of natural enemies in Australia has not been studied.

Pink bollworm and pink spotted bollworm

Pectinophora gossypiella (Saunders) and *Pectinophora scutigera* (Holdaway)

The pink spotted bollworm occurs in coastal and central Queensland, and will attack cotton as well as its primary hosts (cottonwood tree – *Hibiscus tiliaceus* and broadleaf bottle tree – *Brachychiton australis*). In Australia the pink bollworm is only found in the NT and north of WA where it is a pest of cotton.

Bt cotton is not registered to control this pest but observations in the Australian environment as well as global Monsanto data suggests that it provides excellent control[1].

Identification: Larvae are up to 18mm long and are yellowish-pink with a dark brown head and rows of darker markings along the back. Moths are 12mm long, dark grey or silvery-grey and hold their wings over the body when at rest.

Lifecycle: Larvae hatch from small eggs and tunnel into large squares, flowers or bolls. Mature larvae pupate in bolls, stems or surface trash. The life cycle takes about 6 weeks, but usually only one generation of pink spotted bollworm occurs during late January-March in conventional cotton.

The pink spotted bollworm does not have an overwintering diapause. However, larvae can remain alive for long periods and survive by feeding on dry cotton seed in trash. Live larvae have even been found in seed cotton in modules awaiting the gin.

Damage: Larvae bore into green bolls feeding internally and to a lesser extent into squares and flowers. This results in damaged lint due to feeding and the entry of boll-rotting fungi.

Control: Effective management of cotton crop residues will help minimise subsequent infestation in cotton. In northern Australia growing cotton in the dry season avoids major damage from pink bollworm.

Pink spotted bollworm moths and larva. (Moth – right 12mm) (Photo: P. Room)

Damaged lint due to pink spotted bollworm feeding and the entry of boll-rotting fungi. (Photo; D. Ironside)

Pumpkin beetles will attack all commercial cucurbit crops and are sometimes found in cotton but are not known to cause damage. 6–8mm (Photo: C. Mares)

Pumpkin beetles

Aulacophora hilaris and *Aulacophora abdominalis*

There are two types of pumpkin beetles: The banded pumpkin beetle *Aulacophora hilaris* and the plain pumpkin beetle *Aulacophora abdominalis*. Both species attack all commercial cucurbit crops. Both species are sometimes found in cotton but not known to cause damage.

Identification: Adults are 6–7mm in length and yellow/orange. The banded pumpkin beetle has four large black spots on the back and the plain pumpkin beetle has no spots. Larvae of both types are creamy-white in colour and about 10–12mm long.

May be confused with: The redshouldered leaf beetle. However the redshouldered leaf beetle is more yellow with reddish patches on the shoulder and back, whereas the pumpkin beetle is more orange and either plain or with black patches.

Lifecycle: Adults lay up to 500 eggs in clusters on dead leaves or into the soil amongst the roots of the plants where, once hatched, the creamy white larvae will feed until they pupate and emerge as adults. Adults can live for around 9 months.

Damage: Pumpkin beetles are usually found in aggregations within the crop on both young and old leaves. Adult pumpkin beetles feed on the leaves of cucurbits, chewing large holes and often leaving only the veins of the leaves. Young seedlings are particularly susceptible to damage as small numbers of beetles can cause total defoliation and death. Larval damage to the roots is usually minimal and the plants are rarely affected.

Redbanded shield bug

Piezodorus hybneri (Gmelin)

The redbanded shield bug (RBSB) is found in most cotton regions, though it is generally more abundant in the northern areas such as central Qld.

Identification: Adults are 8–10mm long, shield shaped and pale green with a noticeable band across their shoulder. Most females have a pink (not red) band across their shoulders and pink lines along their sides. In contrast, most males have an off-white band across the shoulders and pale yellow lines along their flanks.

This bug has a very distinctive twin row raft with dark elliptical eggs (in cross section), ringed by small spines. Egg rafts contain 15–40 eggs.

Newly hatched nymphs are orange with black markings and larger nymphs are pale green with dark red and brown markings in the centre of their back.

May be confused with: The newly hatched nymphs are similar to newly hatched nymphs of many other shield bugs. However they can be correctly identified by examining the distinctive egg raft from which they emerged.

Lifecycle: Eggs take 4–5 days to hatch. RBSB has five nymphal stages. Total development time (eggs to adult) is 18–35 days depending on temperature.

Damage: Damage is visible by external feeding marks (black spots on bolls), internal wart like growths on the inner boll wall or lint staining.

Monitoring: Thorough inspections are important as RBSB infestations tend to be patchy. Like many insects, the RBSB is most visible in the mornings. Currently the best method to sample for the RBSB is by using a 'beat sheet'. Damage should also be assessed regularly from boll set to boll maturity, by randomly selecting 14 day old bolls, and squashing them into the palm of the hand to look for the presence of warts or stained lint.

The redbanded shield bug's distinctive twin row raft of eggs, ringed by small spines. *(Photo: C. Mares)*

This female redbanded shield bug adult has the characteristic pink (not red) band across her shoulders and pink lines along her sides. 9mm *(Photo: L. Wilson)*

Newly hatched nymphs can be easily confused with other shield bug nymphs. If possible correct identification can be made by examining the distinctive egg raft from which they emerged. 6mm *(Photo: C. Mares)*

Little is known of the behaviour of the red eyes bug in cotton. They are currently neither a pest or beneficial. 15mm (Photo: CSIRO)

Red eyes bug

Leptocoris mitellata (Bergroth)

This species may be confused with cotton stainers. Little is known of the behaviour of the red eyes bug in cotton. Their pest status in cotton is currently unknown. However if they are present, ensure bolls are monitored for signs of plant bug damage.

Identification: The red eyes bug adult is 15mm in length, has bright red eyes and a red abdomen. Its thorax and front wing covers are reddish-brown in colour, whereas the cotton stainer is orange with a distinct dark spot. Its legs and antenna are all black. The nymph looks similar to the adult bugs except their wings are not fully developed.

Lifecycle: Females lay eggs in plant debris or on the underside of leaves; nymphs hatch and go through several instars before they develop into fully winged adults.

Habitat: This bug can be found on different types of plants throughout south-eastern Australia. They feed on both native plants and cultivated plants, including passion vines, stone fruit trees, tomatoes and other vegetables. They are attracted to light and will often shelter in large numbers around houses. They are native insects however and also use native plants in the Sapindaceae family, such as the hopbush. These plants are found mostly in the tropics and sub-tropics.

Redshouldered leaf beetle

Monolepta australis (Jacoby)

This beetle rarely attacks cotton, but in high numbers can cause quite severe damage to small patches of plants. It chews terminal buds, leaves, squares and the surfaces of bolls.

Identification: Beetles are about 6mm long, yellow in colour with red patches over the shoulders and near the distal end of the elytra (wing covers).

May be confused with: Pumpkin beetles. However the redshouldered leaf beetle is more yellow with reddish patches on the shoulder and back, whereas the pumpkin beetle is more orange and either plain or with black patches.

Lifecycle: Eggs are laid in the soil surface, mainly in pastures, and the larvae, which are about 5mm long when fully grown, feed on grass roots and pupate in the soil. The life cycle takes about 2 months during the summer and there are three to four generations annually. Adults usually emerge from the soil after good rains following a dry spell. If larval populations in the soil are high, the multitude of emerging beetles will form an aggregation and swarms may migrate into tree crops at any time of the year.

Host range: The host range is large and includes avocado, carambolas, cotton, corn, eucalyptus spp., grasses, legumes, longans, lychee, macadamia, mango, strawberry, and numerous ornamentals.

Damage: Significant damage in cotton is uncommon and is usually confined to patches along the edges of fields. However swarms can invade orchards and cause serious damage within 2 to 3 hours.

Redshouldered leaf beetles are yellow in colour with red patches over the shoulders and towards the back of the wing covers. 5mm (Photo: J. Wessels)

Redshouldered leaf beetles rarely attack cotton. When it does it chews terminal buds, leaves, squares and the surfaces of bolls. (Photo: A. Bishop)

Rough bollworm eggs are initially blue-green and difficult to find. Before the eggs hatch they develop brownish red rings. <1mm (Photo: C. Mares)

Rough bollworm larvae are up to 18mm long, thickset, mottled grey and brown with irregular yellow-orange spots in rows along the back. The weed, bladder ketmia is its major host. 10mm
(Photo: L. Wilson)

Rough bollworm moths are off-white with a green or brown stripe on the forewing. 11mm
(Photo: L. Wilson)

Rough bollworm

Earias huegeliana (Gaede)

Rough bollworm occurs widely on malvaceous plants including cotton in Australia and the Pacific Islands. One other species, the northern rough bollworm, *Earias vittella* (Fabricius), is of minor importance on cotton in northern Australia.

Although rough bollworm may cause serious damage to unsprayed cotton, it is normally controlled incidentally by sprays applied to control *Helicoverpa* in conventional cotton.

Bt cotton is not registered to control this pest but observations in the Australian environment as well as global Monsanto data suggests that it provides excellent control[1].

Identification: Larvae grow up to 18mm long, are thickset, mottled grey and brown with irregular yellow-orange spots in rows along the back. Moths are 11mm long and are off-white with a green or brown stripe on the forewing. Eggs are initially blue-green and difficult to find.

Lifecycle: Eggs take about 3 days to hatch. There are five larval instars lasting in total about 2 weeks. Pupae are housed in papery, brown cocoons on the stem or on an old leaf. A generation takes about 5 weeks to complete under optimum conditions. There appears to be no diapause in winter, but the life cycle can be very prolonged at temperatures below 10°C.

Host range: The weed, bladder ketmia (*Hibiscus trionum*) is its major host. Upsurges of rough bollworm in cotton are frequently associated with the maturing of these wild hosts.

Damage: Damage is caused directly to bolls by larval tunnelling, although larvae can also be found in squares. Larvae may also tunnel down the main-stem causing destruction of the primary growing point at any growth stage including seedlings.

Rutherglen bug

Nysius vinitor (Bergroth)

Adult rutherglen bugs are often found on cotton but they do not tend to feed and are unable to reproduce on the crop.

Identification: Adults are 3–4mm long, mottled grey-brown-black, and have clear wings folded flat over the back. Nymphs are wingless, with a reddish-brown, pear-shaped body.

Lifecycle: Females lay up to 400 eggs, singly or in small groups on the soil surface, or in flower heads of crops and weeds. The 1mm long eggs are creamy and turn amber, taking about a week to hatch. The small reddish brown, wingless nymphs are pear shaped. Wing buds appear in the fourth and fifth nymph stages. Egg to adult takes about 4 weeks, with the life of an adult being another 4 weeks in warm weather. Several generations occur between spring and autumn. Adults and late stage nymphs overwinter in plant debris on the soil surface.

Host range: They breed on many weeds and field crops as well as horticultural crops.

Damage: Occasionally very hungry rutherglen bugs may survive through winter in cotton fields and feed on cotton seedlings resulting in establishment problems and gappy stands. This can occur where cotton crops follow sunflowers (from the previous summer). The bugs maintain their populations on fallen sunflower seeds and migrate to cotton as the seedlings emerge. They can also build in some winter weeds or crops and then move into adjacent seedling cotton in the spring. Damage to squaring or flowering cotton is rare and they are unlikely to be a threat to mature cotton. If bug numbers are high, monitor plant growth and damage.

Control: Rutherglen bugs can be controlled by removing weed hosts and by ploughing a deep furrow around the crop, preventing wingless bugs from migrating from weeds.

Adult rutherglen bugs are often found on cotton but they do not tend to feed and are unable to reproduce on the crop. This bug is pictured on sorghum. 4mm (Photo: K. Power)

This image shows the top and underside of rutherglen bug adults (left) and nymphs (right). (Photo: QDPI)

The most common field crop attacked by the rutherglen bug is sunflowers. (Photo: M. Dillon)

This podsucking bug may be confused with the pale cotton stainer. If they are present, ensure bolls are monitored for signs of plant bug damage. 15mm (Photo: J. Wessels DEEDI)

Seed-eating bug

Melanerythrus mactans (Stal)

This podsucking bug is a pest of sorghum, soybeans, mungbeans and cowpeas.

This species may be confused with cotton stainers. Little is known of the behaviour of these species in cotton. Their pest status in cotton is currently unknown. If they are present, ensure bolls are monitored for signs of plant bug damage.

Identification: These bugs are about 9mm long, the base colour is orange/red and they have black and orange markings on the back in a 'cross' pattern. These differ from the cotton strainers, which has plain orange wings with two distinct spots.

Lifecycle: Females lay eggs in plant debris or on the underside of leaves; nymphs hatch and go through several instars before they develop into fully winged adults.

