2009–10

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Cotton Pest Management Guide

Cotton CRC Extension Team

Cotton Catchment Communities CRC

Queensland Government

NSW Government Industry & Investment

Australian Government
Cotton Research and Development Corporation

Bayer CropScience Amparo full page colour

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ALWAYS READ THE LABEL

Users of agricultural chemical products must always read the label and any Permit before using the product, and strictly comply with the directions on the label and the conditions of any Permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or not made in this publication.

IMPORTANT: USE OF PESTICIDES

Pesticides must only be used for the purpose for which they are registered and must not be used in any other situation or in any manner contrary to the directions on the label. Some chemical products have more than one retail name. All retail products containing the same chemical may not be registered for use on the same crops. Registration may also vary between States. Check carefully that the label on the retail product carries information on the crop to be sprayed.

This publication is only a guide to the use of pesticides. The correct choice of chemical, selection of rate, and method of application is the responsibility of the user. Pesticides may contaminate the environment. When spraying, care must be taken to avoid spray drift on to adjoining land or waterways.

Pesticide residues may accumulate in animals treated with any pesticides or fed any crop product, including crop residues, which have been sprayed with pesticides. In the absence of any specified grazing withholding period(s), grazing of any treated crop is at the owner's risk. Withholding periods for stock treated with any pesticides or fed on any pesticide treated plant matter must also be observed. Animals which test positive for chemical residues (i.e. with readings which exceed maximum residue limits for certain chemicals) at slaughter will be rejected. Pesticide residues may also contaminate grains, oils and other plant products for human use and consumption. Growers should observe harvest withholding periods on the pesticide label and should not assume that in the absence of a withholding period or after the expiry of a withholding period that the plant products will be free of pesticide residues.

Some of the chemical use patterns quoted in this publication are approved under Permits issued by the Australian Pesticides and Veterinary Medicines Authority (APVMA) at the time the publication was prepared. Persons wishing to use a chemical in a manner approved under Permit should obtain a copy of the relevant Permit from the APVMA and must read all the details, conditions and limitations relevant to that Permit, and must comply with the details, conditions and limitations prior to use.

This publication replaces all previous cotton pesticide guides and cotton pest management guides.

The author:
Cotton CRC Extension Team

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Cover design: Yvette Cunningham (Cotton CRC)
Produced by Cotton Catchment Communities CRC, Narrabri and Industry & Investment NSW, Orange
November 2009

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Tables

Note from the editor

The Australian cotton industry continues to remain innovative and proactive despite a number of challenges. The 2009/10 Cotton Pest Management Guide is the key resource in cotton crop protection and this year's updates reflect many of the new and ongoing challenges the industry faces. Adopting best practice in pest management is vital in protecting yields, maximising returns and ensuring viability of the industry into the future.

The Cotton CRC extension team have all contributed to coordinating the many changes to the 2009/10 Cotton Pest Management Guide. Both the weed and spray application sectors have been fully reviewed and there are some great practical tips including what to do if you suspect herbicide resistance and how to set up spray equipment to maximise efficacy. There is an excellent description of the current situation for Bt resistance in the preamble to the Bollgard II® Resistance Management Plan (RMP).

Additions to this year's Guide include the;

- Profiling of cotton stainers in the Key Insect and Mite Pests section.
- Description of Q-biotype in the whitefly profile.
- Explanation of neonicotinoid resistance situation in the aphid profile.
- Inclusion of photographs in the Biosecurity section to assist in field identification of exotic pests and diseases that are threats to the Australian cotton industry.

Thank you to Bayer, Caltex, and Syngenta for supporting the Cotton Pest Management Guide in these difficult times. The annual production of this resource is dependent upon advertising revenue. Thank you to Cotton Catchment Communities CRC and CRDC for meeting the substantial shortfall and allowing the 2009/10 edition to proceed.

Special thanks also to Tracey Farrell, editor of the Cotton Pest Management Guide for the previous five years. Her continued contribution, is a reflection of her dedication to this publication and to the industry. Thanks to Yvette Cunningham for her contribution to the layout of the Guide.

Good luck for the season ahead.

Regards,

Susan Maas
Cotton CRC Extension Team

ACKNOWLEDGEMENTS

The updates for this season's version of the *Guide* would not be possible without assistance provided by many people (in aphabetical order) from; ***Cotton CRC Extension Team*** Sally Ceeney, Yvette Cunningham, James Hill, Dallas King, Susan Maas and Duncan Weir. ***CRDC*** Tracey Farrell. ***Industry & Investment NSW (I&I NSW)*** Graham Charles, Barry Jensen, David Larsen, Louise Rossiter, Andrew Storrie and Mark Scott. From ***CSIRO*** Sharon Downes and Lewis Wilson. From ***Department of Employment, Economic Development and Innovation (DEEDI)*** Zara Ludgate. ***Also*** Stephen Allen CSD.

Cover photos Mary Whitehouse, Alison Seyb, Todd Green, Helen Squires and James Hill.

FURTHER INFORMATION AND PUBLICATIONS

For further information contact you regional cotton extension officer, district agronomist or the Technology Resource Centre of the CRC;

Cotton Catchment Communities CRC
Technology Resource Centre
Australian Cotton Research Institute
Locked Bag 59 Narrabri, NSW 2390
Phone (02) 6799 1534 Fax (02) 6799 1582

Publications available from the TRC include; *CottonLOGIC CD, Cotton Pest and Beneficial Insect Guide, Integrated Pest Management Guidelines for Cotton Production Systems in Australia, ENTOpak, MACHINEpak, SOILpak, WEEDpak, NUTRIpak, SPRAYpak, Integrated Disease Management Guidelines, WATERpak, Managing riparian lands in the cotton industry,* **COTTONpaks CD (includes all above publications),** *Cotton CRC Info Sheets.*

Other publications including *Australian Cotton Industry Best Management Practice* (BMP) *Manual* are also available from:
Cotton Research and Development Corporation
PO Box 282, Narrabri NSW 2390
Phone (02) 6792 4088 Fax (02) 6792 4400

Websites for further information

Cotton Catchment Communities CRC (Cotton CRC)
www.cottoncrc.org.au
Cotton Research & Development Corporation (CRDC) www.crdc.com.au
Cotton Australia (CA)
www.cottonaustralia.com.au
Industry & Investment NSW (I&I NSW)
www.industry.nsw.gov.au
Department of Employment, Economic Development and Innovation (DEEDI)
www.dpi.qld.gov.au
Australian Pesticides & Veterinary Medicines Authority (APVMA) www.apvma.gov.au


Spotted anything unusual?

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 *Helicoverpa* 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:

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

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

<table>
<tr><th>Occasional detection of resistance</th><th>Widespread resistance</th></tr>
<tr><td>Indoxacarb
Spinosad
emamectin benzoate
chlorpyrifos (OP)
profenofos (OP)
bifenthrin (SP)</td><td>Endosulfan (OC) – low frequency
methomyl/thiodicarb (carbamate) (moderate frequency)
pyrethroids (high frequency)</td></tr>
<tr><th colspan="2">Cross Resistance</th></tr>
<tr><td colspan="2">A negative cross resistance exists between indoxacarb and pyrethroids. The esterases produced by H. armigera that are associated with pyrethroid resistance increase the insecticidal activity of indoxacarb.
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.</td></tr>
</table>

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

DEEDI, Toowoomba
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, 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

DEEDI, Toowoomba
Melina Miles: (07) 4688 1369

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.

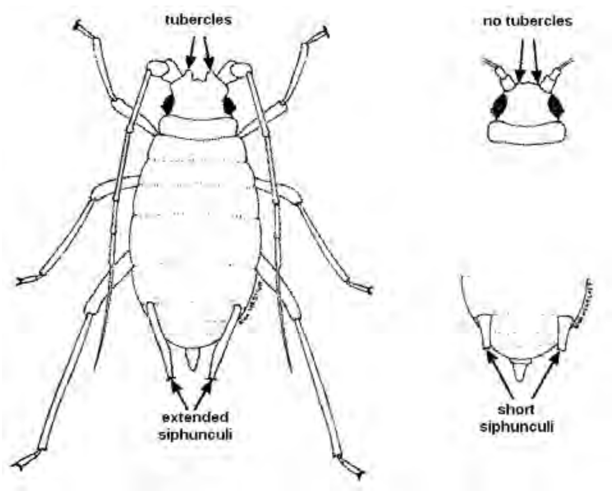
Population: Sample for non-adults and nymphs on the underside of mainstem leaves 3–4 nodes below the plant terminal. If a high proportion of plants have only the winged form, recheck within a few days to see if they have settled and young are being produced.

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.

Green peach aphid
Myzus persicae

Cotton aphid
Aphis gossypii



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 cm^2. 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 actives 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 judicial 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 and discolouration 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 amouts 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

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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

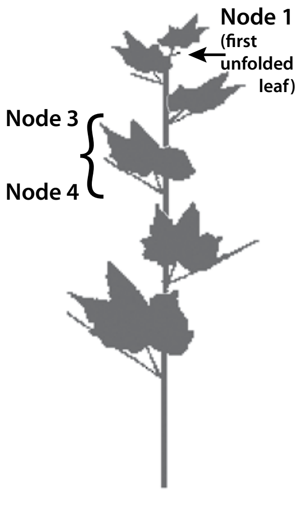
Abamectin resistance has occassionally been detected at high levels in two-spotted spider mite in horticulture, but not in cotton. Populations of the bean spider mite and the strawberry spider mite have not been tested for resistance to miticides because they are so rarely a problem in cotton.

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.

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.

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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Grant Herron: (02) 4640 6471

Whitefly

Silverleaf whitefly (SLW) or B biotype – *Bemisia tabaci*
Q-biotype, *Bemisia tabaci*
Eastern Australian native whitefly (EAN) – *Bemisia tabaci*
Greenhouse whitefly (GHW) – *Trialeurodes vaporiorum*

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 similiarly 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.

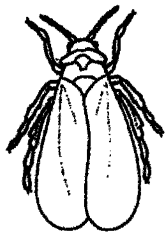
Frequency
Sample the **population** at weekly intervals from first flower. From peak flowering, twice weekly sampling is highly recommended. Continue twice weekly sampling until defoliation. The **species** composition may change during the season. Species verification should be done more than once. 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

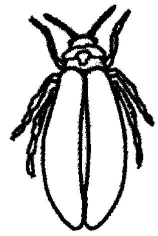
For SLW, there are separate thresholds for early season suppression, the use of IGRs (Insect Growth Regulators) and for knockdown late in the season. Thresholds are based on rates of population increase relative to the accumulation of day degrees and crop development. A threshold matrix has been developed 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 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.



Trialeurodes vaporiorum

Greenhouse whitefly



Bemisia tabaci

Eastern Australian native whitefly or

Silverleaf whitefly or Q-biotype

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 managment 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 thesholds 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 then 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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DEEDI, Toowoomba
Richard Lloyd: (07) 4688 1315
Zara Ludgate: (07) 4688 1436

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 cm^2, 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 benificial 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
Lewis Wilson: (02) 6799 1550 or 0427 991 550

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

DEEDI, Kingaroy
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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 lambdacyhalothrin (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

DEEDI, Kingaroy
Moazzem Khan: (07) 4160 0705 or 0428 600 705
CSIRO Plant Industry, Narrabri
Lewis Wilson: (02) 6799 1550

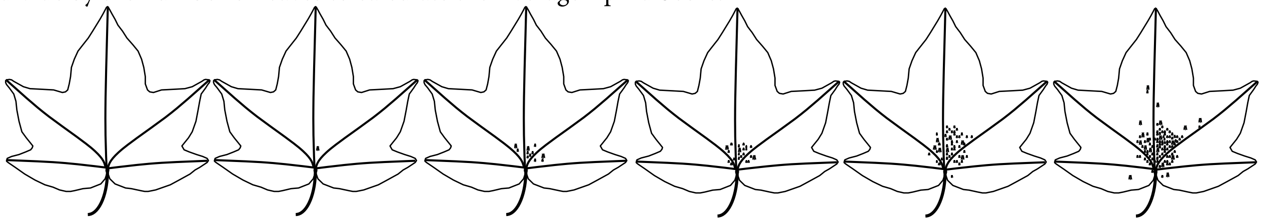
Sampling protocols for cotton aphid for use until first open boll

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.



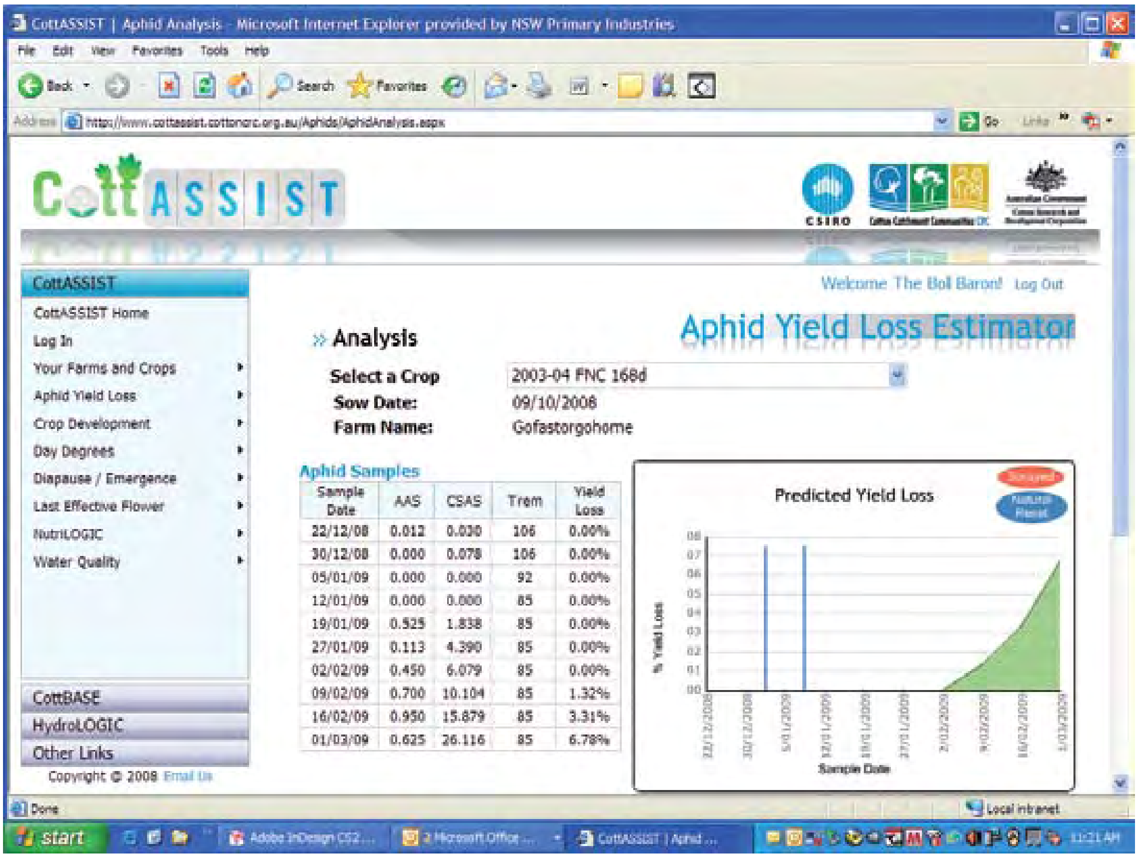
Score = **0**	Score =**1**	Score = **2**	Score = **3**	Score = **4**	Score = **5**
No aphids	1–10 aphids	11–20 aphids	21–50 aphids	51–100 aphids	> 100 aphids

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.



Sample Date	AAS	CSAS	Trem	Yield Loss
22/12/08	0.012	0.030	106	0.00%
30/12/08	0.000	0.078	106	0.00%
05/01/09	0.000	0.000	92	0.00%
12/01/09	0.000	0.000	85	0.00%
19/01/09	0.525	1.838	85	0.00%
27/01/09	0.113	4.390	85	0.00%
02/02/09	0.450	6.079	85	0.00%
09/02/09	0.700	10.104	85	1.32%
16/02/09	0.950	15.879	85	3.31%
01/03/09	0.625	26.116	85	6.78%

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 *last* check	Average score *this* 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
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 ....

....

....

....

....

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.

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).

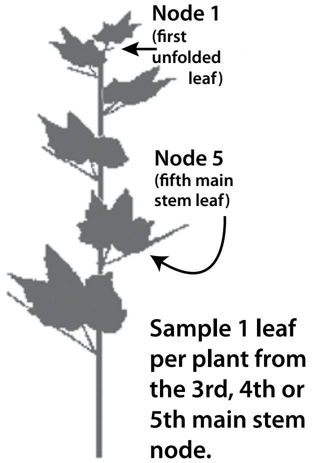
2. Choose a plant to sample

- 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

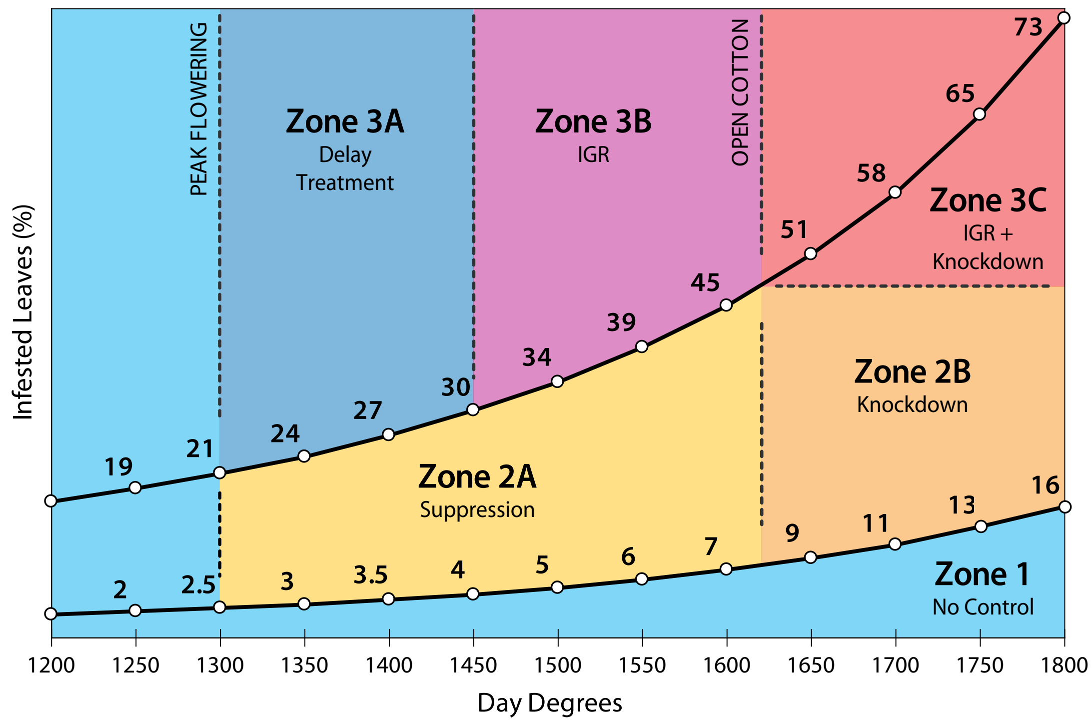
- Binomial sampling (presence/absence) is highly recommended as it is less prone to bias than averaging the number of whitefly/leaf.
- Score leaves with 2 or more whitefly adults as 'infested'. Score leaves with 0 or 1 whitefly adults as 'uninfested'.
- Calculate the percentage of infested leaves.

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 poulations of aphids and mites.

SLW Threshold Matrix



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 °C – 12) + (Min °C – 12)] ÷ 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. *Biloela, Bourke, Emerald, Macintyre, Mungindi, St. George, Theodore and Walgett*																					
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. *Dalby, Gwydir, Lockyer, Lower Namoi*																					
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. *Boggabri, Breeza, Cecil Plains, Pittsworth, Trangie*																					
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	
Medium and large larvae/m	1	1	1	2	**Larval thresholds** 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.
Helicoverpa Tip damage	100–200%	–	–	–	
(% of plants affected)	(100% of plants tipped once or twice)	–	*Helicoverpa* control can cease at 30–40% bolls open.		The *Helicoverpa* 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.
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%	–		If only the terminal is blackened, damage could be considered light.
Boll damage		20%	20%		
Tip damage (% of plants affected)					If the terminal plus one or more true leaves are blackened, damage could be considered heavy.
(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. * 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.
honey dew presence	–	monitor for the presence of honey dew	10% infestation if honey dew present		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 supressed 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: Up to 15% open	1 open boll/m to harvest: After 15% open	Comments
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		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		
Damage to small bolls (14 day old)	–	20%	20%		
Pale cotton stainers					
Visual	–	1.5	1.5		Threshold is based on relationship between cotton stainer damage and damage caused by other plant bugs. Both numphs (usually 3rd to 5th stage nymphs) and adults cause similar amounts of damage.
Beat sheet		3	3		
Damaged bolls (%)		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		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%		
Pink spotted bollworm					
% bolls infested	–	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		

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.

Phone: 02 6799 1534 or email: david.larsen@industry.nsw.gov.au

Cotton Industry Biosecurity Plan

Compiled by Sharyn Taylor, Plant Health Australia; Susan Maas and Cherie Gambley, Department of Employment, Economic Development and Innovation; Lewis Wilson CSIRO and Greg Kauter, Cotton Australia .

In 2009, Plant Health Australia (PHA), Cotton Australia Ltd and the Cotton Industry Biosecurity Group reviewed the Cotton Industry Biosecurity Plan (IBP). This plan, originally released in 2006 was formulated by industry, state and federal governments and Plant Health Australia to assist with identification of biosecurity priorities and allocation of resources to critical areas and the generation of strategies to maximise adoption of recommended practices and awareness of new biosecurity threats.

WHY DOES THE AUSTRALIAN COTTON INDUSTRY NEED A BIOSECURITY PLAN?

Australia's geographic isolation has meant that it is relatively free of many pests that cause significant problems for cotton production overseas. Maintaining Australia's freedom from these exotic pests will help ensure the future profitability, sustainability and marketability of Australian cotton.

Industry biosecurity aims to minimise risks posed by exotic organisms. For this to be effective it relies on the involvement of all stakeholders – including growers, industry, government agencies and the public. Through the IBP the cotton industry has in place procedures to:

– identify the highest risk pests from overseas (threat identification and analysis);

– guard the industry against exotic pests (risk mitigation activities);

– know when an exotic pest has arrived (surveillance) and identify it (diagnostics); and

– deal with exotic pests if they are found (contingency plans).

To date, 12 key organisms have been identified as threats to the industry based on the economic risk they present should they become established in Australia. At this stage, only invertebrate pests an diseases have been identified as threats although weeds may be revisited at future reviews.

A copy of Version 2 of the Cotton IBP will be available from the PHA website biosecurity section from December 2009.

HOW HAVE THE PEST AND DISEASE THREATS BEEN DETERMINED?

The relative importance of potential pest problems have been ranked by experts in the IBG by estimating the level of threat associated with the probability of the pest's entry into Australia, factors influencing the pest's establishment and spread, the difficulty of identification and/or eradication, as well as the likely impacts of the pest on production and market access.

FARM BIOSECURITY

Cotton growers are the key to protecting Australian cotton crops from exotic insects and diseases. Growers should look out for unusual crop symptoms and implement practices that prevent or minimise pest incursions.

Good farm hygiene – come clean, go clean – should be practiced on all farms regardless of whether pests or diseases are present. Pest control based on thorough monitoring will not only minimise the impact of pests on your crop but can also minimise the spread of an exotic pest before their presence is known or after they are identified. Diseases can be spread by animals, people and machinery so farm hygiene and restricting unnecessary people and vehicle movement around the farm will prevent disease spread. Volunteers and some weeds can harbour pests and diseases. Controlling weeds in non-crop areas around the farm reduces the potential for pest and disease build up.

Visits to farms overseas should be declared on re-entry to Australia. Prior to returning to Australia, wash all clothes and foot wear as well as hair which may carry fungal spores.

To assist provide information on Farm Biosecurity measures, PHA, in conjunction with Animal Health Australia, has initiated the Farm Biosecurity Program, which brings together a range of practices that to keep crops free of pests. For further information visit farmbiosecurity.com.au.

SURVEILLANCE IN THE COTTON INDUSTRY

A major part of implementing the Cotton IBP and Farm Biosecurity measures is surveillance for exotic plant pests. The key aim of surveillance is for detection of pests as early as possible. The benefits of early detection of a new pest to the cotton industry will be:

– an increased chance that eradication or containment within a limited area will be successful;

– reduced cost to industry and the surrounding community if eradication or containment can be achieved; and

– more rapid implementation of new management practices if eradication is not possible.

While AQIS has strict controls for the introduction of cotton plants and seeds at the border, many of these pests are small or difficult to see. There is still a chance of their accidental introduction as hitchhikers, such as in packing material or in soil or plants in poorly cleaned machinery and equipment. Some pests can also arrive on people's clothing, boots and hair or in accidentally or deliberately undeclared plant material.

Surveillance for several exotic pathogens is undertaken as part of routine assessment of cotton field trials by I&I NSW, QPI&F and cotton breeding programs.

REPORTING UNUSUAL PESTS

Any unusual plant pest should be reported immediately to your Department of Primary Industry (DPI) or by ringing the Exotic Plant Pest Hotline. Early reporting enhances the chance of effective control and eradication. It is important to note that suspect material should not be moved or collected without seeking advice from the DPI as incorrect handling could spread the pest or render samples unsuitable for identification.

HOW CAN WE LEARN MORE?

More information about prevention and control of pests and diseases can be found on the Cotton CRC website at www.cottoncrc.org.au

Further information on cotton industry biosecurity activities please contact Greg Kauter (02) 9669 5222 or go to www.cottonaustralia.com.au/research/biosecurity/

To view the Australian Cotton Industry Biosecurity Plan visit: www.planthealthaustralia.com.au/

Phone the Exotic Plant Pest Hotline on 1800 084 881.

EXOTIC PLANT PEST HOTLINE
1800 084 881

Exotic pests and diseases of greatest threat to Australian cotton

COTTON BOLL WEEVIL (*ANTHOMONUS GRANDIS*)

Cotton boll weevil is specific to cotton and causes large yield losses due to damage to developing bolls and subsequent reduction in lint production. In the USA, control of cotton boll weevil using insecticides costs hundreds of millions of dollars.

Boll weevil (Jack Kelly Clark, University of California, www.ipm.ucdavis.edu)

SPIDER MITES (TETRANYCHID MITES)

Spider mites are in the group that includes ticks. They feed on the undersides of leaves, sucking out the cell contents. Their damage causes a characteristic bronzing of leaves, and if uncontrolled can dramatically reduce yield and fibre quality. Several species are found in Australian cotton, the most common of which is the two-spotted spider mite. However, overseas there are a range of other species that have different host preferences, cause more severe damage or have resistance to some of our key acaricides.

Adult female carmine spider mite, Tetranychus cinnabarinus (Jack Clark, University of California, www.ipm.ucdavis.edu)

INDIAN GREEN JASSID (*AMRASCA DEVESTANS*)

Indian green jassid is a sap-sucking insect pest that can cause yield losses of up to 25%. While several 'jassid' species are found in Australian cotton the damage they cause is relatively minor, rarely if ever affecting yield. Green jassids inject a toxin as they feed that causes leaves and bolls to drop and can stunt plant growth. Elsewhere green jassids can be managed using resistant varieties and insecticides. Hairy-leafed varieties are used in parts of Africa and the sub-continent where cotton is hand harvested to provide effective resistance against green jassids. Such varieties are not suitable for mechanical harvest as the leaf hairs cause excessive leaf trash in the cotton lint.

Indian green jassid (Industry & Investment NSW)

TARNISHED PLANT BUG (*LYGUS LINEOLARIS*)

The tarnished plant bug is a pest of over 250 plant species. In cotton, its feeding causes seed abortion, stem or leaf wilting and poor seed germination. It has 2–5 generations per year and can therefore quickly build up to high levels.

Lygus bug (Jack Kelly Clark, University of California, www.ipm.ucdavis.edu)

WHITEFLY (*BEMISIA TABACI* B-TYPE OR Q-TYPE)

Whitefly feeding results in a sticky residue, sooty moulds, reduced boll size and poor lint quality. Although the B-type whitefly is present in Australia there is a risk of other B-type strains and other biotypes, e.g. Q-type, entering the country with different insecticide resistance profiles. Whiteflies are also vectors of damaging exotic viruses such as cotton leaf curl disease.

Bemisia tabaci B-type (Neil Forester)

MELON APHID (*APHIS GOSSIPYI* EXOTIC STRAINS)

Aphids damage cotton by feeding on young leaves and bolls which can reduce yield. They produce a sticky residue that can cover leaves resulting in reduced photosynthesis and contamination of lint as bolls open, reducing the crop's value. This species may also carry exotic diseases such as blue disease. As well as the risk of disease, there is a risk that new aphid strains entering the country will have different insecticide resistance profiles, making control more difficult.

Melon Aphid (Lewis Wilson, CSIRO)

VERTICILIUM WILT – DEFOILATING STRAINS

Australian strains of Verticilium wilt are described as mild in comparison to the defoliating stratins that originated in North America but are now becoming more widespread. If established in Australia, management would be reliant on the use of resistant varieties, with a lag of several years before adapted varieties were available.

COTTON LEAF CURL DISEASE (CLCUD)

CLCuD, sometimes referred to as Gemini virus, can cause yield losses of up to 35% in cotton. It is spread by a whitefly vector. There are at least seven different begomoviruses and several different DNA satellite molecules associated with CLCuD. A cotton plant needs to be infected with at least one begomovirus and one satellite to develop CLCuD.

Symptoms of CLCuD are seen on leaves and initially appear as a swelling and darkening of leaf veins, followed by a deep downward cupping of the youngest leaves then either an upward or downward curling of the leaf margins. Leaf-like structures (enations) on the veins are common and vary in size from only a few millimetres in diameter to almost the size of a normal leaf. These larger structures are often cup-shaped.

Leaf Curl Disease (Cherie Gambley, QPIF)

FUSARIUM WILT (*FUSARIUM OXYSPORUM F. SP. VASINFECTUM* – EXOTIC STRAINS)

Fusarium wilt is a fungal disease. Strains of Fusarium were identified in Australia in 1993 however the introduction of new strains (races) would increase the difficulty of management as new resistant varieties would be required.

External symptoms can appear in the crop at any stage but most commonly appear in either the seedling phase or after flowering when bolls are filling. Leaves appear dull and wilted before yellowing or browning progresses to eventual death from the top of the plant. Seedlings may either wilt and die or survive, but often with stunted growth. Adult plants may wilt and die, especially under conditions of stress. Some affected plants may re-shoot from the base of the stem. Lengthwise cutting of the stem from affected plants will show continuous brown discolouration of the tissue. The internal discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecks. Sometimes the discolouration is visible in only one side of the stem. External symptoms do not always reflect the extent of discolouration in the stem.

Fusarium wilt causing vascular discolouration and root knots caused by nematodes. (Chris Anderson, I&I NSW)

TEXAS ROOT ROT (*PHYMATOTRICHOPSIS OMNIVORE*)

Texas root rot is an extremely damaging fungal disease with a wide host range. It causes sudden death of affected plants, usually during the warmer months. In cotton, infection can result in 100% crop loss. If this disease became established in Australia, control would be extremely difficult as management using rotations and fungicides is usually only partially effective.

Symptoms include yellowing or bronzing of leaves, leaves wilt and die; dead leaves usually remain on plant. At this stage, roots are dead and surface is covered with network of tan fungal strands.

Texas Root (Chris Anderson, I&I NSW)

BLUE DISEASE

Blue disease is a virus specific to cotton that can reduce yield potential by up to 20%. It is spread by a vector, the cotton aphid. It has been associated with plants infected with cotton leaf roll dwarf virus (CLRDV) and has similarities with cotton bunchy top, anthocyanosis and cotton leaf roll. It is not known if the same pathogen causes all these diseases or if there are multiple pathogens causing similar symptoms. CLRDV was not detected from Australian cotton affected by cotton bunchy top disease. Cotton blue disease affected leaves tend to be smaller, thick, more brittle and leathery and have an intense green to bluish colour with yellow veins. Reddening of stem petioles and leaf veins can occur in some infections. Leaf edges tend to roll downwards and under and plants become stunted due to a shortening of the branch internodes and produce many branches, giving a bunchy zig-zag stem habit. Symptoms are more obvious in plants infected at an early age and stunting is more pronounced. Infected plants also produce smaller bolls and boll shed may occur. Single infected plants can be overlooked if overgrown by nearby healthy plants.

