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<http://www.dpi.nsw.gov.au/agriculture/field/field-crops/fibres/cotton/cotton-pest-management-guide>

Key insect and mite pests of Australian cotton

Compiled by Tracey Farrell formerly Industry & Investment NSW, Robert Mensah, Industry & Investment NSW; Richard Sequeria, Queensland Primary Industries and Fisheries; Lewis Wilson CSIRO; and Martin Dillon, formerly CSIRO

This section provides specific management information for each of the key insect and mite pests of Australian cotton. For each pest, information is provided under the sub-headings of

- Damage symptoms
- Sampling
- Thresholds
- Key beneficial insects
- Selecting an insecticide/miticide
- Survival strategies

Damage symptoms indicate that a pest could be influencing crop development and possibly yield potential. In some instances, damage symptoms will be observed without the pest. This may mean that the pest is there but cannot be observed or that the pest has caused the damage but since left the crop. In other instances, the pest will be observed but there will be no symptoms of damage to the crop. Knowledge of pest presence and crop damage should be used in combination to make pest management decisions.

Sampling is the process of collecting the day-to-day information on pest abundance and damage that is used to make pest management decisions. **Thresholds** provide a rational basis for making decisions and are a means of keeping decisions consistent. Knowing the **key beneficial** predators and parasitoids for each pest is important for developing confidence in IPM approaches to pest management. **Selecting an insecticide** (or miticide) can be a complex decision based on trade offs between preventing pest damage and conserving beneficials, or reducing one pest but risking the outbreak of another. All pests have **survival strategies** that allow them to live and breed in cotton farming systems. Knowing the survival strategies that are employed by the pest can help with decision making at the farming systems-level (e.g. choice of rotation crops) and also can help to anticipate pest outbreaks.

Information in this section links to a number of tables in the Guide;

Table 1	p 21	Yield reduction caused by mites
Table 2	p 22	Insect pest and damage thresholds
Table 3 & 4	p 40 & 42	Impact of insecticides and miticides on predators, parasitoids and bees in cotton
Table 9	p 78	Control of aphids
Table 10	p 79	Control of cotton leafhopper and silverleaf whitefly
Table 11	p 79	Control of green vegetable bug, mirids and thrips
Table 12	p 80	Control of <i>Helicoverpa</i> spp.
Table 15	p 85	Control of mites

Cotton bollworm

Helicoverpa armigera

Damage symptoms

Larvae attack all stages of plant growth. In conventional cotton (non-Bt varieties), larval feeding can result in; seedlings being tipped out, chewing damage to squares and small bolls causing them to shed, and chewed holes in maturing bolls, preventing normal development and encouraging boll rot. In any year an average of 15% of Bollgard II® area may carry *Helicoverpa* larvae for a short period during peak to late flower. Chewing damage is mostly confined to fruit and may lead to yield loss.

Sampling

Sample what?

Sample the **egg and larval growth stages** of the pest. The growth stages of the cotton bollworm are defined as:

White egg	WE	pearly white
Brown egg	BE	off-white to brown
Very small larvae	VS	0 mm–3 mm
Small larvae	S	3 mm–7 mm
Medium larvae	M	7 mm–20 mm
Large larvae	L	> 20 mm

Eggs are laid on plant terminals, leaves, stems and the bracts of fruit. Larvae may be found on terminals, the upper or lower surface of leaves, inside squares, flowers and bolls and along stems. Sample the whole plant. If using CottonLOGIC, adopt the faster terminal sampling techniques for *Helicoverpa* as the season progresses and plant size increases. These are described in the IPM Guides for Australian Cotton II.

Sample **fruit retention** or fruiting factors once squaring begins, to gauge what level of damage is being caused to the crop.

Sample **key beneficials**. This information will allow thresholds based on the predator to pest ratio to

be applied. Collect eggs to check for parasitism by *Trichogramma*.

Frequency

Check at least 2 times/week in both conventional and Bollgard II® crops.

Begin cotton bollworm sampling at seedling emergence. Cease sampling when the crop has 30–40% open bolls.

Methods

Through the entire season, cotton bollworms are most accurately sampled using visual methods. Check at least 30 plants or 3 separate metres of row for every 50 ha of crop. CottonLOGIC supports data entered either as number/metre row or as number/plant.

Larger samples will give more accurate estimates. Fields are rarely uniform, lush areas often occur in head ditches and these are more attractive to insects. The crop variability within the field may determine the minimum number of sampling points required.

Thresholds

Using eggs as the basis of a threshold can be very misleading as not all eggs hatch. Successful egg hatch has been measured to be 20% early season, 25% mid season and 40% late season. Early in the season eggs are particularly prone to desiccation and being washed or blown from the small plants. Parasitism and predation also reduce survival. *Trichogramma* parasitoids have the potential to reduce egg survival by over 90%. Larval thresholds are also impacted on by beneficial insects. Therefore it is important to assess beneficial insect numbers when making pest control decisions. Fruit retention can also be used to determine whether pests have caused or are at risk of causing economic damage.

Conventional cotton

Helicoverpa spp.

Seedling to Flowering	Flowering to Cut-out
2 larvae /m or 1 larvae > 8 mm /m	2 larvae /m or 1 larvae > 8 mm /m or 5 brown eggs /m

Cut-out to 15% open bolls	15% to 40% open bolls
3 larvae /m or 1 larvae > 8 mm /m or 5 brown eggs /m	5 larvae /m or 2 larvae > 8 mm /m or 5 brown eggs /m

Bollgard II® cotton

Calculation of spray thresholds in Bollgard II® cotton should exclude larvae that are smaller than 3 mm and all eggs. Be sure to objectively assess larval size.

Helicoverpa spp.

Seedling to 40% open bolls
2 larvae > 3 mm /m in 2 consecutive checks or 1 larvae > 8 mm /m

Where larvae between 3 mm and 8 mm are observed on Bollgard II® cotton, consecutive checks are essential for decision making. *Helicoverpa* spp. must feed in order to ingest the Bt toxin. If the number of 3–8 mm larvae are above threshold on a given check, chances are that a large portion of these will ingest sufficient dose of the toxin and die before the next check.

Using the Predator/Pest Ratio

The predator/pest ratio can be applied in conventional and Bollgard II® cotton. The ratio is calculated as:

$$\frac{\text{Total predators}^*}{\text{Helicoverpa spp. (eggs + VS + S larvae)}}$$

At least 30 plants or 3 separate metres of row by visual sampling or 20 metres of row by suction sampling is needed in order to use the ratio. The total number of predators must only include the key predator insects (marked with an asterisk in the list below). At least 3 of the key predator species need to be present.

When the predator/pest ratio is 0.5 or higher, the *Helicoverpa* population should remain below the threshold of 2 larvae /m.

The predator to pest ratio calculated above does not incorporate parasitoids, particularly *Trichogramma*, in the calculation. To use both predators and parasitoids, the level of egg parasitism should be deducted from the number of *Helicoverpa* eggs before the predator to pest ratio is calculated. Levels of egg parasitism can vary greatly from farm to farm, region to region and from season to season. Generally levels decline as the season progresses. Notes on how to monitor egg parasitism levels can be found in the IPM Guidelines, Objective 2, page 31.

For more details on how to use the predator/pest ratio refer to the IPM Guidelines, Objective 3, page 36.

* The total number of predators must only include the key predator insects.

Key beneficial insects

Predators of eggs – red and blue beetle*, damsel bug*, green lacewing larvae*, brown lacewing*, ants, nightstalking spiders.

Predators of larvae – glossy, brown* and predatory shield bugs, big-eyed bug*, damsel bug*, assassin bug*, red and blue beetle*, brown lacewing*, common brown earwig, lynx, tangleweb and jumping spiders.

Predators of pupae – common brown earwig

Predators of moths – orb-weaver spiders and bats

Parasitoids of eggs – *Trichogramma* spp., *Telenomus* spp.

Parasitoids of larvae – *Microplitis demolitor*, orange caterpillar parasite, two-toned caterpillar parasite

Parasitoids of pupae – banded caterpillar parasite

Selecting an insecticide

The insecticide products registered for the control of *Helicoverpa* spp. in cotton are presented in Table 12 on page 80. The use of more selective insecticide options will help to conserve beneficial insects. Refer to Table 3 on page 40–41.

Insecticide resistance has declined in recent years. Some chemistries that once experienced moderate/high resistance now have lower resistance frequencies. The results from the 2007–08 insecticide resistance monitoring program can be accessed on the Cotton CRC website; www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/InsectResistanceManagement.aspx

Survival strategies

Resistance profile

Conventional cotton

Occasional detection of resistance	Widespread resistance
Indoxacarb Spinosad emamectin benzoate chlorpyrifos (OP) profenofos (OP) bifenthrin (SP)	Endosulfan (OC) – low frequency methomyl/thiodicarb (carbamate) (moderate frequency) pyrethroids (high frequency)
Cross Resistance	
<p>A negative cross resistance exists between indoxacarb and pyrethroids. The esterases produced by <i>H. armigera</i> that are associated with pyrethroid resistance increase the insecticidal activity of indoxacarb.</p> <p>There is a different mechanism of resistance for profenofos compared to chlorpyrifos and chlorpyrifos methyl. While all three belong to the OP chemistry group, profenofos is treated as a separate group in the IRMS.</p>	

Bollgard II® cotton

A gene is present in field populations of *H. armigera* that has the potential to confer high-level resistance to Cry1Ac. CSIRO and Monsanto data suggests that this gene occurs at a low frequency which is probably less than one in a million. It is not cross-resistant to Cry2Ab and in certain environments is largely recessive.

A gene that confers high level resistance to Cry2Ab is also present in field populations of *H. armigera*. This gene does not confer cross-resistance to Cry1Ac. In 2008/09 around 3–5% of the *H. armigera* population carried the Cry2Ab resistance gene. Bollgard II®'s continued efficacy has become even more dependent on how the industry manages its refuges and implements the other elements of the resistance management plan (RMP). For further details, including information about recent changes in the frequency of Cry2Ab resistance genes in *H. armigera*, refer to the Preamble to the RMP for Bollgard II® on page 56.

Over-wintering habit

The cotton bollworm over-winters in cotton fields as diapausing pupae. These pupae are the major carriers of resistance from one season to the next. The initiation of diapause in the pupae is caused by falling temperatures and shortening day lengths. The proportion of pupae entering diapause increases from 0% in late February to +90% in late April – early May, depending on the region. Across all regions (Central Queensland, Macintyre, Namoi and Macquarie Valleys) diapause is initiated in at least 50% of pupae by the first week in April. Diapause termination is based on rising soil temperatures beginning in mid to late September in most regions. Emergence from diapause usually occurs over a 6 to 8 week period in each valley.

Alternative hosts

Spring host crops include; faba beans, chickpeas, safflower, linseed and canola. Pastures and weed flushes also sustain emerging spring populations. Summer host crops include; soybeans, mungbeans, pigeon pea, sunflower, sorghum and maize. The cotton bollworm will attack flowering crops of sorghum and maize preferentially over most other crop hosts.

Further Information

CSIRO Entomology, Narrabri

Sharon Downes: (02) 6799 1576 or 0427 480 967

Colin Tann: (02) 6799 1557 or 0429 991 501

I&I NSW, Narabri

Lousie Rossiter: (02) 6799 2428 or 0429 726 285

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Melina Miles: (07) 4688 1369

Native budworm

Helicoverpa punctigera

Damage symptoms

Larvae cause early to mid season damage to terminals, buds, flowers and bolls of conventional cotton (non-Bt varieties) in a similar manner to *H. armigera*.