Habitat: Widespread in Australia found in sorghum, soybeans, mungbeans, cowpeas and cotton. They are attracted to light and will often shelter in large numbers around houses.

Silverleaf whitefly

Bemisia tabaci B-Biotype

Three main types of whitefly are found on cotton in Australia, the greenhouse whitefly *Trialeurodes vaporariorum* and two strains of *Bemisia tabaci*, silverleaf whitefly (*Bemisia tabaci* B-Biotype) and the eastern Australian native (EAN).

Silverleaf whitefly (SLW) poses a greater pest threat than the other 2 species because of its greater host range, quicker reproduction rate, and its ability to rapidly develop resistance to insecticides.

Identification: Adult *Bemisia tabaci* are small 0.8 to 1.2mm long, have white wings and yellow bodies. Adults hold their white powdery wings more like the roof of a house that does not quite join at the apex, so when viewed from above the body can be seen between the wings. Nymphs are pale yellow-green and flat scale-like insects that attach to the underside of leaves. All stages of B-biotype and EAN are identical and a laboratory test is required to separate them. However, EAN is very susceptible to insecticides and will be rare in fields that have recently been sprayed.

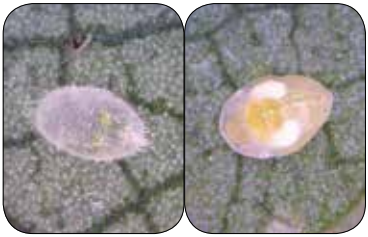
Another practical assessment of the species present can be made through analysing population growth rates. If populations are building rapidly, it is most likely the silverleaf whitefly (B-Biotype) as the native species have much slower growth rates.

May be confused with: The greenhouse whitefly. Although this species holds its wings flat, so from above it is heart or wedge shaped. They do not have the split between the wings and are about twice the size of *Bemisia tabaci*.

Host range: Plant hosts of the SLW include at least 500 broad-leaf crops and ornamental plants worldwide and it is a pest on many of them.

Lifecycle: In warm weather the life cycle of SLW takes from 18 to 28 days, but may take 30 to 48 days in winter, starting with eggs and going

The silverleaf whitefly (left) have a split down between the wings and the wings of the greenhouse whitefly (right) overlap. 1.5mm *(Photos: R. Lloyd)*



Note the absence of hairs on the silverleaf whitefly nymph (right) compared to the presence of them on the greenhouse whitefly nymph (Left). <1mm *(Photo: Z. Hall)*

Large numbers of whitefly can retard plants and secrete large quantities of sticky honeydew interfering with photosynthesis and causing major problems with cotton fibre processing. *(Photo: L. Wilson)*

SLW adults and nymphs produce honeydew, which is the sticky sugar rich substance on this leaf. (Photo: L Wilson)

SLW honeydew contaminates the lint of open bolls, providing a substrate for sooty moulds. It also causes problems with later processing that can lead to significant price discounts – both for the grower and the region as a whole.
(Photo: L Wilson)

through four nymphal stages until the winged adults emerge.

Damage: Large numbers can retard plants simply because their feeding removes assimilates from the plant that would normally be distributed into plant growth.

Whitefly also secrete large quantities of sticky honeydew that not only interferes with photosynthesis but also causes major problems with cotton fibre processing. Unfavourable discounts and flawed reputations arise with delivering sticky cotton. It is very important to manage SLW populations to avoid having honeydew contaminated lint.

Monitoring: Once you have confirmed the presence of SLW, it is important to monitor frequently (twice weekly) from peak flowering using presence/ absence sampling. This sampling protocol along with the SLW threshold matrix is detailed in the Cotton Pest Management Guide.

Control: Apart from insecticidal control to reduce the survival of SLW, there are other factors that can be considered. Remove broad-leaved host weeds (including volunteer and ratoon cotton) in and around cotton fields. In crop rotations, allow a host-free over winter period. Do not plant cotton near other source crops, such as soybean. Avoid late soybean plantings that will inherit large numbers of SLW as other crops finish off as it may result in total crop loss. Destroy crop residues after harvest. Aim for a tight planting window across the district. Avoid hairy-leafed cotton varieties. Plant okra-leafed varieties as they are less suitable for whitefly population growth. If possible minimise any stresses (eg water, nutrition) to grow a healthy crop. Conserve beneficial insects by avoiding or delaying the use of broad spectrum chemistry for as long as possible.

Springtails

Collembola family

Springtails are minute, softbodied wingless insects occasionally seen on young cotton.

Identification: Adults are 3mm or less ranging from elongate to globular. Some are patterned, mottled, iridescent or even metallic. In addition to antennae and six legs, springtails jump with an unusual forked structure on the end of their abdomen, called the furcula.

May be confused with: Thrips (although thrips have wings and do not have a furcula) and symphyla.

Lifecycle: Small eggs (0.2mm) are laid singly or in clusters. Juveniles hatch and mature to adults, living up to one year.

Damage: Similar to thrips but seldom require control unless cool, wet conditions persist.

The springtail's most interesting feature is a spring-loaded tail, called a 'furcula', extending from the rear of their abdomens. The furcula is used in jumping. 2mm (Photo: CSIRO)

Symphyla

Symphyla: Scutigerellidae

Symphylans are decomposers and a part of healthy soil biota and have been associated with significant plant reductions in the Dawson Valley.

Identification: Symphylans are white, soft-bodied 'centipede-like', 3–7 mm long with 12 pairs of legs and a pair of antennae.

May be confused with: Springtails.

Lifecycle: Symphylans lay eggs in the soil. Juveniles hatch and develop to adults, which may be very long lived.

Damage: They feed on rootlets and root hairs and damage symptoms are similar to fertiliser burn or compaction. They cause reduced plant stand and stunted plants. As symphylans need to move around in the soil profile, damage is worst where the soil structure is good.

Symphylans are sensitive to light and very active when exposed. 3–7mm (Photo: A. Quade)

The first 10 plants (left to right) are healthy, the next 10 plants have been damaged by symphyla. (Photo: Z. Hall)

A tomato thrips. One of the most common early seedling pests in most cotton growing districts. <1.5mm (Photo: L. Wilson)

Early season thrips damage is usually cosmetic and rarely affects yield or earliness. (Photo: A. Bishop)

Thrips

Thrips are one of the most common seedling pests of cotton in most cotton growing districts. They are also important predators of spider mite eggs. Common species are tobacco thrips *Thrips tabaci* (Lindeman), tomato thrips *Frankliniella schultzei* (Trybom) and western flower thrips *Frankliniella occidentalis*. Tobacco thrips are the most common species on seedling cotton. Both *Frankliniella* species are occasionally pests on seedling cotton but more common once flowering starts. Western flower thrips are poorly controlled by currently available seed treatments or at-planting insecticides. Plague thrips *Thrips imaginis* (Bagnall) is rarely found in cotton.

Identification: Adults are small, cylindrical insects less than 1.5mm in length. They have two pairs of narrow wings fringed with long hairs. The nymphs are less than lmm in length and wingless. First instar larvae are pale white, almost transluscent, while second instars are pale yellow. Adults of tobacco thrips and western flower thrips tend to be straw coloured, while tomato thrips tend to be dark or almost black.

May be confused with: The predatory six-spotted thrips *Scolothrips sexmaculatus* and springtails.

Lifecycle: Adult thrips lay eggs in slits in leaves and growing points. The first two larvae stages are completed on the plant, then the larvae drop to the soil to complete the last two stages. The life cycle from egg to adult varies from 44 days at 11°C to 9 days at 25°C.

Host range: In spring adults can be found on flowers of cereals (wheat, barley), canola and legume crops and on a wide range of weeds such as mexican poppy, turnip weed and paterson's curse. The adult thrips transfer to cotton when the crops and weeds hay off.

Damage: Damage occurs primarily to seedling cotton but can also occur in the mid to late season.

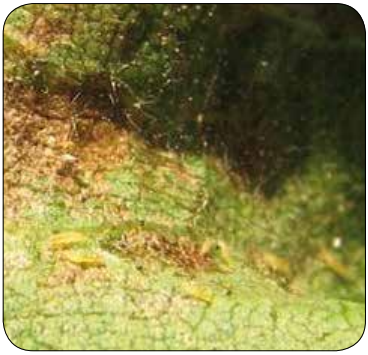
Thrips feed on the undersides of leaves causing 'silvery' damaged areas. On seedling cotton they also feed within the growing terminal. This can result in mild leaf distortion (leaves slightly malformed and crinkled – 1 to 5 thrips per plant), severe leaf distortion (leaves greatly reduced in size and cupped – 5 to 20 thrips per plant) through to complete death of the terminal causing the plant to produce new shoots (20+ thrips per plant). Extreme damage may result in yield loss and delayed maturity and may be exacerbated by cool weather that further slows plant growth. Control is warranted under these circumstances. However all thrips species commonly found in cotton are also predators of spider mite eggs. Thrips populations (*Frankliniella spp.*) can also build in the mid to late season and cause damage to young leaves, resulting in reduced size. However, this late damage is unlikely to affect yield or fibre quality. As a rough guide, leaf area loss of greater than 10–15% could result in yield loss if it occurred before crop cutout. After cutout losses of up to 15–20% could be tolerated with low risk. Late season thrips play an important role in controlling spider mites.

Monitoring: Sample for thrips between seedling emergence and 8 true leaves. Check the total number of thrips per plant. Keep an eye on the presence of nymphs, which is a sure sign that the population is reproducing. Assessing early season tip and leaf damage is also important and thresholds for both thrips numbers and plant damage are available in the Cotton Pest Management Guide.

Control: In warm regions, control of thrips is rarely warranted, while in cool regions, the risk that economic damage will occur is higher and thrips should be managed, preferably with a seed treatment or at-planting insecticide. This approach has less negative effects on beneficials. Application of broad spectrum foliar insecticides is risky, and destruction of beneficials increases the risk of outbreaks of whitefly, mites and aphids.

Natural enemies: Pirate bugs, lacewings and ladybeetles are all good predators of thrips.

Thrips feed directly on the undersides of leaves causing 'silvery' damaged areas. (Photo: L. Wilson)



In the absence of plant hosts, thrips feed on other sources of protein. These thrips have been pictured feeding on eggs in a mite colony. 1mm (Photo: L. Wilson)

The weevils that we see in Australian cotton fields are not the American boll weevils and are generally not damaging. 10mm (Photo: C. Mares)

Weevils

Weevils such as the garden weevil (*Phlyctinus callosus*) are occasionally found in Australian cotton fields. These weevils are generally not damaging. They should not be confused with the boll weevil (*Anthomonus grandis*) which is a major pest in the USA, feeding on squares and attacking bolls (see Page 54).

Identification: Weevils vary in size from 7 to 12mm and depending on the species, can be a range of colours. The adults are characterised by the elongated rostrum (the front part of their head and mouth), which they use to chew holes in plants for food and to make egg chambers. Their antennae are usually elbowed and clubbed. They usually have rigid bodies less than 10mm long. All weevils are plant feeders. The larvae are soil dwelling legless grubs and easily identified through their distinct brown heads and light brown to white bodies.

Lifecycle: Weevil eggs are laid in groups on the soil surface. Young larvae immediately burrow into the soil to feed on plant roots. When larvae finish feeding, they form a smooth-sided earthen cell in which they pupate. The length of the pupal stage is temperature dependant.

Host Range: Depending on the species, the weevils that we see in Australian cotton fields are generally a pest of nursery plants, vegetable crops and tree orchards. They are also found on a wide range of weed species.

Wireworms – True and false

There are two types of wireworm larvae found in cotton. The true wireworm (*Agrypnus variabilis* Candeze), and the false wireworms, which are a mixture of species, principally eastern false wireworm (*Pterohelaeus darlingensis* Carter), large false wireworm (*Pterohelaeus alternatus* Pascoe), southern false wireworm (*Gonocephalum macleayi* Blackburn) and *Saragus spp*. The true wireworm is the larval stage of a click beetle whereas false wireworms are the larvae of beetles of the family Tenebrionidae which includes the flattened pie dish beetles.

Identification: The true wireworm is a soft-bodied, cream-coloured larva growing to about 20mm with a flattened, dark brown head. False wireworms are all very similar, hard-bodied, shiny, tan-coloured larvae growing to about 30mm long. True wireworms have fine hairs on their bodies while false wireworms are completely smooth.

Lifecycle: Eggs are laid in summer and autumn, and larvae feed on organic matter in the soil until they reach full size in spring. Adult females lay eggs either singly on the soil surface or in batches of 10–15 eggs in crevices to 5cm deep in the soil. There are eight larval instars with a total average larval duration of 315 days; the last instar, the most damaging, occupies 48% of this time. Larvae pupate in cells in the soil during October to January. Adults emerge after 14 days.