BACTERIAL BLIGHT (XANTHOMONAS AXONOPODIS OR *X. CAMPESTRIS* PV MAVACEARUM – EXOTIC STRAINS)

Although strains of bacterial blight are already present in Australia, they are no longer a problem due to varietal resistance. Exotic strains (races) occur, however, that are 'hypervirulent' and, if established in Australia, would cause large yield losses. The disease is seed borne allowing easy dispersal and introduction of new races into new areas. Bacterial blight is spread by high temperature, humidity and rainfall.

The initial symptoms include the undersides of leaves have angular water soaked lesions. Lesions dry and darken with age then leaves are shed. Black lesions spread along stem. Bolls often infected at base or tip. Lesions dry out and prevent the boll opening. The pathogen is capable of symptomless transfer and therefore could be undetected through quarantine.

Symptoms include yellowing or bronzing of leaves, leaves wilt and die; dead leaves usually remain on plant. At this stage, roots are dead and surface is covered with network of tan fungal strands.

Blue Disease (Ivan Bonacic INTA – EEA Sáenz Peña)

Integrated Pest Management (IPM) guidelines for Australian cotton II

Lewis Wilson and Sandra Deutscher, CSIRO; Robert Mensah and Annie Johnson, formerly Industry & Investment NSW.

These guidelines are a brief version of the *Integrated Pest Management Guidelines for Australian Cotton II*. For more details on any of the following pages please contact the Australian Cotton Research Institute for a copy of the *IPM Guidelines II*.

WHAT IS IPM?

IPM involves using all means of managing pest populations with the aim of reducing insecticide use whilst maintaining profitability (yield, fibre quality and crop maturity). IPM is a whole year approach to managing pests. This includes management of pests through the cotton growing season, and through the remainder of the year as well. For instance, decisions made in the autumn and winter can have a lasting impact on pest management throughout the year.

WHY DO WE NEED TO DEVELOP IPM PROGRAMS?

Over-reliance on synthetic insecticides creates problems, such as insecticide resistance of the major pests (particularly *H. armigera*), disruption of natural enemies of the pests leading to outbreaks of secondary pests such as mites, aphids or whitefly and other environmental consequences. These problems have cast doubt over the long-term viability of the traditional insecticide dominated approach to pest management.

A major goal for the cotton industry is to reduce dependence on foliar and soil applied insecticides. This can be achieved by developing an IPM program that integrates a range of pro-active management tactics, especially the conservation and use of natural enemies (predators and parasites) to control pests.

HOW DO WE IMPLEMENT IPM?

IPM involves integrating a range of tools and strategies for managing pests. These can be conveniently grouped in seven main objectives:

1. Growing a healthy crop
2. Keeping track of insects and damage
3. Preserving beneficial insects
4. Preventing insecticide resistance
5. Managing crop and weed hosts
6. Using trap crops effectively
7. Communication and training

These objectives are explained below and there is a Seasonal activity plan for IPM in Table 5 on page 46.

Objective 1. Growing a healthy crop

This objective covers the key issues for good crop agronomy and highlights how they interact with IPM.

Crop management can affect IPM. Growing a healthy cotton crop optimises both its yield potential and capacity to compensate for pest damage. In irrigated cotton, a healthy crop begins with good field preparation, soil moisture and plant establishment. Poor fertiliser or irrigation management can delay crop maturity and increase the length of time that the crop requires protection from pests, which can potentially increase insecticide resistance selection.

Field selection

When selecting fields for planting cotton consider proximity to sensitive areas such as watercourses, pastures, buildings, and the prevailing wind direction. Bollgard II® varieties may be appropriate for fields near sensitive areas. Another consideration would be the proximity of these cotton fields to other crops or orchards which can potentially act as a source for secondary pests such as mites, aphids or whitefly. Pest resistant varieties should be kept together, such as Bollgard II® or okra leaf types, rather than mixing them with other varieties. This reduces the chance of sprays applied to conventional fields disrupting fields that do not need spraying at that time.

Seed bed preparation

A tactic often mentioned by cotton growers in achieving an early crop is a good seed-bed, typified by friable, non-cloddy soil and firm, high, well-shaped beds. This helps achieve vigorous, healthy, early growth that tolerates seedling disease better and achieves early crop maturity and high yield potential. High beds also reduce the risk of waterlogging by encouraging good drainage. Planting cotton into standing stubble (wheat, sorghum) may offer some benefit in terms of soil condition, insect management and water infiltration. For more information see the publication *Planting cotton in standing wheat stubble,* available from the Cotton CRC web site www.cottoncrc.org.au

Selecting a variety

The cotton varieties planted should be matched to the region and likely pests and diseases (see seed company variety guides or websites). Select a variety that suits the growing region in terms of length of season. This will benefit the maturity timing of the crop which in turn will benefit fibre quality and defoliation as well as reducing the exposure to late season pest attack. Shorter season varieties may also be considered as the shorter growing period reduces the time the crop needs to be protected from pest damage. Okra-leaf varieties have a degree of resistance to *Helicoverpa* spp., spider mites and silverleaf whitefly, which can potentially reduce the control needed for each pest by about one spray per season. Penetration of insecticides into the crop canopy is better with okra leaf cultivars, which can contribute to better control.

In areas following a wet winter or in fields with poor weed control, the risk of early season aphids increases. It may be advantageous to plant a Cotton Bunchy Top (CBT) resistant variety. This would reduce the need to control aphids at low densities to prevent the spread of CBT therefore also reducing the risk of selecting for insecticide resistant aphids.

Bollgard II® cotton is ideally suited to IPM as the level of control of *Helicoverpa* spp. provided by the plant is usually sufficient to dramatically reduce the need to spray for this pest or other lepidopteran pests such as tipworm, especially early season.

Planting window

In each cotton region there is a period when soil temperatures become suitable for cotton germination, 14°C minimum at planting depth. Planting at this time usually maximises plant establishment and avoids the risk of cold shock (night temperature < 12°C). Cold shock slows early growth and reduces tolerance to herbicides, seedling diseases and early pests, especially thrips. Very late planted cotton has less yield potential and is more susceptible to pests such as whitefly and late season infestations of *H. armigera* both of which are difficult and expensive to control.

Coordinating planting in a region to a specified window avoids a wide spread of crop maturation, especially very late crops that require pest control over a prolonged period. Avoiding prolonged insecticide use helps manage insecticide resistance as it reduces the number of generations of the pest that are exposed to insecticides, therefore reducing the selection pressure for resistant pests.

Planting windows are critical to the success of area-wide management strategies. In areas susceptible to whitefly, coordinated planting windows can provide a period free from host crops to reduce population build up as well as preventing late crops. The 42 day planting window for Bollgard II® cotton is a critical component of the resistance managmenet plan. In specific circumstances growers in a region can apply to the APVMA for a variation in the nominated start/finish dates of their 42 day window. Details of this process can be found on page 63.

Optimising earliness

Although managing a crop for earliness is a good strategy, it does not always maximise yield. For more information on managing for early maturity, refer to the *Integrated Pest Management Booklet – Objective 1. Manage the crop for early maturity* in the *Australian Cotton Industry Best Management Practices Manual.*

Optimising water and nitrogen

Adequate water and nutrition will ensure healthy growth of plants that are more tolerant of pests and diseases. Too much nitrogen creates excessive cotton growth toward the end of the season and perhaps even the need for an extra irrigation. This makes the crop more attractive to pests, requiring additional inputs of insecticides (and mixtures of insecticides) for control, and application of high rates of growth regulators to retard growth. Too much nitrogen also undermines the effectiveness of the last generation trap crop by maintaining the attractiveness of cotton relative to the trap crop. Defoliation can also be more difficult and regrowth may harbour aphids.

Growth regulators

Excessive vegetative growth is a problem because it reduces the retention of fruit and delays maturity. Rank growth of plants also results in reduced efficacy of insecticides due to poor penetration of the canopy.

Optimal irrigation scheduling and nitrogen rates will generally prevent excessive vegetative growth, apart from during hot growing conditions. Appropriate use of growth regulators can help to reduce the likelihood of a rank crop that will not cut-out. Consult the guidelines published by the cotton seed companies to see if growth regulators are required.

Growth regulators are also used at or near cut-out, to reduce the amount of fresh regrowth and the attractiveness of the crop. This strategy is used to lessen the likelihood of late pest infestations and reduce the number of late season sprays.

See Cotton Seed Distributors (www.csd.net.au) calculating vegetative growth rates to determine crop needs.

Final irrigation

The timing of the last irrigation aims to ensure that boll maturity is completed without water stress, and at the same time prevent the occurrence of lush vegetative growth in crops late in the season to avoid the crop being attractive to the *Helicoverpa* spp. and other pests such as aphids and whitefly. Regular assessment of crop maturity will allow the dates of last irrigation and defoliation to be predicted.

Defoliation

The timing of defoliation can be an important IPM tool, as late pest infestation problems can sometimes be overcome by a successful defoliation. The safe timing of defoliation is when the youngest boll expected to reach harvest is physiologically mature. This usually occurs when 60–65% of bolls are open. The other method of assessing physiological maturity is when there are 3–4 nodes of first position bolls above the highest cracked first position boll (last harvestable boll), known as nodes above cracked boll (NACB).

Objective 2. Keeping track of insects and damage

The purpose of crop monitoring is to determine:

- the pest(s) present
- the level of infestation
- the damage they are causing
- the level of beneficial insects
- expected response to control options
- environmental conditions
- the growth stage of the crop

This information provides the basis on which pest management decisions are made.

Check frequently

Crops should be checked frequently for pests, beneficials and for damage and fruit retention. Regular and frequent checking provides an overview of what is happening in a field in relation to pest and beneficials abundance and development. For more detailed information on checking frequency see '*Key insect and mite pests of Australian cotton*' on pages 1–15.

It is generally not possible to make a decision about whether control is needed based on just one check. The decision making system needs to be flexible to allow for the action of beneficials and natural mortality to occur between checks, without the pest population developing to a stage where control is impractical or too expensive.

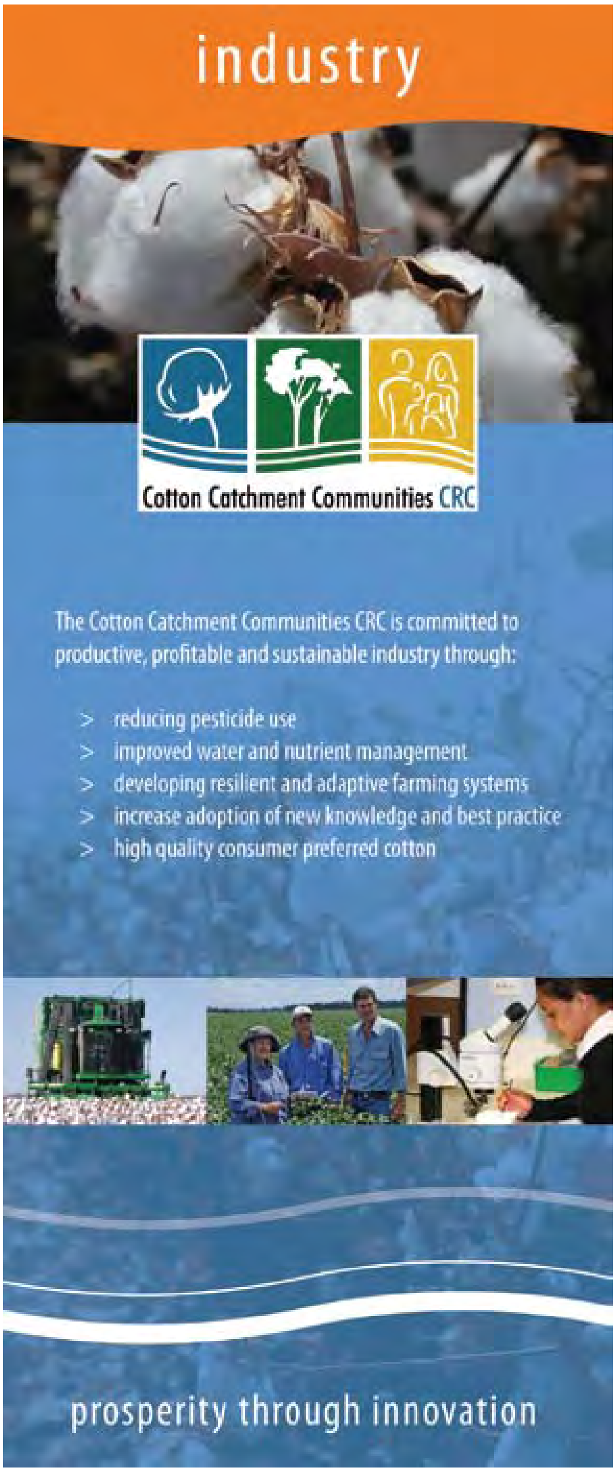
Insect numbers should be recorded either as numbers per metre or as a percentage of plants infested to easily compare numbers with the appropriate industry threshold and to allow a predator to prey or pest ratio to be determined.

MONITORING PESTS AND BENEFICIALS

Types of sampling techniques

Visual sampling: This involves looking at the entire plant, including under leaves, along stems, in squares and around bolls.

Beat sheet sampling: A sheet of yellow canvas 1.5 m × 2 m in size is placed in the furrow and extended up and over the adjacent row of cotton. A metre stick is used to beat the plants 10 times against the beat sheet, moving from the base to the tops of the plants. Insects are dislodged from the plants onto the canvas and are quickly recorded. This method is difficult to use when the field and plants are wet.



D-vac sampling can be used as an alternative to visual checking to sample beneficial insects and spiders.

Sweep net sampling: This method can be used as an alternative to the beat sheet when the field is wet. Sweep netting is an effective method for sampling flighty insects such as mirids, and each sample consists of 20 sweeps along a single row of cotton using a standard (380 mm) sweep net.

Comparison of methods: A recent study has shown that *Helicoverpa* spp., whitefly, mites, aphids, thrips and apple dimpling bug nymphs were best sampled visually, while the beat sheets were superior for the majority of other insects and spiders and the sweep net is particularly useful for sampling flighty insects such as mirid adults. Once the crop reaches 9–10 nodes, beat sheets can detect about 3 times the number of insects compared to visual sampling. Sweep nets can detect about 3 times the number of mirid adults as visual sampling, although only 1.6 times the number of mirid nymphs. These differences must be kept in mind when using the predator to pest ratio or pest threshold, as they are based on visual counts.

Refuge crops

Sampling of lucerne strips or other refugia crops to assess predator abundance should use a similar method but d-vac sampling is the most appropriate and fastest method to assess beneficial insect populations in lucerne.

How much to check

Fields are rarely uniform in crop growth and attractiveness to insects. Lush areas, such as near the head ditch, are more attractive to insects. Awareness of such areas and their size helps you to determine how many sample points are required in a crop.

Visual sampling: Check at least 30 plants or 3 to 4 separate metres of cotton per 50 ha.

Beat sheet sampling: Preliminary studies indicate that you need to beat at least 8–10 metres per field.

Sweep net sampling: Preliminary studies indicate that you need to take at least 6 sweep net samples per field.

Note: Increasing the number of samples usually increases the level of accuracy. For some pest species there are specific recommendations, see pages 1–15.

Monitoring levels of egg parasitism

It is also important to consider natural levels of *Helicoverpa* spp. parasitism caused by parasitoids such as *Trichogramma* spp. and *Telenomus* spp.

The *Trichogramma* spp. wasps are egg parasitoids capable of causing high mortality of *Helicoverpa* spp. in crops. The wasp kills its host by laying an egg inside a *Helicoverpa* spp. egg. The resulting wasp larva then feeds on the developing *Helicoverpa* spp. larva killing it before it hatches.

The most accurate way to monitor egg parasitism by *Trichogramma* spp. is to collect brown eggs and keep them at room temperature (about 25°C) until they hatch (healthy) or turn black (parasitised). Collecting white eggs gives an under-estimate of parasitism because they may have just been laid and not had sufficient time to be found by *Trichogramma* spp..

Monitoring levels of larval parasitism

There are no obvious external signs on larvae parasitised by *Microplitis* spp., but medium larvae (13–15 mm in length) can be split to reveal if the internal parasitoid larva is present. This is a simple procedure and can provide useful information about the potential survival of medium larvae.

Bollgard II® sampling and management

Bollgard II® cotton must be monitored regularly for pests and fruit retention, similar to conventional cotton. Consecutive checks are essential for making decisions about managing *Helicoverpa* spp. in Bollgard II® crops, as the Bt toxin needs to be ingested before the larvae is controlled. Hence if the larvae population is over the threshold on a given check, then chances are that a large proportion of these will ingest the toxin and die before the next check. Bollgard II® does not control a range of pests, especially green mirids which must be monitored to assess if the population will cause yield loss.

MONITORING PLANT DAMAGE

It is important to include an assessment of plant damage when making pest management decisions because insect numbers alone may not give an accurate indication of the need for control. Cotton plants can recover from a degree of damage, especially early season damage with no reduction in yield or delay in maturity. A vigorous, healthy crop can tolerate more damage from pests, without yield or maturity being affected, than a crop with poor vigour (as a result of herbicide damage or water stress for example).

Plant monitoring in conjunction with regular insect monitoring allows an assessment of the effects of mirids or other pests that might be difficult to detect in regular sampling. Plant monitoring can assist in decision making where pest levels are just below threshold or where there are combinations of pests present. Acceptable damage levels will vary depending on yield expectations and climatic conditions.

Fruit load, yield and maturity

Fruit load is a key aspect in determining crop yield and maturity. The loss of fruit during squaring and early flowering is less critical to yield than fruit loss later in the season. It is well documented that excessive early fruit loss can delay final maturity. However, it is also known that holding too much fruit can reduce crop growth, as the plants use their resources to fill the bolls they have set rather than continuing to grow and set more fruit. This is referred to as premature cut-out which results in reduced yield potential.

Dynamic thresholds

Decisions about pest control should take into account both pest numbers and plant fruit load. If retention data indicates that fruit load is too low then it may be necessary to lower the pest threshold. There are several causes of low fruit retention and it is important to identify the problem before action is taken. Low retention could be caused by cool weather, waterlogging, water stress or pests. The combined damage of several pests, each below threshold, may also cause low retention.

Reduce pest thresholds to half the standard level and control those pests exceeding the reduced threshold using the most selective option available. As retention recovers, return to standard pest thresholds. Alternatively, if retention is too high then it may be necessary to raise the pest threshold. This will allow some pest damage and help balance the vegetative and fruit development. This will also avoid yield loss due to premature cut-out. Such an approach treats the pest threshold as dynamic, that is, it varies according to how the plant fruit load is developing.

Check regularly

From the first week of squaring, monitor plant damage at least every 7 days and/or before spray decisions. It is important to monitor the level of fruit loss regularly so that measures can be taken before insect damage becomes excessive.

What to check

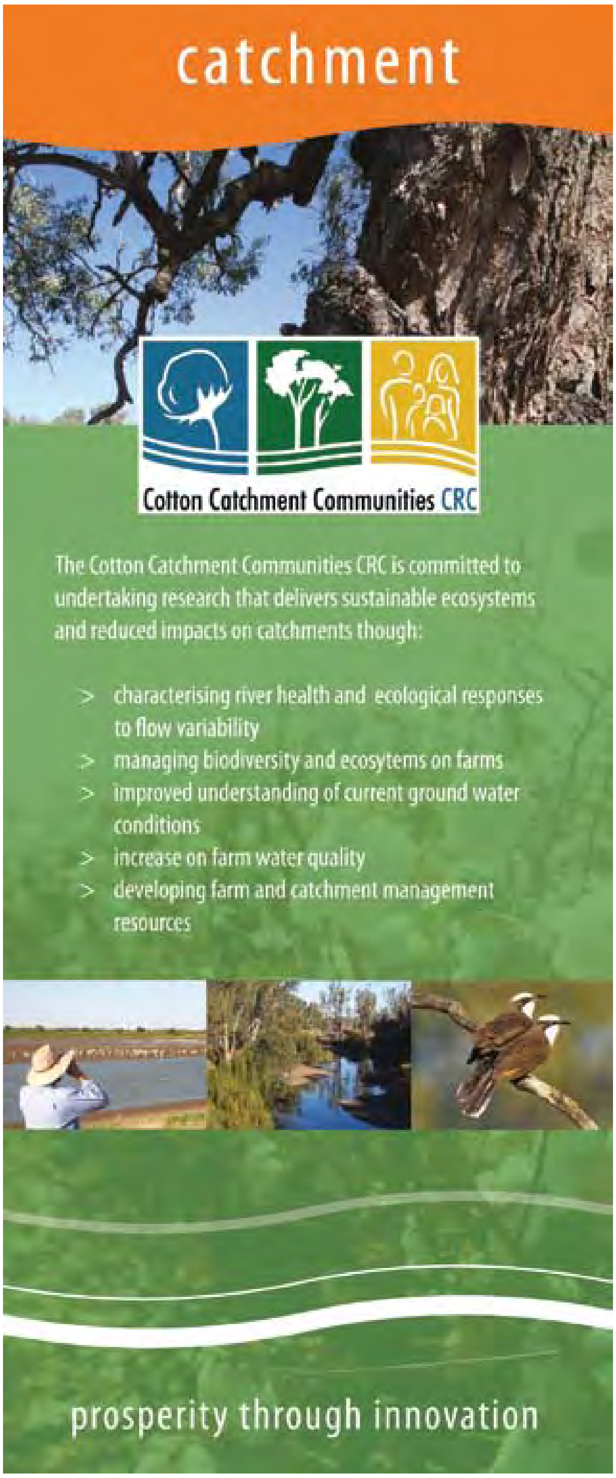
Count a metre of plants (not random plants) in 3 to 4 locations per field. If the crop is uneven increase the number of checks. Do not use the same metre of plants for insect checks.

Damage monitoring includes:

1. Leaf loss (up to the 6 true leaf growth stage)
2. Tip damage
3. Fruit retention or fruiting factor
4. Boll damage.

Crop Development Tool (CDT)

The CDT (formerly the Early Season Diagnostic tool) is a web based calculator that helps to determine whether the rate of crop development is meeting its potential. Using the CDT, the development of squaring nodes, vegetative growth rate, fruit development and nodes above white flower can each be tracked to assist with crop management



decisions. The user enters real crop data as the season progresses. The tool displays this in graphical and tabular formats alongside theoretical potential or optimum. Decisions relating to insect thresholds, growth regulation, nutrition and irrigation scheduling can all be aided by a clear understanding of how crop development is progressing.

The CDT incorporates a data storage function that allows multiple crops to be set up by each user and accessed by an individual logon and password.To use the CDT tool go to the Cotton CRC website; www.cottoncrc.org.au

Development of squaring nodes

For most Australian cotton varieties it is expected that the first fruiting branch will develop on about the seventh mainstem node. This becomes the first squaring node. On a well grown crop, by the time of first flower (~750 DD) there will be about 8 squaring nodes. Fewer than 8 will often reduce yield potential. Measuring squaring nodes can provide early indication of stress in time for remedial action. Once flowering commences it may be too late to recover.

Figure 1 shows the accumulation of sqauring nodes from the CDT between ~500 and ~800 DD. A real crop to the left of the theoretical line is generally ahead in development. This could be due to low fruit retention, in which case pest thresholds should be reconsidered and the vegetative growth rate measured. Measurements below the line indicate development has been delayed, perhaps by factors such as seedling disease or herbicide damage. Resources such as nutrition and water should be monitored closely.

Fruit Development

It is important to ensure that crop growth translates into fruit production at a rate that will help to attain a profitable yield. The CDT's fruit development graph displays the number of observed squares or bolls (/m) plotted against a potential rate of fruit development based on the day degree accumulation after sowing. An example is shown in Figure 2. Potential square development commences at 500 DD and boll development at 750 DD (first flower). The slopes of the boll and square development lines are not parallel as the tool assumes that there is some loss of fruit due to carbon stress, normal in crop growth (not pest, nutritional or water stress).

In Figure 2 the real crop is tracking ahead of schedule. This can occur under optimum growing conditions. Nutrition and water should be monitored closely as this crop is likely to experience high, early demands that could rapidly induce cut-out.

Nodes above white flower (NAWF)

At the time of first flower, there should be about 8 squaring nodes above the flower, or 8 NAWF. The bolls produced on these fruiting branches will contribute a large proportion of final yield. Once boll set commences and the crop is alocating resources to the developing fruit, the rate at which the crop can produce more squaring nodes is in decline.

In Figure 1 the rate of decline in NAWF for the real crop is consistent with the optimum. Very high early retention can cause the number of NAWF to decline more quickly. For crops tracking below the line, consider increasing pest thresholds. Crops above the line may have experienced physiological shedding or early boll loss due to pests, in which case thresholds may need to be reduced. Once there are 4 or fewer NAWF, the crop is said to be 'cut-out'. This signifies that the crop has ceased putting resources into further vegetative growth and that yield potential is dependent on the retention of fruit already produced.

Vegetative Growth Rate (VGR)

The plant growth regulator mepiquat chloride provides growers with a method to help avoid

Figure 1. An example of tracking a crop's accumulation of squaring nodes and then the decline in nodes above white flower from the CDT.

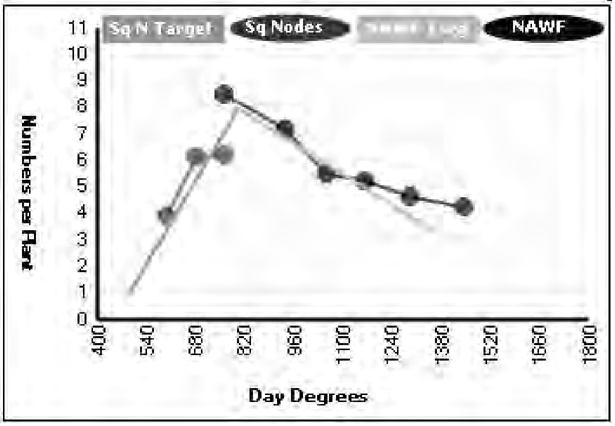
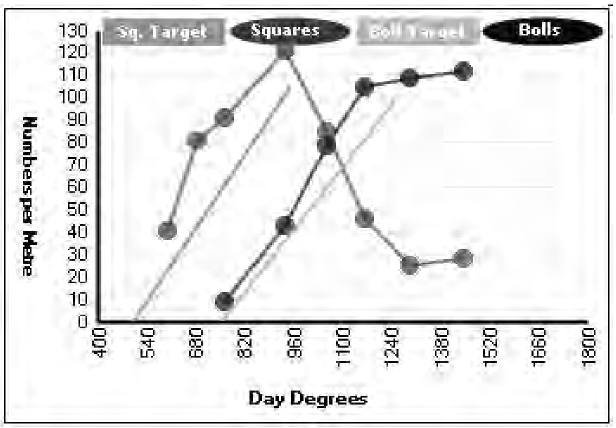


Figure 2. An example of tracking a crop's fruit development from the CDT.



excessive vegetative growth. The VGR tracks the rate of change in plant height relative to the rate of node development. Measurements should start as the crop approaches first flower and continue whilst squaring nodes are being produced. In Figure 3 the upper and lower boundaries represent the zone of desired vegetative growth rates across various regions and systems in Australia. Warmer regions and very fertile soils will have higher VGRs. The real crop is tracking below the lower boundary indicating that growth regulation is not required to maximise yield potential.

First position fruit retention

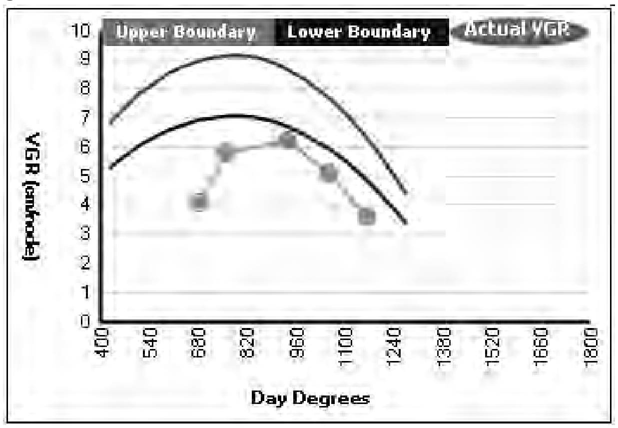
Monitoring first position fruit retention is a technique that is best used from squaring to early flowering. It is a quick way to estimate early signs of insect damage.

- Count the first position fruit on either the top five or all the fruiting branches. The first fruiting branch is the top most branch where the first position leaf is unfolded.
- Monitor both tipped and non-tipped plants.
- Monitor only the dominant stem, not vegetative branches (see Figure 4).
- The percentage of first position fruit present should be calculated dividing the number of first position fruit present by the number of fruiting branches.

Aim to have first position fruit retention of 50–60% by first flower. Low retention (< 50%) increases the risk that yield or crop maturity will be affected. However, very high fruit retention, in excess of 80% may also be associated with a yield penalty.

For the first five fruiting branches on the plant, first position fruit retention can be as low as 30% without affecting yield or maturity, however such levels should trigger close monitoring and a reduction in thresholds.

Figure 3. An example of tracking a crop's vegetative growth rate from the CDT.



Final retention at maturity

Boll numbers will vary according to variety, stage of growth and yield potential. At the end of the season a crop will hold less than 50% of all possible fruiting sites. First position retention will vary from 50–70%. Variety and boll size will also affect final yield.