Sampling

Refer to the section on sampling cotton bollworm on the previous page. It is not possible to visually differentiate the eggs or early larval stages of the native budworm from the cotton bollworm, hence it is appropriate that these pests be sampled as one.

Thresholds

Refer to the section on thresholds for cotton bollworm on the previous page. The thresholds for *Helicoverpa* spp. are based on the assumption of potentially mixed populations of cotton bollworm and native budworm.

Key beneficial insects

Refer to the section on Key Beneficial Insects for the cotton bollworm. These predators and parasitoids also attack the native budworm.

Selecting an insecticide

The insecticide products registered for the control of native budworm in cotton in Australia are presented in Table 12 on page 80. The use of more selective insecticide options will help to conserve beneficial insects. Refer to Table 3 on page 40–41.

Survival strategies

Resistance profile

Conventional cotton

Resistance to insecticides has only rarely been detected in Australia. In conventional cotton, the tendency for the native budworm to occur in mixed populations with the cotton bollworm often limits insecticide control options to those that are also efficacious on the cotton bollworm.

Bollgard II® cotton

A gene that confers high level resistance to Cry2Ab is present in field populations of *H. punctigera*. In 2008/09 around 10% of the *H. punctigera*

population carried a Cry2Ab resistance gene.

Bollgard II®'s continued efficacy has become even more dependent on how the industry manages its refuges and implements the other elements of the resistance management plan (RMP). For further details, including information about recent changes in the frequency of Cry2Ab resistance genes in *H. punctigera* refer to the Preamble to the RMP for Bollgard II® on page 56.

Over-wintering habit

The native budworm has the capacity to over-winter as pupae, but extensive research conducted in the early 1990's found that it is rarely observed to do so in cotton growing areas. However between 20–50% of overwintering pupae collected from numerous crops and fields in cotton regions during 2007 and 2008 were *H. punctigera* suggesting that this strategy may now be more common. If conditions are favourable during winter, sparse but large populations survive and breed on native host plants in inland (central) Australia. As these winter annuals hay-off in spring, large migrations of moths may fly to cotton growing areas in eastern Australia.

Alternative hosts

The native budworm is not as closely associated with crop hosts as the cotton bollworm. The host range of the native budworm appears to be restricted to dicotyledonous (broad-leaved) hosts. Spring crop hosts include; faba beans, chickpeas, safflower, linseed and canola. Uncultivated hosts, particularly naturalised medics, are important in the initial buildup of the first spring generation. Summer crop hosts include; soybeans, mungbeans, pigeon pea and sunflower.

Further Information

CSIRO Entomology, Narabri

Sharon Downes: (02) 6799 1576 or 0427 480 967

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Aphids

Cotton aphid – *Aphis gossypii*

Green peach aphid – *Myzus persicae*

Cowpea aphid – *Aphis craccivora*

Cotton aphid is the most common aphid pest in cotton. Green peach aphid is occasionally a pest of young cotton but declines through the hotter part of the year. Cowpea aphid will colonise cotton but rarely becomes a problem.

Damage symptoms

Nymphs and wingless adults of cotton aphid cause early to late season damage to terminals, leaves, buds and stems. Cotton aphids have been shown to transmit the disease Cotton Bunchy Top (CBT). CBT is described on page 123. Once bolls begin to open, the sugary 'honey dew' excreted by aphids can contaminate the lint.

Sampling

Sample what?

Sampling should focus on non-winged adults together with their nymphs. Winged adults may be transitory, while the presence of non-winged adults together with their nymphs indicates a population has settled in the crop.

Sample for Species and Population

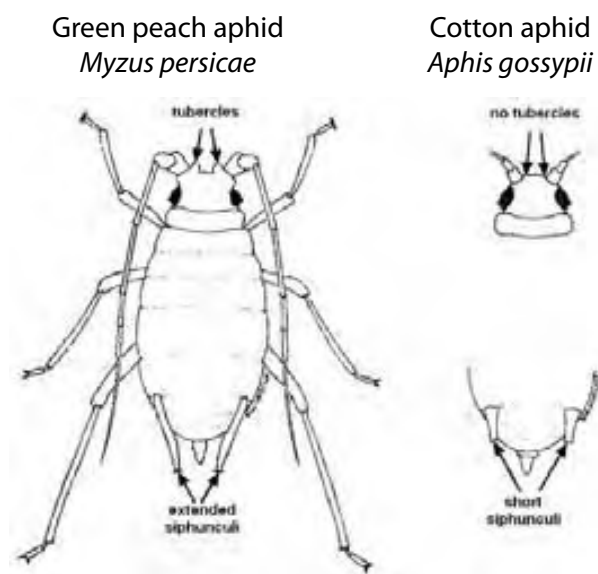
Species: Verify which aphid species is present before implementing any management strategies. Cotton aphid is more common and can be a vector of CBT, but green peach aphid can cause more severe damage than cotton aphid at lower densities.

Cotton aphid can be distinguished from green peach aphid by close examination with a hand lens. The distinguishing features are presence or absence of tubercles (on the head between the antenna), and the length of the siphunculi (between the back legs). As depicted in the diagrams below, green peach aphid has tubercles and long siphunculi. Cotton aphid doesn't have tubercles (the head is smooth between the antenna) and the siphunculi between the back legs are very short. If you are unable to make a determination, or suspect both could be present, contact Lewis Wilson, CSIRO Plant Industry at Narrabri, to arrange for a sample to be sent for identification. Contact details are provided at the end of this section.

Population: Sample for non-adults and nymphs on the underside of mainstem leaves 3–4 nodes below the plant terminal. If a high proportion of plants have only the winged form, recheck within a few days to see if they have settled and young are being produced.

Frequency

Check the **population** at least weekly. Begin aphid sampling at seedling emergence and continue until defoliation. The **species** composition may change during the season. Particularly when aphid infestation occurs early in the season, the species should be verified on more than one occasion during the season.



Methods

Seedling to first open boll: Use a 0–5 scoring system based on the number of aphids /leaf. The protocols for scoring aphids are presented in full on page 16–17. The presence/absence sampling method is no longer recommended during this part of the season as recent research has found that this technique has poor precision in the range from 80–100% plants infested.

If hot spots of cotton aphid are found early season, monitor cotton for symptoms of CBT.

First open boll to harvest: Use a presence/absence scoring system. Check one leaf /plant. Choose a recently expanded leaf, close to the plant terminal. Only score a plant as infested if there are 4 or more non-winged aphids within 2 cm². Aphids are most abundant on the edges of fields so ensure perimeter sampling occurs. Assess plants for the presence of honeydew.

Thresholds

From the seedling stage through until first open boll, thresholds are based on the potential for the aphid population to reduce yield. These thresholds are dynamic, allowing the grower/consultant to consider the value of the crop and the cost of control as part of the decision. After first open boll the thresholds aim to protect the quality of the lint by avoiding contamination from honey dew. As penalties for honey dew contamination are severe, thresholds aim to limit honey dew contamination to trace amounts.

While thresholds do not take into account the risk of CBT, recent research has shown that risks are low unless significant populations of ratoon cotton or alternative weed hosts are neighbouring or within

the field. Only when CBT symptoms are found in crops early in the season do thresholds need to be reduced.

Cotton aphid

Seedling to first open boll	First open boll to harvest
Calculate the Cumulative Season Aphid Score (page 17)	50% plants infested or 10% if trace amounts of honey dew present

Green peach aphid

Seedling to Flowering	Flowering to harvest
25% plants infested	–Populations decline in hot weather. Highly unlikely to be present post-flowering.

Key beneficial insects

Predators – lady beetle larvae and adults, red and blue beetles, damsel bugs, big-eyed bugs, lacewing larvae, hoverfly larvae.

Parasitoids – *Aphidius colemani*, *Lysiphlebus testaceipes* (these cause mummification).

Selecting an insecticide

The insecticide products registered for the control of cotton aphid and green peach aphid in cotton in Australia are presented in Table 9 on page 78.

Survival strategies

Resistance profile – Cotton aphid

Widespread, high levels of resistance	Widespread, low/mod levels of resistance
acetamiprid, clothianidin thiamethoxam, and imidacloprid (chloronicotinyl)	
Occasional detection of high levels of resistance	Occasional detection of low levels of resistance
pyrethroids (SP) dimethoate (OP) omethoate (OP) profenofos (OP) pirimicarb (carbamate)	endosulfan (OC) chlorpyrifos-methyl (OP)
Cross Resistance	
Strong cross-resistance between omethoate or dimethoate and pirimicarb.	
Strong cross-resistance between all the chloronicotinyls (neonicotinoids)	

Neonicotinoid resistance in cotton aphid is of great concern. This group is important because it will control OP/carbamate resistant cotton aphids. The neonicotinoid group includes the active ingredients acetamiprid, thiamethoxam, clothianidin and imidacloprid.

Neonicotinoid resistance was first detected in 2007/08 and in 2008/09 field control failures were reported against acetamiprid and clothianidin in two of twenty four strains tested. Subsequent testing of those strains has shown neonicotinoid resistance to be common with some strains acetamiprid, thiamethoxam, imidacloprid and clothianidin resistant.

A significant reduction in selection pressure will be needed before neonicotinoid resistance declines. This will likely require the judicious use of neonicotinoid foliar sprays. It remains critical to follow the recommendations of the industry's IRMS and rotate insecticide chemistries taking into account the insecticide group of any seed treatment or at-planting insecticide.

Additionally, a critical part of the IRMS for aphids is the 30+ day gap between the end of pirimicarb window and the start of the dimethoate/omethoate window because of cross resistance. Neonicotinoid resistance will place additional pressure on pirimicarb and dimethoate/omethoate and attention should be paid to their effective management.

Resistance profile –Green peach aphid

High levels of resistance	Low / mod levels of resistance
dimethoate (OP) omethoate (OP) chlorpyrifos (OP) monocrotophos (OP)	pirimicarb (carbamate) profenofos (OP)
Cross Resistance (different to Cotton Aphid)	
No cross-resistance between omethoate or dimethoate and pirimicarb	

Over-wintering habit

Aphids don't have an overwintering form, but cool temperatures slow the growth rate of aphids dramatically. In cotton growing areas aphids persist through winter on whatever suitable host plants are available.

Alternative hosts

Cotton aphid has a broad host range, including many common weeds. Winter weed hosts include; marshmallow, capeweed and thistles. Ratoon or volunteer cotton is a host and may also carryover the CBT disease. Some legume crops such as faba beans are also potential winter hosts. Spring and summer weed hosts include; thornapples, nightshades, paddymelon, bladder ketmia and Bathurst burr. Sunflower crops and volunteers also accommodate the cotton aphid.

Winter weeds that support green peach aphids include; turnip weed and marshmallow. Spring

germinations of peach vine and thornapples also host green peach aphid. Canola is an attractive host crop through late winter and early spring.

Further Information

CSIRO Plant Industries, Narrabri

Lewis Wilson: (02) 6799 1550 or 0427 991 550

I&I NSW, Camden

Grant Herron: (02) 4640 6471

Green mirids

Creontiades dilutus

Damage symptoms

Adults and nymphs cause early season damage to terminals and buds and mid season damage to squares and small bolls. Types of damage include blackening and death of terminals of young plants, rapid square loss without the presence of *Helicoverpa* spp. larvae and blackening of pinhead squares. Bolls that are damaged during the first 10 days of development will be shed, while bolls damaged later than this will be retained but not continue normal development. Black, shiny spots indicate feeding sites on the outside of bolls. When sliced open warty growths and discoloration of the immature lint can be seen within the boll.

Sampling

Sample what?