True wireworms prefer wet soil for egg laying (eg irrigated summer crops), whereas false wireworms prefer drier conditions protected by stubble or weeds. Spring infestations can be expected to be worse in newly developed fields, in fallow fields (particularly with heavy trash cover) and in fields following summer crops (particularly soybeans). There should be no problems with fields following conventional cotton, as conventional insecticide use usually prevents beetle survival, however the

The true wireworm is a soft-bodied, cream-coloured larva with a flattened, dark brown head. 20mm (Photo: L. Wilson)

Adult true wireworms are grey to brown elongated beetles that jump and click when disturbed. They are known as click beetles. 25mm (Photo: J. Wessels)

Several species of false wireworms may occur in any particular crop, depending on locality, soil type, organic matter and tillage practices. Larvae feed on germinating seed and chew on seedling roots and shoots, resulting in patchy stands. 35mm (Photo: L. Wilson)

Adults of the large false wireworm (20mm - left) and the southern false wireworm (9mm - right).
(Photo: D. Ironside)

Bt cotton varieties which are less dependant on pesticides may allow more soil insects to survive.

Host range: All field crops.

Damage: Both true and false wireworms damage cotton by either boring into germinating seeds or chewing through young seedlings just below ground level. Damage can occur for up to 4 weeks after sowing; resulting in patchy plant stands which can necessitate replanting.

Monitoring: Wireworms are most difficult to sample. They descend in the soil as it dries out and venture near the surface only after rain or an irrigation event. Hence, they are often not noticed until damage appears. However, by this time it is not possible to control them.

Control: Any control measures must be applied before, or at sowing. The most effective control is an in-furrow band application of either a granular or liquid insecticide, though seed treatments may provide some control.

Yellow peach moth

Conogethes punctiferalis (Guenee)

The yellow peach moth is a rare late season pest of cotton in coastal Queensland. It has not been recorded from cotton in New South Wales.

Bt cotton is not registered to control this pest and it is not known what level of control it provides[1].

Identification: Small larvae resemble those of the pinkspotted bollworm but produce masses of webbing and excreta at the entrances to their tunnels. The moth is bright yellow/orange and dotted with black spots with a wingspan of about 25mm.

Lifecycle/Damage: The life cycle from egg to adult takes 6 weeks in summer. Eggs are laid on bolls and the grey/pink larvae bore into bolls and sometimes stems.

Host Range: The yellow peach moth infests a number of other crops including citrus, cocoa, coconut, maize, mango, papaya, peach, pomegranate, sapodilla, sorghum, custard apple, lychee, macadamia, rambutan and durian.

The yellow peach moth is a minor and infrequent pest. 25mm (Photo: J. Wessels)

[1]The Bollgard II technology by Monsanto is registered by the Australian Pesticides and Veterinary Pesticides Authority (APVMA) to control *Helicoverpa spp.* The control level of other insect species listed is based on observations in the Australian environment as well on global Monsanto data. There is currently no Registration or Warranty for other cotton pests other than *Helicoverpa spp.* for Bollgard II cottonseed containing the Bollgard II technology.

The boll weevil is devastating to cotton crops and requires dedicated area wide management strategies for its control. The characteristic spurs can be seen on the inside of each foreleg. 4–5mm (Photo: USDA–ARS)

Tarnished plant bugs have 2–5 generations per year and can therefore quickly build up to high levels. 6mm (Photo: USDA–ARS)

This late nymphal instar is showing the characteristic four dark spots on its thorax and one spot in the middle of its abdomen. 3–4mm (Photo: USDA–ARS)

Exotic pests of greatest threat to Australian cotton

Cotton boll weevil

Anthonomus grandis

Cotton boll weevil causes large yield losses in the US and the cost of control is massive.

Adults are about 5mm, greyish-brown with a snout about half as long as their body. Larvae are legless, cream grubs with light brown heads.

The cotton boll weevil resembles some native weevil species. However, weevils in Australia rarely attack cotton, so any weevils found feeding on cotton plants or within cotton bolls should be reported.

The tarnished plant bug

Lygus lineolaris

Tarnished plant bugs have a wide host range across eastern US. This bug feeds on all parts of the plant and can reduce yields or delay crop maturity.

This flighty bug is about 6mm long, light brown and variously spotted. Larger nymphs can be recognised by a distinctive pattern of five dots on the back.The tarnished plant bugs look similar to several other lygus species. However all lygus species are exotic and should be reported.

Indian green jassid

Amrasca devastans

Indian green jassid is widespread in the Indian sub-continent. Unlike jassids found in Australian cotton, the Indian green jassid injects a toxin as they feed that causes leaves and bolls to drop and can stunt plant growth. They also predominantly feed on the lower leaf surface while Australian species mostly feed on the upper leaf surface.

Adults are wedge shaped, about 3–5mm long and yellowish-green to yellow during the summer. They have prominent black spots on both sides of the top of the head, and another on each forewing. Nymphs are 1–2mm long and are greenish-yellow with bluish legs.

An adult Indian green jassid. 3–5mm (Photo: Industry & Investment NSW)

Spider mites, whitefly and aphids

Tetranychid mites, Bemisia tabaci B-type or Q-type and *Aphis gossipyi* – exotic strains

Exotic species, strains or biotypes of spider mites, whitefly or aphids may cause more damage, have resistance to our pesticides, and may also carry exotic diseases such as cotton leaf curl or blue disease.

These exotic pests all look very similar to species already present in Australia and will be difficult to spot. Any spider mite, whitefly or aphid that does not respond to treatment or causes atypical damage symptoms (more severe damage, evidence of disease) should be reported.

For further information please refer to the Plant Health Australia Farm Biosecurity Manual for the Cotton Industry. www.planthealthaustralia.com.au
If you see anything unusual, call the Exotic Plant Pest Hotline 1800 084 881.

If a new aphid strain enters the country it may have a different insecticide resistance profile, making control more difficult. (Photo: L. Wilson)

There is a risk of other whitefly B-type strains and other biotypes (eg Q-type), entering the country with different insecticide resistance profiles. (Photo: L. Wilson)

Perennial native vegetation is an important alternate habitat for beneficials like this assassin bug which is feeding on a Helicoverpa larva. (Photo: P. Grundy)

For beneficials to move across the landscape, it is ideal to have areas of native vegetation linked to each other. (Photo: G. Roth)

Sustainable cotton landscapes

Natural enemies, or beneficials, suppress populations of a wide range of pest insects, reducing the potential for pest species to reach outbreak levels in field crops. Conserving and enhancing populations of beneficials is an important component of any integrated pest management (IPM) strategy.

Perennial native vegetation is an important alternate habitat for beneficials. The stability of perennial vegetation provides resources otherwise not found in cropping fields, especially when in fallow. While pest species can be found in native vegetation, most do not use native hosts, so native vegetation has a low risk of increasing pest numbers.

Beneficial are highly mobile and must be able to move between suitable habitats through the landscape to be effective.

There are a range of beneficial insects described in this guide that help control insect pests. In addition, birds, bats, frogs, lizards and some small mammals also prey on insect pests, further adding to the opportunity to reduce the overall need to spray insecticides.

Managing native vegetation also provides other benefits including carbon sequestration, erosion control, nutrient cycling, waste assimilation, water filtration and climate regulation.

The following principles can be used to guide native vegetation management to maximise its value for natural pest control.

PRINCIPLE 1:
Think beyond the crop

To improve the abundance and diversity of beneficials consider native vegetation as part of pest management, in particular the health of individual stands of native vegetation and how they are placed within your landscape.

- Beneficials need habitat to persist during periods of fallow, drought and insecticide spraying.
- Native vegetation in the landscape can provide this habitat.
- Patches of native vegetation need to be linked to each other and cropping areas to assist movement of beneficials across the landscape.
- Consider a range of scales (eg individual patches of vegetation), crops and entire landscapes. How well are these areas connected and how healthy is the native vegetation.

Management actions

- Use planning tools such as *my*BMP to develop a map of native vegetation surrounding cropping areas on the farm and in the local area.
- Assess the size, distance from crops and health of native vegetation on the farm and local area.
- Identify areas between or around native vegetation which could be planted with trees, shrubs and grasses or protected to allow natural regrowth to occur.
- Include areas such as fence line tree plantings, wind breaks, riparian corridors, open grasslands and roadside verges as they all provide habitat for beneficials.
- Plan plantings of crops to maximise natural pest control value. Will this crop require intensive pest control and what implications does this have for other crops and native vegetation?
- Contact your local Natural Resource Management Body, Catchment Management Authority or Landcare Office. There may be incentive funds to assist you.

Many beneficials have limited dispersal ability and can only move up to 1km from native vegetation. Consider linking patches of native vegetation such as riparian corridors or fence line tree plantings to assist beneficials to move between patches of native vegetation and crops.

Beneficials like this spined predatory shield bug, feed on native plant feeding insects to sustain their population in areas of native vegetation. *(Photo: S. Gamez)*

Revegetate areas with a diverse mix of native trees, shrubs and grasses. (Photo: S. Vogel)

Eucalyptus and other species in the Myrtaceae family (eg bottlebrushes, tea trees, etc) provide excellent habitat and food resources for a range of beneficial bugs, as well as birds and bats. (Photo: S. Vogel)

Some beneficials prefer to spend some of their time in open pastures and grasslands. Give grasses a go too. (Photo: S. Vogel)

PRINCIPLE 2: Encourage beneficials with diverse, messy vegetation

Vegetation which is diverse and may appear to us to be messy, provides a suite of resources for beneficials as different organisms have different habitat preferences and food requirements.

- Native vegetation with many layers, from trees and shrubs through to grasses and small herbs encourages a diversity of beneficials.
- Beneficials use a range of vegetation types from woodlands through to open grasslands and pastures.
- Logs, rocks, dead standing trees and litter provide important habitat.
- Prolifically flowering plants attract many beneficials as well as birds and small mammals.

Management actions

- Maintain and protect as many layers in areas of existing native vegetation as possible, by controlling weeds and feral animals such as pigs.
- Leave logs, rocks, dead trees and litter as they provide habitat too.
- Reduce where possible grazing impacts as, if not managed well, these can simplify vegetation by preventing establishment of new plants.
- Incorporate areas of native grassland. Consider introducing a native perennial pasture buffer around crop margins as a refuge for beneficials.
- Revegetate areas of your property with a mix of native plants especially those that flower prolifically such as eucalypts and tea trees or salt bushes.
- Contact your local state forestry nurseries, catchment management authorities or natural resource bodies to find out what species of plants are suitable for your area and where you can source them.

PRINCIPLE 3: Do not disturb, conserve your beneficials

Conserving a good population of beneficial insects starts with making well informed and rational pest management decisions using the following considerations;

- Pesticide use can reduce beneficial abundance.
- Bt cotton reduces the need to spray.
- Pesticide drift onto areas of native vegetation may deplete beneficial numbers there as well.
- Effective pest and plant damage sampling and use of pest thresholds will ensure pesticides are only applied when needed.
- Pesticides vary in their effect on beneficials.

Management actions

- Regularly sample and correctly identify pest and beneficial populations. Observe beneficial activity (eg thrips in mite colonies, parasitised aphid mummies).
- Regularly sample plant damage and observe plant health.
- Use industry pest and damage thresholds.
- If control is required use the most selective effective pesticide. This will leave beneficials to help control any survivors or other pests. Often a more expensive selective spray will save money in the longer term by reducing the risk of inducing pest outbreaks.
- Seed treatments are generally more selective than foliar sprays for control of seedling pests.
- Avoid spray drift into neighbouring crops and areas of native vegetation.
- Consider collating data on gross margins and yields and benchmarking against other farms and farming systems to determine the economic benefits of beneficials.

Sampling techniques, industry pest and plant damage thresholds and insecticide impact tables are updated annually in the *Cotton Pest Management Guide*.

Monitoring crop health and pest damage. Pest numbers alone do not give an accurate indication of the need for pest control. (Photo: M. Dillon)

A virus effected Helicoverpa larvae. Use the most selective insecticide available. (Photo: M. Dillon)

Aerial spraying. Consider the effects on beneficial populations in areas of native vegetation used as spray drift buffer zones. (Image: J. Wark)

Cotton grower James Thomas has built bat boxes to encourage insectivorous bats onto his farm and integrate them into pest management strategies at 'Bloomfield', St George. (Photo: G Roth)

Nightbirds such as the tawny frogmouth and nightjars feed on Helicoverpa moths as they are also active at night. (Photo: Namoi CMA)

Protect big old trees with hollows as they provide habitat for microbats. (Photo: G. Roth)

PRINCIPLE 4: Consider birds and bats as beneficials

In addition to the beneficial arthropods (insects, spiders and mites) that live in cotton growing areas, birds and bats also inhabit these areas and make a significant contribution to pest management. These animals live in areas of native vegetation, but forage for insects within and over the canopy of crops.