Fruiting factor

Fruiting factors can be used throughout the season. They allow total fruit load to be monitored. Fruiting factors should be used when first position retention falls below recommended levels (i.e. 50–60%), to

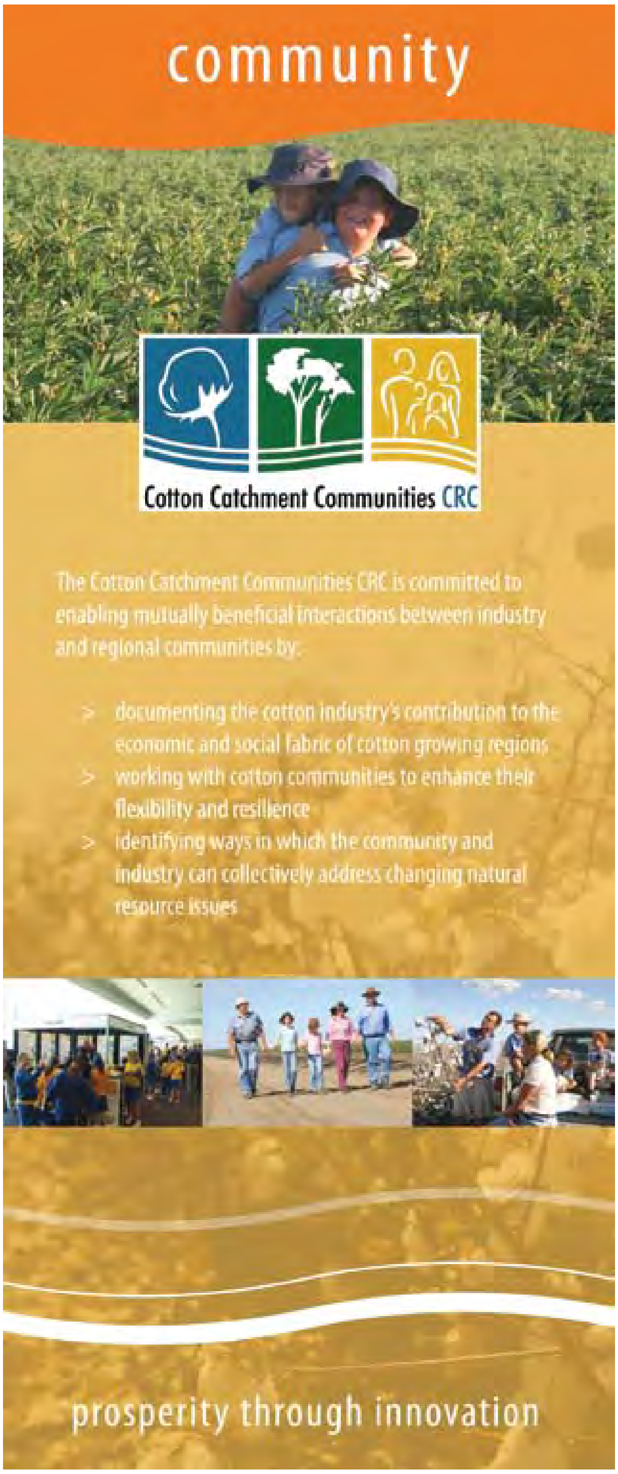
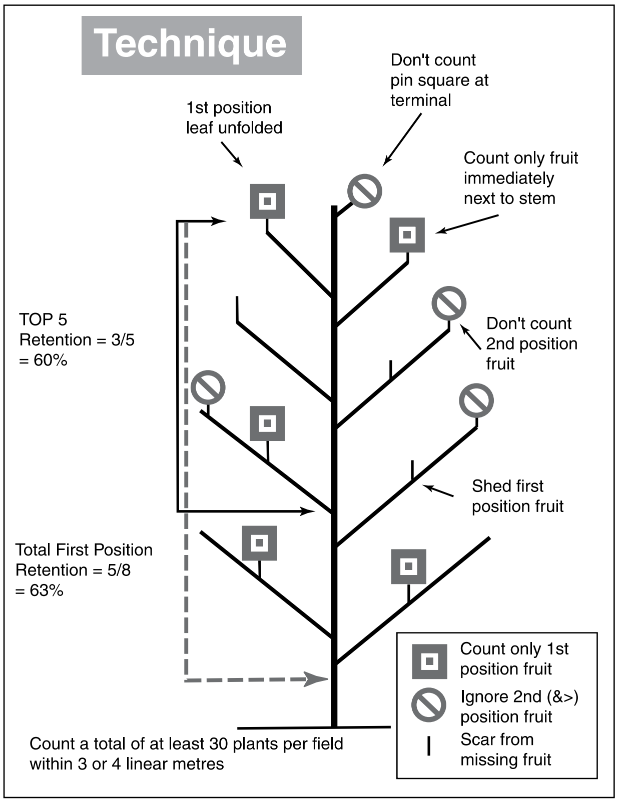


Figure 4. A technique for checking fruit retention



ensure excessive fruit loss has not occurred or in situations where a crop is heavily tipped out and retention is difficult to determine.

From 10–14 days after flowering, the monitoring of first position fruit retention may be less relevant than fruit counts. The fruiting factor technique allows a rapid interpretation of the fruit counts. The technique considers both fruit present and the number of fruiting branches (potential fruit development).

To save time in monitoring the fruiting factor, only count first and second position fruit (squares and bolls), from the main stem and the first dominant vegetative branch. In irrigated crops this should account for 90% of the fruit that will be picked.

To determine the fruiting factor for a crop, simply divide the fruit count by the number of fruiting branches.

$$\text{Fruiting factor} = \frac{\text{Total fruit /m}}{\text{Total number of fruiting branches /m}}$$

The ideal fruiting factor changes throughout the growing season. The fruiting factor will increase throughout flowering as the plants produce a large number of squares. As the crop matures there is a natural reduction in fruit numbers and the fruiting factor declines. Eventually, at maturity the fruiting factor approaches 1.0, which represents the natural maximum fruiting load that plants can carry through to yield.

A key period for measuring fruiting factors is at around early flowering. Values between 1.1 and 1.3 will provide optimum yield potential. Values less than 0.8 or greater than 1.5 can reduce yield.

Guide to using fruiting factors throughout the season

Stage of growth	Fruiting factor
Pre flowering	0.8–1.0
Flowering	1.1–1.3
Peak Flowering	1.3–1.4
Boll maturity	1.0

Guide to using fruiting factors at first flower

Fruiting factor at first flower	Impact on yield and maturity
< 0.8	High risk of yield decline and maturity delay (particularly in cooler regions)
1.1–1.3	Optimum for yield
> 1.5	Risk of premature cut out and yield decline.

Objective 3. Preserving beneficial insects

Predatory insects, spiders and parasitic insects (beneficials) consume pests and other insects in order to develop and/or produce offspring. They can considerably reduce pest numbers thereby reducing the need to control pests using chemical insecticides. The abundance of beneficial insects is affected by food resources, mating partners, over wintering sites, shelter, climatic conditions and insecticide sprays. For an IPM system to work, the conservation of beneficial insects is critical. This can be achieved through the use or provision of natural or crop refuges (e.g. trees, pastures or lucerne strips).
In an IPM system which focuses on managing beneficials the following tools can be used;

- Predator/Pest ratio
- Incorporating parasitoids into spray decisions
- Beneficial releases
- Food sprays
- Lucerne strips
- Appropriate use of pesticides
- Beneficial Disruption Index
- Petroleum spray oils (PSO) mixed with a selective or biological pesticide.

Guidelines for the predator to pest ratio

The most common predators found in cotton farms feed on a wide range of pests and are therefore classified as general predators. The guidelines described here make use of a predator to pest ratio to incorporate the activity of the predators into the pest management decisions.

Calculation of the predator to pest ratio:
The predator to pest ratio is calculated as;

$$\text{Ratio} = \frac{\text{predators}}{(\textit{Helicoverpa}\text{ spp. eggs} + \text{VS} + \text{S})}$$

where VS = very small and S = small larvae. The calculation does not include *Helicoverpa* medium (M) and large (L) larvae since many of the common predatory insects are not effective on these life stages.

Total predators per metre (visual check) should be used in calculating the predator to pest ratio. However, to be confident in the ratio, at least three insects of the most common predators (ladybird beetle, red and blue beetle, damsel bug, big eye bug, assassin bug, brown shield bug and lacewings) should be present.

Decision making protocol in conventional cotton and Bollgard II® crops

Conventional crops

Ratio	*Helicoverpa* spp.	Action
> 0.5	< 2	Do nothing
0.4–0.5	< threshold (mostly eggs)	Yeast based food spray might be applied.
0.4–0.5	< threshold (mostly larvae)	Sugar based food spray and biological insecticide or Petroleum spray oil (see section on lucerne on the following page)
< 0.4	> threshold	Selective insecticide

Bollgard II® crops

The predator to pest threshold is essentially the same as above with a slight addition. If in the next check after a food, PSO or biological spray, *Helicoverpa* neonate numbers are above threshold:

Ratio	*Helicoverpa* spp.	Action
Increasing	≥ threshold	Repeat food /biological spray mixture
No change or 0.42–0.45	≥ threshold	Selective pesticide (possibly mix with PSO)
0.4	> threshold	Selective pesticide (possibly mix with PSO)

For more information on the use of PSOs see the Research Review 'Use of Petroleum Spray Oils to Manage Cotton Pests in IPM Programs' available from the Cotton CRC.

Incorporating parasitoids into spray decisions

Parasitoids are important beneficials in Australian cotton farming systems. There are a range of parasitic wasps and flies that attack *Helicoverpa* spp., green vegetable bugs, aphids and whiteflies. These useful insects are easily overlooked because they are often small or secretive. The predator to prey ratio calculation does not incorporate parasitoids particularly *Trichogramma* spp. (egg parasitoid). For determining parasitism see page 32.

Beneficial insect to pest ratio

$$= \frac{\text{predators}}{(\text{eggs} - (\%\text{ parasitised}) + \text{VS} + \text{S})}$$

The same decision making protocol above is used.

Conserving and enhancing parasitoids

Maintaining habitat diversity. This can be achieved by growing a mixture of crops. Sorghum, maize and sunflowers are all good nursery crops for parasitoids. The capacity of sorghum and maize to act as parasitoid nurseries can be extended by growing staggered plantings. Some crops, such as chickpea, are not good nursery crops because the acidic chickpea leaves are toxic to the adult wasps.

Restricting insecticide use. Natural populations of *Trichogramma* spp., *Microplitis* spp. and other parasitoids that may be in the crop can be encouraged to build up by restricting the use of insecticides that may reduce their population. This applies to nursery crops such as sorghum as well as in cotton.

Releasing *Trichogramma* spp.

Trichogramma spp. can be purchased and released into crops. Two or more releases one week apart are suggested. If possible, the best method is to release the *Trichogramma* spp. into a nearby flowering sorghum or maize crop rather than into cotton. This will provide the *Trichogramma* spp. with enough *Helicoverpa* spp. eggs to carry over the population, given their very short life cycle.

Guidelines for use of food sprays

Food sprays cannot manage cotton pests on their own but combined with other IPM compatible tools they can help manage cotton pests and minimise synthetic insecticide use without sacrificing yield. Commercially, there are two food spray products;

1. Yeast based food spray (Predfeed®) attracts beneficial insects and should be applied when a cotton field does not have enough beneficial insects.
2. Sugar based food spray (Mobait®) retains beneficials that are already present.

Managing predators and mirids in lucerne

If there are lucerne strips or a centrally located lucerne crop on the farm, then before applying a food spray / biological insecticide spray to the cotton, check the lucerne strip or crop to determine numbers of predators and adult green mirids. If beneficial insect numbers are high in the lucerne strips compared to cotton and numbers of adult mirids in the lucerne strips are low (< 5 per 20 metre d-vac sample), then slash half of each of the individual lucerne strips after applying the food spray/biological insecticide mixture sprays to the cotton. This action will enhance the movement of a large number of predators from the lucerne strips into the cotton, but will retain the mirids in the lucerne.

In contrast, if both predator and adult mirid numbers in the lucerne strips are high (> 5 mirids per 20 metres), do not slash or mow the lucerne strips or blocks when a sugar based food spray/biological insecticide mixture spray has been applied to the cotton since this will force too many mirids into the cotton where they may cause damage.

Appropiate use of insecticides

Tolerate non-economic early season damage
Minimising early season sprays helps to conserve the beneficial insect population. The cotton plant has the ability to tolerate a level of damage without affecting yield or crop maturity.

Site specific pest management
Many beneficial species frequently move in and out of cotton, other crops and non-crop habitats. It is important to manage pests on a field by field basis or by a small management unit, not an entire farm.

Pests such as aphids or mites often infest the edge of a field, not the entire field area. It is possible to manage this type of infestation by only spraying the field borders. This enables the beneficial population to re-establish or re-build much faster.

Choose insecticides carefully
Some insecticides have very little impact on beneficial insects including parasitoids.

The Beneficial Disruption Index (BDI)

The BDI provides a basis to measure or benchmark the 'softness' or 'hardness' of an individual field's insecticide spray regime at the end of the season. The BDI score for each insecticide is based on the overall impact of the insecticide on beneficial insect populations, as listed in Tables 3 and 4, on pages 40 and 42. The impact is expressed as a percentage reduction in beneficials after application of the chemical. A chemical that is more disruptive has a higher score or rank. The overall BDI for a cotton field is calculated by summing all the BDI scores for each insecticide used over the whole season. Note that scores for each component of spray mixtures are added together. The lower the overall rank for the season the less disruptive the spray regime is to beneficials.

Objective 4. Preventing insecticide resistance

Resistance occurs when application of insecticides removes susceptible insects from a population leaving those individuals that are resistant. Mating between these resistant individuals gradually increases the proportion of resistance in the pest population as a whole. Eventually this can render an insecticide ineffective, leading to field control failures. Resistance can be due to a trait that is already present in a small portion of the pest population or due to a mutation that provides resistance.

Management of resistance is essential to ensure that valuable insecticides remain effective, the Australian cotton industry has developed the Insecticide Resistance Management Strategy (IRMS). The IRMS is designed to prevent resistance development, while managing existing resistance. Some core principles used in the IRMS include;

- Rotation between chemical groups with different modes of action.
- Limiting the time period during which an insecticide can be used. This restricts the number of generations of a pest that can be selected in each season.
- Limiting the number of applications, thereby restricting the number of selection events.

The *IRMS* 2009/10 appears on pages 52–55, with explanation and answers to many frequently asked questions on pages 47–51.

Resistance monitoring

Resistance monitoring for *Helicoverpa* spp., two-spotted spider mites, aphids and silverleaf whitefly, is conducted each year by the cotton industry and provides the foundation for annual review and updating of the IRMS. **All growers and consultants have access to this industry service to investigate suspected cases of resistance.** For the contact details of the researchers running the resistance monitoring projects, refer to the advertisement on page 90.

Pupae busting

In NSW and southern Queensland, *Helicoverpa spp.* spend the winter in the soil as pupae and emerge as moths in spring to mate and lay eggs. Known as diapause, this resting pupal state is induced by decreasing daylength and temperature in late summer. Most of the pupae which over-winter in cotton fields are *H. armigera*. They are likely to have a high survival rate because of the low numbers of parasites. They have the potential to carry insecticide resistance, including Bt resistance, through to the next season. Therefore, it is important to pupae bust for their control.

Pupae are likely to be found in the top 10 cm of the soil surface. Cultivate to achieve disturbance of the soil sufficiently to destroy pupae or their emergence tunnels. The tillage required for;

- 1 m hills – till the whole hill;
- 2 m beds – till across the whole bed and almost down to furrow level;
- skip-row – till right across the soil surface.

Pupae busting Bollgard II® cotton fields is manditory between picking and the end of July. Prior to the 2007–08 season the IRMS guidelines for pupae busting in sprayed conventional cotton were amended. Details of the amendments are presented on page 50.

Web tool to assist pupae busting decisions

The proportion of pupae entering diapause increases from low levels in March to high levels, almost 100%, by late April. However the rate of diapause induction varies from season to season and region to region. Knowing when diapause is induced is useful for identifying 'high risk' fields, i.e. those fields most likely to have diapausing pupae that should be targeted for pupae busting. On the Cotton CRC website, a web tool is available to help calculate the likely rate of diapause induction for your area, based on local climate data. An example of the web tool output is provided in Figure 5. See page 39. The tool is also able to compare the results for the current season with the long term average and hotter than average or cooler than average seasons.

The web tool can also be used to predict the rate of moth emergence from diapause in spring. This can assist in timing pupae busting operations to maximise their effectiveness. The breaking of diapause is influenced by temperature. The tool calculates the emergence percentage from the day after the threshold temperature of 18°C is reached. To use the tool go to; http://cottassist.cottoncrc.org.au/DIET/DIETTool.aspx

Trap crops and weed control

Trap cropping and weed control assists resistance management, as well as IPM, by reducing the size of the overall pest population which reduces the need to apply insecticides and reduces the selection pressure for the pest to develop resistance.

Resistance management for Bollgard II® cotton

Resistance management for Bollgard II® cotton is critical due to the season long selection of *Helicoverpa* spp. to the Bt toxins produced by Bollgard II®. A proactive Resistance Management Plan (RMP) has been developed to preserve the effective life of Bollgard II®. This plan is provided in full on pages 62–67 and many frequently asked questions about the RMP are answered on pages 56–61.

Resistance management guidelines for all crops

Several other strategies that are relevant to cotton and other spring and summer crops can also help in managing resistance. These include:

1. Avoid cross selection for resistance. Spraying for one pest can be simultaneously selecting resistance in another pest that is present, even though that pest is at sub-threshold levels and not specifically being targeted. For example, if a pyrethroid is used to control a pest other than *Helicoverpa* spp. Do not follow up with another pyrethroid for *H. armigera* control as the first spray may have already selected for pyrethroid resistant *H. armigera*. This applies to all insecticides which target multiple pest species.
2. Selective insecticide use is preferable, consistent with the IRMS, as this helps conserve beneficial insects. Beneficials eat or parasitise resistant as well as susceptible pests. Beneficials can lower overall populations of insect pests.

Figure 5. Estimated rate of *Helicoverpa* entering diapause at Dalby from the 1st of March 2009.

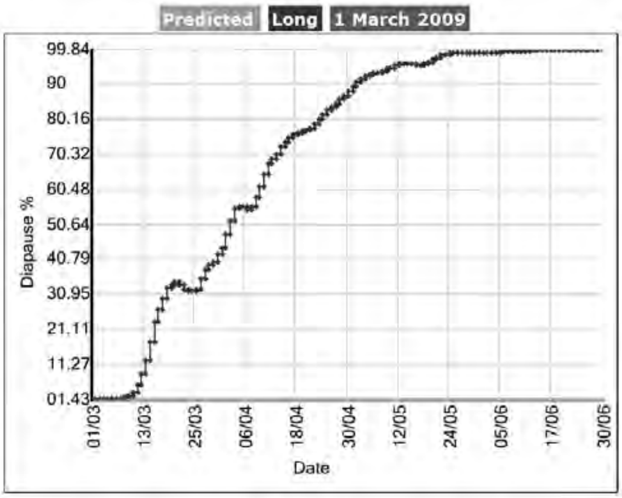
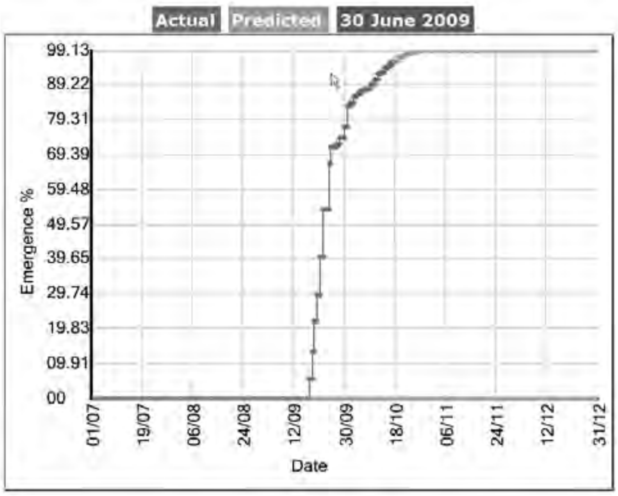


Figure 6. *Helicoverpa* moth emergence from diapause at Dalby run on the 30th of June 2009.



IPM

Table 3. Impact of insecticides and miticides on predators, parasitoids and bees in cotton

By Lewis Wilson[1,7], Simone Heimoana[1,7], Robert Mensah[2,7], Moazzem Khan[3,7], Martin Dillon[5], Mark Wade[4], Brad Scholz[3], DavidMurray[3,7], Richard Lloyd[3], Richard Sequeria[3], Paul DeBarro[5] Viliami Heimoana[6] and Jonathan Holloway[6]. [1]CSIRO Plant Industry, [2] I&I NSW, [3] DEEDI, [4]CSIRO Entomology,[5] Formerly CSIRO Entomology, [6] Formerly I&I NSW, [7] Cotton CRC.

		Target pest(s)								Beneficials																Pest resurgence[12]			
										Predatory beetles				Predatory bugs							Hymenoptera								
Insecticides (in increasing rank order of impact on beneficials)	**Rate** (g ai/ha)	Helicoverpa	Mites	Mirids	Aphids	Thrips	Silverleaf whitefly	Persistence[8]	Overall Ranking[9]	Total[1] Predatory beetles	Red and blue beetle	Minute 2-spotted lady beetle	Other lady beetles	Total[2] Predatory bugs	Damsel bugs	Big-eyed bugs	Other predatory bugs	Apple dimpling bug	Lacewing adults	Spiders	Total wasps	Eretmocerus 19	Trichogramma	Ants	Thrips	Mite	Aphid	Helicoverpa	Toxicity to bees[14]
Bt[11]		✓						very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	–	–	–	VL
NP Virus		✓						very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	–	–	–	VL
Pirimicarb	250				✓			short	very low	VL	VL	VL	VL	L	L	M	VL	VL	VL	VL	VL	M	M	VL	L	–	–	–	VL
PSO (Canopy®)[16]	2 %	✓			✓			short	very low	VL	L	L	VL	VL	VL	VL	VL	VL	VL	L	VL	–	VL	H	VL	–	–	–	VL
Methoxyfenozide	400	✓						medium–long	very low	L	VL	VL	L	L	L	L	VL	VL	VL	VL	VL	–	VL	VL	VL	–	–	–	VL
Pyriproxyfen	50						✓	Long	very low	M	–	M	M	VL	–	–	–	–	L	VL	VL	L	VL	VL	VL	–	–	–	L
Etoxazole	38.5		✓					short	low	VL	VL	–	L	VL	VL	VL	VL	VL	VL	M	L	–	VL	VL	L	–	–	–	VL
Indoxacarb (low)	60			✓				medium	low	L	L	H	M	VL	L	–	L	H	M	VL	VL	–	VL	H	VL	–	+ve	–	–
Indoxacarb (low + salt)	60			✓				medium	low	L	L	H	M	VL	L	–	L	H	M	VL	L	–	VL	H	VL	–	–	–	–
Indoxacarb (low + Canopy)	60			✓				medium	low	L	L	H	M	VL	L	–	L	H	M	VL	L	–	VL	H	VL	–	+ve	–	–
Rynaxypyr	52.5	✓						long	low	L	M	M	L	VL	VL	VL	L	VL	VH	VL	L	–	L	L	VL	–	+ve	–	–
Dicofol[3]	960		✓					long	low	L	–	–	–	L	–	–	–	L	–	L	–	M	–	–	VL	–	–	–	VL
Amorphous silica[17]	2500	✓						short	low	L	L	–	M	M	–	VL	–	L	L	L	L	–	–	M	VL	–	–	–	–
Spinosad	96	✓						medium	low	VL	M	L	VL	M	L	H	VL	L	VL	VL	M	H	H	H	H	+ve	–	–	H[15]
Diafenthiuron	350		✓		✓		✓	medium	low	M	H	VL	M	L	M	VL	L	H	VL	L	L	H	VL	H	L	–	–	+ve	M
Pymetrozine	150				✓			short	low	M	M	M	M	L	L	L	VL	H	M	L	L	L	L	M	VL	–	–	–	VL
Fipronil (v. low)	8			✓				medium	low	L	L	L	VL	L	M	–	L	M	L	M	L	–	–	VH	L	+ve	–	–	VH
Fipronil (v. low + salt)	8			✓				medium	low	L	L	L	VL	L	M	–	L	M	L	M	L	–	–	VH	L	+ve	+ve	+ve	VH
Indoxacarb[13]	127.5	✓		✓				medium	low	H[14]	L	VH	VH	L	L	L	L	VH	L	L	L	–	VL	VH	VL	–	+ve	–	H[15]
Abamectin	5.4	✓[6]	✓					medium	moderate	L	M	H	VL	M	L	M	M	H	VL	M	M	H	M	H	M	–	–	–	H
Emamectin	8.4	✓						medium	moderate	L	VL	M	VL	H	H	H	H	H	L	M	M		M	VL	M	–	–	–	H

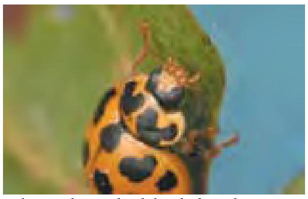
Dimethoate (low)	80		✓[18]	✓	✓[18]	✓		short	moderate	M	L	H	H	M	L	–	H	M	M	L	M	–	M	H	M	+ve	+ve	+ve	H
Dimethoate (low + salt)	80		✓[18]	✓	✓[18]	✓		short	moderate	M	L	H	H	M	L	–	H	M	M	L	M	–	M	H	M	+ve	+ve	+ve	H
Endosulfan (low)	367.5	✓		✓	✓	✓		medium	moderate	M	VL	VH	M	M	M	M	L	H	L	M	VL	–	–	VH	H	–	–	–	M[15]
Propargite	1500		✓					medium	moderate	M	H	H	M	M	H	VL	VL	L	VL	M	M	L	H	H	M	–	+ve	+ve	L
Acetamiprid	22.5				✓			medium	moderate	M	M	VH	H	M	M	H	M	VH	L	VL	L	VH	H	VH	VH	–	–	–	M[15]
Clothianidin (low)	25			✓				medium	moderate	M	VL	–	H	L	M	VL	VL	H	H	M	M	H	M	VH	VL	–	–	+ve	H
Amitraz	400	✓	✓[9]		✓[9]			medium	moderate	H	M	VH	H	L	–	–	–	H	VL	M	M	H	L	H	M	–	–	–	L
Fipronil (low)	12.5			✓		✓		medium	moderate	L	L	H	L	L	H	L	L	VH	L	M	M	–	M	VH	VH	+ve	+ve	+ve	VH
Chlorfenapyr (low)	200	✓	✓					medium	moderate	M	L	VH	VL	M	VL	H	H	VH	L	L	M	–	VH	H	M	–	–	–	H
Thiamethoxam	100				✓			medium	moderate	H	H	H	H	M	M	M	H	H	M	VL	M	–	H	VH	H	+ve	–	+ve	H
Endosulfan (high)	735	✓		✓	✓	✓		medium	moderate	M	VL	VH	M	M	M	M	M	H	L	M	L	H	VH	VH	H	–	–	–	M[15]
Fipronil (high)	25			✓		✓		medium	moderate	L	VL	H	L	M	H	H	L	VH	L	M	M	–	M	VH	VH	+ve	–	+ve	VH
Imidacloprid	49			✓	✓			medium	moderate	H	L	VH	H	H	M	H	L	VH	L	L	L	VH	M	H	H	+ve	–	+ve	M
Clothianidin (high)	50			✓				medium	moderate	H	VL	–	VH	M	M	L	VL	H	H	M	M	VH	H	VH	VL	+ve	–	+ve	H
Methomyl	169	✓						very short	high	H	L	VH	VH	M	L	VH	L	VH	M	M	M	VH	H	H	H	+ve	–	–	H[15]
Thiodicarb	750	✓						long	high	VH	M	VH	VH	M	M	L	L	VH	VL	M	M	–	M	M	H	+ve	+ve	–	M[15]
Dimethoate (high)	200		✓[18]	✓	✓[18]	✓		short	high	M	M	H	H	M	H	–	H	H	VH	M	H	H	H	VH	M	+ve	–	+ve	H
Chlorfenapyr (high)	400	✓	✓					medium	high	H	M	VH	L	H	H	H	H	VH	L	M	M	–	VH	VH	M	–	+ve	–	H
OPs[5]		✓	✓	✓	✓	✓		short–medium	high	H	M	H	H	H	M	H	H	VH	L	M	H	VH	H	VH	H	+ve	–	–	H
Carbaryl[3]								short	high	H	–	–	–	H	–	–	–	–	–	–	–	–	–	–	H	–	–	–	H
Pyrethroids[4]		✓	✓[7]	✓[7]			✓[7]	long	very high	VH	–	–	–	VH	–	–	–	VH	VH	VH	VH	VH	VH	VH	VH	+ve	+ve	+ve	H

1. Total predatory beetles – ladybeetles, red and blue beetles, other predatory beetles.
2. Total predatory bugs – big-eyed bugs, minute pirate bugs, brown smudge bugs, glossy shield bug, predatory shield bug, damsel bug, assassin bug, apple dimpling bug
3. Information; Citrus pests and their natural enemies, edited by Dan Smith; University of California Statewide IPM project, Cotton, Selectivity and persistence of key cotton insecticides and miticides.
4. Pyrethroids; alpha-cypermethrin, cypermethrin,beta-cyfluthrin, cyfluthrin, bifenthrin, fenvalerate, esfenvalerate, deltamethrin, lambda-cyhalothrin
5. Organophosphates; omethoate, monocrotophos, profenofos, chlorpyrifos, chlorpyrifos-methyl, azinophos ethyl, methidathion, parathion-methyl, thiometon
6. *Helicoverpa punctigera* only.
7. Bifenthrin is registered for mite and silverleaf whitefly control; alpha-cypermethrin, beta-cyfluthrin, bifenthrin, deltamethrin and lambda-cyhalothrin are registered for control of mirids
8. Persistence of pest control; short, less than 3 days; medium, 3-7 days, long, greater than 10 days.
9. Suppression of mites and aphids only.
10. Impact rating (% reduction in beneficials following application, based on scores for the major beneficial groups); VL (very low), less than 10%; L (low), 10–20%; M (moderate), 20–40%; H (high), 40–60%; VH (very high), > 60%. A '–' indicates no data available for specific local species.
11. *Bacillus thuringiensis.*
12. Pest resurgence is +ve if repeated applications of a particular product are likely to increase the risk of pest outbreaks or resurgence. Similarly sequential applications of products with a high pest resurgence rating will increase the risk of outbreaks or resurgence of the particular pest species.
13. Very high impact on minute two-spotted ladybeetle and other ladybeetles for wet spray, moderate impact for dried spray.
14. Data Source: British Crop Protection Council. 2003. *The Pesticide Manual: A World Compendium* (Thirteenth Edition). Where LD50 data is not available impacts are based on comments and descriptions. Where LD50 data is available impacts are based on the following scale: very low = LD50 (48h) > 100 ug/bee, low = LD50 (48h) < 100 ug/bee, moderate = LD50 (48h) < 10 ug/bee, high = LD50 (48h) < 1 ug/bee, very high = LD50 (48h) < 0.1 ug/bee. Refer to the Protecting Bees section in this booklet.
15. Wet residue of these products is toxic to bees, however, applying the products in the early evening when bees are not foraging will allow spray to dry, reducing risk to bees the following day.
16. May reduce survival of ladybeetle larvae – rating of M for this group.
17. May be detrimental to eggs and early stages of many insects, generally low toxicity to adults and later stages.
18. Will not control organophosphate resistant pests (e.g. mites, some cotton aphid (Aphis gossypii) populations
19. Rankings for Eretmocerus based on data for E. mundus (P. De Barro, CSIRO, unpublished) and for E. eremicus (Koppert B.V. , The Netherlands (http://side-effects.koppert.nl/#))

Table 4. Impact of insecticides at planting or as seed treatments on key beneficial groups in cotton

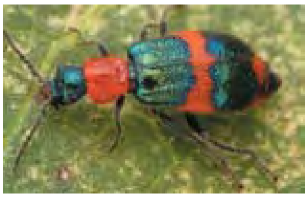
Insecticides	Rate (g ai/ha)	Main target pest(s)					Persistance[6]	Overall[7]	Beneficial group				
		WW	Mite	Mir.	Aph.	Th[5]			Predatory beetles[1]	Predatory bugs[2]	Spiders	Wasps and Ants	Thrips
At Planting													
Aldicarb	450		✓	✓	✓	✓	medium-long	very low[3]	v. low	v. low	v. low	v. low	v. high
Phorate	600	✓	✓	✓	✓	✓	medium-long	very low[3,4]	No data	No data	No data	No data	v. high
Carbosulfan	750–1000	✓		✓		✓	medium-long	very low[3,4]	No data	No data	No data	No data	v. high
Chlorpyrifos	250–750	✓					medium	very low[4]	No data	No data	No data	No data	No data
Seed Treatments													
Thiodicarb	500 g ai/100 kg seed					✓	short	very low[3]	v. low	v. low	v. low	v. low	high
Thiodicarb + Fipronil	259 + 12 g ai/100 kg seed	✓				✓	short-medium	very low[3,4]	No data	No data	No data	No data	high
Imidacloprid	525 g ai/100 kg seed	✓			✓	✓	medium	very low[3]	v. low	v. low	v. low	v. low	v. high
Imidacloprid	700 g ai/100 kg seed	✓			✓	✓	medium	very low[3,4]	v. low	v. low	v. low	v. low	v. high
Thiomethoxam	280 g ai/100 kg seed	✓			✓	✓	medium	very low[3,4]	No data	No data	No data	No data	v. high

1. Predatory beetles – ladybeetles, red and blue beetles, other predatory beetles.
2. Predatory bugs – big-eyed bugs, minute pirate bugs, brown smudge bugs, glossy shield bug, predatory shield bug, damsel bug, assassin bug, apple dimpling bug.
3. Except for effects on thrips which are predators of mites. Note that aldicarb and phorate will also control mites.
4. Based on observations with other soil or seed applied insecticides.
5. WW, wireworm; Mir., mirids; Aph., aphids; Th, thrips.
6. Persistance; short, 2–3 weeks; medium, 3–4 weeks; long, 4–6 weeks.
7. Impact rating (% reduction in beneficials following application); very low, less than 10%; low, 10–20%; moderate, 20–40%; high, 40–60%; very high, > 60%

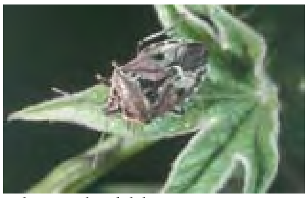

*Three banded ladybird**

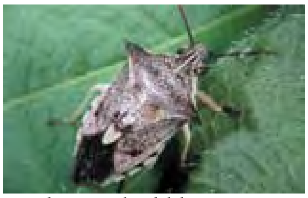

*Transerve ladybird**


Ladybird larva

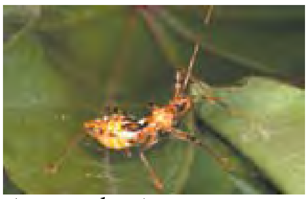

*Red and blue beetle**


*Big-eyed bug**


Glossy shield bug


Predatory shield bug

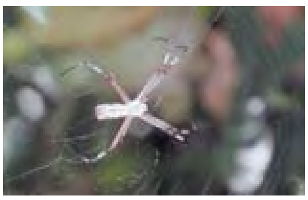

*Damsel bug**


*Assassin bug**


Hoverfly


*Green lacewing adult**


Lynx spider


Orbweaver spider


Orange caterpillar parasite


*Normal and Parasitised eggs**

* Predators that can be used in calculating the predator to pest ratio.