Sample for adults and nymphal instars of the pest. Mirids are a very mobile pest and are easily disturbed during sampling. It is important to include nymphs in the assessment as 4th and 5th instars cause similar amounts of damage to adults.

Sample fruit retention and types of plant damage that are symptoms of mirid feeding such as tip damage (early season) and boll damage (mid season).

Frequency

Sample at least 2 times/week.

Begin sampling at seedling emergence and continue sampling until last effective boll is at least 20 days old.

Methods

Use visual assessment of whole plants, a beat sheet or sweep net. All methods give comparable estimates of mirid abundance when plants are young. As the season progresses, the efficacy of whole plant visual sampling declines. Once the crop reaches 9–10 nodes, sample using either the beat sheet or sweep net.

When beat sheeting, each sample consists of the row of plants being vigorously pushed 10 times with a

1 m stick towards the sheet. Preliminary research has shown that the number of samples required for a good estimation of mirid numbers is between 8–10.

When using a sweep net, a sample can consist of 20 sweeps along a single row of cotton using a standard (380 mm) sweep net. Preliminary research has shown that at least 6 sweep samples are required to achieve a good estimation of mirid numbers.

It is essential to monitor fruit retention and signs of fruit damage as part of gauging the impact mirids are having on the crop. Not all bolls that are damaged by mirids will be shed, so it is important to monitor bolls for mirid damage.

Thresholds

Over the last 3 years research by Dr Moazzem Khan, QPI&F, has confirmed that yield loss due to mirid feeding varies with crop stage. Different thresholds apply at different times of the season, depending on the crop's capacity to compensate for the damage incurred. When applying the thresholds, always use the crop damage component together with the mirid numbers.

The highest risk stage is mid season when bolls are young. From first flower until the time when ~60% of bolls are 20 days old, the crop is most susceptible to fruit loss from mirid damage that will impact on yield. The crop has greater capacity to recover from earlier fruit loss during the squaring stage provided plants do not suffer from any other stress such as water stress. Once bolls are 20 days old the boll wall is hard enough to deter mirid feeding and minimal damage occurs.

		Planting to 1 flower/m	Flowering to 1 open boll/m	1 open boll/m to harvest
Adults or nymphs/m				
Visual Sampling	cool region	0.7	0.5	–
	warm region	1.3	1.0	–
Beatsheet Sampling	cool region	2	1.5	–
	warm region	4	3	–
Sweep net Sampling*	cool region	2 adults + 1.1 nymphs	1.5 adults + 0.8 nymphs	–
	warm region	4 adults + 2.1 nymphs	3 adults + 1.6 nymphs	–
Crop damage				
Fruit retention		60%	60–70%	–
Boll damage		–	20%	20%
Tip damage (% of plants affected)				
(light**)		50%	–	–
(heavy***)		20%	–	–

* After 9–10 nodes

** Light tip damage – embryo leaves within the terminal are black.

*** Heavy tip damage – terminal and 2–3 uppermost nodes are dead.

The use of a beatsheet is recommended for counting the numbers of mirid adults and nymphs present in the crop. The relative importance of the % fruit retention and % boll damage reverses as the season progresses. From the start of squaring through until cut-out, place the emphasis on fruit retention. Not all bolls that are damaged by mirids will be shed. Bolls that are damaged between 10 and 24 days of age will be retained but develop with reduced boll size and lint yield. As the season progresses, the proportion of the retained bolls that are damaged becomes more critical.

Key beneficial insects

There are no beneficial species that are recognised to be regulators of mirid populations in cotton, however damsel bugs, big-eyed bugs, predatory shield bugs, as well as lynx, night stalker and jumping spiders are known to feed on mirid adults, nymphs and eggs.

Selecting an insecticide

The insecticide products registered for the control of green mirid in cotton in Australia are presented in Table 11 on page 79. The use of more selective insecticide options will help to conserve beneficial insects. Refer to Table 3 on page 40–41. Early season use of dimethoate for the control of green mirids may inadvertently select for carbamate resistance in aphids.

Survival strategies

Resistance profile

No resistance to insecticides has been detected in Australia as there is no resistance monitoring program for green mirids. It is possible that resistance to insecticides could develop if a proactive approach to preventing resistance is not taken.

Overwintering habit

Mirids are known to survive on weeds and native plant hosts surrounding cotton fields. They are also known to breed on native hosts in inland (central) Australia in winter and can migrate to cotton growing areas in spring in a similar way to the native budworm (see section on Native Budworm, page 4).

Alternative hosts

Mirids distinctly prefer lucerne to cotton. Lucerne strips or blocks can be used as trap crops to prevent the movement of mirids into cotton crops. If using lucerne to manage green mirids, the lucerne should not be allowed to flower, seed or hay-off. Slashing half the lucerne at 4 weekly intervals and irrigating will ensure that fresh lucerne regrowth is constantly

available for mirid feeding, thus preventing the movement into cotton. Other crop hosts include soybeans, mungbeans, pigeon pea, safflower and sunflowers. It is assumed that mirids migrate between these crops. Weeds hosts include turnip weed, noogoora burr, variegated thistle and volunteer sunflowers.

Further Information

CSIRO Plant Industries, Narrabri

Mary Whitehouse: (02) 6799 1538 or 0428 424 205

I&I NSW, Narrabri

Robert Mensah: (02) 6799 1525 or 0429 992 087

DEEDI, Kingaroy

Moazzem Khan: (07) 4160 0705 or 0428 600 705

Spider mites

Two-spotted spider mite – *Tetranychus urticae*

Bean spider mite – *T. ludeni*

Strawberry spider mite – *T. lambi*

The two-spotted spider mite is the main pest species, the other two species rarely colonise cotton and seldom cause economic damage. Even in high numbers, *T. lambi* infestations still result in very low levels of damage.

Damage symptoms

Nymphs and adults cause mid to late season damage to leaves. Leaves firstly redden and with continued feeding will become necrotic.

Sampling

'Sampling protocols for mites in cotton' is presented in full on page 20.

Sample what?

Look for the presence of any mite stages. Eggs and immature stages are difficult to see with the naked eye, so a hand lens should be used. Mites infest the underside of leaves. Sample the oldest leaf when plants are very young. As plants grow, choose leaves that are from 3, 4 or 5 nodes below the plant terminal.

Check which species is present. Two-spotted spider mite is pale green and has 2 distinct dark green spots on either side. Adults of bean spider mite are a dark red colour. Strawberry spider mite is smaller than the other two spider mites. Their bodies are pale green with 3 dark green spots on either side. They cause very little damage.

Frequency

Sample at least weekly. Begin at seedling emergence.

Sample more frequently if mite populations begin to increase, or if conditions are hot and dry, or if sprays which eliminate predators are used.

Methods

Presence/absence sampling allows many plants to be sampled quickly, thus increasing the likelihood of finding mites if they are present. It is helpful to plot the development of mite populations on a graph. This allows changes in mite population to be seen at a glance. The detailed sampling protocol for monitoring mite populations is on page 20.

Thresholds

A general threshold of 30% of plants infested is advocated through the bulk of the season (squaring to first open boll). Yield loss due to mites depends on when mite populations begin to increase and how quickly they increase.

Seedling emergence to squaring

Mites are normally suppressed by predators, especially by thrips during this period. Mite populations only need to be controlled if they begin to increase, which indicates that natural controls are not keeping them in check. Use Table 1 on page 21 to determine whether the rate of increase warrants control.

Squaring to first open boll

Control if mite populations increase at greater than 1% of plants infested per day in two consecutive checks, or if more than 30% of plants are infested. Refer to Table 1 on page 21 for details.

First open bolls to 20% open bolls

Control is only warranted if mites are well established (greater than 60% plants infested) and are increasing rapidly (faster than 3% of plants infested per day). Refer to Table 1 on page 21 for details.

Crop exceeds 20% open bolls

Control is no longer warranted.

How to use the mite yield reduction charts

The threshold for mites is best expressed as a rate of increase, rather than a number, and 'look-up' charts have been provided for this purpose. The charts shown in Table 1, page 21, are for areas with different season lengths:

Warmer – Bourke, Central Queensland, Macintyre Valley, St George and Walgett

Average – Dalby, Gwydir Valley, Lockyer Valley and Lower Namoi Valley

Cooler – Boggabri, Breeza, Cecil Plains – Pittsworth and Macquarie Valley

The charts use the rate of increase of the mite population. This is calculated by dividing the change in the percentage of plants infested between consecutive checks by the number of days between the checks. For example, if a field had 10% of plants infested a week ago and 24% infested now, this gives a rate of increase of 2% of plants infested per day.

To use the charts, firstly select the chart appropriate for your region. Next go to the section that is closest to the current infestation level of the field i.e. 10%, 30% or 60%. Next, go to the column with the rate of increase closest to that of the mite population in the field. Finally look down this column to the value that corresponds with the current age of the crop.

This value is the predicted yield loss that the mite population is likely to cause if left uncontrolled.

It must be stressed that these charts only provide a guide for potential yield losses caused by mites. You will need to take into account the vigour of the crop, other pests (you may be about to spray with a pyrethroid which may flare mites) and the conditions (that is, mites are generally favoured by hot dry conditions). Differences between the more mite resistant 'okra' leaf varieties and the normal leaf varieties are built into the charts.

Key beneficial insects

Predators – thrips, minute two-spotted ladybird, mite-eating ladybird, damsel bug, big-eyed bug, brown lacewing adults, brown smudge bug, apple dimpling bug, tangleweb spiders.

Selecting a miticide

The miticide products registered for the control of spider mites in cotton in Australia are presented in Table 15 on page 85.

Amitraz and endosulfan are insecticides that may be used for the control of *Helicoverpa* spp. early in the cotton season. When used for this purpose, these products tend to slow, or suppress, the development of mite populations that may also be in the field. Conversely, mite infestations may increase after the application of some broad spectrum insecticides used for *Helicoverpa* or mirid control, such as synthetic pyrethroids, and organophosphates. Known as 'mite flaring', this occurs because these sprays kill key beneficial species allowing mite populations to flourish.

Survival strategies

Resistance profile – two-spotted spider mite

Widespread, high levels of resistance	Widespread, low/mod levels of resistance
bifenthrin (SP) profenofos (OP)	chlorfenapyr
Occasional detection of high levels of resistance	Occasional detection of low levels of resistance
	propargite

Abamectin resistance has occasionally been detected at high levels in two-spotted spider mite in horticulture, but not in cotton. Populations of the bean spider mite and the strawberry spider mite have not been tested for resistance to miticides because they are so rarely a problem in cotton.

Preventing resistance in two-spotted mites is complicated by the fact that most chemicals used for their control in cotton are also registered for the control of other pests, such as aphids or *Helicoverpa*. The bifenthrin and chlorfenapyr resistance that has

developed in mites in recent years has occurred largely due to the use of these compounds against other pests.

Overwintering habit

Mites mostly survive the winter in cotton growing areas as active colonies. While the lifecycle slows in cool temperatures, mites are adapted to exploit ephemeral hosts and to produce large numbers of offspring, especially as conditions warm up in spring.

Alternative hosts

Preferred winter weed hosts are turnip weed, marshmallow, deadnettle, medics, wireweed and sowthistle. Alternate winter and spring host crops include safflower, faba beans and field peas.

Further Information

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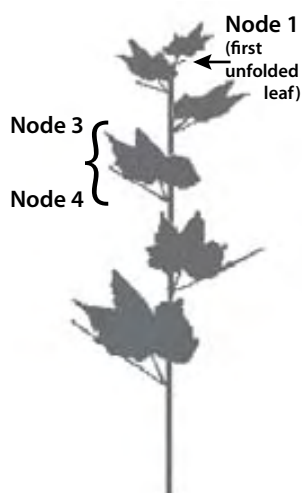
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Grant Herron: (02) 4640 6471

Sampling Tip

...to save time in the field...