- Birds and bats can disturb moth feeding and mating activities and can consume up to 50% of pests in a crop.
- Birds and bats need suitable habitat so that they can persist in the landscape and contribute to pest management.
- Big old trees with hollows provide habitat for a range of native animals including bats and birds.

Management actions

- Go to the CottonInfo natural resource management webpage to assist in determining what constitutes healthy native vegetation: www.cottoninfo.com.au/natural-resource-management
- Read the 'Birds on Cotton Farms' guide to learn more about the birds occupying the farm and what their habitat preferences are.
- Protect big old trees with hollows, dead and living.
- Install bat boxes where old trees with hollows are limited.
- Revegetate or restore areas of native vegetation on farm to encourage birds and bats.
- Consider the effects of spraying at dawn and dusk when birds and bats are most active and vulnerable.

PRINCIPLE 5:
Control weeds on the farm

Many cotton pests use weeds as an alternative host prior to moving into crops. Controlling weeds on farm helps to minimise pest species numbers.

- Weeds on the farm and in areas of native vegetation can provide a host for pests and diseases.
- Cotton volunteers and ratoons are a host for cotton pests and diseases.
- Maintaining healthy native vegetation helps to reduce weed recruitment.
- Overgrazing areas of native vegetation can encourage the spread of weeds by removing competition from native species.

Management actions

- Be on the lookout for new weed populations and control them before they can spread.
- Map and monitor weeds so that the effectiveness of your weed management program can be monitored and modified.
- Control cotton volunteers and ratoons, preferably before cotton crops emerge.
- Work with neighbours to control weeds.
- Be careful spraying herbicide in native vegetation as some species are sensitive to herbicides. Other weed control options such as spot spraying or chipping may be better.
- Follow up control of weeds each year to minimise re-establishment.
- Careful use of grazing methods, such as time control grazing, can minimise soil disturbance and protect native understorey species during establishment.
- Practice 'come clean go clean' guidelines and minimise vehicle movement in native vegetation to reduce spread of weed seeds, pests and diseases.
- Contact your local weeds officer for advice on control of weeds in sensitive areas such as along waterways, creeks and rivers.

Bladder ketmia (Hibiscus trionum) is a host weed for the cotton pest Rough Bollworm (Earias huegeliana Gaede). (Photo: L. Wilson)

Control weeds in areas of native vegetation to reduce pest habitat. (Photo: T. Smith)

Grazing weeds while they are flowering can reduce seed set and hence their populations, however avoid grazing during periods of native vegetation flowering and seed set. (Photo: M. Hobson)

Beneficials mostly get their water from rain drops or dew, but these sources are often unavailable during periods of drought. Reduced water availability means smaller populations of beneficials. (Photo: Namoi CMA)

Waterbirds such as Ibis spend part of the time in wetlands, but have a big appetite for common insect pests. (Photo: G. Roth)

Restore riparian vegetation along creeks and streams. These areas, if healthy, tend to have high populations of beneficial insects, birds and bats. (Photo: M. Hobson)

Principle 6: Consider water availability

The availability of water in the landscape significantly impacts the number of beneficials present to assist in pest management.

- Native vegetation near water sources such as rivers, creeks, water storages or channels have much higher populations of beneficials than vegetation that is not near water.
- Many beneficials need water to survive.

Management actions

- Restore and or maintain riparian vegetation along creeks and streams.
- Consider positioning revegetation areas near artificial water sources (eg channels, storages, head and tail ditches) or table drains.
- Allow floodwaters to inundate areas of native vegetation, such as river red gum, coolibah or black box woodland to maintain vegetation condition.
- Be extra considerate of beneficials during a dry spell. Beneficials need to drink water or their populations will decline.
- Keep open water sources clean and healthy.

Further reading

Natural resource publications and on-line bird and weed ID tools can be referenced at www.cottoninfo.com.au

Ants

Hymenoptera: Formicidae

Some species of Australian ants are important predators of cotton pests, particularly under dryland conditions and in lighter soils where ant colonies can establish within the field.

Identification: Ants found in cotton crops vary in size (1–10mm) and colour (black to light brown). All ants have either one or two small segments between the main body part and the last section. These are absent from almost all other insects. The distinctive ant antennae is segmented and highly flexible. This allows the tips of the antennae to be positioned near the mouthparts to assist in inspecting objects.

Lifecycle: Ant eggs are oval shaped and tiny. Fertilised eggs produce female ants (queens, workers, or soldiers); unfertilised eggs produce male ants. The eggs hatch into larvae and the larvae moult many times to become a pupae and emerge as an adult. The entire life cycle usually lasts from 6 to 10 weeks. Most queen ants live longer than 7 years; some even live up to 15 years.

Habitat: Their abundance is influenced by the presence of foraging trails going in and out of native pastures and encouraged by the presence of structures that they can use – and old logs and other timber around fields will be used.

Inter-row cultivation can reduce some ant populations for 2–4 weeks. Irrigation events change the behaviour of ants as they will switch from foraging to moving their eggs, larvae and pupae to drier locations.

Targeted prey: Ants are generally omnivorous and will take whatever food they encounter which can include various small pests, *Helicoverpa* eggs or immature stages of some pests. Ants can however protect and spread some pests such as aphids and mealybugs in exchange for honeydew.

These ants are pictured tending a cotton aphid colony in exchange for honeydew. (Photo: L. Wilson)

Ants like this Iridimyrex are omnivourus and will take whatever food they encounter which includes small insect pests. 2-3mm
(Photo: C. Mares)

The Paratrechina spp. is a common ant in cotton landscapes. 2-3mm (Photo:C. Mares)

During an irrigation event ants may relocate their eggs higher into the plant canopy. (Photo: C. Mares)

A newly hatched assassin bug nymph on a cluster of eggs. 5mm (Photo: C. Mares)

This young assassin bug nymph is feeding on a cotton looper. 5mm (Photo: J. Wessels DEEDI)

Assassin bugs have a big appetite for a large range of soft-bodied prey. 25mm (Photo: L. Wilson)

Assassin bug

Reduviidae

Several kinds of assassin bugs are found in cotton farms but no one species is regularly abundant. The assassin bug is a stealthy hunter and often approaches its victims from behind and stabs them with strong stylet-like mouthparts that inject a debilitating enzyme. The enzyme dissolves the preys' inner organs and the bugs then suck out the contents using its hollow mouth part leaving behind an empty shell of the prey.

Identification: Adults are brown and range from 10 to 30mm in length, have distinct heads with prominent eyes and their abdomens have a slight waist. Nymphs are black with bright orange abdomens.

Lifecycle: Adult females lay several clusters of 40–80 orange eggs that take 14–16 days to hatch into nymphs during summer. The wingless nymphs pass through five growth stages to adulthood. Nymph development to adult takes approximately 65–95 days depending on temperature and availability of insect prey. Adults may live about 6–10 months.

Habitat: Assassin bugs occur in field crops, but they are also found in urban areas, coastal heaths, forests and woodlands.

Targeted prey: Assassin bugs feed on many different insects, but due to their sucking mouthparts, tend to prefer softer-bodied prey such as caterpillars and small bugs such as green mirids. Assassin bug nymphs have large appetites and can consume up to 160 small to medium-sized *Helicoverpa* larvae over a 9–12 week period.

Bigeyed bug

Geocoris lubra (Kirkaldy)

Bigeyed bug have piercing and sucking mouthparts which they use to kill their prey and feed on their body fluids. They occur in cotton crops in early and mid season and numbers are highest in cotton during flowering. The numbers of bigeyed bugs in cotton are reduced by insecticide sprays, rainfall, high temperature and humidity. Lack of food or prey also reduces their abundance. A related species, *Germalus spp*, is also occasionally found. It is similar in appearance but slightly larger. The two may be distinguished by colour. Geocoris is dark brown to black whereas *Germalus* is brown and green.

Identification: The huge eyes of the bigeyed bug provide easy identification. Bigeyed bugs range in length from 3–5mm and are grey to dark tan. The nymphs resemble the adults but are wingless and more robust.

Lifecycle: The cylindrical, white eggs are laid singly on terminals and under leaves. The eggs hatch after a week and the nymphs pass through 5 growth stages before becoming winged adults. All of these stages are predaceous. Total development time is around 30 days and adults can live for up to 2–3 months.

Habitat: Bigeyed bugs can be found in most crops and landscapes.

Targeted prey: This fast moving day-feeding species is an important predator of eggs of *Helicoverpa* and other species as well as a range of other soft-bodied insects such as whitefly and mites. Bigeyed bugs can survive on nectar and honeydew when prey is scarce.

The bigeyed bug is an important predator of eggs and a range of small soft-bodied insects such as whitefly and mites. 3mm (Photo: M. Dillon)

Bigeyed bug nymphs are small wingless and a brownish colour. Their large eyes provide easy identification. 1mm (Photo: C. Mares)

The brown smudge bug has been found feeding on a range of small pests and in particular mites. 4mm (Photo: C. Mares)

Brown smudge bug nymphs are smaller wingless and maroon coloured. 1–2mm (Photo: L. Wilson)

The slender damsel bug is a very common predator and can be found in any type of crop infested with caterpillars. 8mm (Photo: D. McClenaghan)

Damsel bug nymphs resemble the adults, but are smaller and without wings. 5mm (Photo: C. Mares)

Brown smudge bug

Deraeocoris signatus (Distant)

Identification: The adult brown smudge bug is small (4.5mm) and mottled brown with clear wings folded flat on the back. The adults have a characteristic 'w' shape where the wings overlap near their tail end. Nymphs are smaller and maroon coloured and can look like large aphids.

Habitat: They are abundant in cotton crops especially unsprayed cotton during mid and late cotton season. They are also found in various crops (eg lucerne, soybean, sunflower, peanut and cotton).

Targeted prey: The habits of the brown smudge bug are not well known, though it has been found to feed on *Helicoverpa* eggs, aphids and the apple dimpling bug using their piercing and sucking mouthparts to suck fluid from insects. Both nymphs and adults are very aggressive predators of mites.

Damsel bug

Nabis kinbergii (Reuter)

Identification: Damsel bugs are slender, dull tan to grey with long antennae and legs, and prominent eyes. Nymphs resemble the adults, but are wingless.

Lifecycle: Females lay white cylindrical eggs that are inserted into soft plant tissue so that the circular emergence caps protrude above the surface. The eggs hatch in 8–12 days and nymphs develop within 3–4 weeks.

Habitat: They are usually present in any kind of crop infested with caterpillars. Adult damsel bugs may be found on weeds, winter crops and perennial crops such as lucerne.

Targeted prey: Nymphs and adults use piercing/sucking 'beaks' to feed on many insects, including eggs and larvae of moths, mites and aphids.

Earwigs

Labidura truncata (Kirby) and *Nala lividipes* (Dufour)

Earwigs have distinctive pincers at the 'tail' and hide on and in the ground during the day.

The common brown earwig *Labidura truncata* (Kirby) is a nocturnal predator of caterpillars and the black field earwig, *Nala lividipes* (Dufour) also commonly occurs in cotton fields. It is smaller and entirely black in colour and can be a pest of seeds and seedlings.

Identification: The common brown earwig adult is 24mm long, brown and black with a flattened body and distinctive pincers at the end of the body. The black field earwig is very similar, only shiny black and slightly smaller (15mm long). Adults have wings folded beneath the slate-blue covers on the thorax and can fly. Nymphs resemble adults but are wingless.

When disturbed earwigs may emit a foul smelling liquid as a self defense mechanism, but if further threatened, earwigs bite, or more accurately 'pinch' with the forceps on their tail ends. Earwig bites can be painful but not harmful.

Lifecycle: Earwig adult females guard their oval, white eggs and young nymphs in burrows in the ground. Eggs hatch in 6–7 days at temperatures around 29°C. The developmental time for five nymphal instars is about 7 weeks in clay soils, longer in sandy soils. Nymphs develop into adult females or major or minor males. Longevity is about 20 weeks.

Habitat: Earwigs are widespread and can be found in most rural and urban landscapes.

Targeted prey: Both earwig species can predate on all types of larvae, pupae and wireworms. They also attack *Helicoverpa* pupae in their chambers in the ground.