For more information about beneficials check out the pest and beneficials guide on the website or the COTTONpaks CD version 2.1.

3. Ensure spray applications are accurate, timely and triggered by pest thresholds. Using plant compensation allows for the plant's capacity to recover from a degree of damage without loss, thereby avoiding insecticide applications to prevent non-economic damage.

Objective 5. Managing crop and weed hosts

Weed management

The potential for pests to over-winter on weeds, and infest the subsequent cotton crop early in the season, is often greatest when a mild wet winter occurs. Abundant growth of weeds in these conditions creates difficulties with their control. Ideally, management of weeds, in fallow fields, cropped fields, and in the borders and headlands should be undertaken early in winter and continue through the winter and spring as necessary.

Weeds provide over winter hosts for a number of pests including mites, whitefly, mirids, aphids, tipworm, cutworm and armyworm. The control of weeds also has implications for managing cotton diseases, as some weed species are disease hosts. For example bladder ketmia (*Hibiscus trionum*) is an alternate host for Fusarium wilt (*Fusarium oxysporum* var. *vasinfectum*).

Weeds also harbour beneficials. However, the potential problems that on-farm weeds may cause, by providing over winter hosts for pests and some diseases, generally outweighs their value as a refuge for beneficials. Growing of refuge crops for beneficials, such as lucerne, is an option available to growers who want to enhance beneficial numbers.

Most insect pests that attack cotton utilise one or more weeds, native plants or alternative crops as hosts. For more information see the sub-section *Overwintering habitat* for each pest in the *Key insect and mite pests of Australian cotton* starting on page 1.

Managing cotton regrowth

Regrowth of cotton after harvest (also called ratoon cotton) provides refuge for *Helicoverpa* spp., spider mites, green mirids, apple dimpling bugs and aphids. Regrowth should be controlled by slashing, root pulling and/or mulching to prevent pests being carried between seasons.

Regrowth cotton is also a risk for carry-over of the disease Cotton Bunchy Top (CBT). Cotton aphids feeding on these plants could then pick up CBT and spread it to adjacent cotton crops in the following season. Cotton regrowth also has implications for managing soil-borne diseases (see the Integrated Disease Management guidelines).

Technology Users Agreements for GM cottons require the control of cotton regrowth. For more information on the requirements for managing Bollgard II® volunteers, see pages 64–65, for Roundup Ready Flex® and Roundup Ready® volunteers see pages 104 and for Liberty Link® volunteers see page 102.

Rotation crops

Growing a range of crops can be seen as essential to providing a habitat for a variety of insects. Cotton in monoculture over a wide area provides a little opportunity for beneficials to thrive and persist.

The selection of a rotation crop has many implications for pest management. Rotation crops are hosts for a range of pests, such as mites (faba beans, safflower), aphids (faba beans, canola) or *H. punctigera* (chickpeas, canola). Some rotation crops may also affect carry over of disease or conversely provide a disease break as suggested in IDM guidelines.

Options for managing pests in rotation crops should also be considered. With no major initiative to structure insecticide resistance management in field crops other than cotton, follow the basic IPM principle to use as many methods as possible to manage pests.

For resistance management in rotation crops the guidelines in Objective 4 can be followed, see page 38.

Objective 6. Use trap crops effectively

Trap cropping is an IPM tactic that can be utilised on a farm level or area wide basis. Trap cropping aims to concentrate a pest population into a manageable area by providing the pest with an area of preferred host crop. When strategically planned and managed, trap crops can be utilised at different times throughout the year to help manage a range of pests. This assists resistance management as well as IPM, by reducing the size of the overall population which reduces the need to apply insecticides and reduces the selection pressure for the pest to develop resistance.

First generation or spring trap cropping

Spring trap crops are designed to attract *H. armigera* adults as they emerge from over wintering pupae in spring. Larvae arising from eggs laid in the crop are controlled using a biological insecticide or allowed to pupate and are controlled by cultivation. A trap crop, strategically timed to flower as pupae are emerging in spring combined with effective pupae busting in previous autumn can help to reduce the early season build-up of *H. armigera* in a district.

An ideal first generation trap crop is one that is; very attractive to *H. armigera*, is a good nursery for beneficials, does not host secondary pests or diseases, does not become a weed problem and is easy to establish and manage. Many winter crops have been trialled to measure their potential as a spring trap crop. Chickpea has consistently proven superior to all other crops in its ability to generate large numbers of *H. armigera*, however it is not a good nursery for beneficial insects. Chickpea has also proven to be agronomically robust, being suitable for both dryland and irrigated situations.

Growers must ensure trap crops do not become future nurseries of *Helicoverpa* spp., and so effectively controlling populations in the trap crop by timely destruction of the crop itself is required. Because the trap crop will not be harvested for yield, a fast knock-down insecticide is not required. Bio-pesticides like Bt and virus formulations may be well suited.

In Central Queensland there is minimal over wintering of *H. armigera* because temperatures are generally too warm to trigger diapause. Here spring trap crops are used to concentrate local *H. armigera* populations into areas where they can also be destroyed, at a time when there are few other hosts for the *H. armigera* to infest.

Summer trap cropping

Summer trap cropping has quite a different aim from that of spring trap cropping. A summer trap crop aims to draw *Helicoverpa* spp. away from a main crop such as cotton or mungbeans and concentrate them in a small area planted to another crop such as sorghum, pigeon pea or lab lab. Once concentrated into the trap crop, the larvae can be controlled.

Some summer trap crops may produce large numbers of beneficial insects that can then move into nearby crops, for example, the *Trichogramma* spp. in sorghum and maize.

The aim of a 'last generation' summer trap crop is to attract moths emerging from non-diapausing pupae under cotton. These pupae are likely to be more abundant under conventional cotton and will have had intense insecticide resistance selection on the cotton crop. Concentrating the eggs from these moths in the trap crop allows the resulting larvae to be controlled using biological insecticides such as a virus or by cultivation to kill the resulting pupae.

The trap crop would be planted mid season, to ensure that it was highly attractive to *H. armigera* late in the cotton season. The attractiveness of the cotton crop relative to the trap crop may significantly influence the potential effectiveness of this strategy.

In Central Queensland cotton growers are using summer trap crops of pigeon pea as part of the RMP for Bollgard II® cotton. More information on trap cropping requirements in Bollgard II® cotton is on page 67.

Objective 7. Communication and training

Communicate with neighbours

Communication with neighbouring primary producers is essential to develop a successful IPM program. It is just as important to communicate with non-cotton growing neighbours and if possible encourage your neighbours to reciprocate a level of communication.

Pesticide application management plan

Extract from 'Application of pesticides' booklet of the BMP manual.

The core best management practice for safe and responsible pesticide use is to develop a pesticide application management plan (PAMP). The PAMP will help ensure that everyone involved in a pesticide application has a clear understanding of their responsibilities. It also helps identify the risks associated with pesticide applications so that controls to minimise those risks can be put in place.

A PAMP has two essential aims:

1. Establishing good communication with everybody involved and interested in the application of pesticides. This communication is required both pre-season and during the season. It should exist between the grower, the applicator, the consultant, farm workers and neighbours.
2. Ensuring appropriate application techniques and procedures are used.

Supporting these aims is good record keeping – of each aspect of the PAMP itself, and the details of pesticide application. This record keeping is important to check the effectiveness pesticide applications, to comply with regulatory requirements and to demonstrate due diligence.

For more information and assistance in developing a PAMP consult the BMP manual and contact your Cotton Australia Grower Services Manager.

Area Wide Management (AWM)

AWM groups or IPM groups acknowledge that pest and beneficial insects are mobile, and that the management regimes to control pests imposed on a given field are likely to alter the abundance of beneficial insects and levels of insecticide resistance in pest populations in the surrounding locality. By communicating and coordinating strategies, AWM groups have successfully implemented IPM.

AWM for population management

AWM in the true sense primarily strives to reduce pest pressure by co-ordinating the efforts of growers in an area. The strategy is based on reducing the survival of over wintering, insecticide-resistant *H. armigera* pupae, reducing the early season build-up of *H. armigera* on a regional/district scale, and to reduce the mid-season population pressure on *Helicoverpa*-susceptible crops.

The main tactics are spring trap crops, conservation of beneficial insects and cultivation of diapausing pupae. A critical component is to bring together farmers from a range of different enterprises, including cotton and other dryland crops. As *H. armigera* is a pest common to most of these crops it is vital to have all types of growers involved if AWM is to succeed.

AWM or IPM Groups

These groups focus on communication and co-ordination to achieve agreed IPM goals, These may include conserving beneficials, delaying use of disruptive insecticides, reducing the risk of drift between farms and the planting of trap crops. A key element of most groups that have worked well has been regular meetings before and during the season to share information, discuss strategies and build rapport.

For more information on getting a group started and/or maintaining momentum of a group see the IPM Guidelines II, or contact your regional cotton extension officer or district agronomist.

Meetings

Each winter, meetings are held in each major region to review resistance levels, IPM principles, computerised decision support programs, BMP procedures and other production issues. These meetings improve information exchange between growers, consultants, and research and extension personnel.

Training

The Cotton Production Course is a university based course consisting of four units. The course is available for part time external students at both undergraduate and graduate level. Coordinator – John Stanley (02) 6773 3758.

Table 5. Seasonal activity plan for IPM

Objective	Phases				
	Post harvest	Pre-planting	Planting to 1 flower per metre	1st flower to 1 open boll per metre	1 open boll per metre to harvest
1. Growing a healthy crop	Consider the best rotation crop for your situation. Test soil nutrient status to determine fertiliser requirements for cotton crop. Consider potential disease risks.	Seed bed preparation. Field and cotton variety selection. Plan irrigation and crop management strategies.	Consider planting window. Consider at-planting seed treatment, insecticides and other control options which do not disrupt beneficial insect activity.	Water management. Nutrient status. Growth control. Pest control.	Make final irrigation decisions. Defoliate when crop is mature. Keep on top of pests by using appropriate control options.
2. Keeping track of insects and damage	Sample cotton stubble for *Helicoverpa armigera* pupae after harvest.	Assess risk of wireworm, early thrips, mirids, mites and black field earwigs and decide on seed treatments, granular insecticides or in-furrow insecticide sprays.	Sample for pests, beneficials and parasitism rates in cotton as well as spring trap crop. Monitor early season damage. Track pest trends. Use pest thresholds and the predator to pest ratio.	Sample for pests, beneficials and parasitism rates. Track pest trends and incorporate parasitism into spray decisions. Monitor fruit load. Use pest thresholds and the predator to pest ratio.	Sample for pests, beneficials and parasitism rates in cotton as well as last generation trap crop. Monitor fruit load. Use pest thresholds and the predator to pest ratio. Cease pest control at 30–40% bolls open.
3. Preserving beneficial insects	Plant lucerne (strips or block) in autumn. Consider becoming involved in an IPM or AWM group. Discuss spray management plan with neighbours and consultant.	If planning to release *Trichogramma* during the season, plan to sow other crops e.g. sorghum. Consider growing a diverse habitat to encourage beneficials.	Sample for beneficials and parasitism rates. If chemical control of a pest is required, refer to the beneficial impact table. Keep track of your BDI and predator to pest ratio.	Sample beneficials. Consider releasing *Trichogramma* into sorghum. Keep track of your BDI and predator to pest ratio. Food sprays may be considered. Manage lucerne appropriately.	Sample for beneficials. Encourage beneficials to reduce late season resistant pests by using food sprays and low impact insecticides.
4. Preventing insecticide resistance	Pupae bust to control overwintering *Helicoverpa* and mites as soon as possible after harvest. Plant spring trap crop. Review resistance management results. Reduce the availability of aphid and whitefly hosts over winter.	Consider Bollgard II® refuge option. Consider choice of at – planting insecticides or seed treatment and implications for later aphid sprays.	Use pest and damage thresholds. Follow the IRMS strategy for your region. Encourage beneficials to help reduce resistant pests. Follow Bollgard II® resistance management plan.	Use pest and damage thresholds. Follow the IRMS strategy for your region. Encourage beneficials to help reduce resistant pests. Follow Bollgard II® resistance management plan.	Use pest and damage thresholds. Follow the IRMS strategy for your region. Encourage beneficials to help reduce resistant pests. Follow Bollgard II® resistance management plan.
5. Managing crop and weed hosts	Keep farm weed free over winter. Control cotton re-growth.	Carefully consider summer rotation crops (type and location). Keep farm weed free.	Keep farm weed-free.	Keep farm weed-free.	Consider winter rotation crops (type, location and the potential to host pests or diseases). Keep farm weed-free.
6. Using trap crops effectively	Plant spring trap crop. Consider flowering date to time planting.	Consider summer trap crop. Cultivate all chickpea trap crops by 30 September.	Consider last generation trap crop.	Monitor *Helicoverpa* populations in summer trap crop, control if necessary.	Destroy *Helicoverpa* eggs and larvae in last generation trap crop using biological sprays. Pupae bust last generation trap crop.
7. Communication and training	Consider becoming involved in an IPM or AWM group. Attend regional training and information seminars. Consider doing the IPM short course.	Communicate with neighbours and applicators to discuss spray management plans.	Meet regularly with neighbours and consultant to discuss IPM strategies and attend local field days.	Meet regularly with neighbours and consultant to discuss IPM strategies and attend local field days.	Meet regularly with neighbours and consultant to discuss IPM strategies and attend local field days.

Insecticide Resistance Management Strategy (IRMS) for 2009/10

Louise Rossiter and David Larsen, Industry & Investment NSW; Sharon Downes and Lewis Wilson, CSIRO; Dave Murray and Melina Miles, Department of Employment, Economic Development and Innovation

The use of pesticides selects for resistance in pest populations. The cotton industry IRMS seeks to manage the risk of resistance in *Helicoverpa* spp., aphids, mites and whitefly, both in conventional and Bollgard II® cotton. Additional resistance management requirements are also in place for managing the risk of *Helicoverpa* spp. developing resistance to Bollgard II® (refer to pages 64–65). Below, the key elements of the IRMS are described and questions regarding the design and reasons for the IRMS are answered. In this document, the term 'insecticide' refers generally to pesticides used for insect or mite control.

CHECKLIST

1. Cultivate cotton and residues of alternative host crops as soon as possible after harvest to destroy overwintering *H. armigera* pupae. In Bollgard II® fields, cultivation must be completed before the end of july.
2. Use recommended pest thresholds to minimise insecticide use and reduce resistance selection. Refer to Table 2 on page 22–23.
3. Monitor first position fruit retention at flowering and aim to retain at around 60% or alternatively maintain a fruiting factor of between 1.1 and 1.3.
4. Delay using broad-spectrum sprays, such as organophosphates or pyrethroids, for as long as possible. These products reduce the abundance of beneficial insects and increase the chance of mite, aphid and silverleaf whitefly outbreaks.
5. Avoid early season use of omethoate or dimethoate. This is to prevent selection for organophosphate-carbamate cross-resistance in aphids. Avoiding early season use of these insecticides also reduces the risk of flaring other pests like silverleaf whitefly.
6. Do not apply a first foliar spray from the same insecticide group as a seed treatment. For sucking pests, consider the seed treatment as a 'spray' and alternate chemistries.
7. Monitor mite populations regularly after seedlings emerge. If established mite populations are present (5–10% of plants infested) avoid using broad-spectrum insecticides to control other pests. Instead use selective compounds or compounds that also control or suppress mites, either alone or in mixtures as required.
8. Avoid continuous sprays of any one mode of action group, including Bt products. (Rotate between chemical groups where possible). Do not exceed the maximum acceptable use limits indicated on the Insecticide Resistance Management Strategy charts for cotton (see pages 52–55).
9. Do not respray an apparent failure with a product of the same group – unless the failure is clearly due to factors not related to resistance, such as poor application, timing, etc.
10. Control weeds on farm to minimise alternative hosts for mites, aphids and silverleaf whitefly through winter and particularly in the lead up to cotton planting.
11. Comply with any use restrictions placed on insecticides used on other crops. This will reduce the chance of prolonged selection for resistance over a range of crops.

YOUR QUESTIONS ANSWERED

How was the 2009/10 IRMS decided?

The development of the Insecticide Resistance Management Strategy is driven by the Transgenic and Insect Management Strategies (TIMS) Committee. TIMS is a sub-committee of Cotton Australia The results from the insecticide and miticide resistance monitoring programs, carried out during the season, are used to inform the committee of any field-scale changes in resistance levels. Extensive communication and discussion with cotton growers and consultants is undertaken in all regions of the Australian cotton industry before TIMS finalises their recommendations. Communication is critical for ensuring that the IRMS is practical and can be implemented.

What are the key changes in the IRMS this season?

There were a number of key changes to the IRMS for this season:

1. Darling Downs incorporated into the Central Regions IRMS enabling insecticide use windows to be uniform (thereby minimising selection pressure) across southern Queensland and northern NSW.
2. Southern Regions IRMS for Macquarie, Lachlan and Murrumbidgee allowing for earlier season pyrethroid use (Dec 15 – end of season) on *H. punctigera* populations in areas where silverleaf whitefly does not currently present a problem.
3. Central Regions: pyrethroids moved to start 1 month later (Jan 15 – end of season) due to effect on flaring silverleaf whitefly outbreaks.
4. Altacor windowed after an initial season wide use period last year –
   Central and Southern Regions: Dec 1 – Feb 15
   Northern Regions:Nov 15 – Feb 1.

IRMS

5. Northern Regions: Steward moved to start 15 days later in the season in response to industry feedback, Dec 1 – Feb 15.
6. Shield (Clothianidin) added to the Neonicotinoid group.
7. Chemicals that are registered but currently commercially unavailable have been separated from the main body of the strategy and 'greyed' out to give greater clarity to those insecticides that are actually available for use.

Why is it important to follow the IRMS in Bollgard II® cotton?

Whenever insecticides are used there is selection pressure for resistance. The IRMS should always be consulted when making a spray decision, even in Bollgard II® cotton. This is irrespective of whether the decision has been motivated by above threshold populations of secondary pests, large *Helicoverpa* larvae migrating from refugia or extremely high *Helicoverpa* egg pressure. The IRMS has been designed to fit with IPM principles. Following the IRMS and implementing the Bollgard II® RMP is necessary to minimise all resistance risks to insecticides, miticides and the Cry proteins (in Bollgard II®).

How do insects develop resistance?

Resistance is an outcome of exposing pest populations to a strong selection pressure, such as an insecticide. Genes for resistance naturally occur at very low frequencies in insect populations. They remain rare until they are selected for with a toxin, either from an applied pesticide or from within Bollgard II®. Once a selection pressure is applied, resistance genes can increase in frequency as the insects carrying them are more likely to survive and produce offspring. If selection continues, the proportion of resistant insects relative to susceptible insects may continue to increase until reduced effectiveness of the toxin is observed in the field.

What do the chemical group numbers on the IRMS charts mean?

The numbers appearing beside chemical names or trade names on the IRMS chart are the international mode of action group numbers. To be consistent with insecticide product labels and international agreements among chemical manufacturers, TIMS also include these numbers when listing chemical groups.

Insecticides with the same mode of action kill pests by the same mechanism eg. by affecting the function of nerves or by paralysing mouthparts. Hence, if insects (or mites) develop resistance to one insecticide in a particular mode of action group, they maybe cross resistant to other insecticides in that group.

What is the scientific basis of the IRMS?

The basis of the IRMS is to minimise selection across consecutive generations of the pest. Pest life cycles therefore determine the length of the 'windows' around which the IRMS is built. As the life cycles of *Helicoverpa* spp. and the sucking pests are very different, the strategy for one will not manage resistance for the other.

Helicoverpa spp.

Ideally the length of the 'windows' would be 42 days (average) time from egg to moth) to minimise the selection pressure across consecutive generations. Most chemicals are restricted to windows of between one and two generations to account for the practicalities of pest control. To counteract this compromise there are additional restrictions on the maximum number of applications for each chemical group.

Sucking Pests – mites, aphids and whitefly

The resistance strategy for the short life cycle pests depends on rotation of insecticides/miticides between different chemical groups (different modes of action) to avoid selection over successive generations. Non-consecutive uses of chemistries is particularly important for aphids as they reproduce asexually. All offspring from a resistant aphid will be resistant.There are also restrictions on the maximum number of uses for individual products and chemical groups to further encourage rotation of chemistries.

How do refuges help manage resistance to Bt in Bollgard II®, and do they help manage resistance to insecticides in *Helicoverpa*?

Growing refuge crops is a pre-emptive resistance management strategy. It is being implemented to prevent field-scale resistance to Bollgard II®. This is important as the success of the refuge strategy depends on the majority of the general population being susceptible (SS). When a susceptible moth mates with a resistant moth (RR), the offspring carry one allele from each parent (RS). These offspring are referred to as heterozygotes. In the cases of Bt resistance that have so far been identified, heterozygotes are still controlled by Bollgard II® cotton. Because of the high toxic dose in Bollgard II®, it is only RR individuals that can survive. This is not always the case for resistances to other insecticides. For many of the conventional insecticides (to which resistance has already developed), resistance mechanisms are functionally dominant. This means that heterozygotes survive the application and can make up a large part of the resistant population. In such circumstances the dilution effect created by refuges is far less effective.

Refuges are able to help manage Bt resistance through the generation of SS moths. If RR moths are emerging from Bollgard II® fields, they are more likely to mate with SS moths if a refuge has been grown. The RS offspring is susceptible to Bollgard II® and an increase in the frequency of RR individuals can be prevented.

While refuges cannot assist when insecticide resistance is already prevalent in the field population, such as with synthetic pyrethroids, there may be some benefit from the unsprayed refuge options for new chemistries. Unsprayed refuges will produce moths that have not been exposed to insecticide selection pressure.

How does the migration of moths within a season impact on the IRMS?

The IRMS has always accounted for moth movement among different cotton growing regions. Several field studies have shown that moths can travel large distances. Recently, some genetic work showed that *H.armigera* moths move up to 1200 kilometres between regions. Insecticide resistance in one region can therefore spread to other regions by moth migration. The TIMS Committee designs the IRMS to reduce the chance that moths migrating between regions would be reselected repeatedly by the same insecticide group. This is done by limiting the time period over which most insecticides are available. The strategies also accommodate the different growing seasons from central Queensland through to southern NSW.

Will the large uptake of Bollgard II® reduce the population sizes of *Helicoverpa* spp.?

It is too early to tell whether the widespread use of Bollgard II® will affect the size of natural populations of *Helicoverpa*. *H. armigera* is closely linked with cropping regions so it is possible that a reduction in numbers of this pest will occur over time. In most seasons, the majority of moths are locally generated, so Bollgard II® may act as a 'sink' and influence the overall population size. However, this species uses hosts other than cotton and, even with widespread use of Bollgard II®, population sizes may be regulated by the abundance of these alternative hosts.

In contrast, large populations of *H. punctigera* moths can be generated in inland areas and migrate to cotton growing regions. As these moths are generated in other environments, Bollgard II® will have little effect on the size of these populations, especially early in the season following the annual spring migration events of this species. However the size of these populations will be strongly influence by the availability of hosts, which is largely determined by rainfall. Years where inland areas receive little rainfall may produce few migrating moths.

Why do we need an IRMS in conventional cotton when there are such large areas of Bollgard II®?

Large areas of Bollgard II® will not change the **frequencies** of resistance genes being carried by *H. armigera* moths. The same **proportion** of resistant and susceptible moths will continue to lay eggs in cotton – be it conventional or Bollgard II®. Hence the **likelihood** of resistance development to foliar and soil applied insecticides remains the same, even if the overall size of the *H. armigera* population is reduced. Continuing to follow the IRMS will ensure that the industry retains the ability to control *H. armigera* effectively with insecticides on conventional cotton both now and in the future, in case field-resistance to Bollgard II® develops.

When do stage windows start and stop?

The dates shown on the strategy charts are for the start of each stage. Windows will start at 00:01 h on the date shown as the start (e.g. 15 December for Stage 2 in Central areas) and end at midnight 24:00 h on the day before the start of the next window (e.g. 1 February for Stage 2 in Central areas). For those individual insecticides and miticides that start or end outside window boundaries, the start and end dates are specified and the same principles apply.

What do the terms cross-resistance and multiple resistance mean? How can they be minimised?

Cross-resistance occurs when selection for resistance against one pesticide also confers resistance to another pesticide, either from the same mode of action group or a different group. For example, the mechanism for pirimicarb resistance (Group 1A) in aphids also gives resistance to omethoate/dimethoate (Group 1B). Cross-resistance is important as it means that a pest may be resistant to a chemical to which it has never been exposed (i.e. without selection pressure).

Multiple resistance simply means that an insect is resistant to more than one mode of action group. For instance, *H. armigera* can have metabolic resistance to synthetic pyrethroids (Group 3A) and nerve insensitivity to organophoshates (Group 1B).

The development of both cross-resistance and multiple resistance can be minimised by following the IRMS. The strategy is designed to manage both of these occurrences. For example, in the strategy for aphids, there is a break between the use of pirimicarb and dimethoate/omethoate during which other chemistries should be used. The use of alternative chemistries should minimise the number of pirimicarb-resistant aphids being exposed to dimethoate/omethoate.

Is pupae busting in conventional cotton still important for resistance management?

Yes. Pupae busting is an effective, non-chemical method of preventing resistance carryover from one season to the next.

In 2007/08 the pupae busting guidelines for sprayed conventional cotton were modified according to the likelihood that larvae will enter diapause before a certain date, allowing for removal of pupae busting operations in field specific situations. The estimated commencement date of diapause is based on the model which drives the *Helicoverpa* Diapause Induction and Emergence Tool on the Cotton CRC website. The model was developed from field research conducted on the Darling Downs by QPI&F and has broad application to farming systems in eastern Australia. The web tool predicts the timing of diapause.

Post Harvest Pupae Destruction statement since 2007/08: Sprayed conventional cotton crops defoliated after the 9th March are more likely to harbour insecticide resistant diapausing *Helicoverpa armigera* larvae and should be pupae busted as soon as possible after picking and no later than the end of July.

How does the use of insecticide mixtures fit in the IRMS?

When used repeatedly, mixtures are high-risk and a controversial strategy for managing resistance. They can undermine the IRMS by repeatedly selecting for resistance to the common components in mixtures and by selection for resistance across multiple chemical groups. When mixtures are used frequently, it becomes difficult to determine whether each component is contributing equally to efficacy.

The use of mixtures to overcome the effects of resistance requires very careful consideration. Mixtures may provide improved field control of *H. armigera* in situations where a proportion of the pest population is resistant to one insecticide (i.e. pyrethroid) but is susceptible to another chemical group with a different mode of action (i.e. organophosphate). As a general rule, mixtures are unnecessary in situations where individual products provide adequate control.

Several criteria need to be met for mixtures to be effective. Components of the mixture should;

- be equally persistent,
- have different modes of action,
- not be subject to the same routes of metabolic detoxification,
- be tank-mix compatible.

In addition, the majority of the pest population should not be resistant to any component of a mixture, as this may render it a redundant or 'sleeping partner' in terms of insect control.

When very heavy *Helicoverpa* spp. pressure occurs and egg parasitism percentages have been low, include an ovicide (e.g. amitraz and methomyl) in sprays to take the pressure off larvicides. When targeting sprays against eggs and very small larvae and do not expect 100% control with any insecticide or mixture of insecticides. If larval numbers are reduced below threshold then the treatment should be regarded as effective.

Some mix partners provide more than additive kill (synergism), but this is not always the case. Some mixtures may in fact result in reduced effectiveness. For example the synergists, piperonyl butoxide (PBO) and propargite, may increase the efficacy of pyrethroids against *H. armigera*, but may be antagonistic if mixed with organophosphates or chlorfenapyr.

The Croplife Australia Insecticide Resistance Management Group, recommend that no two compounds from the same chemical group/ mode of action be included in a mixture (e.g. chlorpyrifos and profenofos). The repeated use of any insecticide with different mix partners will also increase selection for resistance e.g. pyrethoid plus propargite, followed by pyrethroid plus amitraz, followed by pyrethroid plus organophosphate.

It is illegal to use rates above those recommended on the label of an insecticide alone or in mixtures. Efficacy will not always improve at rates above the highest label rate or if two insecticides of the same chemical group are applied as a mixture.

TIMS Troubleshooting Committee contacts 2009/10

Name	Telephone	Mobile	Fax	Email
Lewis Wilson (Chair person)	(02) 6799 1550	–	(02) 6793 1186	lewis.wilson@csiro.au
Louise Rossiter	(02) 6799 1500	0429 726 285	(02) 6799 1503	louise.rossiter@industry.nsw.gov.au
CRDC (Tracey Farrell)	(02) 6792 4088	–	(02) 6792 4400	tracey.farrell@crdc.com.au
CA (Greg Kauter)	(02) 9669 5222		(02) 9669 5511	gregk@cotton.org.au

Can emergency changes be made to the IRMS during the season?

Yes, the TIMS Troubleshooting Committee (TTC) was established by TIMS to act on its behalf to respond quickly to requests to vary the Strategy **temporarily** for **specific regions**. The TTC is not able to approve major changes to the Strategy – that is the role of the TIMS Committee.

What is the process for requesting a within-season change to the IRMS?

The TIMS Troubleshooting Committee (TTC) has put in place a clear process for handling requests for within-season changes to the IRMS.

A request to temporarily alter the Strategy for a district or part of a district can be initiated by any grower or consultant, but it will not be considered by the TTC unless it is presented with clear evidence of having been discussed and gained majority support at a local level. This will include:

- Evidence that the local consultants who might be affected by the requested alterations have discussed them and are in agreement.
- A request from the local Cotton Growers Association (CGA) that outlines the problem and the preferred solution.
- Evidence that all reasonable efforts have been made to apply the alternatives available within the strategy.

The request can be faxed or emailed to Louise Rossiter or Lewis Wilson. A return contact name and phone number should be included so that receipt of the request can be acknowledged and further discussion can be held with a TTC member if required.

All members of the TTC will be faxed or emailed the request and asked to respond to an ACRI contact point by 10 a.m. the following morning (or the next working day if the request is lodged on a weekend or public holiday). A decision will then be made and a response issued by 12 noon. All reasonable efforts will be made to meet this level of response, however it should be recognised that complex or poorly communicated requests may take longer to resolve.

The granting of a request by the TTC to temporarily alter the Resistance Strategy applies to a specific district. It does not confer the same temporary changes to other districts unless they have also lodged a request to the TTC in the manner outlined above. TTC changes for a region have a limited duration and do not carry over from one season to the next.