Aphids, mites and whitefly can all be sampled using the same leaves from the 3rd or 4th node below the terminal.



Assess for whitefly while collecting the leaves as adults are mobile. Then assess the collected leaves for both mites and aphids.

Collect leaves from several locations in the field.

While the whitefly sampling protocol requires a minimum of 10 leaves per location, aphid and mite sampling requires at least 20 leaves per location. Using 20 leaves will increase the accuracy of whitefly assessment.

Whitefly

Silverleaf whitefly (SLW) or B biotype – *Bemisia tabaci*

Q-biotype, *Bemisia tabaci*

Eastern Australian native whitefly (EAN) – *Bemisia tabaci*

Greenhouse whitefly (GHW) – *Trialeurodes vaporariorum*

Of these four types of whitefly, SLW is the main pest due to its resistance to many insecticides and capacity to rapidly reproduce on cotton. Q-biotype has only recently been detected in Australia but it has the capacity to become a significant pest of cotton. Q-biotype behaves very similarly to SLW but tends to exhibit higher tolerance to certain chemicals for example, IGR's. Greenhouse whitefly and East Australian native are not considered significant pests in cotton.

Damage symptoms

SLW and Q-biotype adults and nymphs cause mid to late season damage to terminals, leaves and stems and cause contamination of lint through their excretion of 'honey dew'. Silverleaf whitefly honey dew is considered to be worse than aphid honey dew because it has a lower melting point and during the processing stage, can cause machinery to gum up and overheat.

Sampling

'Sampling protocols for Silverleaf whitefly in cotton' are presented in full on page 18.

Sampling what?

Sample for **Species** and **Population**.

Species: Verify which whitefly species are present before implementing any management strategies. SLW and Q-biotype pose the greatest threat to cotton crops.

Greenhouse whitefly can be visually differentiated from *Bemisia tabaci* by comparing their wing shape with those in the diagrams below. Greenhouse whitefly can fly into crops in large numbers off weeds but don't tend to cause the economic damage associated with SLW or Q-biotype because the honeydew does not cause problems for textile processing.

The three *Bemisia* biotypes (SLW, Q-biotype and Eastern Australian native whitefly) can only be differentiated by a biochemical test. Refer to the protocol on page 18 for full details of how to collect samples and send them for testing. If you have a population that is rapidly expanding and it is not GHW, then you have either SLW or Q-biotype, EAN does not behave like this.

Population: Sample for adults and nymphs of the pest on the underside of mainstem leaves 5 nodes below the plant terminals.

Frequency

Sample the **population** at weekly intervals from first flower. From peak flowering, twice weekly sampling is highly recommended. Continue twice weekly sampling until defoliation. The **species** composition may change during the season. Species verification should be done more than once. This is particularly critical since the identification of Q-biotype in Australia as Q-biotype may have high levels of tolerance to Admiral® and other insecticides.

Methods

The protocols for sampling **species** and **population** are presented in full on page 18.

Thresholds

For SLW, there are separate thresholds for early season suppression, the use of IGRs (Insect Growth Regulators) and for knockdown late in the season. Thresholds are based on rates of population increase relative to the accumulation of day degrees and crop development. A threshold matrix has been developed to assist in the interpretation of population monitoring data. Refer to page 19. Frequent population monitoring is essential in order to use the threshold matrix effectively.

Greenhouse whitefly and Eastern Australian native whitefly are not likely to become a problem



Trialeurodes vaporariorum

Greenhouse whitefly



Bemisia tabaci

Eastern Australian native whitefly or

Silverleaf whitefly or Q-biotype

requiring control in cotton. Insecticide products used for the control of mirids and other pests may inadvertently control populations of Greenhouse whitefly and Eastern Australian native whitefly. Thresholds have not been developed for either of these species.

Key beneficial insects

At least 14 species of whitefly parasitoids as well as several species of parasites have also been observed in Australia, including several species of *Encarsia* and *Eretmocerus*.

Predators of nymphs – big-eyed bugs, pirate bugs, lacewing larvae, ladybeetles.

Selecting an insecticide

Natural enemies can play a vital role in the successful management of whitefly. Avoid early season use of broad spectrum insecticides, particularly synthetic pyrethroids and organophosphates.

Currently there are few products registered for the control of whitefly in cotton in Australia.

The insect growth regulator (IGR) pyriproxyfen, tradename Admiral®, is the keystone of effective control of SLW in cotton. It provides excellent control of SLW across a broad range of population densities. It is very selective, allowing survival of whitefly predators and parasitoids. However there is a very high risk that resistance will develop and lead to control failures in the field. ENSURE ONLY A SINGLE APPLICATION OF ADMIRAL® OCCURS WITHIN A SEASON. Twice weekly monitoring from peak flower will ensure that if thresholds are reached, the IGR can be applied at the time when it will be most effective. The overseas experience shows that Q-biotype has higher tolerance to Admiral than SLW. It is critical that you know what biotype you are dealing with by sending a sample (refer to page 18).

Survival strategies

Resistance profile – SLW

Widespread, high levels of resistance	Widespread, low/mod levels of resistance
pyrethroids (SP) organophosphates (OP) carbamates Insect Growth Regulators (IGRs)	endosulfan (OC) imidacloprid amitraz difenthiuron
Cross Resistance	
There is cross-resistance between pyrethroids, most organophosphates, carbamates and some IGRs.	

No resistance to insecticides has been detected in Australia in populations of the Eastern Australian native whitefly. Some resistance has been detected in horticultural populations of the Greenhouse whitefly.

Overwintering habit

Whitefly does not have an overwintering diapause stage. It relies on alternative host plants to survive. Generation times are temperature dependent, slowing down during winter months. From Biloela north, the winter generation time is 80 days, while in the Macintyre, Gwydir and Namoi valleys, generation time increases to 120 days.

Alternative hosts

The availability of a continuous source of hosts is the major contributing factor to a severe whitefly problem. Even a small area of a favoured host can maintain a significant whitefly population.

Preferred weed hosts include; sow thistle, melons, bladder ketmia, native rosella, rhynchosia, vines (cow, bell and potato), rattlepod, native jute, burr gerkin and other Cucurbitaceae weeds, Josephine burr, young volunteer sunflowers, Euphorbia weeds, poinsettia and volunteer cotton.

In cotton growing areas the important alternate crop hosts are soybeans, sunflowers and all cucurbit crops. Spring plantings of these crops may provide a haven for SLW populations to build up in and then move into cotton. Autumn plantings of these crops may be affected by large populations moving out of cotton. Do not plant cotton near good SLW host crops such as melons. Destroy crop residue from all susceptible crops immediately after harvest.

Minimising winter hosts, particularly sowthistle, is important in reducing the base population at the start of the cotton season. Smaller base populations will take longer to reach outbreak levels and reduce the likelihood that a particular field will need to be treated.

Further Information

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Thrips

Tobacco thrips – *Thrips tabaci*

Tomato thrips – *Frankliniella schultzei*

Western flower thrips – *F. occidentalis*

Damage symptoms

Nymphs and adults cause early season damage to terminals, leaves, buds and stems. While recognised as a pest, thrips are also a key predator of spider-mite eggs.

Sampling

Sample what?

Sample for the number of thrips /plant. Check for the presence of nymphs as well as adults. The presence of nymphs tells if the population is actively breeding. Crops that have had an insecticide seed treatment or in-furrow insecticide treatment may have adult thrips but no nymphs and little plant damage.

Sample for the severity of damage to the seedlings. Late season, thrips may reach high numbers in flowers and on cotton leaves, especially in crops where there has been either little or no insecticide use. These thrips help to control mites. Late season thrip damage would rarely justify control.

Frequency

Sample at least weekly.

Begin sampling at seedling emergence and discontinue sampling once the crop has 6 true leaves.

Methods

Use whole plant visual assessment, with the aid of a hand lens for the observation of nymphs. Check the number of thrips on 20–30 separate plants for every 50 ha of crop.

When assessing leaf damage, a rough guide is, if the average size of a thrips damaged leaf is less than 1 cm², then leaf area reduction is often greater than 80%.

Look for symptoms of tip damage. Tip damage caused by thrips appears as extensive crumpling and blackening of the edges of the small leaves within the terminal. For thrips to cause tip damage, they must be present in high numbers (> 30/plant).

Thresholds

Seedling to 6 true leaves
80% reduction in leaf area + 10 thrips /plant (adults and nymphs)

Key beneficial insects

Predators – pirate bug, green lacewing larvae, brown lacewing, ladybeetles.

Selecting an insecticide

The insecticide products registered for the control of thrips in cotton in Australia are presented in Table 11, page 79. When deciding whether or not to control thrips with an insecticide, an important consideration is the benefit of thrips to cotton crops as predators of spider mites.

Survival strategies

Resistance profile – Western flower thrip

Widespread, high levels of resistance	Widespread, low/mod levels of resistance
pyrethroids (SP)	chlorpyrifos (OP)
Occasional detection of high levels of resistance	Occasional detection of low levels of resistance
	dimethoate (OP)

No resistance to insecticides has been detected in Australia for tobacco thrips or tomato thrips.

Overwintering habit

Thrips prefer milder temperatures. Populations decline at temperatures greater than 30°C. Thrips are active and common through winter.

Alternative hosts

In spring, large numbers of thrips have been observed on flowers of cereal crops and winter weeds such as Mexican poppy, turnip weed and Paterson's curse. Thrips then transfer to cotton as these hosts dry out or hay off. Cotton crops planted adjacent to cereal crops are particularly at risk of infestation by thrips. In the absence of plant hosts, thrips feed on other sources of protein such as mite eggs.

Further Information

CSIRO Plant Industries, Narrabri

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Green Vegetable Bug (GVBs)

Nezara viridula

Damage symptoms

Nymphs and adults cause warty growths and brown staining of lint in developing bolls. Damage symptoms cannot be distinguished from those caused by mirids.

Sampling

Sample what?

Sample for adults and nymphal instars of the pest. GVB instars four and five inflict the same amount of damage as adults. Third instar GVBs cause half

the damage of adults, and a cluster (more than 10) of first and second instars cause as much damage as one adult. It is important to correctly identify which instars are present to determine whether or not the population has reached the threshold.

Instar	Instar Length (mm)	Description
1	1	Predominately orange
2	2	Black with 1 or 2 white spots
3	4	Mosaic pattern of green, black and red spots
4	7	More green spots, wings begin to develop during late 4th instar
5	10	Spots start to diminish to green, wings well developed
Adult	15	All green with wings

Monitor fruit retention as well as for the presence of the pest.

Frequency

Sample at least weekly.

The crop is most susceptible to damage from flowering through until one open boll/m. Monitor fruit retention and pest presence from the beginning of squaring.

Methods

GVB's are most visible early to mid morning making checking easier at this time. Visual sampling and beat sheets are equally effective checking methods while the crop is squaring. From flowering onwards when the crop is most susceptible to damage, beat sheeting is twice as efficient for detecting GVB's. Although beat sheet sampling is efficient it may tend to give a lower population than the actual number in the field. It has been found that the 1st and 2nd instars tend to hide in the bracts and may be difficult to dislodge.

Even when pests are not observed, cut or squash 14 day old bolls to check for the presence of feeding damage. This will take the form of warty growths and/or brown staining of the developing lint.