The black field earwig can be a pest and a predator. They can be a seedling pest in a wide range of crops, and also a predator of larvae, pupae and wireworm. 14mm (Photo: K. Power)

The common brown earwig is a nocturnal predator of caterpillars. 24mm (Photo: K. Power)

Carab beetles generally hunt for prey at night and during the day hide in soil cracks and under loose soil and leaf debris. 24mm (Photo: C. Mares)

Green carab beetle

Calosoma schayeri (Erichson)

These fast moving large beetles are common predators in cotton fields. Carab beetle adults hide in soil cracks and under loose soil and leaf debris during the day and hunt for prey at night. Beetles belonging to the family Carabidae are general predators which vary greatly in size and colour.

Identification: Adults are 15mm long with rows of pits running along the wing case; they have a hot-water-bottle-shaped body. If handled roughly they give off an unpleasant smell. Green carab beetles are dark metalic green and shiny with long slender legs and antennae. The larvae are predaceous, worm-like with well developed legs and jaws.

Lifecycle: Eggs are laid in soil or leaf litter. Eggs take up to a week to hatch and larvae go through a series of growth stages before pupating into adults. Beetles which breed in the spring typically overwinter as adults. Carabids that breed during the summer months tend to overwinter as larvae, and then finish their development to adults in the spring.

Habitat: These beetles have a wide range of habitats in urban areas, cropping areas and native vegetation.

Targeted prey: This active beetle hunts caterpillars and other slow-moving prey. The larvae are also predaceous but live in the soil.

Green soldier beetle

Chauliognathus pulchellus (W.S. Macleay)

Green soldier beetles occur in large swarms in eucalypt plantations where they prey mainly on eucalypt defoliating beetles. Adult beetles, sometimes occur in large, flying swarms of low density during the late cotton season. Some swarms seem to be mating aggregations while others seem to be mass dispersal flights. Large numbers of these beetles can arrive in a crop in a very short time.

Identification: Adults are 14mm long and have an elongated, flattened body with a yellow-orange band behind the head. The head and wing case are dark green-black. Beneath the wings, the body is yellow-orange. The soil-dwelling larvae are flat, dark-coloured and covered with hairs that give them a 'velvety' appearance. Soldier beetle larvae are similar to ladybird larvae but are larger and more slender.

Lifecycle: Eggs are laid in the soil. Larvae pupate into adults in the soil in spring.

Habitat: These beetles have a wide range of habitats in gardens, forests, cropping areas and native vegetation.

Targeted prey: Adults feed on moths, larvae, *Helicoverpa* eggs and leaf beetle eggs. Large swarms of adults occasionally invade soy beans, feeding on the leaves. The soil-dwelling larvae eat soft-bodied invertebrates.

The green soldier beetle is omnivorous, feeding on other insects and occasionally leaves. The larvae live on the ground and prey on other insects. 10mm (Photo: C. Mares)

Hover fly larvae are blind, slug-like maggots which have a large appetite for aphids. 5mm (Photo: L. Wilson)

Adult hover flies are harmless even though they look similar to a bee or wasp. They hover around feeding on the pollen and nectar of flowers. 9mm (Photo: C. Mares)

This brown, tear-shaped pupae of the hover fly is pictured under a cotton leaf. 4mm (Photo: L. Wilson)

Hover fly or syrphid

Syrphidae

The larvae of hover flies prey voraciously on soft bodied insects, especially aphids. In contrast, adult hover flies are not predators but feed on nectar and pollen. The adults are distinctively patterned and although harmless they mimic bees and wasps with black and yellow bands across their abdomens. They fly swiftly and also display characteristic hovering flight, staying motionless in the air for short periods.

Identification: Adults are 4–7mm long and have a dark-coloured, flattened body often with yellow markings. Like most flies, they have large eyes and short antenna. They have one pair of clear wings. White, oval eggs are laid near colonies of aphids. Larvae are blind, slug-like maggots which feed voraciously on aphids. The brown, tear-shaped pupae are found under leaves or in ground litter.

Lifecycle: Small eggs usually deposited on, or near the host insect. Development from egg to adult takes between 2–6 weeks.

Habitat: Various crops and plants with infestations of targeted prey.

Targeted prey: Larvae of the hover flies are predators of many soft body insects such as aphids, scale insects, thrips and caterpillars.

Lacewing – Brown

Micromus tasmaniae (Walker)

Adults and larvae of brown lacewings are active predators of soft-bodied insects.

Brown lacewing larvae differ from green lacewing larvae by being longer and thinner and by not camouflaging themselves.

Identification: Adults are mottled brown with long antennae and two pairs of delicate wings folded over the back in an inverted V shape. They have a fluttering style of flight. Larvae have sickle-shaped jaws with a tapering body which is longer and thinner than the green lacewing. The eggs are cream-coloured and oval in shape. They are attached singly to the underside of leaves and are not attached to stalks (like green lacewing eggs).

Lifecycle: After the eggs hatch the larvae undergo three growth stages before pupating. At the end of pupal life, a perfect winged insect emerges, totally unlike the larva which preceded the pupa.

Habitat: Lacewings are found in most habitats in Australia. Both adults and larvae are commonly encountered in urban areas, where the adults are readily attracted to lights.

Targeted prey: Larvae are voracious predators of all insects and adults have been seen to eat *Helicoverpa* eggs, aphids and other soft-bodied insects.

The predacious adult brown lacewing has two pairs of delicate wings which show a dense network of veins. 6mm (Photo: L. Wilson)

Brown lacewing larvae are long and thin and do not camouflage themselves with remnants of dead prey like the green lacewing larvae. 4mm (Photo: C. Mares)

Each egg sits on the end of a slender stalk, which elevates it; decreasing the chance of predation by ants. Green lacewing eggs take about 4 days to hatch. 1mm (Photo: C. Mares)

Green lacewing larvae camouflage themselves with remnants of dead prey which they place onto their backs. 4mm (Photo: C. Mares)

Adult green lacewings are not predators but feed on nectar and honeydew from aphids. This lacewing is covered in pollen from foraging inside a flower. 12mm (Photo: C. Mares)

Lacewing – Green

Mallada signatus

The larvae of green lacewings are predators of a range of cotton pests. In contrast, the adult green lacewing is not a predator but feeds on nectar and honeydew from aphids. The adults are active fliers during the morning, evening and night. They occur in cotton during spring and summer.

Identification: Eggs are white, oval shaped and on stalks. Larvae are 1–8mm long, with large, hollow, sickle-shaped jaws that they drive into soft bodied insects or eggs before sucking up the contents. They camouflage themselves with remnants of dead prey which they place onto their backs. Adults are 14mm long, green with two pairs of delicate transparent wings. The pupal cocoon is also camouflaged with corpses.

Lifecycle: Development from egg to adult is around 25 days. Eggs take about 4 days to hatch, larvae moult 3 times over 12 days, and the pupal period is about 9 days. Adults live for up to 30 days.

Habitat: Since adults feed on nectar and pollen, flowering crops or flowering vegetation nearby will encourage adults to stay in the landscape.

Targeted prey: Larvae are general predators and feed on insects such as thrips, mites, aphids, immature mealybugs, moth eggs and small caterpillars.

Ladybird beetles

Subfamily: *Coccinellinae*

Adults and larvae of ladybird beetles are important predatory insects in most crops, especially early season and when chemicals have not been used against pests. They are voracious predators of aphids and, under most conditions, (along with lacewings and hover flies), stop aphid populations from increasing explosively.

The main ladybird species found in cotton landscapes include:

- Transverse ladybird *Coccinella transversalis*
- Striped ladybird *Micraspis frenata*
- Three-banded ladybird *Harmonia octomaculata*
- Minute two-spotted ladybird *Diomus notescens*
- Mite-eating ladybird *Stethorus spp.*
- Common spotted ladybird *Harmonia conformis*
- Variable ladybird *Coelophora inaequalis*
- White collared ladybird *Hippodamia variegata*
- Mealybug ladybird *Cryptolaemus montrouzieri*

Identification: Eggs can be 0.2–2mm in length, are red, yellow or white and oval or rod shaped. Larvae are between 1–8mm in length, come in various colours, elongate in shape and many are adorned with spines. Adult ladybirds range between 1–10mm in length and can be brown, orange, red, blue or yellow with different coloured patterns or spots, usually oval or dome shaped and may be covered in hairs. Adults have the wings for flight, covering large distances to find new food sources and mating partners. The pupae are usually brightly patterned and can be found attached to the leaves and stems of plants where larvae have fed and developed.

Mealybug ladybird adults are small, dark green in colour, with thorax and head yellowish-brown. Their 'tails' are also brown in colour and look like their head. The mealybug ladybird larvae closely resemble mealybugs.

The transverse ladybird adult. 4mm
(Photo: NSWI&I)

The striped ladybird adult. 4mm (Photo: L. Wilson)

The three-banded ladybird adult. 5mm
(Photo: D. McClenaghan)

The minute two-spotted ladybird adult. 2.5mm (Photo:C. Mares)

A ladybird larvae searching for a meal of aphids. 7mm (Photo: L. Wilson)

An adult mealybug destroyer ladybird. 5mm (Photo: R. Whyte)

Lifecycle: Females lay clusters of 10 to 50 yellow spindle shaped eggs on plants near their food source, such as aphids or other soft bugs. The larva emerges from the eggs after about 1–2 weeks. The larva reaches maturity within 2 weeks. Pupation takes place on plants where the larva fed and the adult emerges from the pupa after 1–2 weeks.

Habitat: Their distribution is worldwide. They live in a variety of habitats, including most rural and urban landscapes. Their abundance however coincides with the availability of their main food source (aphids, scale insects and mites).

Targeted prey: They feed on very small insects such as aphids, scale insects, mealybug and mites. Ladybird adults and larvae can also consume significant numbers of *Helicoverpa* eggs, larvae, mites, whiteflies and jassids. Many ladybirds are especially voracious predators of aphids; the common spotted ladybird can consume up to 2400 aphids in her life-span. The smaller species, such as the mite eating ladybird and minute two-spotted ladybird tend to eat smaller prey, especially spider mites.

Millipede

Class: *Diplopoda*

Identification: Millipedes are 25–50mm long, brown or black, have a long cylindrical segmented body with an extremely high number of legs. They have short feelers, no tail appendages and move more slowly than centipedes. When disturbed, they coil up into a spiral, and may emit a foul smell.

Lifecycle: The female lays her eggs in the soil, under logs or among leaf litter depending on the species. The newly hatched young have 3 to 4 pairs of legs depending on the species. Body segments and legs are added with successive moults as they grow until the adult size is attained.

Habitat: Most millipedes are found in cool, moist environments and many species are common under rocks and logs, in leaf litter and soil and under the bark of trees.

Targeted prey: Millipedes feed primarily on decaying plant material and animal matter.

Millipedes feed on decaying plant and animal matter. So they are neither a pest nor predator. 20mm (Photo: K. Power)

The minute pirate bug is an important predator of thrips and mites. 2.5mm (Photo: L. Wilson)

The distinguishing feature of the minute pirate bug nymph is the orange colouring towards the end of the abdomen. This nymph is pictured feeding on an adult thrips. 1–2mm (Photo: L. Wilson)

Minute pirate bug

Orius spp.

Pirate bugs are important predators of thrips and mites. They are very abundant in sorghum crops through summer. In cotton, they are very effective thrips, mites and egg predators and may also feed on pollen. They often appear in large numbers at flowering when thrips are usually abundant.

Identification: Adults are 3mm long and dark brown or black with wings folded flat on the back. Wings are clear with black markings. The nymphs are colourless when they hatch, then darken to yellow and then dark brown as they develop. They have a distinct orange colour towards the end of the abdomen.

Lifecycle: The pirate bug has seven developmental stages; an egg, five larval stages and an adult – this lifecycle takes about 16–18 days at 25°C to complete. The adult can live for up to 4 weeks.

Habitat: Their distribution is worldwide. Their favoured vegetation is crops that produce flowers with pollen. They are good flyers and nimble, which assists in dispersing throughout the landscape.

Targeted prey: In all its developmental stages, the pirate bug is able to hunt and kill its prey by sucking its body fluids. They primarily feed on thrips and insect eggs, however they will also feed on aphids and spider mites.

Parasitoids of aphids

Lysiphlebus testaceipes, Aphidius colemani

A parasitoid is an insect that kills (parasitises) its host – usually another insect – in order to complete its lifecycle. Parasitoids can play an important role in aphid control at the early stage of aphid establishment before aphid numbers begin to increase exponentially. Parasitoids of aphids are highly effective with the ability to search out scattered populations of aphids and lay their eggs in them. Aphid parasitoids can detect and find aphids from long distances through signals produced by the aphid host as well as the infested plant.

Identification: Both species are small (2–3mm), slender, dark wasps and difficult to distinguish between. The antennae are long and many-jointed. Evidence of their presence is buff-coloured aphid 'mummies'.