CONSIDERATIONS FOLLOWING A SUSPECTED SPRAY FAILURE

In the event of a suspected pest control failure, don't panic as it is important to assess the situation carefully before deciding on a course of action. The presence of live pests following an insecticide application does not necessarily indicate insecticide failure. What is the insecticide's mode of action? Has it been given enough time to work? Products such as thiodicarb, foliar Bt, NPV, spinosad and indoxacarb are stomach poisons and may not give maximum control until 5–7 days after application. Similarly, propargite, abamectin, pyriproxifen and diafenthiuron are slow acting and may take 7–10 days or longer to achieve maximum control. In some instances pest infestation levels remain high following a treatment but little if any economic damage to the crop occurs (e.g. if the pests are sick and have ceased feeding

When diagnosing the cause of an insecticide failure, it is important to remember that there are a wide range of variables that influence insecticide efficacy. These include species complex, population density and age, crop canopy structure, application timing, the application method, carrier and solution pH – and their effects on coverage and the insecticide dose delivered to the target, environmental conditions, assessment timing and insecticide resistance expressed in the pest population. For every insecticide application, it is the interaction of all of these factors that determines the outcome. While it will not be possible to optimise all of these variables all of the time, when more compromises are made, there is a greater likelihood that efficacy will be unsatisfactory.

It is also important to maintain realistic expectations of the efficacy that can be achieved. For example, do not expect satisfactory control of medium and large *Helicoverpa* larvae late in the season, regardless of the insecticide treatment used.

If a field failure is suspected to be due to insecticide resistance, collect a sample of the surviving pest from the sprayed field using the industry guidelines and send to the relevant researcher. For *Helicoverpa* surviving conventional insecticides, Louise Rossiter (02) 6799 1500. For *Helicoverpa* surviving Bt, Sharon Downes (02) 6799 1500. For mites and aphids, Grant Herron (02) 4640 6333. For whitefly, Richard Lloyd (07) 4688 1315. Sending samples for testing can confirm or rule out resistance as the cause of the spray failure and is an important part of assessing the presence of resistance across the industry.

After any spray failure, *do not follow up with an application of the same insecticide group alone or in mixture (at any rate)*. Rotate to an insecticide from a different mode of action group.

Northern Regions:

Central Highlands, Dawson and Callide Valleys

Helicoverpa

See Cotton Pest Management Guide for suggested thresholds

Stage 1	Stage 2 Nov 15	Stage 3 Dec 15	Stage 4 Jan 15	Stage 3 Feb 1

Maximum 2 consecutive sprays of any one insecticide group, alone or in mixtures

- FOLIAR *Bacillus thuringiensis* (BT) -on conventional and Bollgard cotton but EXCLUDING any refuges
- HELICOVERPA VIRUSES (Gemstar, Vivus) avoid season long use of low rates
- Canopy Oil , Abrade - No restrictions
- AMITRAZ - Max of 4
- ENDOSULFAN see label for restrictions
- Affirm
- ABAMECTIN - for *H. punctigera*, Max of 2, including mite sprays
- } Max 3 from 'mectins' group
- Altacor - Max of 3
- Dec 1 Steward* - Max of 3 Feb 15
- PYRETHROIDS & PYRETHROID MIXES
  - PBO, Max of 2
  - Talstar sprays, Max of 2, including mite sprays.
- CHLORPYRIFOS - Max of 3 including mixtures
- Other OPs - Max of 3 including mixtures
- METHOMYL - Max of 4, carbamates Including mixtures
- THIODICARB - Max of 4 carbamates Including mixtures

* September 15th No use of Steward or Tracer on chickpeas after this date

Registered but currently commercially unavailable insecticides

- Prodigy - Max of 3
- Intrepid - Max of 1 at any rate including mite sprays
- Tracer* - Max of 3
- CHLORPYRIFOS METHYL- Max of 3 including mixtures
- PROFENOFOS - Max of 3 including mixtures

Post-Harvest

Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour insecticide resistant diapausing *Helicoverpa armigera* pupae and should be pupae busted as soon as possible after picking and no later than the end of August

Aphids, Mites, SLW, Mirids

See Cotton Pest Management Guide for suggested thresholds

Stage 1	Stage 2 Nov 15	Stage 3 Dec 15	Stage 4 Jan 15	Stage 3 Feb 1

1. Maximum 2 sprays per mode of action group, including mixtures, unless otherwise indicated below.
2. Rotate chemistry. No consecutive use of the same group
3. **Failures** with **neonicotinoids** against aphids **have been confirmed**. Do not follow a seed or planting insecticide with the first foliar spray from the same group. **ALTERNATE**

Pest	Product / restriction	With-holding Period
Aphids	Canopy Oil - No restrictions	Nil See label
Aphids	Cruiser, Gaucho / Genero, Amparo } Seed dressing	Nil See label
Aphids	Confidor - Finish date determined by long withholding period	91 days
Aphids	Actara, Intruder, Shield	28, 10 & 5 days
Aphids	PIRIMICARB - Use when beneficial conservation is important	21 days
Aphids	Fulfill - Crop must be actively growing - Finish date determined by crop growth (see label)	28 days
Aphids	ENDOSULFAN - see label for restrictions	28 days
Aphids	DIMETHOATE & OMETHOATE	14 & 21 days
Aphids	CHLORPYRIFOS - METHYL see Helicoverpa strategy	5 days
Aphids and Mites	ALDICARB - In furrow at sowing	Nil See label
Aphids and Mites	PHORATE - in furrow at sowing or side dress	70 days
Aphids and Mites	CHLORPYRIFOS - See Helicoverpa strategy	28 days
Aphids and Mites	Start date determined by canopy closure (see label) - Pegasus	14 days
Aphids and Mites	PROFENOFOS - See Helicoverpa strategy	28 days
Mites	Paramite - Max of 1	21 days
Mites	ABAMECTIN - Max of 2, including *H. punctigera* sprays	20 days
Mites	Don't use pre squaring - PROPARGITE	28 days
Mites	Talstar - Max of 2, including Helicoverpa sprays.	14 days
Mites	Intrepid - Max of 1 at any rate including Helicoverpa sprays	28 days
SLW	Refer Silverleaf whitefly Threshold Matrix and associated Notes	
Mirids	WARNING Avoid early season omethoate/dimethoate use as it may compromise their efficacy and pirimicarb efficacy against aphids as well as flare other pests including silver leaf whitefly.	

Post-Crop Management

STOP Over wintering resistant populations by practising good farm hygiene (see IPM Guidelines)

2009–2010 Insecticide Resistance Management Strategy for Cotton

Central

Darling Downs, Balonne, Macintyre, Gwydir, Lower & Upper Namoi, Bourke

Helicoverpa

Stage 1 | Stage 2 Dec 15 | Stage 3 Jan 15 | Stage 4 Feb 15

See Cotton Pest Management Guide for suggested thresholds

Maximum 2 consecutive sprays of any one insecticide group, alone or in mixtures

- FOLIAR *Bacillus thuringiensis* (BT) - on conventional and Bollgard cotton but EXCLUDING any refuges
- HELICOVERPA VIRUSES - (GEMSTAR, VIVUS) avoid season long use of low rates
- CANOPY OIL , ABRADE - No restrictions
- AMITRAZ - Max of 4
- ENDOSULFAN see label for restrictions
- AFFIRM — February 1 } Max 3 from 'mectins' group
- ABAMECTIN - for *H. punctigera*, Max of 2, including mite sprays } Max 3 from 'mectins' group
- December 1 ALTACOR - Max of 3
- STEWARD*- Max of 3
- PYRETHROIDS & PYRETHROID MIXES
  - PBO, Max of 2
  - TALSTAR sprays, Max of 2, including mite sprays.
- February 1 {
  - CHLORPYRIFOS - Max of 3 including mixtures
  - Other OPs - Max of 3 including mixtures
  - METHOMYL - Max of 4 carbamates Including mixtures
  - THIODICARB - Max of 4 carbamates Including mixtures

* October 15th No use of Steward or Tracer on chickpeas after this date

Registered but currently commercially unavailable insecticides

- PRODIGY - Max of 3
- December 1 TRACER* - Max of 3
- INTREPID - Max of 1 at any rate including mite sprays
- February 1 {
  - CHLORPYRIFOS METHYL - Max of 3 including mixtures
  - PROFENOFOS - Max of 3 including mixtures

Post-Harvest

Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour insecticide resistant diapausing *Helicoverpa armigera* pupae and should be pupae busted as soon as possible after picking and no later than the end of August

Aphids, Mites, SLW, Mirids

Stage 1 | Stage 2 Dec 15 | Stage 3 Jan 15 | Stage 4 Feb 15

See Cotton Pest Management Guide for suggested thresholds

1. Maximum 2 sprays per mode of action group, including mixtures, unless otherwise indicated below.
2. Rotate chemistry. No consecutive use of the same group
3. **Failures** with **neonicotinoids** against aphids **have been confirmed**. Do not follow a seed or planting insecticide with the first foliar spray from the same group. **ALTERNATE**

Pest	Product / restriction	With-holding Period
Aphids	Canopy Oil - No restrictions	Nil See label
Aphids	CRUISER, GAUCHO / GENERO, AMPARO } Seed dressing	Nil See label
Aphids	CONFIDOR — Finish date determined by long withholding period	91 days
Aphids	ACTARA, INTRUDER, SHIELD	28, 10 & 5 days
Aphids	PIRIMICARB — January 1 Use when beneficial conservation is important	21 days
Aphids	FULFILL - Crop must be actively growing — Finish date determined by crop growth (see label)	28 days
Aphids	ENDOSULFAN - see label for restrictions	28 days
Aphids	February 1 { DIMETHOATE & OMETHOATE	14 & 21 days
Aphids	February 1 { CHLORPYRIFOS -METHYL - see Helicoverpa strategy	5 days
Aphids and Mites	ALDICARB — In furrow at sowing	Nil See label
Aphids and Mites	PHORATE — in furrow at sowing or side dress	70 days
Aphids and Mites	February 1 CHLORPYRIFOS - See Helicoverpa strategy	28 days
Aphids and Mites	Start date determined by canopy closure (see label) PEGASUS	14 days
Aphids and Mites	February 1 PROFENOFOS - See Helicoverpa strategy	28 days
Mites	DICOFOL - NSW only + Ground application only	7 days
Mites	PARAMITE - Max of 1	21 days
Mites	ABAMECTIN - Max of 2, including *H. punctigera* sprays	20 days
Mites	Don't use pre squaring PROPARGITE	28 days
Mites	TALSTAR - sprays, Max of 2, including Helicoverpa sprays.	14 days
Mites	INTREPID - Max of 1 at any rate including Helicoverpa sprays	28 days
SLW	Refer Silverleaf whitefly Threshold Matrix and associated Notes	
Mirids	WARNING Avoid early season omethoate/dimethoate use as it may compromise their efficacy and pirimicarb efficacy against aphids as well as flare other pests including silver leaf whitefly.	

Post-Crop Management

STOP Over wintering resistant populations by practising good farm hygiene (see IPM Guidelines)

2009–2010 Insecticide Resistance Management Strategy for Cotton

Southern Regions:

Macquarie, Lachlan, Murrumbidgee

Helicoverpa

See Cotton Pest Management Guide for suggested thresholds

Stage 1 | Stage 2 Dec 15 | Stage 3 Jan 15 | Stage 4 Feb 15

Maximum 2 consecutive sprays of any one insecticide group, alone or in mixtures

- FOLIAR *Bacillus thuringiensis* (BT) - on conventional and Bollgard cotton but EXCLUDING any refuges
- HELICOVERPA VIRUSES - (GEMSTAR, VIVUS) avoid season long use of low rates
- CANOPY OIL , ABRADE - No restrictions
- AMITRAZ - Max of 4
- ENDOSULFAN see label for restrictions
- AFFIRM — February 1
- ABAMECTIN - for *H. punctigera*, Max of 2, including mite sprays
- } Max 3 from 'mectins' group
- December 1 ALTACOR - Max of 3
- STEWARD*- Max of 3
- PYRETHROIDS & PYRETHROID MIXES
  - PBO, Max of 2
  - TALSTAR sprays, Max of 2, including mite sprays.
- February 1 {
  - CHLORPYRIFOS - Max of 3 including mixtures
  - Other OPs - Max of 3 including mixtures
  - METHOMYL - Max of 4 carbamates Including mixtures
  - THIODICARB - Max of 4 carbamates Including mixtures

* October 15th No use of Steward or Tracer on chickpeas after this date

- PRODIGY - Max of 3
- December 1 TRACER* - Max of 3
- INTREPID - Max of 1 at any rate including mite sprays
- February 1 {
  - CHLORPYRIFOS METHYL - Max of 3 including mixtures
  - PROFENOFOS - Max of 3 including mixtures

Registered but currently commercially unavailable insecticides

Post-Harvest

Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour insecticide resistant diapausing *Helicoverpa armigera* pupae and should be pupae busted as soon as possible after picking and no later than the end of August

Aphids / Aphids and Mites / Mites / SLW / Mirids

See Cotton Pest Management Guide for suggested thresholds

Stage 1 | Stage 2 Dec 15 | Stage 3 Jan 15 | Stage 4 Feb 15

1. Maximum 2 sprays per mode of action group, including mixtures, unless otherwise indicated below.
2. Rotate chemistry. No consecutive use of the same group
3. **Failures** with **neonicotinoids** against aphids **have been confirmed**. Do not follow a seed or planting insecticide with the first foliar spray from the same group. **ALTERNATE**

Pest	Product / restriction	With-holding Period
Aphids	Canopy Oil - No restrictions	Nil See label
Aphids	CRUISER, GAUCHO / GENERO, AMPARO } Seed dressing	Nil See label
Aphids	CONFIDOR — Finish date determined by long withholding period	91 days
Aphids	ACTARA, INTRUDER, SHIELD	28, 10 & 5 days
Aphids	PIRIMICARB — January 1 Use when beneficial conservation is important	21 days
Aphids	FULFILL - Crop must be actively growing — Finish date determined by crop growth (see label)	28 days
Aphids	ENDOSULFAN - see label for restrictions	28 days
Aphids	February 1 { DIMETHOATE & OMETHOATE	14 & 21 days
Aphids	CHLORPYRIFOS-METHYL - see Helicoverpa strategy	5 days
Aphids and Mites	ALDICARB — In furrow at sowing	Nil See label
Aphids and Mites	PHORATE — in furrow at sowing or side dress	70 days
Aphids and Mites	February 1 CHLORPYRIFOS - See Helicoverpa strategy	28 days
Aphids and Mites	Start date determined by canopy closure (see label) PEGASUS	14 days
Aphids and Mites	February 1 PROFENOFOS - See Helicoverpa strategy	28 days
Mites	DICOFOL - NSW only + Ground application only	7 days
Mites	PARAMITE - Max of 1	21 days
Mites	ABAMECTIN - Max of 2, including *H. punctigera* sprays	20 days
Mites	Don't use pre squaring PROPARGITE	28 days
Mites	TALSTAR - sprays, Max of 2, including Helicoverpa sprays.	14 days
Mites	INTREPID - Max of 1 at any rate including Helicoverpa sprays	28 days
SLW	Refer Silverleaf whitefly Threshold Matrix and associated Notes	
Mirids	WARNING Avoid early season omethoate/dimethoate use as it may compromise their efficacy and pirimicarb efficacy against aphids as well as flare other pests including silver leaf whitefly.	

Post-Crop Management

STOP Over wintering resistant populations by practising good farm hygiene (see IPM Guidelines)

Chemical Groups for Rotation

Group.	Chemical:	Sold as	Effective against: Helicoverpa (14)	Mites (7)	Aphids (7)
16A.	METHOXYFENOZIDE (IGR):	PRODIGY			
11C.	BT:	DIPEL, COSTAR, MVP2, etc			
	VIRUS.	HELICOVERPA VIRUS (NPV'S: GEMSTAR, VIVUS)			
	OTHERS,	CANOPY , ABRADE			Canopy
28.	RYNAXYPYR:	ALTACOR			
5A.	SPINOSAD:	TRACER			
3A.	PYRETHROID:	BULLDOCK, DECIS, DOMINEX, FASTAC, KARATE, etc			
3A.	PYRETHROID (BIFENTHRIN):	TALSTAR		Suppress only	
19A.	AMITRAZ:	AMITRAZ, OVASYN etc			
2A.	ENDOSULFAN:	THIODAN etc.			
22A.	INDOXACARB:	STEWARD			
6A.	AVERMECTIN:	EMAMECTIN BENZOATE (AFFIRM)		Suppress only	
6A.	AVERMECTIN:	ABAMECTIN (WIZARD etc)	*H. punctigera* only		
1A.	CARBAMATES:	METHOMYL (NUDRIN, LANNATE etc), THIODICARB (LARVIN etc)			
1A.	CARBAMATE at planting:	ALDICARB			No cross resistance
1A.	CARBAMATE Foliar:	(PIRIMICARB) PIRIMOR, APHIDEX		Cross resistance in Aphids - Treat Pirimicarb and group 1B as one chemical group. Do not use first foliar spray from this group if seed or furrow treatment from this group.	
1B.	CHLORPYRIFOS (+ methyl) (OP):	CHLORFOS, LORSBAN, PREDATOR, (RESCUE, DIPLOMAT) etc	No cross resistance		
1B.	PROFENOFOS (OP):	CURACRON, SABRE etc	No cross resistance		
1B.	Other OPs	At Planting or side-dress : THIMET, PHORATE Foliar: DIMETHOATE, OMETHOATE, PARATHION METHYL.			
13A.	CHLORFENAPYR:	INTREPID			
12B.	DIAFENTHIURON:	PEGASUS			
4A.	NEONICOTINOIDS (IMIDACLOPRID, THIAMETHOXAM ACETAMIPRID & CLOTHIANIDIN):	Seed treatments: GAUCHO, GENERO, AMPARO, CRUISER Foliar: CONFIDOR, ACTARA, INTRUDER, SHIELD	Do not use first foliar spray from group 4a if seed /furrow treatment from this group		
9A.	PYMETROZINE:	FULFILL			
2B.	DICOFOL:	KELTHANE, MITIFOL			
14A.	PROPARGITE:	COMITE, BULLET			
10A.	ETOXAZOLE:	PARAMITE			

Key Changes

1. Altacor windowed:
Northern regions - Nov 15 - Feb 1
Central and southern regions: Dec 1 - Feb 15.
2. Incorporation of the Darling Downs with the Central regions
3. New Southern Region IRMS incorporating Macquarie, Lachlan and Murrumbidgee
4. Northern: Steward moved 15 days further into the season, Dec 1 - Feb 15.
5. Central: pyrethroids moved 1 month further into the season, Jan 15 - end
6. Shield (clothianidin) added to Neonicotinoid group
7. Chemicals registered but not commercially available identified.

Key Guidelines

1. Pupae bust cotton and alternative crop residues as soon as possible.
2. Use recommended thresholds for all pests.
3. Monitor 1st position fruit retention at flowering.
4. Avoid using broad spectrum sprays.
5. Monitor pest and beneficial populations.
6. Avoid continuous sprays from same group.
7. Do not respray apparent failure with same group.
8. Control weeds on farm which are hosts for pests.
9. Comply with any insecticide use restrictions according to label

For more detailed information see web page:
http://www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/Insect_Resistance_Management.aspx

Trouble shooting: A TIMS sub-committee has been established to arbitrate in cases where individuals, groups or regions expect to have difficulties following the strategy guidelines. It includes representation from: CSIRO, Industry and Investment NSW; Department of Employment, Economic Development and Innovation Qld; Cotton Australia.

If problems arise, contact: Tracey Farrell Phone 02 6792 4088 Fax: 02 6792 4400 Email: tracey.farrell@crdc.com.au

Produced by: Cotton Catchment Communities CRC, CRDC, CropLife, TIMS

Layout and design– Cotton Catchment Communities CRC - Technology Resource Centre,

TRC-09 09

Preamble to the Resistance Management Plan (RMP) for Bollgard II® 2009/10

Sharon Downes and Lewis Wilson, CSIRO; Greg Kauter, Cotton Australia; Tracey Farrell formerly I&I NSW; Kristen Knight, Monsanto Australia Limited.

Resistance is the greatest threat to the continued availability and efficacy of Bollgard II® cotton in Australia. Even though the Bt proteins in Bollgard II® are delivered in the plant tissues, there is still the selection for the survival of resistant individuals. The RMP for Bollgard II® was established by regulatory authorities to mitigate the risks of resistance developing to either of the proteins contained in Bollgard II® cotton. As it is difficult to be precise about the probability of resistance developing in *Helicoverpa* spp. to the proteins contained in Bollgard II® cotton the industry implemented a pre-emptive management plan that aims to prevent field level changes in resistance.

A key component of the RMP for INGARD® was a limitation on the area of INGARD® cotton that could be planted. This restriction limited selection for resistance to the Cry1Ac protein in INGARD®. The industry has so far been able to preserve the efficacy of this gene. Now that Bollgard II® has replaced INGARD®, the constraint on the area of transgenic cotton has been removed. Bollgard II® contains both Cry1Ac and Cry2Ab. Computer simulation models of resistance development indicate that it will be more difficult for a pest to develop resistance to both of the insecticidal proteins. However, it is not impossible for *Helicoverpa* spp. to adapt to this technology.

Recent work has shown that for *H. armigera* and *H. punctigera* the assumed baseline frequency of Cry2Ab resistance genes in populations is substantially higher than previously thought. The recent data for *H. punctigera* also demonstrate significant increases over seasons in the frequency of Cry2Ab resistance genes (for more details see below). The continued efficacy of Bollgard II cotton is therefore even more dependent on the effective implementation of the RMP.

The total area of cotton planted in the 2009/10 season is predicted to continue to be relatively low, but the Bollgard II® acreage will still represent around 80% of the total area planted to cotton in Australia. Given the selection pressure exerted by Bollgard II® cotton, as well as the high (and potentially increasing) baseline frequency of genes conferring resistance to Cry2Ab in *Helicoverpa* spp. it is critical to abide by the obligations under the RMP.

Future transgenic cottons may also rely on either of the two existing insecticidal genes within Bollgard II®. In particular, Monsanto's third generation Bt-cotton will build on the existing Bollgard II cotton platform. Protecting Bollgard II® cotton therefore also represents an investment in the protection of future transgenic technology for the Australian cotton industry. If field resistance to Bollgard II® cotton were to eventuate it may make it more difficult to market new transgenic products in cotton, and the perceptions of other industries, growers and the public could be unduly affected. Modelling undertaken by CSIRO also suggests that Cry2Ab resistance levels in *Helicoverpa* spp. at the time of introducing the third generation Bt-cotton will directly impact on the requirements for the RMP for that technology. Therefore, it is critical that the industry complies fully and effectively with the RMP for Bollgard II®.

The 5 Elements of the Bollgard II® RMP

The five elements of the RMP impose limitations and requirements for management on farms that grow Bollgard II®. These are: mandatory growing of refuges; control of volunteer and ratoon plants; a defined planting window; restrictions on the use of foliar Bt; and mandatory cultivation of crop residues. In theory the interaction of all of these elements should effectively slow the evolution of resistance.

YOUR QUESTIONS ANSWERED

How do we test whether the RMP is effective?

To evaluate the effectiveness of the RMP the CRDC funds a program that monitors field populations of moths for resistance to Cry1Ac and Cry2Ab. Monsanto Australia operate a separate monitoring program. These data provide an early warning to the industry of the onset of resistance to Bollgard II®. They are used to make decisions about the need to modify the RMP from one season to the next to ensure its ongoing effectiveness at managing resistance. Two sorts of tests are conducted. F2 screens involve testing the grandchildren of pairs of moths raised from eggs collected from field populations, and therefore take about 10 weeks to run. To increase the number of insects that could be processed during the season, CSIRO developed protocols for testing the frequency of the Cry2Ab resistance gene detected with F2 screens using a shorter method called an F1 test. F1 screens involve testing the offspring of single-pair matings between moths from Cry2Ab resistant strains maintained in the laboratory (SP15 for *H. armigera* and Hp4-13 for *H. punctigera*) and moths raised from eggs collected from field populations. They take around 5 weeks to conduct.

What is the current situation for Bt resistance in H. armigera in Australia?

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 1 in 1,000,000 (<0.000001 or 0.0001%). This gene does not confer cross-resistance to Cry2Ab and in certain environments is largely recessive. It also has a high fitness cost (i.e. resistant individuals develop slowly and are more likely to die) but this disadvantage is not likely to greatly impact on the development of resistance. In addition, Dr Robin Gunning (I&I NSW) suggests that other resistance mechanisms may be present in *H. armigera*.

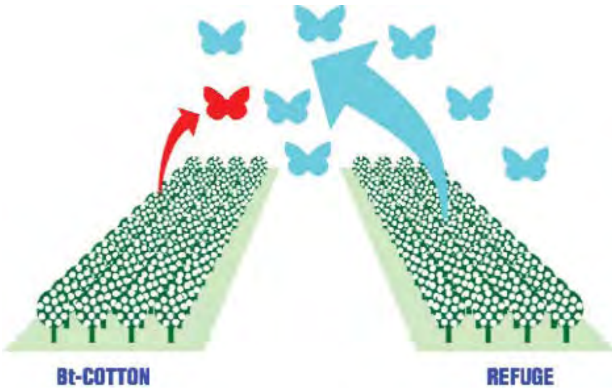
A gene that confers high level resistance to Cry2Ab is present in field populations of *H. armigera.* This gene does not confer cross-resistance to Cry1Ac. The most extensively studied colony of insects with this resistance (called SP15) appears to be as fit as susceptible insects. The resistance in such colonies is recessive. The mechanism conferring resistance to Cry2Ab in *H. armigera* has been shown to be an alteration of a binding site in the gut of the insect.

F2 tests indicated that the frequency of the gene for resistance to Cry2Ab in 2008/09 was less than 9 in 1000 (0.009, 0.9%). In 2004 CSIRO developed protocols for testing the frequency of resistance using a modified and shorter version of the F2 method called an F1 test. This method assumes that the various isolates of Cry2Ab detected so far are of the same kind. These protocols were immediately adopted by Monsanto. During the following two years CSIRO performed experiments which verified that the same mechanism appears to confer resistance in all of the isolates of Cry2Ab detected to date. In 2007/08 CSIRO began F1 tests in *H. armigera* in earnest.

Results with *H. armigera* show that the estimate of Cry2Ab resistance frequency for F1 screens is higher than for F2 tests. Of particular concern was the high frequency of Cry2Ab resistance genes at the end of the 2008/09 season – approximately 2 in 100 (0.02, 2%). Currently, we believe that the frequencies obtained from the F1 screens are likely to most accurately reflect the situation in the field. Both Monsanto and CSIRO are working together to better understand the differences between the F2 and F1 screens but to date have not determined the reason for this discrepancy.

What is the current situation for Bt resistance in* H. punctigera *in Australia

Before 2008/09 more than 4000 genes from *H. punctigera* had been screened and none had scored positive for resistance to Cry1Ac. However, in 2008/09 a gene was isolated from field populations of *H. punctigera* that confers resistance to Cry1Ac.



Moths produced from refuges dilute resistance genes in the population.

F2 tests indicate that the frequency of this gene in 2008/09 was less than 2 in 1000 (0.002, 0.2%). It is not cross-resistant to Cry2Ab. Researchers are currently attempting to establish a colony containing this gene for further characterisation.

A gene that confers high level resistance to Cry2Ab is present in field populations of *H. punctigera*. This gene does not confer cross-resistance to Cry1Ac. The most extensively studied colony of resistant insects (called Hp4-13) demonstrates the same broad characteristics as the SP15 strain of Cry2Ab resistant *H. armigera*. The resistance is recessive, occurs at a high level, and is due to an alteration of a binding site in the gut of the insect. F2 tests indicated that the frequency of this gene in 2008/09 was less than 8 in 1000 (0.008, 0.8%).

In 2007/08 CSIRO began F1 tests in *H. punctigera*. As with *H. armigera*, the Cry2Ab resistance frequency in *H. punctigera* for F1 screens is higher than that determined with the F2 tests. At the end of the 2008/09 season, the frequency of Cry2Ab genes in *H. punctigera* was approximately 5 in 100 (0.05, 5%).

Why is there a high baseline frequency of Cry2Ab genes in field populations?

The high frequency of individuals carrying the Cry2Ab resistant gene in field populations is unexpected because, until the widespread adoption of Bollgard II, there has presumably been little exposure of *Helicoverpa spp*. to this toxin and therefore little selection for resistance. Although the Cry2Ab toxin from Bt is present in some Australian soils, it is not common. In contrast, the Cry1Ac toxin is far more common in Australian soils, yet resistance to this toxin in *Helicoverpa spp*. is rare. Mutations that confer resistance to Cry2Ab may occur in field populations of *Helicoverpa spp*. at a very high rate.

Collection of *H. punctigera* moths from inland regions were made in winter 2009 to see of these populations, which would have little exposure to Bollgard II, carry resistance to Cry2Ab. F1 screens conducted by CSIRO on these populations show they carry the same Cry2Ab resistance gene present in the cropping areas but at a much lower frequency of 5 in 1000 (0.005, 0.5%). We do not have an F1 resistance frequency for Cry2Ab in *H. punctigera* prior to the widespread adoption of Bollgard II. However, in both years that we have F2 and F1 screen data for *H. punctigera* in the cropping regions the difference in the estimated frequencies is four-fold. We can estimate an F1 screen frequency for a time close to the introduction of Bollgard II® (2004/05) by multiplying the F2 screen frequency for that season by four. This gives a frequency of 6 in 1000 (0.006, 0.6%) which is similar to the current frequency in inland regions. Hence it is likely that the background resistance in *H. punctigera* to CryAb was common even before Bollgard II® was released.

Is the frequency of Cry2Ab genes increasing in field populations of H. armigera?
F2 data for *H. armigera* do not demonstrate a significant change in frequency of Cry2Ab resistance over time. Since 2004/05 Monsanto has used the F1 protocol developed by CSIRO to screen for resistance to Cry2Ab. This data set shows no significant difference in frequencies over time. CSIRO also have F1 screen data for *H. armigera* since 2007/08. There is no statistically significant difference within a season between the CSIRO and Monsanto data for 2007/08 and 2008/09. The combined 2007/08 data set shows a significantly greater Cry2Ab frequency compared to the previous years; in 2008/09 this frequency did not continue to increase nor did it drop to below the pre-2007/08 levels. However a recent analysis showed that despite both organisations utilising identical robust protocols, and sampling from the same hosts and regions, the frequencies scored by Monsanto are consistently lower than those scored by CSIRO. This is the case for 8 of 9 sets of data collected using the same screen method, species and sampling period where positives were scored by at least one organisation. This suggests that screens are being scored differently by CSIRO and Monsanto and since the size of this difference is not consistent among data sets it is not possible to apply a simple correction. Irrespective of changes through time the frequencies of Cry2Ab in *H. armigera* are higher than expected and this finding is a concern (see above).

Is the frequency of Cry2Ab genes increasing in field populations of H. punctigera?
The F2 and F1 data sets from CSIRO demonstrate significant increases in the frequency of Cry2Ab resistance genes in field populations of *H. punctigera*. CSIRO began collecting F2 screen data for *H. punctigera* in 2002/03. Each year since 2006/07 there has been an increase in the frequencies of resistance to Cry2Ab. This gradual increase over time became statistically significant in 2007/08 and remained highly significant in 2008/09. The 2008/09 F1 data set for *H. punctigera* demonstrates at least a 5 fold increase in frequency compared to 2007/08 which is statistically significant.

Why is H. punctigera developing resistance to Cry2Ab when it has no history of resistance to insecticide sprays?
H. punctigera has the capacity to develop resistance to insecticide sprays but it has been presumed that any resistance selection in cotton regions was kept in check by dilution from susceptible immigrants from central Australia each spring. There may be some recent changes to the ecology of *H. punctigera* that could impact on their ability to develop resistance including a greater tendency to overwinter in cotton regions and less immigration of inland individuals than in the past due to low rainfall inland.

Is the current RMP adequate for controlling further increases in resistance frequencies?
There have been no reported field failures of Bollgard II® due to resistance. However the recent finding of a higher baseline frequency of Cry2Ab genes (F1 tests) than previously detected using F2 screens is a major concern. Of even more concern is the demonstrated significant increase in Cry2Ab resistance frequency in *H. punctigera*. It is imperative that all users of Bollgard II® take responsibility for the stewardship of this technology. In particular, it is critical that closer attention is paid to managing refuges and that effective pupae busting occurs in a timely fashion.