Thresholds

Sampling Method	Flowering to First open boll	First open boll to Harvest
Visual	0.5 adults /m	0.5 adults /m
Beat Sheet	1.0 adult /m	1.0 adult /m
Damage to small bolls (14 days old)	20%	20%

Convert nymph numbers to adult equivalents and include in the counts. Fourth or fifth instars are

each equivalent to 1.0 adult, each third instar counts as 0.5 adult and clusters of 10+ first/second instars count as 1.0 adult.

Key beneficial insects

Parasites – *Trissolcus basalis*, *Trichopoda giacomellii*

Selecting an insecticide

The insecticide products registered for the control of GVBs in cotton in Australia are presented in Table 11 on page 79. Mid-season use of dimethoate for GVB control could have implications for managing insecticide resistance in aphids.

Survival strategies

Resistance profile

No resistance to insecticides has been detected in Australia for GVBs.

Overwintering habit

GVB adults enter a dormant phase during late autumn. They overwinter in a variety of sheltered locations such as under bark, in sheds, and under the leaves of unharvested maize crops.

Alternate hosts

In Queensland there are two GVB generations during the warmer part of the year. The preferred weed hosts of the first, spring generation include turnip weed, wild radish and variegated thistle. Early mungbean crops are also a favoured host in spring. The second generation breeds in late summer and early autumn. Pulse crops – particularly soybeans and mungbeans – are key hosts for this generation. GVB populations are usually much lower in mid summer, mainly due to a lack of suitable hosts. In NSW there is a summer/autumn generation, similar to the second generation in Queensland.

Further Information

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Pale Cotton Stainers

Dysdercus sidae

Damage symptoms

Pale cotton stainers are recognized as occasional pests of cotton in Australia. Economic damage is unusual because of their;

- susceptibility to insecticides used for other pests;
- inability to survive high temperatures (> 40°C).
- need for free water to be present.

However in mild seasons Bollgard II® crops may be a favourable environment for cotton stainers and they may need to be managed.

Pale cotton stainers are able to feed on both developing and mature cotton seed. Seed weight, oil content and seed viability all decline as a result of cotton stainer feeding. Loss of seed viability can be substantial and should be a consideration in pure seed crops.

Pale cotton stainers are able to damage bolls at any age. They will feed on young bolls, up to two weeks old, and severe attacks on these bolls can kill developing seeds leading to boll shedding. Damage to older bolls, from two weeks old onwards usually doesn't cause shedding, but seeds will be damaged, reducing their growth and sometimes lint production. Hence, yield may also be reduced as a secondary effect of feeding. Tightlock can result around damaged seeds, preventing the lint from fluffing out as the boll opens, and damaged locks (boll segments) often appear yellow or stained.

Sampling

Sample what?

Sample for adults and nymphal instars of the pest as both stages can cause similar amounts of damage. Where adults and nymphs are observed feeding, monitor percentage damaged bolls.

Frequency

Sample at least weekly once bolls are present.

Usually cotton becomes infested by adults that fly into fields around the time of first open boll, though sometimes, perhaps due to seasonal conditions populations can be found earlier, during boll maturation. Flights of up to 15 km have been recorded. Adults will mate soon after arrival. The expanding population of developing nymphs will be the cause of economic damage.

Methods

Distribution through the field and through the canopy can be quite patchy, as adult females lay eggs in clusters in the soil or sometimes in open bolls. To avoid under/over estimating abundance ensure sampling occurs at multiple sites spread throughout the field. The beat sheet is a suitable sampling method to monitor the bugs, but as some growth stages favour the lower canopy, visual searching is also a good complementary technique.

Bolls of varying ages should be cut open to confirm and monitor for signs of damage. Studies have shown pale cotton stainer bug cause almost no marking to the boll surface. Warty growths may be

found on the inside of the boll wall if young bolls are damaged, but older bolls will not have these. To confirm damage bolls need to be opened and seeds cut and examined for browned, dried damage areas. Some time after damage, usually 7 or more days, the lint may begin to have a more yellow appearance and locks will be stuck to the boll wall – a good indication of pale cotton stainer feeding.

The mild, wet conditions that favour the survival of pale cotton stainers in cotton will also favour the occurrence of secondary infections by yeasts, *Alternaria* and bacteria in cracked bolls. These infections can cause tightlock and lint staining. The presence of pale cotton stainers when such damage occurs may be coincidental.

Thresholds

Action Threshold during Boll Development:

When adults and nymphs are observed in the crop and damage to developing bolls is detected, an action threshold of 3 pale cotton stainers/m is recommended. This threshold is based on the relationship between cotton stainer damage and the damage caused by other plant bugs. Studies have shown that pale cotton stainer bugs cause only one third as much boll damage as green vegetable bugs. Since the action threshold for green vegetable bug is 1/m, the action threshold for pale cotton stainer bug should be 3/m. Both nymphs (usually 3rd to 5th stage nymphs) and adults cause similar amounts of damage.

Action Threshold after First Open Boll:

When adults and nymphs are observed feeding in open bolls, the threshold must consider the potential for quality downgrades of the lint as well as the loss of seed weight and seed viability. Where staining is observed a threshold of 30% of bolls affected should be used to prevent a colour downgrade.

Key beneficial insects

A range of natural enemies such as Tachinids (parasitic flies) and predatory reduvid bugs (e.g. assassin bugs) have been recorded in Africa. However, they have mainly exerted pressure when cotton stainers have been feeding on native hosts rather than in cropping situations. The role of natural enemies in the control of developing populations of pale cotton stainers in Australia has not been studied.

Selecting an insecticide

As an occasional pest, there are few products registered for their control. The synthetic pyrethroids lambda-cyhalothrin (Karate Zeon®, Matador®) and gamma-cyhalothrin (Trojan®) are registered; check the labels of these products for more information. However their status as an occasional pest is influenced by their susceptibility to insecticides used for the control of *Helicoverpa* and other pests. Cotton stainers may be incidentally controlled when carbamates such as carbaryl or organophosphates such as dimethoate are used.

Survival strategies

Resistance profile

Worldwide there are few records of resistance to insecticides developing in the field, however cotton stainers will react to selection pressure under laboratory conditions. Any decision to use broad spectrum insecticides such as SPs should take into account their impact on beneficial insects and the subsequent risk of flaring whitefly and other secondary pests should also be considered

Overwintering habit

As there is no resting stage in the cotton stainer's lifecycle, cultural controls between cotton seasons assist greatly in limiting population development (see below).

Alternative hosts

Fuzzy cotton seed used for stockfeed is an important alternative source of food for cotton stainers. Avoid storing fuzzy seed in exposed places where cotton stainers can access this food source over long periods. Controlling ratoon cotton and cotton volunteers is important for limiting cotton stainer's access to alternative food source.

Further Information

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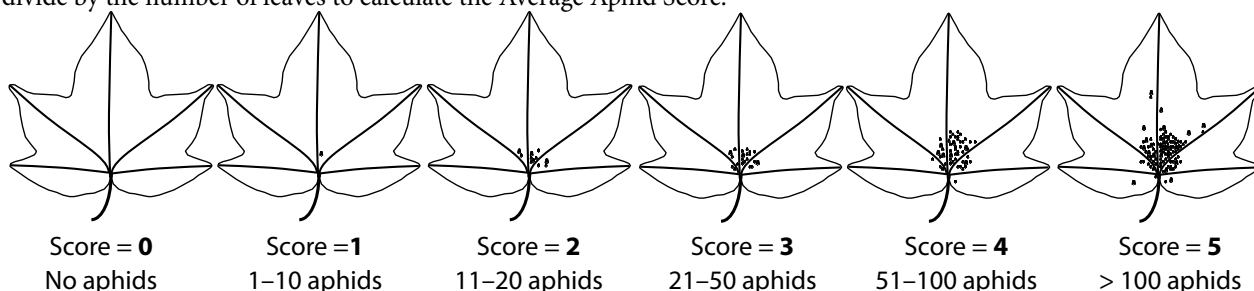
Sampling protocols for cotton aphid for use until first open boll

STEP 1. COLLECT LEAVES.

Fields should be sampled in several locations as aphids tend to be patchy in distribution. At each location collect at least 20 leaves, taking only one leaf per plant. Choose mainstem leaves from 3–4 nodes below the terminal. The same leaves can also be used for mite and whitefly scoring. It is important to sample for aphids regularly, even if it is suspected that none are present. The estimate of yield loss will be most accurate when sampling detects the time aphids first arrive in the crop.

STEP 2. SCORE LEAVES.

Allocate each leaf a score of 0, 1, 2, 3, 4 or 5 based on the number of aphids on the leaf. After counting aphids a few times, you will quickly gain confidence in estimating abundance. As a guide, the diagrams below represent the minimum population for each score. Discount pale brown bloated aphids as these are parasitised. Sum the scores and divide by the number of leaves to calculate the Average Aphid Score.

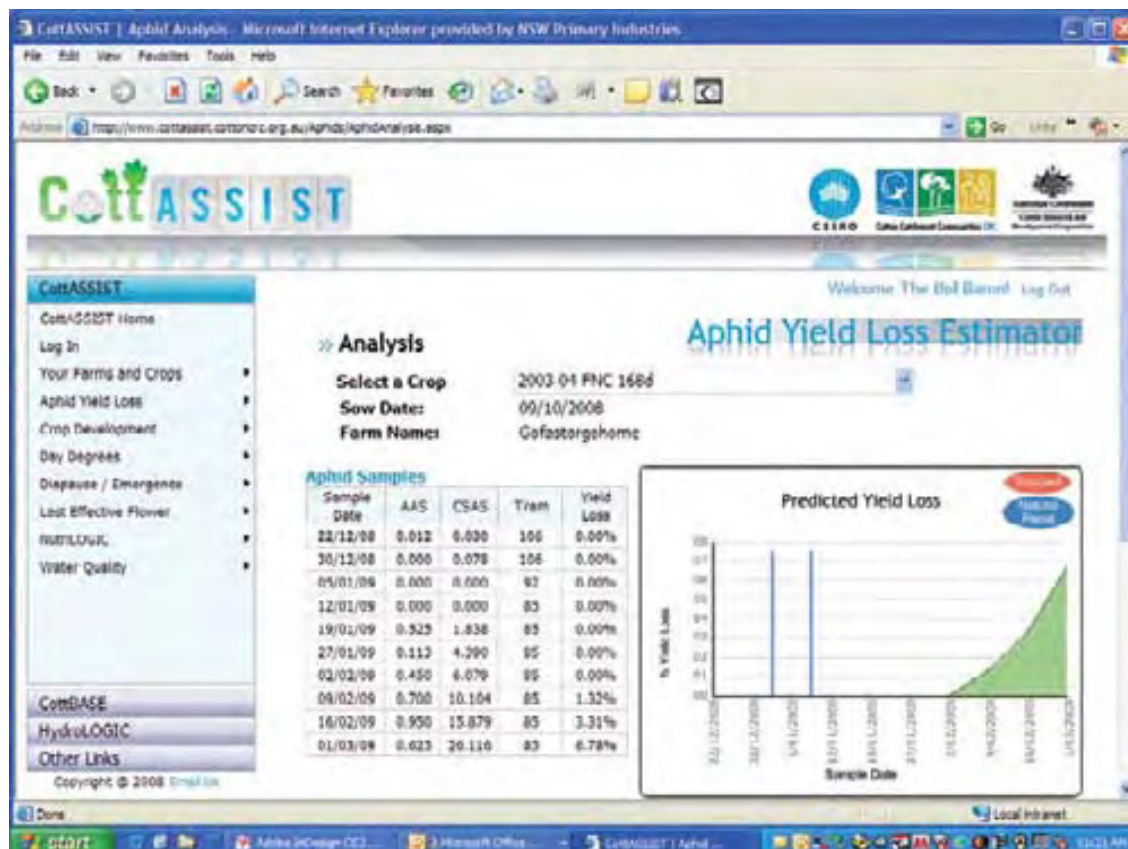


STEP 3. USE THE APHID YIELD LOSS ESTIMATOR ON THE WEB.