Lifecycles: Female wasps insert an egg into the aphid and the developing larvae feeds inside the aphid, eventually killing it. The aphid generally reaches an adult stage, which may be winged or wingless, before it is visibly affected. The wasp larva then attaches the body of the aphid to the leaf and spins a cocoon within the aphid, in which it pupates. The dead aphid takes on a golden brown, papery, swollen appearance, often called a 'mummy'. The new adult wasp emerges from the 'mummy' by cutting a hole in the skin. The length of the life cycle is temperature-dependent, and is about 13 days at 21°C.

Habitat: The parasitoids live in a wide range of crops, especially those crops infested by aphids, and edge habitat between native remnant vegetation and crops, and grassy margins. Their larvae overwinter in the host. Therefore, the survival of the aphid will determine the overall survival of the parasitoids.

Targeted prey: *Lysiphlebus testaceipes* attacks cotton, corn and cowpea aphids. *Aphidius colemani* attacks cotton, green peach, turnip and oat aphids.

This Lysiphlebus wasp has recently emerged from the aphid 'mummy'. 2–3mm (Photo:M. Miles)

Parasitised aphids become papery and swollen. They are known as 'mummies'. Photo: L. Wilson)

The two-toned parasite is a slender, black wasp with an orange abdomen, yellow legs and clear wings. 20mm (Photo: P. Reid)

The orange caterpillar parasite is a slender plain orange coloured wasp which is attracted to lights. 18mm (Photo: C. Mares)

Parasitoids of lepidopteran larvae

The following parasitoids are the most common *Helicoverpa* larvae parasitoids found in and around the cotton farm and includes the two toned *Heteropelma scaposum* (Morley); Orange *Netelia producta* (Brullè); orchid dupe *Lissopimpla excelsa* (Costa), *Microplitis demolitor* (Wilkinson); and, *Tachinid sp.* flies.

Identification:

Two-toned caterpillar parasite is a medium-sized (20mm), slender, black wasp with an orange abdomen, yellow legs and clear wings.

Orange caterpillar parasite is a slender, medium-sized (18mm) orange wasp. The best place to see this wasp is at night around outdoor lights.

The orchard dupe is a stout, medium-sized wasp (25mm) with an orange body, black wings and the abdomen has a chequered pattern of black and white spots on the upper surface.

Microplitis is a small (3mm) black wasp with an orange abdomen and black wings.

Most *Tachinid* flies that attack *Helicoverpa* are the same size and general appearance as a blowfly (7–10mm).

Lifecycles:

The two-toned caterpillar parasite stings caterpillars at third instar stage and older. The caterpillar continues to grow and pupates. However, shortly after pupation, parasitoid feeding kills the host. When the two-toned larva is fully developed, it pupates within the *Helicoverpa* pupal shell and emerges as an adult wasp.

The orange caterpillar parasite attacks *Helicoverpa* and armyworm caterpillars from third instar and older. The wasp stings the caterpillar and lays an egg close to its head. The wasp larvae hatches and

develops externally, hanging on behind the head of the caterpillar. After the caterpillar pupates, wasp larvae kill the host before pupating in their own black furry cocoon within the chamber.

The orchard dupe lifecycle is similar to that of the two-toned caterpillar parasite.

Microplitis sting second instar *Helicoverpa* larvae. The wasp larva then feeds internally and chews a hole in the side of its host to emerge and pupate externally. Host caterpillars are killed before they do much feeding damage. The whole *Microplitis* lifecycle (egg–adult) takes about 10–12 days.

Tachinid flies use three main strategies to parasitise their caterpillar hosts:

1. Fly eggs hatch into leech-like larvae which latch onto a caterpillar passing by. The fly larvae then burrow through the skin of the caterpillar and feed on its internal tissues.
2. Fly eggs are laid on the caterpillar. The fly larvae hatch then burrows through the skin of the caterpillar and feed on its internal tissues.
3. Tiny fly eggs are laid on leaves. The caterpillar accidently eats the fly eggs. Once inside the host, the eggs hatch and the larvae penetrate the gut wall and feed on tissues within the body cavity of the caterpillar.

Habitat: All of these species are found in crops, but the two-toned, orange, orchid dupe and *Microplitis* are also found in the edge habitat between crops and native vegetation remnants – particularly those remnants along water courses or commonly referred to as riparian vegetation. *Microplitis*, can also be found deep into native remnant vegetation. Some of these wasps are attracted by light and so are very common in gardens and houses.

Targeted prey: Most of these parasitoids attack both *Helicoverpa* and armyworm larvae. However the *Tachinid* fly will attack a wide range of insect species.

This wasp is called the orchid dupe because some orchids mimic the odour and appearance of a female orchid dupe wasp. The male wasp mistakes the flower for a female and incidentally pollinates the orchard. 20mm (Photo: NSW I&I)

The Microplitis wasp pupae is attached to this medium Helicoverpa larvae. 6–7mm
(Photo: M. Dillon)

This Tachinid fly prepares to attack the Helicoverpa larvae. 5–6mm
(Photo: J. Wessels DEEDI)

The banded caterpillar wasp is a pupal parasite capable of locating 'under-ground' pupal chambers. 14mm (Photo: P. Reid)

The Brachymeria sp. wasp has distinctive thick hind legs. 7mm (Photo: C. Champagne)

Parasitoids of pupae

Banded caterpillar parasite *Ichneumon promissorius* (Erichson), and *Brachymeria sp.*

The following parasitoids are known as true pupae parasitoids, where they specifically search for and parasitise moth pupae.

Identification:

The banded caterpillar parasite is a medium-sized (14mm) wasp, with a white band on the antenna. Its body is black with white dots on thorax and white-banded abdomen. The legs are orange-brown in colours.

The *Brachymeria sp.* parasitic wasp ranges in length from 5–10mm, with its main feature being swollen looking hind legs.

Lifecycle: For both species, the wasp locates and penetrates the *Helicoverpa* pupal chamber. It then lays an egg in the *Helicoverpa* pupa and feeds on the fluids from the puncture wound. The *Helicoverpa* pupa dies and the pupal case stiffens as the wasp larva consumes the tissues. The adult wasp emerges from the pupal case. The *Brachymeria sp.* will also locate and attack 'above ground' pupae (eg looper caterpillar pupae).

Habitat: They can be found in crops, and edge habitat of crops and riparian native vegetation.

Targeted prey: The banded caterpillar parasite attacks both *Helicoverpa* and armyworm pupae and the *Brachymeria sp.* is less selective attacking a range of moth and butterfly pupae.

Parasitoids of moth eggs

Trichogramma, Trichogrammatoidea and *Telenomus*

Egg parasitoids kill their hosts before larval hatch, thus preventing crop damage by emerging caterpillars. Egg parasitoids are difficult to see because of their small size, even smaller than the size of a moth egg. The best way to find and identify them is to collect brown *Helicoverpa* eggs and store them in a clear container. If parasitised, these eggs will turn black and adult wasps will emerge in about 10 days. Unparasitised eggs will produce *Helicoverpa* larvae in 3–5 days.

Identification:

Trichogramma and *Trichogrammatoidea* wasps are very tiny. They are less than 0.5mm long – that is smaller than a pin head. These wasps are brown or yellowish with red eyes. There are two species commonly found in cotton – *Trichogramma pretiosum* and *Trichogrammatoidea bactrae*. These species are difficult to distinguish without the aid of a good microscope and taxonomic skills.

The *Telenomus* wasp is also tiny (about 0.8mm long) and has a black body and black eyes. This wasp is not abundant in cotton.

Lifecycles: Typically two to four *Trichogramma* or *Trichogrammatoidea* wasps develop within one *Helicoverpa* egg. *Trichogramma* uses its antennae to measure the size of the host egg in order to determine the number of eggs it will lay in it. In contrast, only one *Telenomus* wasp develops per *Helicoverpa* egg. For all species, parasitised eggs turn black after 3 days and fail to hatch caterpillars but will eventually produce one or more wasps. Adult wasps emerge from parasitised *Helicoverpa* eggs after 8–10 days development during summer.

Habitat: *Helicoverpa* egg parasitoids occur in all cotton districts, but are reduced in regions which are sprayed regularly with broad spectrum insecticides. These egg parasitoids are crop

This Trichogramma wasp is laying up to 4 eggs in a Helicoverpa egg. The egg will eventually produce 1 or more wasps instead of a Helicoverpa larva. 0.4mm (Photo: B. Scholz)

Telenomus wasps are not as common as Trichogramma. This wasp will only lay one egg inside a Helicoverpa egg. 0.8mm (Photo: B. Scholz)

Normal eggs (left) and parasitised eggs (right). (Photo: B. Scholtz)

Unsprayed sorghum is a good nursery crop for egg parasitoids. (Photo: M. Dillon)

specialists, are mainly found in the crop, but also on the edge habitat of crops and remnant vegetation, making them even more susceptible to broad spectrum insecticides. Small populations are found in native vegetation which in some areas serve as an overwintering habitat. The ecology of egg parasitoids is poorly understood. However, unsprayed sorghum and maize are good nursery crops for egg parasitoids in summer, particularly if selective insecticides, such as GemStar, are used to manage *Helicoverpa* caterpillars. Crops such as faba beans and canola are the best nursery crops in winter/spring, although will not be found in chickpeas. Early season build up of parasitoids is enhanced by having good unsprayed habitats such as native vegetation and soft selective sprays on early *Helicoverpa* pressure. Heavy grazing in native vegetation also reduces *Trichogramma* numbers in those habitats.

Targeted prey: Both species primarily attack *Helicoverpa* eggs.

Parasitoids of green vegetable bugs

Trichopoda giacomellii and *Trissolcus basalis*

The green vegetable bug (GVB) parasitoid (*Trichopoda giacomellii*) has been introduced to some cotton growing areas. This fly was released in 1994 and is native to South America where it is an important natural enemy of GVB.

GVB eggs are frequently parasitised by a tiny introduced wasp called *Trissolcus basalis*. This wasp is native to Europe but is well established in many countries.

Identification:
Trichopoda adult flies are about 8mm long, female flies are black, males orange.

Trissolcus is a minute black wasp with downward elbowed antennae and flattened abdomen.

Lifecycles:
The *Trichopoda* fly attacks late instar (four and five instar) nymphs and adults of GVB, attaching small white eggs predominantly on the thorax and pronotum (just behind the head). The eggs hatch out to larvae within two or three days. Larvae burrow into the bug and feed on its internal organs and body fluids. Within two weeks, final-instar larvae emerge from the host and pupate in nearby soil. Adult flies emerge from pupae after 15 days and live for a maximum of 10 days.

Trissolcus adults mate immediately after emerging from host eggs. The female typically inserts one egg into a GVB egg. Heaviest parasitoid egg production occurs during the first few days after emergence, then tapers off. Adults emerge from the blackened host eggs in 9 to 12 days. The life-cycle averages about 23 days at 22°C.

Habitat: Both parasitoids most likely occur in all crops attacked by the GVB.

Targeted prey: Green vegetable bug

This green vegetable bug is hosting 4 Trichopoda eggs. The Trichopoda larvae will hatch and immediately burrow into the bug, feeding on internal tissue and killing the host bug. Egg<1mm (Photo: T. Smith)

This tiny Trissolcus wasp is busy inserting her eggs into the green vegetable bug eggs. 0.5mm (Photo: T. Smith)

Adult Encarsia lays its eggs into the second, third and fourth nymphal stages of the whitefly. 1–2mm (Photo: C. Mares)

Whitefly parasitised by Encarsia turn dark brown or black. <1mm (Photo: Z. Hall)

Adult Eretmocerus lays its egg into the 1st and 2nd stage whitefly nymphs (mostly 2nd). 1–2mm (Photo: Z. Hall)

Parasitoids of whitefly

Encarsia formosa and *Eretmocerus hayati*

Whitefly parasitoids are small wasps. There are two parasitoids that are commonly encountered on cotton farms, *Encarsia* and *Eretmocerus*.

The two parasitoids target different nymphal stages of whitefly making them complementary rather than competitive.

Identification:

Encarsia is tiny (<1mm long) parasitic wasp which has an orange coloured abdomen and black head and thorax. Whitefly parasitised by *Encarsia* turn dark brown or black.

Eretmocerus is also tiny, although slightly larger than *Encarsia*, and completely yellow except for three distinctive red ocelli on the top of the head arranged in a triangle. They are winged and can travel several hundred metres in a day, possibly wind assisted. Males are very rare. Whitefly parasitised by *Eretmocerus* turn yellow/brown with red to green eyes visible within the whitefly shell just prior to emergence. The adult *Eretmocerus* cuts a circular emergence hole in the upper shell.