In addition, the TIMS Bt Technical Panel have developed a working document entitled 'Contingency Plan for Mitigating Resistance to the Toxins Within Bollgard II® Cotton' which provides background information and recommendations for the Cotton Australia convened TIMS Committee. This document includes possible measures to be taken in response to further increases in resistance frequencies to the Cry2Ab toxin in Bollgard II® cotton by *Helicoverpa spp*. to mitigate the risk of levels being attained that would lead to field failures. This document is undergoing a process of consultative stakeholder review prior to ratification by the Cotton Australia TIMS Committee before March 2010. The Contingency Plan will be reviewed annually in light of new information on resistance frequencies in *Helicoverpa* spp. and knowledge of and tactics for Bt resistance management. Note that the RMP will continue to be the document that informs growers of their responsibilities in managing Bollgard II® cotton while the contingency plan contains other mitigation strategies that may be introduced into the RMP.

1. Refuges

What is the purpose of refuges?
The aim of refuge crops is to generate significant numbers of susceptible moths (SS) that have

not been exposed to selection pressure from the Bt proteins. As detailed above, this production is especially critical in a drought year because there is reduced contribution from non-cropping vegetation and dryland crops. Moths produced in the refuge crops will disperse to form part of the local mating population where they may mate with any potentially resistant moths (RR) emerging from Bollgard II® crops. This reduces the chance that resistant moths will meet and mate.

The offspring from matings between one resistant and one susceptible moth will carry one gene from each parent (RS) and are referred to as heterozygotes. In the cases of Bt resistance that have so far been identified, heterozygotes are still controlled by Bollgard II® cotton. Therefore, the critical function of the refuge is to dilute the frequency of RR individuals within the population. It is crucial that the timing of the production of moths from refuges matches that of Bollgard II® crops. For this reason, refuge crop options (sorghum, corn) which have shorter periods of producing moths than cotton, need to have several staggered plantings to extend the period over which moths are produced. While the use of planting windows and use of two Bt genes in Bollgard II® cotton are aimed at reducing selection pressure for Bt resistance, the use of refuge crops is to try to **balance** or **counter** the selection that will still occur.

How were the current requirements for refuge crops determined?
The relative sizes of refuge crops required in the RMP are based on models and knowledge of *Helicoverpa* moth emergence for different crop types. The likely moth productivity of the different refuge options has been determined through large-scale field experiments conducted by the Cotton CRC over several seasons. Only refuge options that have been assessed in this way are currently approved by the APVMA. In these experiments, a refuge of 10% unsprayed cotton was considered as the reference point. On average pigeon pea produced twice as many moths as the same area of unsprayed cotton, hence a 5% refuge, half that of an unsprayed cotton refuge, is required for this crop. Sorghum and corn were effective, however were only highly attractive during flowering. Hence staggered plantings of these options are required to increase the period over which moths are produced.

Is there a minimum size to a refuge crop?
Where sprayed conventional cotton is grown on the farm unit, each refuge crop must be at least 48 metres wide and a minimum of 2 hectares. This is to minimise the risk of spray drift onto the refuge, as this would decrease the effectiveness of the refuge in producing moths.

If no sprayed conventional cotton is grown on the farm, the minimum size of a refuge must be 24 metres wide and 24 metres long. Sprayed and unsprayed refuges must be planted separately.

Can mixtures of the refuge crop options be used to meet the refuge requirements?
It is possible to combine more than one type of refuge, provided that the total requirements for area equivalence are met. For example, 1 hectare of pigeon pea can be grown alongside 1 hectare of unsprayed cotton, rather than 2 hectares of either. Each type of refuge must be managed so that it is productive and other restrictions on minimum dimensions, number of plantings and location also need to be met. However, sprayed and unsprayed refuge options cannot be mixed in the same field. For example, it would not be acceptable to use 1 hectare of pigeon pea grown alongside 30 hectares of sprayed cotton as a substitute for 2 hectares of pigeon pea.

Why can't a conventional crop from a neighbouring property act as a refuge?
In some cases, a conventional crop grown on a neighbouring property may satisfy the requirements of a refuge for Bollgard II®. However, the crop may not be managed in a way that complies with the RMP. Since growers cannot control the management of a neighbour's crop, it is not sensible to rely on these areas as refuges for Bollgard II®.

Why do the refuge options differ for dryland Bollgard II® and irrigated Bollgard II®?
For dryland Bollgard II® crops the only available dryland refuge options are sprayed or unsprayed cotton. The reason for this is that the other refuge options available in irrigated Bollgard II® (pigeon pea, sorghum, corn) tend to be planted after the cotton and in dryland situations there is uncertainty about whether soil moisture will be adequate to successfully establish future crops. However CSIRO and Monsanto are currently conducting work on the suitability of pigeon pea as a dryland refuge option for dryland Bollgard II® cotton. CSIRO and Monsanto are also working with growers in several valleys to investigate the suitability of dryland conventional cotton treated and not treated by slashing as a potential refuge option. There are also irrigated refuge options for dryland Bollgard II® cotton. These options are sprayed or unsprayed irrigated cotton and unsprayed irrigated pigeon pea, and were chosen because to date they have been the most widely adopted refuges for irrigated Bollgard II®.

How can the 'effectiveness' of an individual refuge be evaluated?
The productivity of refuges will vary considerably across regions and seasons. It is not possible to place a value on the effectiveness of each refuge. Looking after refuges, including nutrition, weed control,

timely irrigation and all factors that make the refuge 'attractive' to female moths laying eggs, is the key to ensuring that they are effective. Managing resistance is a population level activity, and every refuge makes an important contribution to the overall RMP for the valley, and because *Helicoverpa spp*. disperse widely, on a larger scale for the whole industry. Especially during a drought season it is imperative that all refuges produce their quota of susceptible (SS) moths. Monsanto audits the quality of refuges on every farm that grows Bollgard II® to ensure that they are well maintained and effective.

Why is the location of refuge crops important?
For the refuge principle to be successful, refuge crop areas must be in close proximity to the Bollgard II® crop(s) to ensure that it is highly likely that moths emerging from the Bollgard II® will mate with susceptible moths from the refuge crop. *Helicoverpa* moths are capable of migrating long distances, but during the summer cropping season a significant part of the population may remain localised and move only a few kilometres within a region. The level of movement will depend on the mix of crops and their attractiveness at the time of moth emergence. For this reason the best location for a refuge crop is close as possible to the Bollgard II® crop, at least within 2 km.

Is there an alternative to growing refuges for resistance management?
No, though alternatives are being investigated. It is important to recognise that the costs associated with refuge crops are an investment in the longer term value of transgenic technology for the industry. The costs associated with growing an attractive refuge should be considered as an integral part of growing Bollgard II®.

2. Volunteers

Why is it important to control conventional cotton volunteers or ratoon plants in Bollgard II®?
In terms of the RMP, it is important to prevent the establishment of conventional cotton in Bollgard II® fields because larger larvae that have grown on conventional cotton plants are moderately tolerant to Bt. If large larvae migrate to neighbouring Bt plants, those that are heterozygotes (RS) may survive and contribute to increasing the frequency of resistance genes in the *Helicoverpa spp*. population. In the cases of Bt resistance that have so far been identified, heterozygotes are controlled by Bollgard II® cotton. By removing conventional volunteers from Bollgard II® fields, heterozygotes will have no opportunity to grow large enough to be able to tolerate Bt plants and therefore contribute their resistance genes to the next generation of moths.

Why is it important to control Bollgard II® volunteers or ratoon plants in conventional cotton?
The same logic applies as in the previous question. The presence of Bollgard II® volunteer plants in a conventional crop exerts a selection pressure for Bt resistance. Heterozygous (RS) larvae that emerge from eggs laid on conventional cotton may grow and during their development move onto Bollgard II® volunteers. In this way RS larvae become exposed to Bt at later growth stages when they can survive to produce offspring. This will lead to an increase in the frequency of resistant individuals (both RS and RR) in the population. If the field happens to be designated as a refuge crop, the presence of the Bollgard II® volunteers will diminish the value of the refuge.

3. Planting Windows

Why do we need a Bollgard II® planting window?
The purpose of restricting the planting window is to limit the number of generations of *H. armigera* that will be exposed to Bollgard II® in any one season. This measure effectively restricts the selection pressure on *H. armigera* to develop resistance to Bollgard II®.

Is it possible to vary the Bollgard II® planting window?
Where exceptional circumstances exist, requests for a variation to the planting window will be considered. In the past Monsanto approached the APVMA on behalf of a grower or Cotton Grower's Association to consider requests. From 2006/07 onwards, the TIMS Committee will consider requests. Requests must satisfy a number of criteria as outlined in the 'Request for variation to the Bollgard II® planting window' document, found on page **63**. If a request is approved, the variation only affects the planting window component of the RMP for the requestee/s for the current season. All other components of the RMP remain the same.

4. No Bt sprays

Why is it important that foliar Bt sprays are not used on refuges?
By preventing the use of foliar Bt on all refuges (sprayed and unsprayed), the likelihood of producing moths that are susceptible (SS) rather than resistant (RR) to Bt is maximised. This is an important part of the RMP because susceptible refuge moths are presumed to mate with any resistant moths in the population to produce heterozygotes (RS) that are killed by Bollgard II®.

With regard to refuge crops, what does the term 'unsprayed' mean?
The term 'unsprayed' encompasses all management activities which are likely to reduce the survival of *Helicoverpa* in these crops. Insecticides with activity against *Helicoverpa* cannot be used in unsprayed refuges. Food sprays cannot be used in unsprayed

refuges as these aim to reduce *Helicoverpa* survival through increased predation and parasitism. Similarly, *Trichogramma* and other biolocial control agents cannot be released in unsprayed refuges as they too aim to reduce *Helicoverpa* survival.

5. Pupae Destruction

Given that few larvae survive in Bollgard II®, why is it important to pupae bust?

Cultivating between seasons prevents any moths that developed resistance in the previous year from contributing to the population in the following year. Although we expect few larvae to survive in Bollgard II®, those that do are most likely resistant and these are precisely the ones that must be killed so that the next generation of moths (emerging the following spring) are not enriched with resistant individuals. This is especially the case in a drought year because of the increased opportunity for 'resistance genes' to increase in frequency.

Am I required to pupae bust in my refuges?

Refuges must produce moths during the cotton season when Bollgard II® is grown but unsprayed refuges can continue to provide benefits for resistance management by being left in place until the following spring. By doing this any pupae produced in the autumn may be carried over the spring and provide additional genetic dilution of resistant survivors. Once Bollgard II® crops begin flowering and are highly attractive to *Helicoverpa* moths, cultivation of the refuge (e.g. for weed control, row formation etc) must be matched by cultivation of the associated Bollgard II® field(s).

Why are there requirements for trap cropping in central Queensland?

In central Queensland *Helicoverpa spp*. pupae produced late in the cotton season do not remain in the soil, but emerge within 15 days of pupating. Pupae busting is not an effective resistance management tool in these warmer areas and trap crops are required as an alternative. Trap crops of pigeon peas are planted after the cotton and are timed to be at their most attractive after the cotton has cut-out. Thus moths emerging from Bollgard II® cotton fields at the end of the season will be attracted to the trap crops and are likely to lay their eggs in the trap crop. The egg and larval stages can last 30+ days. Once the cotton has been harvested, the trap crop should be destroyed, removing the food source from the larvae (which will then die) and the soil then cultivated to destroy any pupae. See the 2009/10 RMP for more details.

Guidelines for *Helicoverpa* management in Bollgard II® cotton

Since 2005/06 there have been occasional reports of larvae surviving for several weeks at threshold levels in Bollgard II® fields. All affected fields were at mid-flowering to late-flowering and the survivors included *H. armigera* and *H. punctigera.*

Work conducted by CSIRO and Monsanto demonstrated that these larvae did not survive on Bollgard II® due to Bt resistance or because of the absence of Bt genes in the cotton. It is possible that the survival is due to a modified or existing behaviour of larvae that enables them to target sites of the plant that do not express at high levels (e.g., pollen in flowers). It is also possible that the survival is due to a temporary decline in the expression of toxins in the whole plant. Work is underway to investigate these possibilities.

Irrespective of how survival occurs, it is recommended that if larvae reach thresholds in Bollgard II® fields they should be controlled by spraying. Work conducted by Monsanto suggests that it is unlikely that there will be a yield penalty associated with larvae survival in Bollgard II® fields. One experiment conducted by PhD student Baoqian One experiment conducted by PhD student Baoqian Lu within Bollgard II® fields at threshold involved removing larvae from plots and leaving larvae in other plots. In a field that was sprayed for *Helicoverpa* after setting up the trial there was no difference between the two types of plots. However in a field that was not sprayed for *Helicoverpa* the plots with larvae had significantly less cotton lint compared to the plots where larvae were removed. Additionally, in some instances the surviving larvae are able to pupate and emerge. This poses a threat because the larvae will presumably have been exposed to Bt toxin at a low level which may select for resistance if some dominance is present.

With the increased risk of resistance to Cry2Ab in *Helicoverpa* it is critical that we monitor the distribution and proportions of fields that are affected by surviving larvae, and the number of fields that are sprayed to control *Helicoverpa*. At the end of every season, CCA members will be asked to contribute to the ongoing 'Sprays for surviving *Helicoverpa* in Bollgard II® survey 2009' available on the Cotton CRC website (www.cottoncrc.org.au/content/Industry/IndustryHome.aspx – go to 'tools').

If you experience above threshold levels of *Helicoverpa* in your Bollgard II® fields please immediately contact;

- Sharon Downes: 02 6799 1576 / 0427 480 967,
- Baoqian Lu: 02 6799 2479 / 0407 237 404, or
- Kristen Knight 07 4634 8400 / 0429 666 086.

Collection kits are also available from your Regional Cotton Extension Officer.

Insecticide selection for Bollgard II® crops

When controlling *Helicoverpa* within Bollgard II® crops, insecticide selection should comply with the cotton industry's Insecticide Resistance Management Strategy (pages 52–55). The predator/pest ratio (described on page 2) should also be given careful consideration when the application of an insecticide is being considered. If an insecticide is required, try to choose the most effective product that is the least disruptive to the beneficial complex. Refer to page 38–39. While foliar Bt can be used on Bollgard II® crops, it is a requirement of the Bollgard II® Resistance Management Plan that foliar Bt not be used on any refuge crops.

Helicoverpa thresholds

Do not include any larvae <3 mm long in spray threshold counts. For economic management of *Helicoverpa*, larval populations should be controlled with an insecticide if a threshold of; 2 larvae /m >3 mm long are found over 2 consecutive checks; or 1 larvae /m >8 mm long is found in any check. Application of these thresholds requires careful and accurate assessment. Checks should be made over the whole plant including the terminals, squares and especially flowers and small bolls. Be sure to objectively assess larval size. A complete description of the sampling protocols for *Helicoverpa* can be found on page 1.

Guidelines for amending Bollgard II® planting windows 2009/10

Developed by the Transgenic and Insect Management Strategies Committee of Cotton Australia

Note: Requests for variation to the Bollgard II planting window only affect the planting window component of the RMP for the requestee/s for the current season.

Planting Windows in the Bollgard II® RMP are the key element in the strategy for restricting the number of generations of *Helicoverpa* spp. exposed to Bollgard II® in a region. This is necessary to limit the rate of evolution of resistance to Bt toxins. These guidelines allow a degree of flexibility to accommodate unforseen circumstances without jeopardising this objective.

The TIMS Committee will only consider requests for a variation to the planting window in situations in which exceptional circumstances exist (emergencies).

If the request is accepted and agreed to by the TIMS committee then a 'Bollgard II® Planting Window Variation Notice' will be issued by Monsanto. This variation only affects the planting window component of the Resistance Management Plan (RMP). All other components of the RMP remain the same.

Process

Monsanto is responsible for the issuing of a 'Bollgard II® Planting Window Variation Notice' under the APVMA Notice of Variation of Registration of Agricultural Product – Bollgard II® cotton (March 23, 2006).

Cotton Growers who wish to request a variation to Bollgard II® planting window dates for them or their region will need to make a formal request to the TIMS Committee who will make a written recommendation to Monsanto. The request must be in writing from their local CGA and received where possible, by the end of the first week of September.

It is essential that there has been wide consultation regarding the proposal including; CGA members, local consultants, Industry Development Officers and researchers and the local Monsanto Accounts & Stewardship Specialist. Requests that are supported by TIMS will be approved by Monsanto. The Variation Notice will be communicated to relevant organisations and individuals by TIMS and Monsanto.

Criteria for assessing the application to change a planting window:

1. The local Cotton Growers Association (CGA) must request and approve the change with a majority vote and advise all growers of the outcome of the vote. The majority decision affects TUA compliance for all licensed growers. Evidence of this process will be required from the CGA in writing together with the information requested below.
2. The region (or individual grower) requesting the variation is more than 100 kms from any other significant Bollgard II® planting.
3. Planting of Bollgard II® in the region has not exceeded 10% of the anticipated Bollgard II® cotton area.
4. No Bollgard II® cotton has been planted in excess of 21 days prior to the opening of the new window.
5. There are no known threats to the efficacy of refuges in the region (e.g., plague locust pressure).
6. The requested planting window variation must be a 42 day window that falls entirely within the period September 1 to December 15.

Essential information to be submitted with a request for a Bollgard II® planting window variation:

1. Describe the reasons for the request.
2. Proposed new window start and finish dates.
3. Map or description of the region concerned.
4. Distance of the relevant region to nearest neighbouring cotton.
5. Time of first Bollgard II® cotton planted in the region.
6. Area of Bollgard II® already planted in the region.
7. Projected total area to be planted to Bollgard II® in the region.
8. Statement confirming approval and agreement of all cotton growers in the region to abide by the requested changes to the window.
9. Statement acknowledging capacity to still meet pupae busting requirements in the RMP when a later planting window is requested.

Resistance Management Plan for Bollgard II® Cotton 2009/10

Developed by Monsanto Australia Limited and the Transgenic and Insect Management Strategies (TIMS) Committee of the Cotton Australia Ltd.

The resistance management plan is based on the two basic principles: (1) minimising the exposure of *Helicoverpa* spp. to the Bacillus thuringiensis (Bt) proteins Cry 1Ac and Cry 2Ab: (2) providing a population of susceptible individuals that can mate with any resistant individuals and hence dilute any potential resistance: and (3) removing resistant individuals at the end of the cotton season.

Growers of Bollgard II® cotton are required to practice preventative resistance management as set out below. Compliance with the Resistance Management Plan is required under the terms of the Bollgard II® Technology User Agreement and under the conditions of registration (*Agricultural and Veterinary Chemicals Act* 1994).

Section 1 is applicable to all regions in NSW and QLD that grow cotton while sections 2 and 3 detail specific requirements for NSW, Southern Queensland and Central Queensland respectively.

SECTION 1: NSW/SOUTHERN QUEENSLAND SECTION & CENTRAL QUEENSLAND

1. Refuges

Growers planting Bollgard II® cotton will also be required to grow a refuge crop that is capable of producing large numbers of *Helicoverpa spp*. moths which have not been exposed to selection with Bt proteins Cry 1Ac and Cry 2Ab. These unselected moths are expected to dominate matings with any survivors from Bollgard II® crops and thus help to maintain Bt resistance to Bt proteins Cry 1Ac and Cry 2Ab at low levels.

All refuge options are based on the requirement of a 10% unsprayed cotton refuge or its equivalent as determined by the relative production of *Helicoverpa spp*. from each of the refuge types as described in Tables 1 and 2 for irrigated and dryland production scenarios respectively.

For each area of irrigated Bollgard II® cotton planted, a grower is required to plant a minimum of one or combination of the following:

Table 1: Irrigated Bollgard II® cotton refuge options

Crop	*Conditions*	*% of Bollgard II*
Cotton	Irrigated, sprayed conventional cotton	100
	Irrigated, unsprayed conventional cotton	10
Pigeon Pea	Irrigated, unsprayed	5
Sorghum	Irrigated, unsprayed – conditions apply, see box below	15
Corn	Irrigated, unsprayed – conditions apply, see box below	20

Table 2: Dryland Bollgard II® cotton refuge options

Crop	*Conditions*	*% of Bollgard II*
Cotton	Dryland or irrigated, sprayed conventional cotton	100
	Dryland or irrigated, unsprayed conventional cotton	10
Pigeon Pea	Irrigated, unsprayed pigeon pea	5

No other refuge options are approved for dryland Bollgard II.

Notes: Unsprayed means unsprayed with insecticides that affect any life stage of *Helicoverpa* spp.

Bt products must not be applied to any refuge (including sprayed cotton).

If the viability of an unsprayed conventional cotton refuge is at risk due to early season pressure by *Helicoverpa spp*., with prior approval from the Monsanto Compliance Manager, a non-Bt heliocide can be applied up to the 4th true leaf stage.

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Notes cont.: An unsprayed refuge should not be planted in the same field as any crop sprayed with a rate of insecticide that is registered for *Helicoverpa* spp, with the exception of Bollgard II. Sprayed crops and unsprayed refuges that are planted in adjacent fields must be separated by sufficient distance to *minimise the likelihood of insecticide drift onto the unsprayed refuge*.

For the purposes of this Resistance Management Plan, conventional cotton includes any cotton varieties that do not have Bt proteins in the plant that control *Helicoverpa spp*. moths.

Irrigated sorghum or corn

NB: The following special conditions apply to growers who wish to grow sorghum or corn as refuges:

- A plan indicating how either of these refuges will be managed must be submitted to, and approved by, the local Accounts & Stewardship Specialist before planting either of these two options. A farm map must be included with the plan.

  Either refuge option requires three sequential plantings of the same variety. The initial planting date should be determined by the time taken to flower for the varieties chosen for use in each particular area so that the need for part of the refuge to be in flower from January 15 is satisfied. Subsequent plantings should follow at 2-weekly intervals so that some of the refuge is continuously in flower until February 28.
- A single planting of mixed maturity varieties is not acceptable.
- Each planting should be one third of the total area required for that refuge type, as described in Table 1 or Table 2. If there is no sprayed conventional cotton on the same farm unit the refuge must be a minimum of 24 metres wide. However, if there is sprayed conventional cotton on the same farm unit the refuge must be a minimum of 48 metres wide (see also clause (f) below).
- These refuge options will be closely monitored during the season to ensure refuge that they are managed appropriately and are effective and attractive from 15 January to 28 February.
- Corn refuges may be harvested after complete cob maturity.
- Sorghum refuges may be harvested after complete head maturity.

General conditions for all refuges are:

(a) Refuge crops are to be planted and managed so that they are attractive to *Helicoverpa* spp. during the growing period of the Bollgard II cotton varieties. It is preferable that all refuge is planted within the 2 week period prior to planting Bollgard II. If this is not possible, refuge planting must be completed within 3 weeks of the first day of sowing of Bollgard II. At this time, sufficient refuge must have been planted to cover all of the Bollgard II cotton proposed to be planted for the season (including Bollgard II already planted and any that remains unplanted). Should additional Bollgard II planting be made after this date, which is not already covered by refuge, additional refuge must be planted as soon as possible and no more than 2 weeks after sowing of the additional Bollgard II.

(b) Pigeon pea refuges should not be planted until the soil temperature reaches 17°C, which is the requirement for germination. If soil temperatures are not suitable to allow germination of pigeon peas in line with condition (a), an alternative refuge must be planted in its place within the prescribed period (under (a) above).

(c) Once the Bollgard II crops begin flowering, and are highly attractive to *Helicoverpa* spp. moths, cultivation of refuges (e.g. for weed control, row formation etc) must be matched by cultivation of the associated Bollgard II field(s).

(d) Insecticide preparations containing Bt may be used on Bollgard II cotton throughout the season BUT NOT on any refuge crops.

(e) All refuges are to be planted within the farm unit growing Bollgard II cotton. Subject to clause (f) below all reasonable effort should be taken to plant the refuge either on one side of, or next to a Bollgard II cotton field, and all Bollgard II fields must be no more than 2 km from the nearest Bollgard II refuge.

(f) To minimise the possibility of refuge attractiveness being affected by herbicide drift, non-herbicide tolerant refuges should be separated from herbicide tolerant Bollgard II cotton crops by a sufficient distance to minimise such drift but no more than 2km from the Bollgard II cotton.

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(g) To account for possible insecticide drift, the options for the width of refuge crops vary according to spray regime. If any sprayed conventional cotton is grown on the same farm unit, Bollgard II refuge crops must be at least 48 metres wide and each refuge area must be a minimum of 2 hectares. If no sprayed conventional cotton is grown on the same farm unit, Bollgard II refuge crops must be at least 24 metres wide and 24 metres long. Different unsprayed refuge options may be planted in the same field as a single unit; however a sprayed conventional cotton refuge must not be planted in a field that is also planted to an unsprayed refuge type.

(h) In New South Wales and Southern Queensland, to ensure maximum emergence of late pupae from associated refuges, soil disturbance of refuge crops should not be undertaken until after the pupae busting in Bollgard II cotton crops on the farm unit is complete. In Central Queensland soil disturbance of refuge crops can only occur after Bollgard II cotton plants have been removed. In all regions, destruction of refuges other than corn and sorghum should only be carried out after Bollgard II cotton lint removal has been completed.

(i) Refuges for dryland Bollgard II crops must be planted in the same row configuration as the Bollgard II crop unless the refuge is irrigated. If an irrigated option is utilised for a dryland Bollgard II crop, then that refuge may be planted in a solid configuration. Dryland cotton is measured as green hectares (calculated as defined in the Technology User Agreement).

2. Control of Volunteer and Ratoon cotton

Volunteer and ratoon cotton may impose additional selection pressure on *Helicoverpa spp*. to develop resistance to the Bt Cry 1Ac and Cry 2Ab proteins produced by Bollgard II® cotton.

Growers must make all reasonable efforts to remove volunteer and ratoon plants, as soon as possible from all fields, including fallow areas, Bollgard II® crops, conventional cotton crops and all refuges.

3. Post-harvest crop destruction

As soon as practical after harvest, Bollgard II® cotton crops must be destroyed by cultivation or herbicide so that they do not continue to act as hosts for *Helicoverpa* spp. Unsprayed refuges should preferably be left uncultivated for 2 weeks after harvest to allow emergence of any pupating *Helicoverpa* spp.

SECTION 2: NSW AND SOUTHERN QUEENSLAND ONLY

1. Planting windows

All Bollgard II® crops are to be planted into moisture or watered up by 15 November unless otherwise advised by a Bollgard II® Planting Window Variation Notice.

2. Pupae destruction

In Bollgard II® cotton fields, each grower will be required to undertake *Helicoverpa spp*. pupae destruction after harvest according to the following key guidelines:

- Bollgard II® crops should be slashed or mulched and fields cultivated for pupae control within 4 weeks of harvesting. All pupae busting must be completed by July 31.
- Ensure disturbance of the whole soil surface to a depth of 10 cm.
- All fields that are sown to any winter crop following a Bollgard II® crop must be inspected by the Technology Service Provider before sowing commences to ensure that pupae busting has occurred.

In Refuge crops:

- All unsprayed refuges should preferably be left uncultivated until the following October.

3. Failed crops

Bollgard II crops that will not be grown through to harvest for various reasons and are declared to, and verified by, Monsanto as failed must be destroyed within two weeks after verification, in such a way that prevents regrowth. Crops abandoned before February 28 do not require pupae busting. Crops abandoned on February 28 or later must be pupae busted.

NB: If any grower encounters problems in complying with the Resistance Management Plan please contact your local local Accounts & Stewardship Specialist.

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SECTION 3: CENTRAL QUEENSLAND ONLY

1. Planting Windows

Emerald: All Bollgard II® crops are to be planted into moisture or watered up in the period between September 15 and October 26 unless advised otherwise by a 'Bollgard II® Planting Window Variation Notice'.

Dawson Callide Valleys: All Bollgard II® crops are to be planted into moisture or watered up in the period between September 15 and October 26 unless advised otherwise by a 'Bollgard II® Planting Window Variation Notice'.

Belyando: All Bollgard II® crops are to be planted into moisture or watered up in the period between October 10 and November 20 unless advised otherwise by a 'Bollgard II® Planting Window Variation Notice'.

2. Late Summer Trap Crop

A late summer trap crop (pigeon pea) must be planted for all Bollgard II cotton grown in Central Queensland. The planting configuration of the trap crop should be the same as that of the Bollgard II crop. Irrigated Bollgard II must have an irrigated trap crop. Table 3 shows the requirements for the late summer pigeon pea trap crop. Dryland Bollgard II growers who do not have any irrigated cotton on their farm should contact their Accounts & Stewardship Specialist for alternative options.

Refuge and late summer trap crops have different purposes and, if pigeon pea is selected for both, two separate plantings are required.

Table 3: Late summer trap crop requirements for pigeon pea in Central Queensland

Criterion	Trap Crop* *
Minimum Area and Dimension requirements	A trap crop of 1% of planted Bollgard II crop is required.If sprayed conventional cotton is grown on that farm unit: the trap crop must be at least 48m x 48m. If no sprayed conventional cotton is grown on that farm unit: the trap crop must be at least 24m x 24m.
Planting time	The trap crop must be planted between November 20 and December 20.
Planting rate**	35 kg/ha (recommended establishment greater than 4 plants per metre).
Insect control	The trap crop can be sprayed with virus after flowering; while avoiding insecticide spray drift.
Irrigation	Irrigation of the trap crop must be the same as for cotton, plus one additional irrigation after cotton is finished.
Weed control	Keep free of weeds.
Crop destruction	The trap crop must be destroyed 2 to 4 weeks after defoliation of Bollgard II cotton (slash and pupae bust – full soil disturbance to a depth of 10cm across the entire trap crop area).

** A pigeon pea trap crop is to be planted such that it is attractive (flowering) to *Helicoverpa* spp. after the cotton crop has cut out and as any survivors from the Bollgard II® crop emerge. Planting pigeon pea too early (e.g. before mid-November) or too late (e.g. January) is not adequate for cotton crops planted during September through to October.

*** The planting rate is based on a minimum of 85% seed germination.

NB: If any grower encounters problems in complying with the resistance management plan, please contact your Accounts and Stewardship Specialist.

For further background information on the various components of this plan see the 'Preamble to the Resistance Management Plan for Bollgard II' in the current Cotton Pest Management Guide.

Toby Makim	Emerald, Dawson Callide, Darling Downs & MacIntyre	0400 691 881
Mark Dawson	St George, Dirranbandi, Mungindi, Gwydir, Upper & Lower Namoi	0428 106 090
Luke Sampson	Bourke, Walgett, Tandou, Macquarie, Murrumbidgee & Lachlan	0427 701 986

Legal responsibilities in applying pesticides

Mark Scott, Industry & Investment NSW and
Lisa Dixon, ClemClear®.

Pesticides Act

The *Pesticides Act 1999* is the primary legislative instrument controlling the use of pesticides in NSW and is administered by the Department of Environment, Climate Change and Water (DECCW). The underlying principle of the Pesticides Act is that pesticides must only be used for the purpose described on the product label and all the instructions on the label must be followed. Consequently, all label directions must be read by or explained to the user prior to each use of the pesticide.

All pesticide users should take reasonable care to protect their own health and the health of others when using a pesticide. They should also make every reasonable attempt to prevent damage occurring from the use of a pesticide, such as off-target drift onto sensitive areas or harm to endangered and protected species.

A regulation was gazetted in 2009 requiring all commercial pesticide users, i.e. all farmers and spray contractors, to keep records of their pesticide application

While no set form is required for records they must include the following:

- full product name,
- description of the crop or situation,
- rate of application and quantity applied,
- description of the equipment used,
- address of the property, identification of the area treated and order of paddocks treated,
- date and time of the application (including start and finish),
- name, address, and contact details of the applicator and of the employer or owner if an employee or contractor is the applicator,
- estimated wind speed and direction (including any significant changes during application),
- other weather conditions specified on label as being relevant (e.g. temperature, rainfall, relative humidity).

An example form that captures all the information required by the Pesticides Regulation 2009 is provided on the following page. Notes on how to fill it in, can be downloaded from the I&I NSW website. A self-carbonating record book is available for purchase through the DEEDI Dalby and Toowoomba offices and through the I&I NSW SMARTtrain National Support Centre at Yanco.

Records must be made within 24 hours of application, be made in legible English, and kept for 3 years.

The Pesticides Regulation 2009 also requires all commercial pesticide users to be trained in pesticide application.