In order to estimate yield loss, the Average Aphid Score must firstly be transformed into a Sample Aphid Score and then into a Cummulative Season Aphid Score. Record keeping and calculation of these Scores can be simplified by using the Aphid Yield Loss Estimator in CottASSIST on the web. The Tool allows users to keep records for multiple crops on multiple farms throughout the season. After initial set up, the user enters the Average Aphid Score from Step 2 and the date of each check. The Tool then calculates the Scores and tracks the estimate of yield loss. Find CottASSIST on the 'Industry' home page in the Cotton CRC website.

Alternatively, the Scores can be calculated manually by following Steps 4 and 5.

Example yield loss estimate from the Aphid Yield Loss Estimator web tool.



STEP 4. MANUAL CALCULATION OF THE CUMMULATIVE SEASON APHID SCORE.

Use the Look Up Table below to firstly convert the Average Aphid Score calculated in Step 2 to a Sample Aphid Score. This step accounts for the length of time the observed aphids have been present in the crop. If aphids are found in the first assessment of the season, assume the 'Score last check' was '0' and that it occurred 5 days ago.

Find the value in the table where 'this check' and the 'last check' intersect. **Multiply this value by the number of days that have lapsed between checks.** This value is the Sample Aphid Score.

As the season progresses, add this check's Sample Aphid Score to the previous value to give the Cummulative Season Aphid Score.

When aphids are sprayed, or, if during the season the Average Aphid Scores return to '0' in 2 consecutive checks, reset the Cummulative Season Aphid Score to '0'. Disappearance of aphids can occur for reasons such as predation by beneficials, changes in the weather and insecticide application.

Average score <i>last</i> check	Average score <i>this</i> check										
	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0	0.0	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5
0.5	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.8
1.0	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0
1.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3
2.0	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5
2.5	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8
3.0	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.0
3.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.3
4.0	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.3	4.5
4.5	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.3	4.5	4.8
5.0	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.3	4.5	4.8	5.0

STEP 5. MANUAL CALCULATION OF THE YIELD LOSS ESTIMATE.

Use the table to estimate the yield loss that aphids have already caused. The 'Time Remaining' in the season needs to be determined the first time aphids are found in the crop. The data set is based on 165 days from planting to 60% open bolls. If for example aphids are first found 9 weeks after planting, the Time remaining would be ~100 days. As the Season Aphid Score accumulates with each consecutive check, continue to read down the '100' days remaining column to estimate yield loss. When aphids are sprayed, or, if aphids disappear from the crop then reappear at a later time, reassess the time remaining based on the number of days left in the season at the time of their reappearance.

Crop sensitivity to yield loss declines as the crop gets older. The estimate takes into account factors that affect the rate of aphid population development, such as beneficials, weather and variety. Yield reductions >4% are highlighted, however the value of the crop and cost of control should be used to determine how much yield loss can be tolerated before intervention is required.

Cumulative Season Aphid Score	Time Remaining (days until 60% open bolls at the time when aphids are first observed)									
	100	90	80	70	60	50	40	30	20	10
0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
10	2	2	1	1	1	0	0	0	0	0
15	5	4	3	3	2	1	1	0	0	0
20	7	6	5	4	3	2	1	1	0	0
25	9	8	7	6	5	3	2	1	0	0
30	11	10	8	7	6	5	3	2	1	0
40	15	13	12	10	8	7	5	3	1	0
50	19	17	15	13	11	9	7	5	2	0
60	23	21	18	16	13	11	8	6	3	1
80	31	28	25	22	18	15	12	8	5	1
100	38	34	31	27	23	19	15	11	7	2
120	45	41	37	32	28	23	18	13	9	3

Sampling protocols for Silverleaf whitefly (SLW) in cotton

SPECIES VERIFICATION AND RESISTANCE MONITORING

Action should be taken to identify the whitefly species as soon as any are noted. Greenhouse whitefly and *Bemisia* spp. can be differentiated visually. The three *Bemisia tabaci* biotypes cannot be distinguished by eye. A biochemical test is needed. This test and the industry's resistance monitoring program are being conducted by Richard Lloyd at DEEDI, Toowoomba.

In fields where whitefly have been seen, collect 200 leaves from random plants throughout the crop (i.e. don't search for leaves that have whitefly present). The whitefly can be identified from both the adults and nymphs.

Collect only 1 leaf /plant, choosing the leaf from between 5 and 8 nodes below the plant terminal.

Sending Collections to DEEDI Toowoomba

Pack the leaves in a paper bag and then inside a plastic bag. Pack this in an esky with an ice brick that has been wrapped in newspaper. Send by overnight courier to;

Richard Lloyd
Queensland Primary Industries & Fisheries

Some important points to note

- Species composition may change rapidly during the season due to factors such as insecticide applications and climate.
- Greenhouse and EAN whiteflies will not generally reproduce rapidly in cotton. If large increases in population occur, this probably indicates the predominance of SLW.
- Greenhouse and EAN whitefly are both susceptible to many of the insecticides used to control other pests, whilst SLW are resistant to most insecticides. Consider insecticide application history for the crop as a clue to species composition.

203 Tor Street, Toowoomba QLD 4350
Phone (07) 4688 1315

Ensure samples are clearly labelled and include the following information:

Collector's Name.....
Phone No.
Farm Name
Fax No.
Email address
Field..... Postcode
Region (e.g. Gwydir).....
Date of collection /..... /.....
Comments
.....
.....
.....

POPULATION MONITORING

Once you have confirmed the presence of SLW, effective sampling is the key to successful management. Sampling should commence at flowering and occur twice weekly from peak flowering (1300 Day Degrees).

1. Define your management unit

- A management unit can be a whole field or part of a field – no larger than 25 ha.
- Each management unit should have a minimum of 2 sampling sites.
- Sample 10 leaves/site (20 leaves/management unit).

2. Choose a plant to sample

- Move at least 10 m into the field before choosing a plant to sample.
- Choose healthy plants at random, avoiding plants disturbed by sweep sampling.
- Take only one leaf from each plant.
- Sample along a diagonal or zigzag line. Move over several rows, taking 5–10 steps before selecting a new plant.

3. Choose a leaf

- From each plant choose a mainstem leaf from either the 3rd, 4th or preferably the 5th node below the terminal of the plant, as shown in the diagram.

ESTIMATE WHITEFLY ABUNDANCE

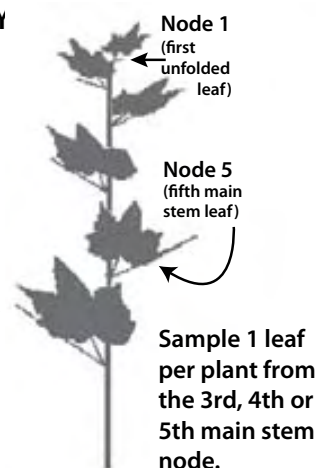
Adults

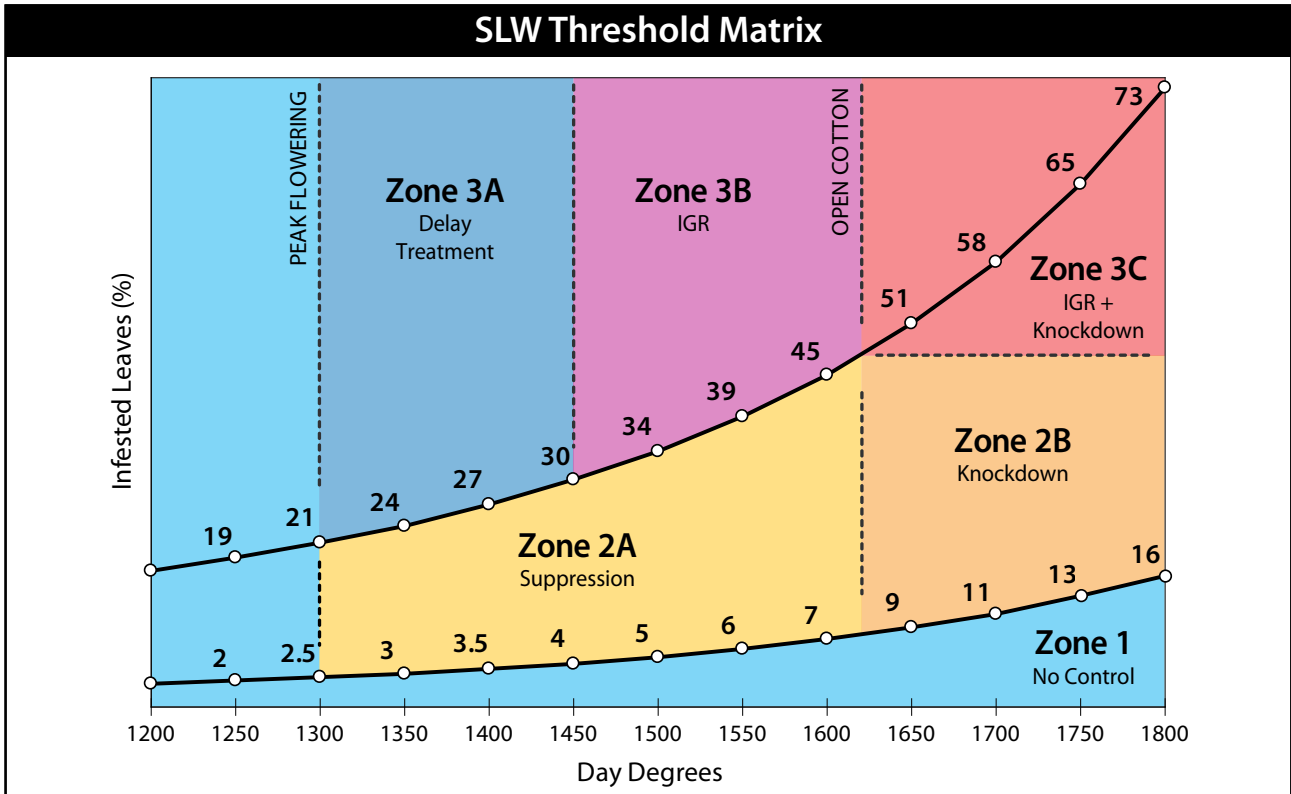
- Binomial sampling (presence/absence) is highly recommended as it is less prone to bias than averaging the number of whitefly/leaf.
- Score leaves with 2 or more whitefly adults as 'infested'. Score leaves with 0 or 1 whitefly adults as 'uninfested'.
- Calculate the percentage of infested leaves.

Nymphs

- Nymph abundance is not used in the Threshold Matrix. Use it as supporting information only.
- The presence of large nymphs on leaves at 6, 7 and 8 nodes below the plant terminal validate the assumptions about SLW population dynamics that underpin the spray thresholds.

As leaves are assessed for SLW, they can be picked and used to monitor populations of aphids and mites.