Lifecycles:

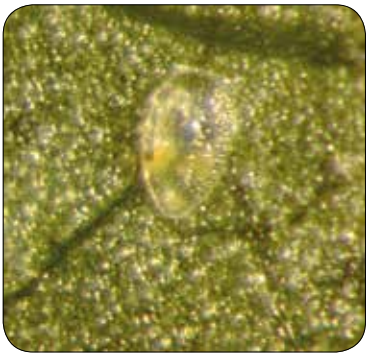
Encarsia lays its eggs into the second, third and fourth nymphal stages of the whitefly. The egg hatches inside the immature whitefly (also known as scale) and the wasp larva feeds inside it. Within two weeks the scale turns black and a wasp emerges.

Eretmocerus lays its egg into the 1st and 2nd stage whitefly nymphs (mostly 2nd) depositing a single egg under the surface of the whitefly nymph. On hatching, after (~4 days), the tiny larva bores into the whitefly nymph over the next 3–4 days and waits until the whitefly pupates. At this stage the whitefly pupae is a cream colour. It then releases digestive enzymes which dissolve the whitefly

innards which are used by the wasp larva to complete development. With three larval stages, development from egg to adult takes about 14–28 days, depending on temperature.

Habitat: *Eretmocerus* are crops specialists, but are also found in grassy margins with broad leaf weeds that harbour *Bemisia*. *Encarsia* are found in more habitat types including native remnant vegetation, the edge habitat between remnants and crops.

Targeted prey: Both parasitoid species attack whitefly *Bemisia* types in varying proportions through the season.



Non-parasitised whitefly nymphs have mycetomes (small yellow bodies) that are symmetrically aligned. <1mm (Photo: T. Smith)

This parasitised whitefly nymph shows displaced mycetomes (small yellow bodies) appearing as a squiggle within its body. <1mm (Photo: Z. Hall)

P. persimilis (left) does not naturally occur in cotton but can be purchased and released to control the two-spotted spider mite (right). <1mm (Photo: Bioworksonline.com.au)

This predatory mite (Amblyseius spp.) is a voracious feeder on all stages of spider mites. <0.5mm (Photo: L. Wilson)

Predatory mites

Amblyseius spp. and *Phytoseiulus persimilis*

Predatory mites are important predators of two-spotted spider mites in many agricultural crops. They have fast lifecycles so they can increase quickly and are voracious on all stages of spider mites. They are able to use 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.

Identification: *Amblyseius spp.* are small shiny fast moving brown mites. They are not common but can occasionally be found on young cotton. *P. persimilis* is orange, medium in size (slightly larger than spider mites), fast moving, tear drop shaped and has long front legs.

Lifecycle: The development from egg to adult is generally completed in 4–7 days. High humidity is required for eggs to hatch. Hot dry conditions in cotton crops do not favour these species; however previous research shows that they can increase late season in cooler conditions in irrigated crops where canopy humidity is higher.

Habitat: Crops with dense foliage grown in humid areas are more suitable for the establishment of these mites. *P. persimilis* does not occur naturally in cotton – however they can be purchased and released in crops from a range of commercial suppliers. Previous research shows that this is not likely to be effective during the peak of summer (Dec–Feb).

Targeted prey: They mostly feed on two-spotted mites and bean mites.

Red and blue beetle

Dicranolaius bellulus (Guerin-Meneville)

This important native predator occurs throughout the summer season. The adults are partly carnivorous and search actively over cotton plants during the day. Adults are found in the crop canopy in the mornings and after sunset. On hot afternoons or when disturbed, they generally shelter in soil cracks under plants and thus sometimes escape insecticide sprays.

Identification: Adults are 5mm long with bright red and metallic blue bands across the body and a dark head, legs and antennae.

Lifecycle: The red and blue beetle lays eggs in clusters on soil debris. The egg, larval and pupal stages occur in the soil. Their life cycle generally takes about one year. They overwinter as adults.

Habitat: The distinctive red and blue beetle is extremely abundant in a range of habitats in some years and is rare in other years. They have been found in gardens, bushland and cropping landscapes.

Targeted prey: They eat eggs and very small and small *Helicoverpa* larvae, aphids and other slow-moving insects. The larvae feed on small worms and other soil organisms. It has been reported that the larvae of a related species, *D. Villosus* (Lea), prey on locust eggs.

The well known beetle will eat eggs and small slow-moving pests. They are normally abundant in a range of rural and urban landscapes. 5mm
(Photo: D. McClenaghan)

Shield bug eggs are laid in irregular-shaped rafts and are black with short white spines around the rim. 20mm (Photo: T. Smith)

The spined predatory shield bug has prominent spines on either side of the shoulder. 12mm (Photo: L. Wilson)

The glossy shield bug has a large appetite for a large range of caterpillars. 12mm (Photo: J. Wessels DEEDI)

Shield bugs

Oechalia schellenbergii (Guerin-Meneville) and *Cermatulus nasalis* (Westwood)

The spined predatory shield bug, *Oechalia schellenbergii* (Guerin-Meneville) and the glossy shield bug, *Cermatulus nasalis* (Westwood) are both important predators of pests in cotton including *Helicoverpa* and looper larvae. Adults and nymphs are usually abundant in cotton from December to February.

Identification: The spined predatory shield bug – adults are 12mm long and have a grey-brown, shield-shaped body with a light marking in the middle of the back and a pair of prominent spines on either side of the shoulder. Nymphs are dark grey with a characteristic red ring on the back. Eggs are laid in irregular-shaped rafts and are black with short white spines around the rim.

The glossy shield bug – adults are 12mm long and have shiny brown, shield-shaped bodies. Patterns include darker brown and small yellow markings. Nymphs are dark red and brown with the early instars being bright red. The black eggs, which are laid in 'rafts' of 50 or more, have short, white spines around the rim.

Lifecycle: The development of both shield bugs from egg to adult takes about 3 weeks.

Habitat: They are found all year round on weeds, in native vegetation and other crops – especially on crops infested with moth larvae.

Targeted prey: Shield bug adults and older nymphs use piercing/sucking mouthparts to feed on insects. They prey on moth larvae, including *Helicoverpa* and loopers.

Silverfly

Leucopis formosana

The larvae of the silverfly is an important predator of aphids and is relatively widespread throughout all cotton regions. The name silverfly comes from the adults having a greyish or silvery appearance. The silverfly are from the family Chamaemyiidae.

Identification: Adult silverflies are small (about 1mm long) and are greyish in colour. Silverfly larvae are very small when newly hatched and grow to about 2–2.5mm. The larvae look somewhat like small hoverfly larvae but can be distinguished by the two 'horns' at the rear end of the body.

Lifecycle: Female silverflies lay white, sausage shaped eggs amongst aphid colonies. The eggs are minute (about 0.5mm long and 0.15mm wide). They hatch after about 3 days and larval development which includes two moults, takes about a week. When finished feeding the larvae form into a hard brown pupa, about 2.0mm long, which can easily be seen on a leaf. After 8–9 days the adults emerge. The whole life cycle takes approximately three weeks.

Silverflies overwinter by continued breeding on cotton aphids on winter weed hosts.

Habitat: Silverfly larvae have also been found feeding on cotton aphids on other plant hosts including ornamental hibiscus, cobblers pegs, paddy's lucerne, bladder ketmia and peruvian primose bush.

Targeted prey: Adults are not predatory and feed on aphid honeydew. The adults obtain honeydew which has fallen on the leaf surface but can also 'milk' it directly from aphids by tapping the aphids with their feet. Silverfly larvae prey mainly on cotton aphids although their consumption rate is low compared to hoverfly, ladybrids and lacewings. Studies have found that silverfly larvae can consume about 20–30 aphids during their development.

Silverflies lay white, sausage shaped eggs amongst aphid colonies. 0.5mm long (Photo: N. Parker)

Adult silverfly are not predatory and feed on aphid honeydew. (Photo: A. Cleary)

The silverfly can be distinguished from the hover fly larvae by the two 'horns' at the rear end of the body. 2–2.5mm (Photo: L. Wilson)

This sixspotted thrips is feeding on a spider mite. Note the 3 pairs of spots on its wings. 2–3mm (Photo: L. Wilson)

Sixspotted (predatory) thrips

Scolothrips sexmaculatus (Pergande)

Sixspotted or predatory thrips are generalist predators and active hunters, but given their small size can only feed on very small prey such as other thrips, mites and small eggs.

Identification: Eggs are kidney shaped, translucent, very small and laid into leaf tissue. Larvae of this species are always pale and semi translucent. Adults are roughly 2–3mm in length, pale yellow with grey markings. They have three pairs of spots on the wings which are visible with a hand lens. Their head is wider than it is long and they have segmented antennae.

May be confused with: The larvae of the sixspotted thrips look similar to many other thrips species.

Lifecycle: Small eggs are laid into leaf tissue. All thrips have two larval and two pupal instars before emerging as adults.

Habitat: These thrips are widespread and can be found feeding on mites in various crops and natural vegetation.

Targeted prey: The adults and nymphs of sixspotted thrips feed on spider mites by piercing the body and sucking out the contents.

Spiders – The hunters

The most common hunting spiders found in and around the cotton farm include: Lynx spiders (*Oxyopidae*), wolf spiders (*Lycosidae*), Yellow night stalkers *(*Clubionidae*, Cheiracanthium*), jumping spiders *(Salticidae)*, crab spiders *(Thomisidae)* and water spiders *(Pisauridae)*.

These spiders either stalk or ambush their prey. Some stay mainly on the ground and others can be found roaming the foliage. They are important generalist predators and have been found feeding on mirids, moth larvae and a variety of soft-bodied moving insects.

Identification:

Lynx spiders are the most common group of spiders on Australian cotton farms. Their main distinguishing features are the large spines on their legs. They hunt mainly at night by waiting on leaves or face down on the stems of cotton bushes with their first two pairs of legs stretched out wide, for prey to come within lunging reach.

Wolf spiders range from 5–20mm, live in burrows and are nocturnal. Their colouring is non-descript ranging from grey brown through shades of mottled brown to black. They have a distinctive eye pattern consisting of two large eyes underlined by a row of four small eyes. If you shine a torch on the ground at night, you will see small blue lights reflecting back at you, which are the wolf spider's eyes. Wolf spiders are generalist predators that mainly hunt on the ground, but can also climb into the plants to hunt.

Yellow night stalkers are another robust, nocturnal spider (body length about 10mm) which are pale yellow with a faint grey mark on the abdomen. During the day they can be found hiding in silken retreats on the underside of leaves and during the night they stalk the plants in search of slow-moving prey. They are a generalist predator whose prey include mirids and *Helicoverpa* eggs.

Lynx spiders, especially the plain brown lynx, are fierce predators of mirids. 12mm (Photo: D. McClenaghan)

A wolf spider showing a high degree of maternal care carrying young on her back. 20mm (Photo: R. McMahon)

This yellow night stalker is feeding on an adult green mirid. 20mm (Photo: D. McClenaghan)

Jumping spiders are normally small and are active during the day jumping on unexpected prey including jassids. 8mm (Photo: D. McClenaghan)

Crab spiders hunt by camouflaging themselves on cotton flowers to catch unexpected prey. 6mm (Photo:R. Whyte)

The very common water spider is often seen running across water surfaces. 6mm (Photo: R. Whyte)

Jumping spiders are small (4–8mm) with two particularly large, forward-facing eyes which give them excellent binocular vision. In cotton they are normally dark or grey in colour and have relatively short legs. They actively roam plants during the day jumping on unexpected prey, including jasids, mirids, *Helicoverpa* larvae.

Crab spiders are up to 6mm in length, have crab-liked legs and are usually yellow or green as they hunt by camouflaging themselves on cotton flowers from where they attack unsuspecting prey.

Water spiders are particularly common on cotton in northern Australia. They are plain brown and similar in appearance to wolf spiders but they lack the wolf spider's distinctive eye pattern and tend to be much smaller (< 6mm). Water spiders can run across water surfaces.

Lifecycles: The life cycle is variable according to the species. Eggs are produced in strong silken sacs, or in a silken mass curled in leaves or on the bark. The eggs are often protected by the female. The female wolf spider carries her eggs in a ball attached to her abdomen. As in almost all spiders, the young disperse by 'ballooning' from tall plants where the silk is played out into the breeze until the pull lifts and carries them away.

Habitats: These spiders are widespread and can be found in most rural and urban landscapes.

Targeted prey: A large range of soft-bodied moving insects such as mirids and caterpillars. Studies have shown the lynx spider to be an effective predator of mirids and the yellow night stalker will eat *Helicoverpa* eggs as well as larvae. Crab spiders specialise in ambushing small insects attracted to nectar and pollen and large wolf spiders have been seen killing large *Helicoverpa* larvae.