The training of aerial applicators, pest control operators and fumigators is recognised as satisfying the requirements of the regulation. Apart from these groups, all commercial users must have a prescribed qualification. Only domestic use, such as home gardens, is excluded, provided the pesticide is a specific domestic/home garden product. Covered by the regulation is pest control by/on:

- public authorities, e.g. State Rail,
- golf courses, sporting fields and bowling greens,
- agricultural, horticultural, aquacultural and forestry operations,
- businesses, educational institutions, and hospitals.

The minimum prescribed training qualification will be the AQF2 unit of competency, 'Apply chemicals under supervision', although owner-applicators are encouraged to train and be assessed in the two higher AQF3 competencies, 'Prepare and apply chemicals' and 'Transport, handle and store chemicals'.

Growers are recommended to undertake the SMARTtrain course, Chemical Application, or the standard ChemCert course, both of which cover the higher AQF3 competencies. For growers with literacy and/or numeracy problems, the lower level AQF2 competency will provide a minimum qualification that satisfies the Regulation.

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Location, Applicator, Date of Application

Property/Holding: (residential address)					Date:
Applicator's Full Name:			Owner (if not applicator):		
Address:			Address:		
		Phone:			Phone:
Mobile:	Fax:	Email:	Mobile:	Fax:	Email:
Sensitive Areas (including distances, buffers):			Comments (including risk control measures for sensitive areas):		

	N	
W	Treated Area	E
	S	

Host/Pest

Paddock Number/Name:	Paddock Area:	Order of Paddocks Sprayed:

Crop/Situation:	Type of Animals:
Crop/Pasture Variety:	Age/Growth Stage:
Growth Stage:	Mob/Paddock/Shed:
Pest/Disease/Weed:	Animals — Number Treated:
	Pest Density/Incidence: ❑ Heavy ❑ Medium ❑ Light

Application Data

Full Label Product Name:			Rate/Dose:		Water Rate L/ha:
Permit No.:	Expiry Date:		Additives/Wetters:		
Total L or kg:	WHP:	ESI*:	Date Suitable for Sale:		
Equipment Type:		Nozzle Type:		Nozzle Angle:	Pressure:
Date Last Calibrated:	Water Quality (pH or description):				

Weather

❑ Showers ❑ Overcast ❑ Light Cloud ❑ Clear Sky

Rainfall (24 hours before and after)
Before: mm During: mm After: mm

Time (show time in this column)	Temperature °C	Relative Humidity (%)	Wind Speed	Direction	Variability (e.g. gusting)
Start					
Finish					

Comments:

* When using herbicides in mixtures with fungicides and insecticides, an ESI may apply to the non-herbicide component of the mixture.

Hazardous Substances Legislation

Many registered pesticides are classified as hazardous substances and most of those that are not pose some risk to the health of those who use them or are exposed to them.

The Occupational Health and Safety Act 2000, and the Hazardous Substances section of the Occupational Health and Safety Regulation 2001, detail legal requirements of suppliers, employers and employees in the workplace for hazardous substances management. The Act and accompanying Regulation are intended to protect workers from both the short and long-term health effects of exposure to hazardous substances and to improve current health and safety practices by:

- provision of health and safety information to workers (including a list or register of all hazardous substances and an MSDS (Material Safety Data Sheet) for each hazardous substance),
- consultation with workers,
- training of workers,
- assessment of the risks arising from hazardous substances exposure,
- control of the risks, and
- recording of the risk assessment and control measures implemented, training of both those applying and exposed to hazardous substances, and health surveillance (if warranted by the risk assessment in respect of organophosphates).

Both storage and use are covered by the OH&S legislation. Records of training and risk assessments have to be kept for 5 years.

Dangerous Goods legislation has been revised to bring it into line with hazardous substances legislation. The new requirements came into force after a phase-in period ending September 1, 2006. The main requirements include;

- provision of MSDSs,
- carrying out and documenting risk assessments, and
- keeping a register of Dangerous Goods.

All these requirements already apply to hazardous substances. In practice, the only change will be to add to existing management and recording and record systems any Dangerous Goods that are not also hazardous substances.

Storage limits have changed. Premises storing large quantities require placarding of both the storage shed and the entrances to the premises. If very large quantities are stored, which would be rare on-farm, a manifest, site plan and written emergency plan are required. Consult your local WorkCover office for advice.

Farm chemicals are registered pesticides, and many are either hazardous substances or Dangerous Goods or both. As different legislation applies to each category, farmers must ensure their pesticide use complies with all relevant legislation.

WorkCover NSW's *Code of practice for the safe use and storage of chemicals (including pesticides and herbicides) in agriculture* is an approved industry code of practice and provides practical guidance for farm chemical users to comply with the legislation. This has recently been revised to reflect the new Dangerous Goods requirements. Copies can be obtained from your local WorkCover office, by download from the WorkCover website – www.workcover.nsw.gov.au – or by phoning 1300 799 003.

The cotton industry's guidelines for handling, storage and application of pesticides can be found in Part 1 and 2 of the *Australian Cotton Industry Best Management Practices Manual.*

Pesticides and the Environment

The cotton industry's guidelines for minimising risk to the environment can be found in Part 6 of the *Australian Cotton Industry Best Management Practices Manual.*

Most insecticides are toxic to aquatic organisms, bees and birds. Fungicides and herbicides are relatively safe to bees in terms of their active ingredients, but their carriers and surfactants may be toxic. The risks that a particular product poses to the environment are reflected in statements on the label under headings like 'Protecting wildlife, fish, crustacea and the environment'.

PROTECTING BEES

The cotton growing environment is a high risk environment for bees. Bees are particularly susceptible to many of the insecticides used on cotton farms, such as abamectin, fipronil, indoxacarb, pyrethroids and profenofos. The productivity of hives can be damaged if bees or the hives are contaminated. Insecticides that are particularly toxic to bees are identified as such with the following special statement on the label;

Dangerous to bees. DO NOT spray any plants in flower while bees are foraging.

The relative toxicities of cotton insecticides to honeybees are listed in Table 3 on page 40–41.

Table 3 ranks the acute toxicities of products to bees based on LD_{50} information. The residual toxicity of insecticides, that is, the amount of time the product remains toxic to bees after the time of application, should also be considered when information is available. For the majority of insecticides used in cotton the residual toxicities are unknown. Table 6 summarises the currently available information.

Bees are generally active between 7:00 am and 4:00 pm and most bees forage within a 2 to 4 km radius of their hive. They may travel up to 7 km away in search of pollen and nectar, though only when nearby pollen and nectar sources are in decline or are of poor quality. Bees collect nectar from extra-floral nectaries (eg under leaves) as well as from cotton flowers so they may forage in cotton crops before, during and after flowering. As well as bees foraging in cotton crops, damage may occur to bees when pesticides drift over hives or over neighbouring vegetation that is being foraged by bees eg. coolibah.

Coolibah trees (*Eucalyptus microtheca*) are a primary soure of nectar and pollen for honey bees. These trees grow on the black soil plains along many of the river courses in the cotton growing areas. Budding and flowering occurs in response to good spring rains. In northem NSW the buds appear in November and the trees begin to flower mid-late December finishing about about the end of January, budding and flowering times vary by a few weeks in both the the southem and central Qld areas. When heavy budding occurs beekeepers often move large numbers of hives into cotton growing areas for honey production.

With good communication and good will, it is possible for apiarists and cotton growers to work together to minimise risks to bees, as both the honey industry and cotton industry are important to regional development.

The pesticide risk to bees can be reduced by:

- applying pesticides toxic to bees in the evening when bees are not foraging;
- notifying the apiarist when beehives are in the vicinity of crops to be sprayed to allow removal of the hives before spraying. Beekeepers require as much notice possible, preferably 48 hours, to move an apiary;
- where possible, using EC and granular formulations in preference to wettable powders which are particularly hazardous to bees. Micro-encapsulated formulations such as that used for lambda-cyhalothrin are particularly hazardous to bees because of their persistence in the environment and because bees transport the micro-capsules back to the hive along with the pollen;

Protect bees when using Regent® Insecticide
The Regent® Insecticide label states;
'Dangerous to bees. DO NOT apply where bees from managed hives are known to be foraging, and crops, weeds or cover crops are in flower at the time of spraying, or are expected to flower within 28 days (7 days for pastures and sorghum).
Before spraying, notify beekeepers to move hives to a safe location with an untreated source of nectar, if there is any potential for managed bees to be affected by the spray or spray drift. If an area has been sprayed inadvertently, in which the crop, weeds or cover crop were in flower or subsequently came into flower, notify beekeepers in order to keep managed bees out of the area for at least 28 days (7 days for pastures and sorghum) from the time of spraying. Where the owner of managed hives in the vacinity of a crop to be sprayed is not known, contact your State Department of Primary Industries/Agriculture, citing the registration number, for assistance in contacting the owner.'

Table 6. Cotton insecticides with known residual toxicities to honey bees

Active Ingredient	Chemical Group	Residual Toxicity to Bees[1]	Comment
fipronil	phenyl pyrazole	7 to 28 days	Long residual. See label extract above.
clorfenapyr	pyrrole	2 days	Foraging beaviour could be affected for longer than 2 days[2].
spinosad	spinosyn	1 day	Not hazardous once the spray has dried. Avoid drift onto hives.
betacyfluthrin	synthetic pyrethroid	>1 day	Longer residual expected in Australian conditions.
esfenvalerate	synthetic pyrethroid	1 day	
lambda–cyhalothrin	synthetic pyrethroid	>7 days	Micro-encapsulated formulation has longer residual.
carbaryl	carbamate	up to 7 days	
chlorpyrifos	organophosphate	up to 1 day	
dimethoate	organophosphate	up to 3 days	
parathion	organophosphate	1 day	Depending on weather conditions, residual may be 4–6 days[3].

Source: Primefact 149, *Pesticides – a guide to their effect on honey bees.*

[1] Residual toxicity is the amount of time the pesticide remains toxic after application. Data is derived from United States field trials conducted by the University of California (Atkins et al. 1981, *Reducing pesticide hazards to honey bees*) and Washington State University (Mayer et al. 1999, *How to reduce bee poisoning from pesticides*) unless otherwise indicated.

[2] APVMA, when formerly the National Registration Authority.

[3] United States Environment Protection Agency.

- inform contract pesticide applicators operating on the property of the locations of apiaries;
- paying particular attention to windspeed and direction, air temperature and time of day before applying pesticides;
- using buffer zones as a mechanism to reduce the impact of spray drift or overspray; and
- avoiding drift and contamination of surface waters where bees may drink (see advice on risk management for aquatic organisms).

Bee Alert

The Cotton CRC website hosts a voluntary service called **'Bee Alert'** that aims to improve communication between hive owners and cotton growers. Bee Alert is a free service which allows beekeepers to regularly update information about their hives on the web page for use by cotton growers. The Cotton CRC oversees the placement of data, allowing the Regional Cotton Extenion Officer to be notified when new listings are made in a region. Communication with growers and aerial operators can then be co-ordinated locally. Each Bee Alert provides;

- a description of where the hives are located,
- the likely duration of their stay, and
- contact details for the apiarist to be used in the event that hives may need to be moved.

When communicating with beekeepers, encourage them to use this service, particularly when aparies are being placed within bee flight range of flowering crops.

Further information about protecting bees or to contact the owner of bee hives

NSW Apiarist Association
Ms Julie Lockhart, Secretary
PO Box 3018, Toongabbie East, NSW 2146
Phone (02) 9631 3934. Fax (02) 9631 0585

QLD Beekeepers Association Inc.
Mr Bob Johnson, State Secretary
PO Box 49, Mapleton QLD 4560
Phone: (07) 5445 7512
Email: qba@hypermax.net.au

I&I NSW
Dr Doug Somerville,
Technical Specialist – Honeybees
PO Box 389, Goulburn NSW 2580
Phone: (02) 4828 6619. Mobile: 0427 311 410
Email: doug.somerville@dpi.nsw.gov.au

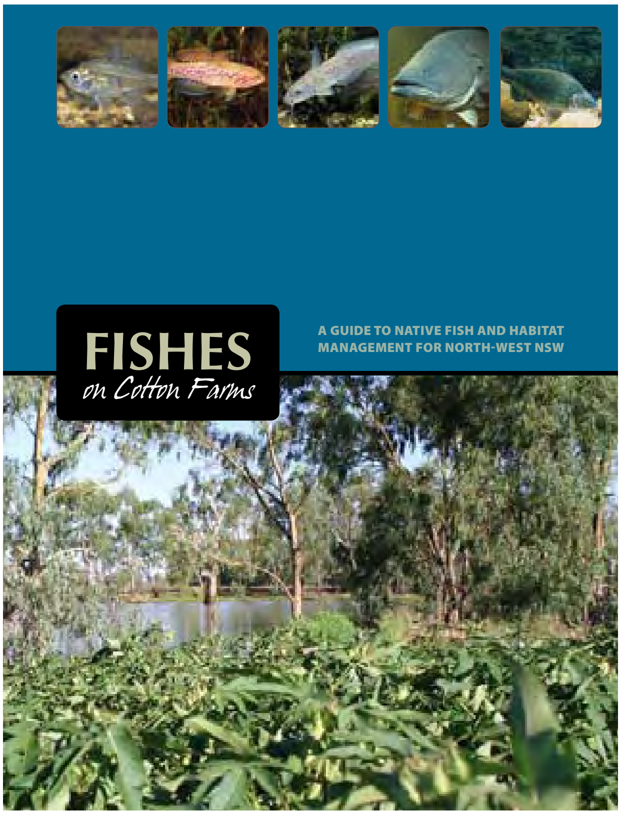
DEEDI
Peter Warhurst, Apiary Officer
Locked Bag 17, Warwick QLD 4370
Phone: (07) 4661 6623. Mobile: 0428 616 623
Email: peter.warhurst@dpi.qld.gov.au

Cotton CRC weblink;
www.cottoncrc.org.au/content/Industry/Tools/BeeAlert/Bee_Sites_All_Regions.aspx

PROTECTING THE AQUATIC ENVIRONMENT

The risk to aquatic organisms can be managed by:

- preventing drift into surface waters during application;
- locating mixing/loading and decontaminating facilities away from surface waters and providing such facilities with bunding and sumps to prevent movement of either concentrate or rinsate into surface waters;
- installing valves which prevent back-flow when filling spray tanks from surface waters and in suction lines for chemigation systems which draw directly from surface waters;
- avoiding aerial application of spray on fields during irrigation;
- building sufficient on-farm storage capacity (including provision for storm run-off) to contain pesticide contaminated tail water from irrigation;
- spraying in an upstream direction, when it is necessary to spray near surface waters, to reduce the maximum concentration at any one point in the watercourse;



NEW Fishes on Cotton Farms Guide available through the Cotton Catchment Communities CRC; www.cottoncrc.org.au or (02) 6799 1534

- using only registered products to control aquatic weeds, e.g. Roundup Bioactive® rather than Roundup®; and
- avoiding disposal of used containers in surface waters and on flood plains and river catchments.

PROTECTING BIRDS

The organophosphate and carbamate insecticides can be particularly toxic to birds, especially in granular formulations. Bird kills from diazinon, monocrotophos and carbofuran have been well documented in Australia and overseas. Insecticidal seed dressings can pose similar risks. Just a few seeds and granules can be lethal. Spillages can be very hazardous as birds can easily ingest a toxic dose from a small area.

Risks to birds from granular products can be managed by:

- ensuring complete incorporation beneath the soil, particularly at row ends where spillage may occur; and
- immediate clean up of spillage, however small.

Bait materials for control of rodents or soil insect pests can also be hazardous to birds, either through direct consumption of the bait or from feeding on bait-affected animals or pests. The risks to birds from baits can be managed by:

- ensuring even bait distribution, with no locally high concentrations;
- not baiting over bare ground or in more open situations, such as near crop perimeters, where birds may see the baits;
- not baiting near bird habitat such as remnant native vegetation;
- use of bait stations which prevent access by birds, particularly near bird habitat;
- only baiting where pest pressure is high;
- baiting late in the evening when birds have finished feeding;
- prompt collection and burial of rodent carcasses where these occur in open situations; and
- immediate clean up of spillage, however small.

Foliar applied insecticide sprays can also be hazardous to birds, either because of direct contact with the sprayed chemical, or by feeding on sprayed insect pests or crops. Even where birds are not killed, they may be sufficiently affected to make them more vulnerable to predation. Contaminated seed and insects collected from sprayed fields by parent birds can also be lethal to young chicks still in the nest. Risks to feeding and nesting birds can be managed by:

- minimising drift into remnant vegetation, wildlife corridors, nesting sites, or other bird habitats;
- actively discouraging birds from feeding in crops which are to be sprayed;
- spraying late in the day when birds have finished feeding; and
- using only low toxicity chemicals when large concentrations of birds are nesting nearby.

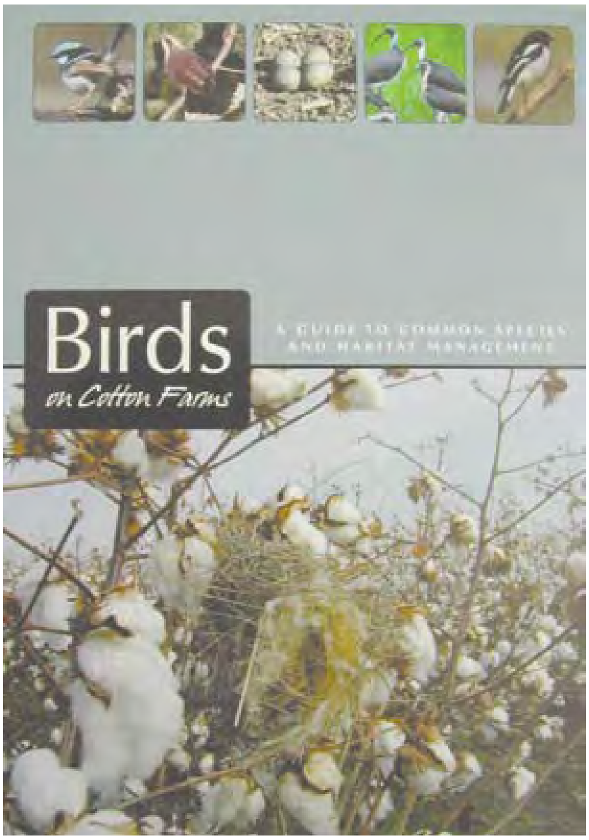
The best way to manage any long term adverse environmental risks is to follow the protection

Birds on Cotton Farms

'Birds on Cotton Farms' has been re-printed by the Cotton Catchment Communities CRC. The guide provides cotton growers of Northern New South Wales and Southern Queensland with an easy to use field guide of common bird species and their habitat requirements in the farming landscape. Some simple management practices that cotton growers can employ to maintain and improve local bird population densities and diversity are outlined.

This guide complements the management guidelines outlined in the Australian Cotton Best Management Practice (BMP) Manual.

Within the Guide there is a checklist of more than 300 bird species known to occur on farms, grasslands, wetlands and woodlands across these cotton production regions. This list represents more than one-third of all Australian birds. Also included are photographs of 118 common and significant bird species plus a brief description of their appearance, behaviour, habitat and preferred diet. The guides are available through the Cotton Catchment Communities CRC;
Locked Bag 1001 Narrabri NSW, 2390
Phone (02) 6799 1534 www.cottoncrc.org.au



statements on labels, minimise spray drift, and to dispose of chemical containers and waste in accordance with label directions and codes of practice.

RECYCLE CHEMICAL CONTAINERS

Recycling is now possible for properly rinsed metal and plastic containers used for farm chemicals. *drumMUSTER* is the national program for the collection and recycling of non-returnable crop production and animal health product chemical containers.

The containers when presented at a *drumMUSTER* receival site MUST BE: Free of chemical residue with the lids removed. Some stains are acceptable but physical chemical residue is **not**. Dirt, dust and mould are not reasons for rejection.

Inspection of containers at *drumMUSTER* collection points is necessary to ensure that containers can be safely recycled. There must be no product residue on the inside or the outside of the container, including the thread and cap. Visible residues could be powder, flake, coloured /dark fluid or clear fluid.

Preparing chemical drums for recycling

Always follow these procedures to ensure your drums are suitable for delivery to a collection centre;

1. Triple or pressure rinse your containers immediately after use (residues are more difficult to remove when dry). Pour the rinse water back into the spray tank.
2. Thoroughly clean the container thread and outside surfaces with a hose into the spray tank. Rinse all caps separately in a bucket of clean water, and pour the rinsate into the spray tank.
3. Inspect the container, particularly the thread and screw neck to ensure all chemical residue has been removed.
4. Metal containers should be punctured using a steel rod or crowbar, this should be done by passing it through the neck/pouring opening and out the base of the container. This also allows the containers to vent and remove any residual odour.
5. Allow the containers to drain completely and air dry them (this may take a number of days) to ensure they do not retain any rinse water.
6. Store cleaned containers in a sheltered place with caps removed, where they will remain clean and dry until they can be delivered to a *drumMUSTE*R collection centre.

If containers are rejected the user is responsible for ensuring that the container is taken back to the property and cleaned using all rinsate to make up an application of the same chemical according to the label recommendations.

For information on the *drumMUSTER* program phone 1800 008 707 or contact your local representative;

Northern NSW	Southern QLD	Northern QLD
Phil Tucker	Colin Hoey	Bill Davis
0427 925 274	0428 964 576	0427 691 760

SAFELY DISPOSE OF UNWANTED CHEMICALS

ChemClear® is an industry stewardship program which is funded to collect currently registered agricultural and veterinary chemicals at the end of their life cycle, or, when they become surplus. The program is targeted to meet disposal requirements of ag and vet chemical users, and, whilst doing so diverts potential hazardous chemicals from being dumped in landfills, creeks or being inappropriately disposed of in the community.

Unwanted rural chemicals may result from; discontinued use of a chemicals because of changes in cropping or animal practices, development of newer, more effective or safe chemicals, changes in a chemicals registration through the APVMA and/or banning from use, unknown product, sale of property, inherited product and deceased estates. Any unwanted or unknown chemicals held on farm are potential hazards to people, the environment and the community. The ChemClear® program aranges for the collection of unwanted chemicals for their appropriate environmental disposal.

Registering to use the ChemClear® program

There are six simple steps in using the program;

1. Take an inventory of any unwanted rural chemicals. The inventory should include all identifiable features of the container including label, manufacturer, expiry date, size of container and the remaining quantity of chemical left in the container.
2. Register the inventory for the next collection in your area. Book on; free-call 1800 008 182 or at; www.chemclear.com.au
3. Continue to store your registered chemicals safely and securely.
4. ChemClear® will contact you direct to advise the location for retrieval.
5. Prepare chemicals for delivery to collection site.
6. Deliver chemicals.

The cost to use the ChemClear® service depends on the chemical to be collected. Group 1 chemicals are collected free of charge under the program. These chemicals are currently registered ag and vet chemicals manufactured by companies supporting the Industry Waste Reduction Stewardship initiative. Group 2 chemicals are those chemicals that are no longer registered, unknown, unlabelled, out of date, or mixed ag and vet chemicals. A fee applies for disposal.

Re-entry periods after spraying

Mark Scott, Industry & Investment NSW

The re-entry period is the period in which a treated field must not be re-entered by unprotected persons after the application of a chemical on a crop. This should be considered as part of the risk assessment. Workers including chippers must be advised on the correct time lapse. It is important to observe the re-entry period when contact between foliage and skin is unavoidable. Herbicides are not included in the tables below as they are generally not as toxic.

Always check the label for the re-entry period.

Where no re-entry period is stated, a minimum of 24 hours should be observed or until the chemical has dried upon the crop, whichever is the later (subject to risk assessment), unless appropriate Personal Protective Equipment (PPE) is provided and worn as intended. Caution should be exercised when entering wet crops where chemicals have previously been applied, irrespective of the time lapse between application and re-entry.

Even after the re-entry period has been observed, some PPE may be necessary. Appropriate PPE should be indicated by the risk assessment.

Re-entry periods and the PPE to be worn are found in the General Instructions section of the label, which follows the Directions for Use table. All information will be found under the heading 'Re-entry Period'.

Re-entry periods may vary with formulation and product. The examples given in the table below may not be the same for all products with the active ingredient. Older labels for the same product may have different or no re-entry restrictions. Check the label of the product you are using and follow the directions.

If entry is necessary before the time stated, limit duration of entry and wear cotton overalls buttoned to the neck and wrist (or equivalent clothing), a washable hat, and elbow-length chemical resistant PVC gloves. Clothing must be laundered after each day's use.

Re-entry periods may change or be added to labels as chemicals are re-evaluated. Always read the label.

Refer to Table 16, page 86 for the trade names of active ingredients.

Insecticides without label re-entry periods

Active ingredient	Hazard Classification (WHO 2000–2002)
Spinosad, Bt	Unlikely to present acute hazard in normal use
Dicofol, Propargite	Slight
Alpha-cypermethrin, Pirimicarb	Moderate

Common insecticides with label re-entry periods

Active Ingredient	Re-entry Period
Abamectin	Under field conditions the spray should be allowed to dry on the foliage before re-entry into treated areas.
Acetamiprid	Do not allow entry into treated areas until the spray deposits have dried.
Amitraz	Do not allow entry into treated areas until the spray deposits have dried.
Amorphous silica	Do not allow entry into the treated area until the spray has dried.
Bifenthrin	Do not re-enter treated field/crop until spray deposits have dried.
Beta-cyfluthrin	Do not allow entry into treated areas until spray has dried.
Chlorfenapyr	Do not allow entry into treated areas for 12 hours after treatment.
Chlorpyrifos	Do not allow entry into treated areas until spray deposits have dried.*
Deltamethrin	Do not allow entry into treated areas until the spray deposits have dried.
Diafenthiuron	Do not allow entry into treated areas for 24 hours after treatment.*
Emamectin benzoate	Do not allow entry into treated areas for 12 hours after treatment.
Endosulfan	Re-entry to treated areas is permitted once the spray has dried.
Etoxazole	Do not allow entry into treated areas until the spray has dried.
Gamma cyhalothrin	Do not allow entry into treated areas until spray has dried
Indoxacarb	Do not allow entry into treated areas until spray has dried.
Lambda-cyhalothrin	Do not allow entry into treated areas until the spray has dried.
Methomyl	Do not allow entry into treated areas until at least 24 hours after treatment.
Methoxyfenozide	Do not allow entry into treated areas until spray has dried.
NPV	Do not allow entry into treated areas until spray has dried.
Profenofos	Do not enter treated areas without protective clothing until 24 hours after spraying.
Pymetrozine	Do not allow entry into treated areas until spray has dried.
Pyriproxyfen	Do not allow re-entry into treated area until the spray has dried.
Spinosad	Do not allow entry into treated areas until spray has dried.
Thiametoxam	Do not allow entry into the treated areas until spray has dried.
Thiodicarb	Do not allow entry into treated areas for 1 day after treatment.

* Check label instructions for cotton chippers.

Withholding period (WHP) after pesticide application

Mark Scott, Industry & Investment NSW

WHP is the minimum time period from when a pesticide is applied to when the treated area is allowed to be grazed, cut for fodder or harvested.

Some pesticide labels prohabit grazing by livestock or cutting fodder for livestock. Where a product has a no grazing WHP, crops treated with the product should not be grazed prior to harvest. Stock that graze the stubble or are fed by-products of the treated crop may develop detectable residues of the chemical. Growers should read the label and contact the chemical manufacturer for advice on managing chemical residues in stock.

Pesticides users must comply with these instructions or they may be prosecuted under offence provisions of the *Pesticides Act 1999* for use of a pesticide in disregard of a label.

Withholding period after application for common chemicals

Active ingredient	Crops not to be harvested for:	No grazing or cutting as stock fodder for:
Insecticides/miticides		
Abamectin	20 days	20 days
Acetamiprid	10 days	Do not graze or cut for stock fodder.
Aldicarb	0	Do not graze or cut for fodder. Do not cotton trash to animals feed
Alphamethrin	14 days	not stated
Alpha-cypermethrin	14 days	not stated
Amitraz	21 days	not stated
Amorphous silica	0	0
Bacillus thuringiensis	0	0
Bifenthrin	14 days	not stated
Beta-cyfluthrin	28 days	not stated
Carbaryl	3 days	1 day
Chlorantraniprole	28 days	Do not allow livestock to graze crops, stubble or gin trash
Chlorfenapyr	28 days	Do not graze or cut for fodder
Chlorpyrifos	28 days	28 days
Chlorpyrifos-methyl	28 days	Do not graze crop or stubble
Clothianidin	5 days	Do not graze or cut for stockfeed. Do not feed gin trash to livestock
Cypermethrin	14 days	not stated
Deltamethrin	7 days	not stated
Diafenthiuron	14 days	Do not graze or cut for fodder
Dicofol	7 days	Do not graze or cut for fodder
Dimethoate	14 days	not stated
Disulfoton	70 days	70 days
Emamectin benzoate	28 days	Do not feed cotton trash from treated areas to animals
Active ingredient	**Crops not to be harvested for:**	**No grazing or cutting as stock fodder for:**
Endosulfan	56 days	Do not feed cotton fodder, stubble or trash to livestock.
Esfenvalerate	7 days	not stated
Etoxazole	21 days	Do not graze treated area or cut treated area for stock feed
Fipronil	28 days	Do not graze or cut for fodder
Gamma-cyhaldthrin	21 days	not stated
Imidacloprid	91 days	Do not graze or cut for fodder
Indoxacarb	28 days	Do not graze or cut for fodder
Lambda-cyhalothrin	21 days	not stated
Methidathion	3 days	not stated
Methomyl	0	Do not graze or cut for fodder
Methoxyfenoziole	28 days	Do not graze or cut for fodder
NPV	0	0
Omethoate	21 days	not stated
Paraffinic oil	1 day	not stated
Parathion	14 days	Do not graze or cut for fodder
Pirimicarb	21 days	21 days
Profenofos	28 days	not stated
Propargite	28 days	Do not graze or cut for fodder
Pymetrozine	28 days	Do not graze crop stubble or gin trash
Pyriproxyfen	28 days	Do not graze on or cut for stock feed. Do not feed treated cotton trash to livestock
Spinosad	28 days	Do not graze or cut for fodder
Thiamethoxam	28 days	Do not graze or feed cotton trash to stock
Thiodicarb	21 days	21 days
Growth regulator and defoliant chemicals		
Dimethipin	7 days	7 days
Endothal	1 day	Do not graze
Ethephon	7 days	Do not graze
Ethephon + cyclanilide	7 days	Do not graze
Mepiquat	28 days	Do not graze
Paraquat + diquat	7 days	1 day
Sodium chlorate	0	0
Thidiazuron	0	Do not graze or cut for fodder

The WHP given may not be the same for all products with that active ingredient. Always check the label.

Refer to Table 13 for the trade names of active ingredients.

Cotton Insect Control Guide – Registered chemicals as at 15 October 2009

Tracey Farrell, formerly Industry & Investment NSW.

Registration of a pesticide is not a recommendation from I&I NSW for the use of a specific pesticide in a particular situation. Growers must satisfy themselves that the pesticide they choose is the best one for the crop and pest. Growers and users must also carefully study the container label before using any pesticide, so that specific instructions relating to the rate, timing, application and safety are noted. This publication is presented as a guide to assist growers in planning their pesticide programs.

Growers must also ensure that their insecticide program fits in with the Insecticide Resistance Management Strategy for *Helicoverpa*, aphids, mites and whitefly (see pages 52–55). Insecticides can be the most costly part of cotton production. Ensure that industry thresholds (pages 20 to 21) are followed to prevent unnecessary spraying.

IMPORTANT— AVOID SPRAY DRIFT

Take every precaution to minimise the risk of causing or suffering spray drift damage by:

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions near property boundaries. Make it clear that you expect the same courtesy from them.
- Carefully following all label directions.
- Paying particular attention to wind speed and direction, air temperature and time of day before applying pesticides using buffer zones as a mechanism to reduce the impact of spray drift or overspray.
- Keeping records of chemical use and weather conditions at the time of spraying.

SPRAY LOG BOOKS

To assist in record keeping for pesticide applications, Spray Log Books can be purchased from the state departments of primary industries.

Contacting DEEDI to place an order;

Toowoomba – Natalie Fletcher 07 4688 1460 or Rebecca Simmons 07 4688 1360.
Dalby Office – 07 4669 0800.