NOTES

Sampling protocol	Sample 20 leaves @ 5th node below the terminal/25 ha weekly from first flower (777 DD) and twice weekly from peak flowering (1300 DD). Convert to % Infested leaves. Infested leaves are those with 2 or more adults. Uninfested leaves are those with 0 or 1 adult.
Day Degrees	Daily Day Degrees (DD) are calculated using the formula; $DD = [(Max\ ^\circ C - 12) + (Min\ ^\circ C - 12)] \div 2$ For day degree information from your nearest SILO weather station visit www.cottoncrc.org.au For a mid-September planting in Emerald, long term average weather data predicts the duration of Zone 3A is 9 days, Zone 3B is 11 days and Zone 3C is 14 days.
Zone 1 No Control	Insecticide use is not warranted for fields with low SLW densities. In this zone the risk of yield loss or lint contamination is negligible, even when populations are sustained throughout flowering and boll fill.
Zone 2A Suppression	This Zone represents a wide window of opportunity for the most economic and low-risk control of SLW. Conventional (non-IGR) insecticides, such as diafenthiuron (Pegasus®), can control or provide useful suppression of low-medium density populations. In early sown crops, endosulfan may be used to control aphids and some other pests through until flowering. When used for these purposes, endosulfan can also suppress the development of low-medium SLW populations. The window for endosulfan application by ground rig closes on the 15 January. Refer to label directions and the IRMS.
Zone 2B Knockdown	Lint contamination can result from uncontrolled medium density populations in crops with open bolls. Early action in Zone 2A can prevent the need for higher-risk remedial action in Zone 2B. Pegasus® may be effective for remedial control (knockdown) of population densities up to 45% infested leaves in Zone 2B. (NOTE: The Pegasus® label indicates that the product may not give satisfactory control of populations >25% infested leaves. This is based on an overseas sampling model. For Australian conditions this equates to ~45% infested leaves). Efficacy will depend upon coverage and environmental conditions. For higher densities approaching the Zone's upper boundary, an application of IGR may ultimately be required.
Zone 3A Delay Treatment	Controlling high density populations before 1450 DD is not recommended due to the likely resurgence of the population and need for additional control to protect lint from honey dew. Delay control until Zone 3B.
Zone 3B IGR	For optimum efficacy of pryiproxifen, trade name Admiral®, target high density populations when the crop is between 1450 and 1650 DD, prior to the onset of boll opening. ENSURE ONLY A SINGLE APPLICATION OF ADMIRAL® OCCURS WITHIN A SEASON. Delaying IGR use beyond 50% infested leaves or 1650 DD can result in yield loss, lower efficacy of the IGR and significant lint contamination.
Zone 3C Knockdown + IGR	Once the populations exceeds 50% leaves infested, the use of an IGR by itself is unlikely to prevent lint contamination due to the inherent time delay in population decline following application. Rapid knockdown of the population using a conventional insecticide is required before applying the IGR. The lack of insecticides offering robust knockdown of SLW at high densities make this a 'high risk' zone.

Sampling protocols for mites in cotton

POPULATION MONITORING

1. Walk into the field about 40 m. (Early in the season it is also advisable to sample near the field edges to see if significant influxes of mites have occurred).
2. Take a leaf from the first plant on the right or left. The leaf should be from the third, fourth or fifth main-stem node below the terminal. If the plant has less than three leaves, sample the oldest. Note that early in the season, up to the point that the plant has about five true leaves, it is simplest to pull out whole plants.
3. Walk five steps and take a leaf from the next plant, on the opposite side to the previous one, and so on until you have 50 leaves. (Wait until you have collected all the leaves before scoring them).
4. Once all the leaves have been collected score each leaf by turning it over, looking at the underside, firstly near the stalk, then scanning the rest of the leaf. If mites of any stage (eggs or motiles) are present score the leaf as infested. A hand lens will be needed to see mite eggs because they cannot be seen with the naked eye.
5. Repeat this simple procedure at several widely separated places in the field to allow for differences in mite abundance within the field. Depending on the size of the field, 4–6 sites are needed to obtain a good estimate of mite abundance.

6. When finished sampling, calculate the percentage of plants infested in the field.

Additional recommendations for monitoring mites in seedling cotton

- On seedling cotton (up to 6–8 true leaves) sample regularly to determine the level of infestation using the standard presence/absence technique described above.
- When more than 5% of plants are infested it is also advisable to count the numbers of mites on plants, and to score the mite damage level (i.e. estimate the % of the plants total leaf area that is damaged by mites).
- Continue to monitor mite numbers, damage levels and infestation levels at least weekly, or more frequently if infestation levels are high (> 30% of plants infested).
- If the level of infestation, damage level or mite number per plant declines then control is unnecessary, but monitoring should continue.
- If mite numbers per plant do not decline after about 6 weeks, if the damage levels exceed an average of 20% of plant leaf area, or if infestation levels increase, then predators are not abundant enough to control mites and a miticide should be applied.
- After about 6–8 true leaves, specific mite counts and damage scoring can cease, but continue to use the presence/absence sampling method (points 1–6) until 20% open bolls.

MITICIDE RESISTANCE MONITORING

1. If mites are being collected after a miticide application, ensure sufficient time has lapsed for the miticide to be fully activated. Depending on the product, this may take 7 to 10 days.
2. Collect 50 infested leaves per field. Only collect one sample per field. Keep samples from different fields separate. If mite numbers per leaf are very low, consider collecting up to 100 leaves.
3. Try to avoid collecting all the leaves from only 2 or 3 plants. Where possible collect infested leaves from different areas across the field.
4. Phone Grant Herron and let him know you are sending the sample. Avoid making collections and sending samples on Thursdays or Fridays.
5. Ensure samples are clearly labelled and that labels include the following information:

Farm Name

Field.....

Region (e.g. Gwydir)

Collector's Name.....

Phone No.....

Fax No

Email address.....

Date of collection /..... /.....

Comments e.g. details of the problem if a control failure has occurred

Sending Collections to EMAI

Pack the leaves loosely in a paper bag, fold and staple the top. Pack this in a 6-pack esky. Attach the sample details and send by overnight courier to;

Dr Grant Herron
Industry & Investment NSW,
Elizabeth McArthur Agricultural Institute,
Woodbridge Road,
Menangle NSW 2568. Phone: (02) 4640 6471

Table 1. Yield reduction caused by mites

The charts below can be used to estimate the percentage of yield reduction caused by mites, for different cotton growing regions.

Days from planting	Current % plants infested with mites																							
	10								30								60							
	Observed rate of increase (%/day)								Observed rate of increase (%/day)								Observed rate of increase (%/day)							
	0.5	1	1.5	2	3	5	7		0.5	1	1.5	2	3	5	7		0.5	1	1.5	2	3	5	7	
Warmer regions; planting to 60% bolls open in 134–154 days. <i>Biloela, Bourke, Emerald, Macintyre, Mungindi, St. George, Theodore and Walgett</i>																								
10	1.1	4.0	8.6	14.9	32.8	89.3	100.0	1.8	5.2	17.2	10.3	36.1	94.7	100.0	3.1	7.3	13.2	20.8	41.2	100.0	100.0			
20	1.0	3.5	7.4	12.9	28.2	76.7	100.0	1.6	4.6	9.0	14.9	31.2	81.6	100.0	2.6	5.8	10.3	16.0	31.2	76.7	100.0			
30	0.9	3.0	6.3	10.9	23.9	65.0	100.0	1.5	4.0	7.8	12.9	26.7	69.6	100.0	2.6	5.8	10.3	16.0	31.2	76.7	100.0			
40	0.7	2.5	5.3	9.2	20.0	54.3	100.0	1.3	3.5	6.7	10.9	22.6	58.4	100.0	2.4	5.2	9.0	13.9	26.7	65.0	100.0			
50	0.6	2.1	4.4	7.6	16.5	44.5	86.2	1.1	3.0	5.6	9.2	18.8	48.3	91.5	2.2	4.6	7.8	11.9	22.6	54.3	99.6			
60	0.5	1.7	3.6	6.1	13.3	35.7	69.1	1.0	2.5	4.7	7.6	15.4	39.1	73.8	2.0	4.0	6.7	10.0	18.8	44.5	81.1			
70	0.4	1.4	2.8	4.8	10.4	27.9	53.9	0.9	2.1	3.8	6.1	12.3	30.9	58.0	1.8	3.5	5.6	8.4	15.4	35.7	64.5			
80	0.3	1.1	2.2	3.7	7.9	21.0	40.5	0.7	1.7	3.1	4.8	9.5	23.7	44.1	1.6	3.0	4.7	6.8	12.3	27.9	49.9			
90	0.3	0.8	1.6	2.7	5.7	15.1	29.1	0.6	1.4	2.4	3.7	7.1	17.4	32.2	1.5	2.5	3.8	5.5	9.5	21.0	37.1			
100	0.2	0.6	1.1	1.9	3.9	10.2	19.5	0.5	1.1	2.8	2.7	5.1	12.1	22.1	1.3	2.1	3.1	4.2	7.1	15.1	26.2			
110	0.1	0.4	0.7	1.2	2.4	6.3	11.9	0.4	0.8	1.3	1.9	3.4	7.7	13.9	1.1	1.7	2.4	3.2	5.1	10.2	17.2			
120	0.1	0.2	0.4	0.6	1.3	3.3	6.1	0.3	0.6	0.8	1.2	2.0	4.3	7.6	1.0	1.4	1.8	2.3	3.4	6.3	10.0			
130	0.1	0.1	0.2	0.3	0.5	1.2	2.3	0.3	0.4	0.5	0.6	1.0	1.9	3.2	0.9	1.1	1.3	1.5	2.0	3.3	4.8			
140	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.2	0.2	0.3	0.3	0.3	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.2	1.5			
Average regions; planting to 60% bolls open in 161–170 days. <i>Dalby, Gwydir, Lockyer, Lower Namoi</i>																								
10	1.5	5.3	11.5	20.0	44.1	100.0	100.0	2.3	6.7	13.5	22.6	47.9	100.0	100.0	3.7	9.0	16.7	26.7	53.9	100.0	100.0			
20	1.3	4.7	10.1	17.6	38.8	100.0	100.0	2.0	6.0	12.0	20.0	42.3	100.0	100.0	3.4	8.2	15.0	23.9	47.9	100.0	100.0			
30	1.2	4.1	8.8	15.4	33.8	92.0	100.0	1.9	5.3	10.6	17.6	37.1	97.4	100.0	3.2	7.4	13.5	21.3	42.3	100.0	100.0			
40	1.0	3.6	7.7	13.3	29.1	79.1	100.0	1.7	4.7	9.3	15.4	32.2	84.2	100.0	2.9	6.7	12.0	18.8	37.1	92.0	100.0			
50	0.9	3.1	6.5	11.3	24.8	67.3	100.0	1.5	4.1	8.0	13.3	27.6	71.9	100.0	2.7	6.0	10.6	16.5	32.2	79.1	100.0			
60	0.8	2.6	5.5	9.5	20.8	56.3	100.0	1.3	3.6	6.9	11.3	23.4	60.6	100.0	2.5	5.3	9.3	14.3	27.6	67.3	100.0			
70	0.6	2.2	4.6	7.9	17.2	46.4	89.9	1.2	3.1	5.8	9.5	19.5	50.3	95.2	2.3	4.7	8.0	12.3	23.4	56.3	100.0			
80	0.5	1.8	3.7	6.4	13.9	37.4	72.4	1.0	2.6	4.9	7.9	16.0	40.9	77.2	2.0	4.1	6.9	10.4	19.5	46.4	84.7			
90	0.4	1.4	3.0	5.1	10.9	29.4	56.8	0.9	2.2	4.0	6.4	12.9	32.5	61.0	1.9	3.6	5.8	8.7	16.0	37.4	67.7			
100	0.4	1.1	2.3	3.9	8.4	22.3	43.0	0.8	1.8	3.2	5.1	10.0	25.0	46.8	1.7	3.1	4.9	7.1	12.9	29.4	52.6			
110	0.3	0.8	1.7	2.9	6.1	16.2	21.2	0.6	1.4	2.5	3.9	7.6	18.6	34.4	1.5	2.6	4.0	5.7	10.0	22.3	39.5			
120	0.2	0.6	1.2	2.0	4.2	11.1	21.3	0.5	1.1	1.9	2.9	5.5	13.1	23.9	1.3	2.2	3.2	4.5	7.6	16.2	28.2			
130	0.2	0.4	0.8	1.3	2.7	7.0	13.3	0.4	0.8	1.4	2.0	3.7	8.5	15.4	1.2	1.8	2.5	3.4	5.5	11.1	18.8			
140	0.1	0.3	0.5	0.7	1.5	3.8	7.1	0.4	0.6	0.9	1.3	2.3	4.9	8.7	1.0	1.4	1.9	2.4	3.7	7.0	11.3			
150	0.1	0.1	0.2	0.3	0.6	1.6	2.9	0.3	0.4	0.6	0.7	1.2	2.3	3.9	0.9	1.1	1.4	1.6	2.3	3.8	5.7			
160	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.2	0.3	0.3	0.3	0.4	0.7	1.0	0.8	0.8	0.9	1.0	1.2	1.6	2.0			
Cooler regions; planting to 60% boll open in > 170 days. <i>Boggabri, Breeza, Cecil Plains, Pittsworth, Trangie</i>																								
10	1.7	6.3	13.6	23.7	52.2	100.0	100.0	2.6	7.7	15.7	26.5	56.3	100.0	100.0	4.1	10.2	19.2	30.9	62.8	100.0	100.0			
20	1.6	5.6	12.1	21.0	46.4	100.0	100.0	2.3	7.0	14.1	23.7	50.3	100.0	100.0	3.8	9.4	17.4	27.9	56.3	100.0	100.0			
30	1.4	4.9	10.7	18.6	40.9	100.0	100.0	2.1	6.3	12.6	21.0	44.5	100.0	100.0	3.5	8.5	15.7	25.0	50.3	100.0	100.0			
40	1.2	4.3	9.4	16.2	35.7	97.4	100.0	1.9	5.6	11.1	18.6	39.1	100.0	100.0	3.3	7.7	14.1	22.3	44.5	100.0	100.0			
50	1.1	3.8	8.1	14.1	30.9	84.2	100.0	1.7	4.9	9.8	16.2	34.1	89.3	100.0	3.0	7.0	12.6	19.8	39.1	97.4	100.0			
60	0.9	3.3	7.0	12.1	26.5	71.9	100.0	1.6	4.3	8.5	14.1	29.4	76.7	100.0	2.8	6.3	11.1	17.4	34.1	84.2	100.0			
70	0.8	2.8	5.9	10.2	22.3	60.6	100.0	1.4	3.8	7.3	12.1	25.0	65.0	100.0	2.6	5.6	9.8	15.1	29.4	71.9	100.0			
80	0.7	2.3	4.9	8.5	18.6	50.3	97.4	1.2	3.3	6.3	10.2	21.0	54.3	100.0	2.3	4.9	8.5	13.1	25.0	60.6	100.0			
90	0.6	1.9	4.1	7.0	15.1	40.9	79.1	1.1	2.8	5.3	8.5	17.4	44.5	84.2	2.1	4.3	7.3	11.1	21.0	50.3	92.0			
100	0.5	1.6	3.3	5.6	12.1	32.5	62.8	0.9	2.3	4.3	7.0	14.1	35.7	67.3	1.9	3.8	6.3	9.4	17.4	40.9	74.3			
110	0.4	1.2	2.6	4.3	9.4	25.0	48.3	0.8	1.9	3.5	5.6	11.1	27.9	52.2	1.7	3.3	5.3	7.7	14.1	32.5	58.4			
120	0.3	0.9	1.9	3.3	7.0	18.6	35.7	0.7	1.6	2.8	4.3	8.5	21.0	39.1	1.5	2.8	4.3	6.3	11.1	25.0	44.5			
130	0.2	0.7	1.4	2.3	4.9	13.1	25.0	0.6	1.2	2.1	3.3	6.3	15.1	27.9	1.4	2.3	3.5	4.9	8.5	18.6	32.5			
140	0.2	0.5	0.9	1.6	3.3	8.5	16.2	0.5	0.9	1.6	2.3	4.3	10.2	18.6	1.2	1.9	2.8	3.8	6.3	13.1	22.3			
150	0.1	0.3	0.6	0.9	1.9	4.9	9.4	0.4	0.7	1.1	1.6	2.8	6.3	11.1	1.1	1.6	2.1	2.8	4.3	8.5	14.1			
160	0.1	0.2	0.3	0.5	0.9	2.3	4.3	0.3	0.5	0.7	0.9	1.6	3.3	5.6	0.9	1.2	1.6	1.9	2.8	4.9	7.7			
170	0.0	0.1	0.1	0.2	0.3	0.7	1.2	0.2	0.3	0.4	0.5	0.7	1.2	1.9	0.8	0.9	1.1	1.2	1.6	2.3	3.3			