Spiders – The web-builders

The most common web-building spiders found in cotton landscapes include the orb weaving spiders: the Christmas, jewel or 6-spinned spider (*Austracantha minnax; Araneidae*); garden orb weaver *(Euriophora spp; Araneidae)*; St Andrews cross *(Argiope spp; Araneidae)*; and the tangle web spiders: red back spiders *(Latrodectus hasselti; Theridiidae)* and other tangle web spiders *(Achaearanea spp; Theridiidae)*.

These spiders either build large webs between the cotton rows or smaller webs on leaves or within the plant. Most of these web-builders commonly hide under nearby leaves waiting for insects to become trapped in their webs. One exception to this is the St Andrews cross spider who rests in the centre of the web, with their legs arranged in the shape of a cross.

Identification:

The Christmas spider can grow up to about 8mm in length and has six distinct spines projecting from its back. The broad abdomen is patterned with bright yellow and white on a black background. The main characteristic of this harmless spider is its social behaviour, building large communal webs shared by many Christmas spiders.

The garden orb weaver is a large spider (up to 30mm) and is very diverse in appearance, ranging from different shades of mottled brown. Their large abdomen is shaped like a diamond and the body is compact, hairy and with red inner 'thighs' (femurs). This harmless nocturnal spider builds its web after sunset between the cotton rows.

The adult St Andrews cross spider females grow to 15mm in body length. The abdomen is flat oval shaped with transverse white, yellow and reddish-brown stripes. The thorax and head are brownish-silver under sun light. All legs are brown in colour, with yellow bands at the middle. The common

The Christmas spider is a brightly coloured and harmless spider that can build large communal webs. 15mm (Photo: R. Whyte)

The garden orb weaver is a harmless nocturnal spider that is often found on its web after sunset between the cotton rows. 15mm
(Photo: D. McClenaghan)

This St Andrews Cross spider rests on her cross of serrated silk. 15mm (Photo: R. Whyte)

The red back spider is capable of capturing larger animals such as small lizards. 14mm
(Photo: D. McClenaghan)

The tangle web is a small spider that builds its tangle web under or between leaves. 6mm
(Photo: D. McClenaghan)

name of this harmless spider is derived from its habit of producing and resting on a stabilimentum, which is a cross of serrated (zigzag) silk.

The well known red back spider can grow up to 14mm and is easily recognised by the red pear-shaped marking on their abdomens. Large red back spiders build sticky webbed snares or traps between rows of cotton low to the ground. From the web they have 'trip-wires' of silk under tension stuck to the ground with glue. When an animal stumbles into the silk, it is stuck to the glue and hoisted up into the web where the red back spider catches it.

The tangle web spider is related to the red back but is much smaller (up to 6mm) with a globular, mottled abdomen and fairly long legs. This very common and harmless spider normally resides high in the cotton canopy, building its tangle web under or between leaves.

Lifecycles: Most of these spiders begin life within an egg sac which can comprise of up to 300 spiderlings. The silken egg sacs can be a variety of shapes and are usually attached to the upper part of the web or to a twig close to the web. After the spiderlings emerge their dispersal is like many other spiders which use special silk that the spiderlings spin and use as a 'balloon' to float wherever the wind takes them.

Habitats: Bushland remnants are important habitats for spiders in rural landscapes. Christmas spiders tend to prefer shrubby bushland near creeks and swamps. Red backs tend to live in urban areas where lights and shelter attract their potential prey and orb weavers are commonly found in gardens and bushland.

Targeted prey: These important generalist predators target a large range of flying insects (eg moths, mirids, jassids and whitefly). Many of these spiders will also eat *Helicoverpa* larvae.

Glossary…

Abdomem: The third region of the insect body containing the digestive tract and reproductive organs.
Alates: Winged aphids.
Antennae: A paired appendage at the front of an insect used to sense touch, air motion, heat, sound, smell or taste.
Apterae: Wingless stage of an insect (often used in reference to aphids).
Aphid colony: 4 or more aphids within 2 cm.
Aphid mummies: When parasitised, the dead aphids become swollen, tanned and hardened to form a protective case for the developing wasp pupa.
Beat sheet: A sheet of yellow canvas 1.5 m x 2 m in size, placed in the furrow and extended up and over the adjacent row of cotton. A metre stick is used to beat the plants against the beat sheet. Insects are dislodged from the plants onto the canvas and are quickly counted.
Biological insecticides: Insecticides based on living organisms or products of living organisms. Eg. Gemstar (virus) and Dipel (bacteria).
Bt cotton: Genetically modified cotton variety containing the insecticidal proteins Cry1Ac and Cry2A which provide control of Helicoverpa spp. under field conditions.
Broad-spectrum insecticide: Insecticides with a high negative effect on beneficial insects and spiders.
Buffer zone: An area of land or crop downwind of a sprayed area that is used to collect spray droplets that may otherwise drift onto sensitive areas.
Consecutive checks: Refers to successive insect checks.
Conventional cotton: A cotton variety that does not contain insecticidal proteins to control Helicoverpa spp.
Corridors: Strips of vegetation that connect areas of native vegetation, such as wind breaks and fence line tree plantings, and allow beneficials to move from patches of native vegetation, through the landscape and onto crops.
Cotyledon: The first leaves of a seedling.
Cotton Bunchy Top (CBT): A plant virus disease spread by the cotton aphid (Aphis gossypii, Glover). Symptoms include mottled leaves, reduced yield, plant height, leaf surface area, petiole length and internode length.
Crop compensation: The capacity for a cotton plant to 'catch-up' after insect damage without affecting yield or maturity.
Crop maturity: Cotton bolls are mature when the fibre is well developed, the seeds are firm and the seed coats are turning brown. This usually occurs when 60–65% of bolls are open.
Cut-out: As the plant continues to develop bolls, the demand for carbohydrates that are produced in the leaves increases. At some point this demand by the bolls exceeds supply and the production of new fruiting nodes ceases. This point is known as cut-out. Cotton plants usually cut-out when they reach 4 nodes above white flower (NAWF).
Defoliation: The removal of leaves from the cotton plant in preparation for harvest. This is done by artificially enhancing the natural process of senescence and abscission with the use of specific chemicals.
Diapause: A period of physiologically controlled dormancy in insects.
Earliness: Minimising the number of days between sowing and crop maturity.
Efficacy: The effectiveness of a product or beneficial insect.
Egg raft: An arrangement of insect eggs laid in rows often in the shape of a raft.
Egg parasitoids: Egg parasitoids, such as Trichogramma attack the egg stage of Helicoverpa. The wasp lays its eggs in the Helicoverpa egg, and the wasp larvae which hatch consume the contents of the host egg. Instead of a small Helicoverpa larva hatching, up to four wasps may emerge from each host egg. Thus the host is killed before causing damage.
Elliptical eggs: Oval shaped eggs.
Fruit retention: Refers to the percentage of fruit (squares or bolls) that the cotton plant or crop has maintained.
Furcula: The furcula is a spike that is held underneath the body of Springtails to help propel the insect into the air.
Fuzzy seed: Non-delinted ginned cotton seed.
Gappy stand: Cotton that establishes with substantial spaces between the plants.
Habitat diversity: A mixture of crops, trees and natural vegetation in the landscape.
Honeydew: A sticky sugar rich waste excreted by feeding aphid or whitefly. It can interfere with photosynthesis and cause problems with fibre processing.
In-furrow insecticide: An insecticide applied in the soil to the plant line, mostly at planting.
Insecticide resistance: Where a pest develops the capacity to survive an insecticide application.
Insecticide Resistance Management Strategy: An industry-regulated strategy that sets limits on which insecticides can be used, when they can be used and how many times they can be used. This helps prevent the development of insecticide resistance.
Instar: A development stage between each molt until maturity is reached.
Internode: A segment of a stem between two nodes.
Inter-row cultivation: Mechanical cultivation of the soil between the rows of cotton.
Larval parasitoids: A wasp that lays their egg on or in a larva, such as a *Helicoverpa* larvae. The parasitoid egg hatches and the immature parasite enters the larva and feeds on its internal structures, usually resulting in its death.
Leaf crumpling: Leaves that are wrinkled, cupped and smaller than normal. This is often caused by Thrips.

Legume: A plant in the family Fabaceae or Leguminosae (eg peas, beans, lentils, lupins). They are noted for their ability to fix atmospheric nitrogen.
Lint: Cotton/cotton fibres.
Main stem node: A point on the main stem from which a new leaf grows, and from which a fruiting of vegetatitive branch may also grow.
Malvaceous: A plant relating to, or belonging to the Malvaceae, a family of plants that includes mallow, cotton, okra etc.
Mycetomes: Small yellow bodies within a whitefly nymph. They are special organs which help metabolise essential vitamins and other substances.
Natural enemies: Predators and parasites of pests.
Natural mortality: The expected death rate of insects in the field mainly due to climatic conditions and predation/parasitism.
Node: A leaf-bearing joint of a stem, an important character for plant mapping in cotton where nodes refer to the leaves or abscised leaf scars on the main stem (see also Mainstem node).
Nursery: A habitat which attracts and sustains an insect (pest or beneficial) through multiple generations.
Nymph: The immature stage of insects such as mirids, aphids and whiteflies that gradually aquire adult form through a series of moults without passing through a pupal stage.
Okra leaf type: Okra leaf cotton varieties have deeply lobed leaves similar to the leaves on the Okra (*Abelmoschus esculentus*) plant, which is related to cotton and hibiscus.
Parasitisation: To live on or in a host organism as a parasite.
Peak flowering: The date at which the number of flowers opening per day is at its peak.
Perennial: Lasting or active through the year or through many years.
Pest damage: Damage to the cotton plant caused by pests. This can be either damaged to the growing terminals, the leaves, or the fruit (including squares or bolls).
Pest resurgence: An increase in a pest population following a pesticide application intended to reduce it.
Pest threshold: The level of pest population at which a pesticide or other control measure is needed to prevent eventual economic injury to the crop.
Petiole: The stalk that attaches the leaf to the stem.
Photosynthesis: A vital process among photoautotrophs, like plants, to create their own food directly from inorganic compounds using light energy.
Presence/absence: The binomial insect sampling technique records the presence or absence of a pest rather than absolute numbers on plant terminals as opposed to whole plants.
Prophylactic: Refers to regular insecticide sprays that are part of a schedule, not as a result of monitoring pest levels or damage.
Pupation: The nonfeeding stage between the larva and adult in the metamorphosis of holometabolous insects, during which the larva typically undergoes complete transformation within a protective cocoon or hardened case.
Pyrethroid: A synthetic compound similar to pyrethrin, used as an insecticide. They are generally non-selective insecticides.
Ratoon cotton: A cotton crop in which the stalks are cut down after harvest, but the crown and rootstock are left in the ground to regrow the following season. For pest and disease reasons, this form of cropping is not used in Australia. Ratoon plants could provide an unwanted over winter hosts for important pests and diseases and should be eliminated.
Bt cotton refuge: This term is used to refer to crops grown specifically as a requirement of the Bt cotton licence to produce Bacillus thuringiensis (BT) susceptible Helicoverpa spp.
Riparian vegetation: Plant habitats and communities along the river margins and banks.
Secondary pests: Pests which are generally controlled by natural enemies unless these are reduced in abundance by insecticides used against primary pests such as *Helicoverpa armigera* (cotton bollworm) and *H. punctigera* (native budworm). The fast lifecycles and high reproductive rates of these 'secondary pests' allows them to build quickly in the absence of mortality from natural enemies.
Seed treatment: An insecticide/fungicide used to coat cotton seeds to offer a period of protection during germination and establishment against some ground dwelling pests (eg wireworm).
Selection pressure: The number of selection events for pests to develop resistance to insecticides.
Shothole perforation: A leaf that has many small holes – usually resulting from feeding by flea beetles.
Siphunculi: One pair of small upright backward-pointing tubes found on the dorsal side of the last segment of the bodies of aphids.
Skeletonise: Insect feeding damage where the leaf is thinned with veins visible.
Sporadic pest: A pest that occurs upon occasion or in a scattered, isolated or seemingly a random way.
Stippled effect: A leaf covered in very small dots.
Stylet: A needle like organ of an insect used for feeding.
Sweep net: A large gauze (muslin) net (approximately 60 cm deep) attached to a round aluminum frame which is about 40 cm in diameter with a handle (1 m in length). Used to sample insects.
Synthetic insecticides: Non-biological insecticides.
Terminal: The growing tip of a stem, particularly the main stem.
Thorax: The division of an insect that lies between the head and the abdomen.
Tightlock: A condition often caused by insect damage where the cotton lint does not 'fluff out'.
Tip damage: When the plant terminal has been damaged.
True leaves: Any leaf produced after the cotyledons.
Tubercles: Small bumps between the aphids antennae.

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