Table 2. Insect pest and damage thresholds

Insect pest	Planting to flowering (1 flower/m)	Flowering to 1 open boll/m	1 open boll/m to harvest		Comments
			Up to 15% open	After 15% open	
Helicoverpa spp. in conventional cotton					
White eggs/m	–	–	–	–	Egg thresholds
Brown eggs/m	–	5	5	5	No egg threshold during pre-flowering due to high natural mortality.
Total larvae/m	2	2	3	5	Larval thresholds
Medium and large larvae/m	1	1	1	2	Research on increasing the end of season thresholds has been carried out, and suggests that the threshold after 15% open can be raised to 5 total larvae/metre or 2 medium+large larvae /m. This research however, is preliminary and requires further analysis.
<i>Helicoverpa</i> Tip damage (% of plants affected)	100–200% (100% of plants tipped once or twice)	– –	– – <i>Helicoverpa</i> control can cease at 30–40% bolls open.		The <i>Helicoverpa</i> development model in CottonLOGIC can be used to estimate the development of a given egg and larval population over the next three days, taking into account estimated natural mortality levels for the time of season.
Helicoverpa spp. in Bollgard II® cotton					
	All season				
White eggs/m	–				
Brown eggs/m	–				
Total larvae/m (excluding larvae < 3 mm)	2/m over 2 consecutive checks				
Medium and large larvae/m	1/m on the first check				
Green mirids					
Adults and nymphs/m					The relative importance of the % fruit retention and % boll damage reverses as the season progresses. From the start of squaring through until cut-out, place the emphasis on fruit retention. Not all bolls that are damaged by mirids will be shed, so after cut-out it is important to monitor bolls for mirid damage. If only the terminal is blackened, damage could be considered light. If the terminal plus one or more true leaves are blackened, damage could be considered heavy.
cool region – visual	0.7	0.5	–	–	
warm region – visual	1.3	1.0	–	–	
cool region – beatsheet	2	1.5	–	–	
warm region – beatsheet	4	3	–	–	
Fruit retention	< 65%	< 65%	–	–	
Boll damage		20%		20%	
Tip damage (% of plants affected)					
(heavy)	20%	–	–	–	
(light)	50%	–	–	–	
Cotton aphid (check species)					
Presence of adults and nymphs	Calculate Cumulative Season Aphid Score*	Calculate Cumulative Season Aphid Score	50% infestation		Until 1% of the bolls are open calculate the Cumulative Season Aphid Score to determine the threshold.
honey dew presence	–	monitor for the presence of honey dew	10% infestation if honey dew present		* When using this Score in very young cotton, yield loss predictions should be treated with caution as in many cases aphid populations will naturally decline. Once open bolls are present in the crop, use 50% infestation. When 1% of bolls are open and honey dew is present, the aphid threshold is reduced to 10% infestation. Check field borders and spray them separately where necessary. Some cotton aphid strains are resistant to organophosphates and carbamates. Aphids can carry and transmit cotton bunchy top virus. Monitor plants in aphid hotspots for symptoms of this disease, such as mottling of leaf margins.
Green peach aphid					
% of plants infested	25%				May be a problem early season, populations normally decline in hot weather. Some populations are resistant to organophosphates and carbamates.
Mites					
% of leaves infested	30% Normally suppressed by predators. Use the table on page 19.	30% or population increases at > 1% of infested plants/day in 2 consecutive checks	> 60% No effect on yield after 20% bolls open.		A nominal threshold of 30% of leaves infested is used from seedling emergence up to 20% of bolls open. Alternatively, use the table on page 19 to base thresholds on potential yield loss. Yield loss is estimated using time of infestation and rate of population increase.

Table 2. Insect pest and damage thresholds (continued)

Insect pest	Planting to flowering (1 flower/m)	Flowering to 1 open boll/m	1 open boll/m to harvest		Comments
			Up to 15% open	After 15% open	
Thrips					
Adults and nymphs/plant	10	–	–	–	Control is justified if there are 10 thrips/plant plus the reduction in leaf area due to thrips is greater than 80% (roughly leaves less than 1 cm long). Control is also justified if there is a reduction in leaf area of more than 50% once the plant has reached the six true leaf stage. Thereafter, thrips are unlikely to affect the yield or maturity date of cotton crops. If conditions were cool or the plant had another set-back then the thresholds could be reduced.
Damage (reduction in leaf area)	80%	–	–	–	
Green vegetable bug					
Visual	–	0.5	0.5	0.5	Green vegetable bug cause significantly more damage to bolls less than 21 days old and prefer bolls 10 days old or less. Older bolls are generally not preferred. Instars 4, 5 and adults do the same amount of damage. Instar 3 does half the damage of instar 4 and 5 and adults. A cluster (more than 10) of first and second instars does as much damage as one adult. Thresholds are in adult equivalents.
Beat sheet, OR	–	1	1	1	
Damage to small bolls (14 day old)	–	20%	20%	20%	
Pale cotton stainers					
Visual	–	1.5	1.5	1.5	Threshold is based on relationship between cotton stainer damage and damage caused by other plant bugs. Both nymphs (usually 3rd to 5th stage nymphs) and adults cause similar amounts of damage.
Beat sheet	–	3	3	3	
Damaged bolls (%)	–	30%	30%	30%	
Cotton leafhopper					
(jassids)/m	50	–	–	–	
Tipworm					
Larvae/m	1–2	–	–	–	Sample for tipworm up until first flower. Larvae tend to burrow into the terminals and squares so may not be found using the beat sheet or sweep nets. Visual sampling methods are the most accurate. Bollgard II [®] cotton provides good control of tipworm.
Tip damage (% of plants affected) (not entrenched)	100–200%	–	–	–	
(entrenched)	50–100%	–	–	–	
Armyworm					
Large larvae/m	1	–	–	–	
Small larvae/m	2	–	–	–	
Rough bollworm					
Larvae/m	2	3	3	3	Susceptibility to rough bollworm starts when there are more than 5 bolls/m over 2 weeks old. Susceptibility ceases when there are fewer than 5 growing bolls/m less than 2 weeks old. Bollgard II [®] cotton provides good control of rough bollworm.
Damaged bolls (%)	–	3%	3%	3%	
Pink spotted bollworm					
% bolls infested	–	5	5	5	The threshold for pink spotted bollworm is based on the infestation as determined by examining inner boll walls. Bollgard II [®] cotton provides good control of pink spotted bollworm.
Loopers					
Larvae/m	–	20	50	50	

Identification via the computer

Photographs of insect pests and the damage they cause can be found on the Cotton CRC website and on the COTTONpaks CD version 2.1. The website and CD also contain detailed information on pest and beneficial identification, ecology and thresholds. For easy reference, pests and beneficials can be searched by image, common name or by scientific name.

www.cottoncrc.org.au/content/Industry/IndustryHome.aspx and look for Cotton Insect Id tool under Tools menu.

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