The cost $6.60 each plus postage.

Contacting I&I NSW to place an order;

Yanco – SMARTtrain National Resource Centre 1800 138 351.

The cost is $12.00 plus postage.

ABBREVIATIONS USED IN THE TABLES 7–18

AC	=	Aqueous concentrate	L	=	Liquid	SL	=	Soluble liquid
CS	=	Capsule suspension	LC	=	Liquid concentrate	ULV	=	Ultra low volume
EC	=	Emulsifiable concentrate	ME	=	Microencapsulated	WDG	=	Water dispersible granule
EC/ULV	=	Dual formulation	OL	=	Oil miscible liquid	WP	=	Wettable powder
G	=	Granule	SC	=	Suspension concentrate			

Table 7. Control of armyworm, cutworm and tipworm

Active ingredient	Concentration and formulation	Application rate of product	Comments
Armyworm (Lesser) *Spodoptera exigua*			
Chlorpyrifos	500 g/L EC	0.7 or 0.9 L/ha	When 'army' is moving treat broad strip over and in advance of the infestation. Use higher rate for larvae > 3 cm.
Cutworm *Agrotis* spp.			
Chlorpyrifos	500 g/L EC	0.9 L/ha	Apply immediately infestation is oberved. Apply in a minimum of 100 L of water.
Endosulfan	350 g/L EC	2.1 L/ha	Apply at first sign of infestation. Ensure pesticide application management plan (PAMP) is completed.
Tipworm *Crocidosema plebejana*			
Endosulfan	350 g/L EC	2.1 L/ha	Apply at first sign of infestation. Ensure pesticide application management plan (PAMP) is completed.

Insecticides

Table 8. Control of wireworm

Active ingredient	Concentration and formulation	Application rate of product	Comments
Wireworm *Apryprius variabilis* and False wireworm *Pterohelaeus* spp.			
Aldicarb	150 g/kg G	3.0–7.0 kg/ha	Apply into the seed furrow at sowing.
Bifenthrin	100 g/L EC	0.375 L/ha	Apply as spray into the furrow at planting. Use a spray nozzle which will deliver a coarse spray in a total volume of 60–100 L/ha.
Chlorpyrifos	300 g/L EC, EC/ULV 500 g/L EC	0.8–2.5 L/ha 0.5–1.5 L/ha	Use higher rate with extreme population numbers. Use rates for row spacing of 1 m. Apply as band spray at least 10 cm wide into open furrow at sowing. Use minimum spray volume of 20 L per sown ha.
Phorate	200 g/kg G	3.0 kg/ha	Apply into the seed furrow at sowing.

Table 9. Control of aphids

Active ingredient	Concentration and formulation	Application rate of product	*A. gossipii* resistance detected	Comments
Cotton aphid *Aphis gossypii* and Green peach aphid *Myzus persicae*				
Acetamiprid	225 g/L SL	0.05–0.1 L/ha	Yes	Ensure good coverage. Use high rate under sustained heavy pressure.
Aldicarb	150 g/kg G	3.0–7.0 kg/ha	No	Apply into the seed furrow at sowing. Refer to the label for the method of distribution.
Amitraz	200 g/L EC	2.0 L/ha	No	Suppression when used for controlling *Helicoverpa*.
Chlorpyrifos	300 g/L EC, EC/ULV 500 g/L EC	0 5–0.7 L/ha 0.3–0.4 L/ha	No	Use higher rates on heavy infestations.
Clothianidin	200g/L SC	0.125-0.25L/ha	Yes	Apply when aphid numbers are low and beginning to build.
Diafenthiuron	500 g/L SC	0.6 or 0.8 L/ha	Yes low level	Apply before damage occurs. Only use lower rate when spraying by ground rig.
Dimethoate	400 g/L EC	0.5 L/ha	No	Do not use where resistant strains are present.
Disulfoton	50 g/kg G	14.0 kg/ha	No	Apply in band near seed at planting.
Endosulfan	350 g/L EC	2.1 L/ha	No	Apply at first sign of infestation. Ensure pesticide application management plan (PAMP) is completed.
Imidacloprid	200 g/L SC	0.25 L/ha	Yes	Add Pulse penetrant at 0.2% v/v (2 mL/L water)
Omethoate	800 g/L SL	0.25 L/ha	No	Apply by ground or air.
Paraffinic oil	792 g/L	2% or 2L/100 L of water	No	Apply by ground rig using a minimum of 80L/ha of water. If populations exceed 20 per terminal use in a mixture with another aphicide.
Parathion-methyl	500 g/L EC	0.7–1.4 L/ha	No	Use low rate on light infestations and open crops. Ground application only. Higher rate in NSW only.
Phorate	100 g/kg G	6.0 kg/ha	No	For short residual control.
		11.0–17.0 kg/ha	No	For extended period of control. Only use the highest rate on heavy soils when conditions favour good emergence.
	200 g/kg G	3.0 kg/ha	No	For short residual control.
		5.5–8.5 kg/ha	No	NSW registration only.
Pirimicarb	500 g/kg WDG, WP	0.5 or 0.75 kg/ha	No	Thorough spray coverage essential for best results.
Profenofos	250 g/L EC 500 g/L EC	2.0 L/ha 1.0 L/ha	No	Spray timing is important. For best results apply when pest levels have reached commercial thresholds.
Pymetrozine	500 g/kg WDG	0.4 kg/ha	No	Apply to an actively growing crop prior to cut out. Add 0.2% v/v organo-silicone surfactant.
Thiamethoxam	250 g/kg WDG	0.2 kg/ha	Yes	Add 0.2% w/v organo-silicone surfactant. Apply to aphid population in early stages of development. DO NOT apply more than twice per season or as consecutive sprays.

Table 10. Control of cotton leafhopper and silverleaf whitefly

Active ingredient	Concentration and formulation	Application rate of product	Comments
Cotton leafhopper (jassids) *Amrasca terraereginae* and Vegetable leafhopper *Austroasca viridigrisea*			
Aldicarb	150 g/kg G	3.0–7.0 kg/ha	Planting into moist soil will allow greater and faster uptake. Use higher rate for longer residual control.
Dimethoate	400 g/L EC	0.35–0.375 L/ha	Use the higher rate for heavy infestations. Lower rate in NSW
Endosulfan (jassids only)	350 g/L EC	2.1 L./ha	Apply at first sign of infestation. Ensure pesticide application management plan (PAMP) is completed.
Gamma-cyhalothrin	150 g/L CS	0.05 L/ha	Apply at recommended threshold levels as indicated by field checks.
Omethoate	800 g/L SL	0.28 L/ha	Apply by ground or air.
Phorate	100 g/kg G	6.0 kg/ha	For short residual control.
		11.0–17.0 kg/ha	For extended period of control. Only use the highest rate on heavy soils when conditions favour good emergence.
	200 g/kg G	3.0 kg/ha	For short residual control
		5.5–8.5 kg/ha	NSW registration only.
Silverleaf whitefly *Bemesia tabaci* B-biotype			
Bifenthrin	100 g/L EC 250 g/L EC	0.8 L/ha 0.32 L/ha	The adult stage should be targeted. Do not spray crops with a high population of the juvenile stages. Thorough coverage of the crop canopy is essential. Do not apply more than 2 applications per crop.
Diafenthiuron	500 g/L SC	0.6 or 0.8 L/ha	Apply when population densities are 10–20% leaves infested. Suppression may not be satisfactory once population densities exceed 25% infestation, or when high numbers of adults are invading from nearby fields.
Pyriproxyfen	100 g/L EC	0.5 L/ha	Ensure thorough coverage. Apply when industry recommended thresholds are exceeded. If a second spray is required observe a two week retreatment interval. DO NOT apply more than twice in one season.

Table 11. Control of green vegetable bug, mirids and thrips

Active ingredient	Concentration and formulation	Application rate of product	Comments
Green vegetable bug *Nezara viridula*			
Dimethoate	400 g/L EC	0.34–0.5 L/ha	Apply when pests appear.
Endosulfan	350 g/L EC	2.1 L/ha	Apply at first sign of infestation. Ensure pesticide application management plan (PAMP) is completed.
Mirids (Green mirid *Creontiades dilutus* and Yellow mirid or Apple dimpling bug *Campylomma liebknechti)*			
Acetamiprid	225 g/L SC	0.1 L/ha	Apply with 0.2% Incide penetrant. Target nymphs and/or adults. On above threshold or increasing populations, suppression only may be observed.
Aldicarb	150 g/kg G	5.0 kg/ha	Apply into the seed furrow at planting.
Alpha-cypermethrin	16 g/L ULV 100 g/L EC	2.0–2.5 L/ha 0.3–0.4 L/ha	Apply at recommended threshold levels as indicated by field checks. Use the higher rate when pest pressure is high and increased residual protection is required.
Beta-cyfluthrin	25 g/L EC	0.6 L/ha	When *Helicoverpa spp.* are present follow *Helicoverpa spp.* instructions. Otherwise apply at threshold levles as determined by field checks.
Bifenthrin	100 g/L EC	0.6–0.8 L/ha	Apply at recommended threshold levels as indicated by field checks. Use the higher rate for increased pest pressure and longer residual control.
Chlorpyrifos-methyl	500 g/L EC	1.0–2.0 L/ha	Apply when pest numbers approach threshold levels.
Deltamethrin	27.5 g/L EC	0.18 L/ha	Suppression only.
Dimethoate	400 g/L EC	0.34–0.5 L/ha	Apply when pests appear.
Emamectin benzoate	17 g/L EC	0.55–0.7 L/ha	For suppression only. Apply to developing populations that are predominantly nymphs.
Fipronil	200 g/L SC	0.0625–0.125 L/ha	Apply spray to achieve thorough coverage. Use higher rate under sustained heavy pressure.

Table 11. Control of green vegetable bug, mirids and thrips (continued)

Active ingredient	Concentration and formulation	Application rate of product	Comments
Fipronil	200 g/L SC	0.0625–0.125 L/ha	Apply spray to achieve thorough coverage. Use higher rate under sustained heavy pressure.
Gamma-cyhalothrin	150 g/L CS	0.05 L/ha	Apply at recommended threshold levels as indicated by field check.
Imidacloprid	200 g/L SC	0.25 L/ha	Add Pulse penetrant at 0.2% v/v (2 mL/L water). See withholding period.
Indoxacarb	150 g/L EC	0.65 L/ha or 0.85 L/ha	Under high populations suppression only may be observed.
Lambda-cyhalothrin	250 g/L ME	0.06 L/ha	Apply at recommended threshold levels as indicated by field checks.
Omethoate	800 g/L SL	0.14–0.28 L/ha	Use high rate where population exceeds 1/m row.
Paraffinic Oil	792 g/L SL	2–5% v/v or 2–5 L/100 L of water	Apply low rate for suppression of fewer than 0.5 mirids/m. Apply high rate if population reaches threshold of 0.5 mirids/m or apply 2 successive low rate sprays not more than 7 days apart.
		1–2% or 1–2 L/100 L of water	Suppression only. Include Canopy® in tank-mix when applying any other insecticide by ground rig.
Phorate	200 g/kg G	50 g/100 m row	QLD only. Suppression only. Apply into seed furrow at planting.
Thrips (Tobacco thrip *Thrips tabaci* and Tomato thrip *Frankliniella schultzei*)			
Aldicarb	150 g/kg G	3.0–7.0 kg/ha	Apply into the seed furrow at planting.
Dimethoate	400 g/L EC	0.35–0.375 L/ha	Apply by ground rig or air. Aircraft may use double track spacing with a reliable cross wind.
Disulfoton	50 g/kg G	14.0 kg/ha	Apply in band near seed at planting.
Endosulfan	350 g/L EC	2.1 L/ha	Apply at first sign of infestation. Ensure pesticide application management plan (PAMP) is completed.
Fipronil	200 g/L SC	0.0625–0.125 L/ha	Regent will take 3–4 days to reach full effectiveness. Use higher rates under high pressure
Omethoate	800 g/L SL	0.14–0.28 L/ha	Use higher rate for longer residual control
Phorate	100 g/kg G	6.0 kg/ha	For short residual control.
		11.0–17.0 kg/ha	For extended period of control. Only use the highest rate on heavy soils when conditions favour good emergence.
	200 g/kg G	3.0 kg/ha	For short residual control
		5.5–8.5 kg/ha	NSW registration only.

Table 12. Control of *Helicoverpa* spp.

Active ingredient	Concentration and formulation	Application rate of product	*H. armigera* resistance present	Comments
Cotton bollworm, *Helicoverpa armigera*, and native budworm, *Helicoverpa punctigera*				
Abamectin	18 g/L EC	0.3 or 0.6 L/ha	No	For the control of *Helicoverpa punctigera* only. Use the higher rate alone or the lower rate with a suitable mixing partner. Do not use more than twice in one season for *H. punctigera* control.
Alpha-cypermethrin	16 g/L ULV 100 g/L EC	2.0, 2.5 or 3.0 L/ha 0.3, 0.4 or 0.5 L/ha	Yes	Use low rate for eggs or newly hatched larvae. Use higher rates for higher egg pressure or larger larvae.
Amitraz	200 g/L EC	2.0 L/ha	No	Apply as an ovicide with larvicide when eggs or very small larvae are detected. May suppress mites.
Amorphous silica	450 g/L SC	2.5–5.0 L/ha	No	Apply during egg lay to egg hatch. Best results are obtained from two sequential applications 6–7 days apart.
Bacillus thuringiensis	Btk SC	1.0–4.0 L/ha	No	Use alone or with mixtures. Refer to relevant label for details.
Beta-cyfluthrin	25 g/L EC	0.46–0.8 L/ha	Yes	Can be mixed with mineral spraying oil for ULV applications or with water for EC applications.
Bifenthrin	100 g/L EC	0.6–0.8 L/ha	No	Time spray to coincide with egg hatch. DO NOT apply to larvae > 5 cm.
Chlorpyrifos	300 g/L EC	4.0–5.0 L/ha	No	Target sprays against brown eggs and newly hatched, very small and small larvae.

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Table 12. Control of *Helicoverpa* spp. (continued)

Active ingredient	Concentration and formulation	Application rate of product	*H. armigera* resistance present	Comments
Cotton bollworm, *Helicoverpa armigera*, and native budworm, *Helicoverpa punctigera*				
Chlorpyrifos-methyl	500 g/L EC	1.0–2.0 L/ha	No	Use the lower rate at or when just exceeding threshold levels. Increase rate as numbers increase.
Cyfluthrin	50 g/L EC	0.6 L./ha or 0.8 L/ha	Yes	Application should be timed to coincide with egg hatch.
Cypermethrin	40 g/L ULV 200 g/L EC 250 g/L EC 260 g/L EC	2.0–3.25 L/ha 0.3–0.7 L/ha 0.3–0.5 L/ha 0.385–0.48 L/ha	Yes	Use high rate if *H. punctigera* larvae > 1 cm are present or *H. armigera* larvae < 5 cm are present.
Deltamethrin	5.5 g/L ULV 27.5 g/L EC	2.5–3.5 L/ha 0.5–0.7 L/ha	Yes	Use low rate as ovicide and high rates for small to medium larvae.
Emamectin benzoate	17 g/L EC	0.55–0.7 L/ha	No	Apply at or just prior to hatching. DO NOT target larvae > 5mm.
Endosulfan	350 g/L EC	2.1 L/ha	Yes	Apply at or just prior to egg hatching. Larvae larger than 7–10 mm are not readily controlled. Ensure pesticide application management plan (PAMP) is completed.
Esfenvalerate	50 g/L EC	0.5–0.7 L/ha	Yes	Use low rate when larvae are small and pressure is low.
Ethion + zeta-cypermethrin	360 g + 20 g/L EC	2.0–2.5 L/ha	Yes	Application of low rate should be timed to coincide with egg hatch and small larvae.
Gamma-cyhalothrin	150 g/L CS	0.05 L/ha 0.06 or 0.07 L/ha	Yes	Ovidicidal rate. Use low rate for newly hatched larvae.
Indoxacarb	150 g/L EC	0.65 or 0.85 L/ha	No	Use low rate for eggs and small larvae.
Lambda-cyhalothrin	250 g/L ME	0.06 L/ha, 0.07 or 0.085 L/ha	Yes	Ovicidal rate. Use low rate for newly hatched larvae.
Helicoverpa NPV	2000 M-Obs/ mL LC	0.5 L/ha	No	Alone or with compatible larvicide. See label for details. Target application to coincide with egg hatching.
Magnet		0.5L/100 m row (10–50 cm bands) in 72 m or 36 m		Use including insecticides as per label instructions
Methomyl	225 g/L SL	0.5–1.0 L/ha 1.8–2.4 L/ha	Yes	Ovicidal rate. Larvicidal rate. Higher rate of larvicidal rate may cause reddening of foliage, if excessive use an alternative. Do not apply during periods of plant stress.
Methoxyfenozide	240 g/L SC	1.7 L/ha or 2.5 L/ha	No	Apply with recommended adjuvant. Use high rate on rapidly growing crops.
Paraffinic oil	792 g/L	2% or 2L/100L of water	No	See page 22 for thresholds. Use a minimum of 80L/ haof water. Apply only by ground rig before crop closure.
Parathion methyl	500 g/L EC		Yes	Apply to larvae < 10 mm in length.
Piperonyl butoxide	800 g/L EC			Use as a synergist when applying synthetic pyrethroids. See label.
Profenofos	250 g/L EC		Yes	Ovicidal rate Larvicidal rate
			Yes	Ovicidal rate Larvicidal rate. Higher rates may injure older leaves.
Rynaxypyr (chlorantraniliprole)	350 g/kg WDG	0.090 or 0.150 g/ha + non ionic surfactant @ 125 gai/100 L	No	Target brown eggs or hatchling to 2nd instar larvae before they become entrenched in squares, flowers and bolls. Use high rate where the potential is for >3.5 larvae/m to achieve longer residual control.
Spinosad	125 g/L ULV 480 g/L SC 800 g/kg	0.6–0.8 L/ha 0.15–0.2 L/ha 90-100 g/ha	No	Maximum three sprays per season. Use low rate against light infestations. target sprays against brown eggs and newly hatched very small larvae
Thiodicarb	375 g/L SC	2.0–2.5 L/ha 0.5–1.0 L/ha	Yes	Larvicidal rate. Ovicidal rate.

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Table 13. Control of rough bollworm

Active ingredient	Concentration and formulation	Application rate of product	Comments
Rough bollworm (*Earias huegeli*) (This pest is not normally a problem where a *Helicoverpa* species control program is adopted.)			
Alpha-cypermethrin	16 g/L ULV 100 g/L EC	2.0–2.5 L/ha 0.3–0.4 L/ha	It is essential to detect and treat infestations before larvae are established or concealed in bolls deep in the canopy. Use high rate for large larvae.
Beta-cyfluthrin	25 g/L EC	0.6 or 0.8 L/ha	Application should be timed to coincide with egg hatching.
Carbaryl	500 g/L SC	2.2 L/ha	NSW only. Apply when pest appears. DO NOT use on cotton after 25% of bolls have opened.
Cypermethrin	40 g/L ULV 200 g/L EC 250 g/L EC 260 g/L EC	1.9–2.5 L/ha 0.375–0.5 L/ha 0.3–0.4 L/ha 0.29–0.385 L/ha	Rates vary. See product label for specific rates. Use highest rate when canopy is dense. Effectiveness is lower for established and concealed infestations.
Endosulfan	350 g/L EC	2.1 L/ha	Apply at or just prior to egg hatching. Ensure pesticide application management plan (PAMP) is completed.
Methoxyfenozide	240 g/L SC	1.7 L/ha or 2.5 L/ha	Apply with recommended adjuvant. Use high rate on rapidly growing crops.
Rynaxypyr (chlorantraniliprole)	350 g/kg	150 g/ha + non ionic surfactant @ 125 gai/100 L	Target brown eggs or hatchling to 2nd instar larvae before they become entrenched in terminals or bolls.

Table 14. Control of pink spotted bollworm

Active ingredient	Concentration and formulation	Application rate of products	Comments
Pink spotted bollworm (*Pectinophora scutigera*)			
Chlorpyrifos	300 g/L EC 500 g/L EC	1.75 L/ha 1.0 L/ha	QLD only. Apply when 10–15 moths are trapped on two consecutive nights to prevent infestation of bolls by larvae.
Deltamethrin	5.5 g/L ULV 27.5 g/L EC	2.5–3.0 L/ha 0.5–0.6 L/ha	QLD only. Apply at first sign of activity before larvae enter boll.
Esfenvalerate	50 g/L EC	0.4 L/ha	Central QLD only. Apply at this rate when pink spotted bollworm is only pest present.
Gamma-cyhalothrin	150 g/L CS	0.06 L/ha	QLD only. If *Helicoverpa* spp. are not present apply when more than 10 adults moths are caught in pheromone traps on 2 consecutive nights.
Lambda-cyhalothrin	250 g/L ME	0.07 L/ha	As above

Table 15. Control of mites

Active ingredient	Concentration and formulation	Application rate of product	Comments
Mite (*Tetranychus*) species			
Abamectin	18 g/L EC	0.3 L/ha	Best results will be obtained when applied to low mite populations. Do not use more than twice in one season.
Aldicarb	150 g/kg G	3.0–7.0 kg/ha	Apply into the seed furrow at sowing.
Amitraz	200 g/L EC	2.0 L/ha	Suppression when used for controlling *Helicoverpa*
Bifenthrin	100 g/L EC	0.6–0.8 L/ha	Applications against *Helicoverpa* spp. will give good control of low mite populations.
Chlorpyrifos	300 g/L EC	1.0–1.5 L/ha	Mix with pyrethroids as a preventative spray to minimise buildup of mite populations.
		2.5 L/ha	For established mite populations.
Diafenthiuron	500 g/L SC	0.6 or 0.8 L/ha	Treatment at higher infestation levels may lead to unsatisfactory results.
Dicofol	240 g/L EC	4.0 L/ha	NSW registration only. Apply by ground rig at first appearance of mites before row closure.
Dimethoate	400 g/L EC	0.34–0.5 L/ha	Will not control organophosphate-resistant mites.
Disulfoton	50 g/kg G	14.0 kg/ha	Apply in a band near seed at planting.
Emamectin benzoate	17 g/L EC	0.55–0.7 L/ha	When applied for *Helicoverpa* control will reduce the rate of mite population development. Suppression only.
Etoxazole	110 g/L SC	0.35 L/ha	Apply by ground rig only. Best results when used on low to increasing populations.
Methidathion	400 g/L EC	1.4 L/ha	Knockdown and short residual control.
Phorate	100 g/kg G	6.0 kg/ha	For short residual control.
		11.0–17.0 kg/ha	For extended period of control. Only use the highest rate on heavy soils when conditions favour good emergence.
	200 g/kg G	3.0 kg/ha	For short residual control.
		5.5–8.5 kg/ha	NSW registration only.
Profenofos	250 g/L EC	1.0–2.0 L/ha	Use low rate to suppress build up. Use high rate if aphids present.
	500 g/L EC	0.5–1.0 L/ha	
Propargite	600 g/L EC	2.5 L/ha	Apply as spray before mite infestations reach damaging levels.

Table 16. Insecticide trade names and marketers – Registered chemicals as at 15 Oct 2009

Active ingredient	Chemical group	Insecticide group	Concentration and formulation	Trade name	Marketed by
Abamectin	avermectin	6A	18 g/L EC	ABA 18	Genfarm
			18 g/L EC	Abachem	ChemAg
			18 g/L EC	Abamect	Nufarm
			18 g/L EC	Abamectin	eChem
			18 g/L EC	Abamectin	Accensi
			18 g/L EC	Abamectin	4Farmers
			18 g/L EC	Abamectin	Chemtura
			18 g/L EC	Agrimec	Syngenta
			18 g/L EC	Biomectin	Jurox
			18 g/L EC	Gremlin	Sipcam
			18 g/L EC	Kill-a-mite	Sevroc
			18 g/L EC	Romectin	Rotam Australasia
			18 g/L EC	Romite	Rotam Limited
			18 g/L EC	Stealth	PCT Holdings
			18 g/L EC	Vantal 18 EW	Ospray
			18 g/L EC	Wizard 18	Farmoz
Acetamiprid	chloronicotinyl	4A	225 g/L SL	Intruder	Du Pont
Aldicarb	carbamate	1A	150 g/kg G	Temik 150G	Bayer CropScience
Alpha-cypermethrin	pyrethroid	3A	16 g/L ULV	Alpha-Scud ULV	Farmoz
			16 g/L ULV	Dictate ULV	ChemAg
			16 g/L ULV/EC	Fastac Duo ULV	Nufarm
			16 g/L ULV	Dominex 16 ULV	FMC Australasia
			16 g/L ULV	Alpha-cyp ULV	eChem
			100 g/L EC	Alpha 100	Conquest
			100 g/L EC	Alpha 100	Innova
			100 g/L EC	Alpha-Cyp 100 DUO	eChem
			100 g/L EC	Alpha-cyper	Tradelands
			100 g/L EC	Alpha-Cypermethrin 100	4Farmers
			100 g/L EC	Alpha-Cypermethrin 100	Accensi
			100 g/L EC	Alpha-Cypermethrin 100	Chemforce
			100 g/L EC	Alpha-Cypermethrin 100	Halley
			100 g/L EC	Alpha-Cypermethrin 100	Ospray
			100 g/L EC	Alpha-Cypermethrin 100	Titan
			100 g/L EC	Alpha DuoAlpha Duo	Genfarm
			100 g/L EC	Alpha Duop 100	Grow Choice
			100 g/L EC	Alpha-Scud Elite	Farmoz
			100 g/L EC	Alphasip Duo	Sipcam
			100 g/L EC	Astound Duo	Nufarm
			100 g/L EC	Biotis Alpha 100	Biotis Life Science
			100 g/L EC	Buzzard	PCT International
			100 g/L EC	Centaur 100	Genfarm
			100 g/L EC	Dictate 100	ChemAg
			100 g/L EC	Dictate Duo 100	ChemAg
			100 g/L EC	Dominex Duo	Crop Care
			100 g/L EC	Dominex Duo	FMC
			100 g/L EC	G. valley Alpha-Cypermethrin 100	Grassvalley
			100 g/L EC	Fastac Duo	forrmulations
			100 g/L EC	Ken-Tac 100	Nufarm
			100 g/L EC	Unialphacyper	Kenso AgCare
					United Farmers Co-op
Amitraz	triazapentadiene	19A	200 g/L EC	Amitraz 200 EC/ULV	ChemAg
			200 g/L EC	Amitraz 200 EC/ULV	Jurox
			200 g/L EC	Amitraz EC/ULV	eChem
			200 g/L EC	Amitraz Elite EC/ULV	Farmoz
			200 g/L EC	Amitraz Duo	Genfarm Crop Protection
			200 g/L EC	Hitraz 200 EC/ULV	Rotam
			200 g/L EC	Mitra 200 EC/ULV	United Phosphorus
			200 g/L EC	Opal Duo	Nufarm
			200 g/L EC	Ovasyn Options	Arysta Lifescience
			200 g/L EC	Rotaz 200 EC/ULV	Rotam Australasia
Amorphous silica	not a member of any chemical group		450 g/L SC	Abrade Abrasive Barrier	Grow Choice
Bacillus thuringiensis	Bt microbials	11C	Btk* HD1** SC	Dipel SC	Valent BioSciences, Sumitomo Chemicals
Betacyfluthrin	pyrethroid	3A	25 g/L EC	Bulldock Duo	Bayer CropScience

* *Bacillus thuringiensis* subspecies KURSTAKI. ** Strain type.

Table 16. Insecticide trade names and marketers (continued)

Active ingredient	Chemical group	Insecticide group	Concentration and formulation	Trade name	Marketed by
Bifenthrin	pyrethroid	3A	100 g/L EC	Agfen 100 EC	Agriwest
			100 g/L EC	Arrow 100 EC	Conquest
			100 g/L EC	Bifen 100	ChemAg
			100 g/L EC	BiFendoff 100	Grow Choice
			100 g/L EC	Bifenthrin	4 Farmers
			100 g/L EC	Bifenthrin 100	Genfarm
			100 g/L EC	Bifenthrin 100	United Farmers Co-op
			100 g/L EC	Bifenthrin 100 EC	Accensi
			100 g/L EC	Bifenthrin 100 EC	Ospray
			100 g/L EC	Disect 100 EC	UPL
			100 g/L EC	Sarritor	Nuchem
			100 g/L EC	Tal-Ken 100	Kenso Agcare
			100 g/L EC	Talstar 100 EC	Crop Care
			100 g/L EC	Venom 100	Farmoz
			100 g/L EC	Webzone	Webcot
			250 g/L EC	Talstar 250 EC	Crop Care
Carbaryl	carbamate	1A	500 g/L SC	Bugmaster Flowable	Bayer CropScience
Chlorpyrifos	organophosphate	1B	300 g/L EC	Instinct 300	Farmoz
			300 g/L EC	Kensban 300 Duo	Kenso AgCare
			300 g/L EC	Prowler 300	ChemAg
			500 g/L EC	Chlorpyrifos 500	4Farmers
			500 g/L EC	Chlorpyrifos 500	Accensi
			500 g/L EC	Chlorpyrifos 500	Agspray
			500 g/L EC	Chlorpyrifos 500	ChemAg
			500 g/L EC	Chlorpyrifos 500	Chemforce
			500 g/L EC	Chlorpyrifos 500	Conquest
			500 g/L EC	Chlorpyrifos 500	David Grays
			500 g/L EC	Chlorpyrifos 500	Genfarm
			500 g/L EC	Chlorpyrifos 500	Halley
			500 g/L EC	Chlorpyrifos 500	Titan
			500 g/L EC	Chlorpyrifos 500	United Farmers Co-op
			500 g/L EC	Chlorpyrifos 500 EC	Nufarm
			500 g/L EC	Chlorpyrifos 500 EC	WSD
			500 g/L EC	Cyren 500	Ospray
			500 g/L EC	Fortune 500	PCT International
			500 g/L EC	Generifos	Grow Choice
			500 g/L EC	Kensban 500	Kenso Corporation
			500 g/L EC	Lorsban 500	Dow AgroSciences
			500 g/L EC	Strike-out 500 EC	Farmoz
Chlorpyrifos-methyl	organophosphate	1B	500 g/L EC	Diplomat	ChemAg
Cypermethrin	pyrethroid	3A	40 g/L ULV	Cypershield ULV 40	ChemAg
			40 g/L ULV	Scud 40 ULV	Farmoz
			200g/L ULV	Boom 200	Genfarm
			200 g/L EC	Cypermethrin 200	Halley
			200 g/L EC	Cypermethrin 200	Titan
			200 g/L EC	Cypermethrin 200 EC	WSD
			200 g/L EC	Cypermethrin 200 EC	United Farmers Co-op
			200 g/L EC	Cypershield 200	ChemAg
			200 g/L EC	Ken-Cyper 200	Kenso AgCare
			200 g/L EC	Scud Elite	Farmoz
			200 g/L EC	Sonic 200 EC	Nufarm
			250 g/L EC	Cyper 250 Plus	Genfarm
			250 g/L EC	Cypermethrin 250	Conquest
			250 g/L EC	Cyrux 250 EC	United Phosphorus
			260 g/L EC	Cypermethrin 260 EC	4Farmers
Deltamethrin	pyrethroid	3A	5.5 g/L ULV	Ballistic ULV	Farmoz
			5.5 g/L ULV	Deltaguard ULV	PCT International
			27.5 g/L EC	Ballistic Elite	Farmoz
			27.5 g/L EC	D-Sect	PCT International
			27.5 g/L EC	Decis Options	Bayer CropScience
			27.5 g/L EC	Delta Duo	ChemAg
			27.5 g/L EC	Deltamethrin Duo	Halley
			27.5 g/L EC	Deltashield 27.5	ChemAg
Diafenthiuron	thiourea	12B	500 g/L SC	Pegasus	Syngenta
Dicofol	organochlorine	2B	240 g/L EC	Miti-Fol EC	Farmoz

Table 16. Insecticide trade names and marketers (continued)

Active ingredient	Chemical group	Insecticide group	Concentration and formulation	Trade name	Marketed by
Dimethoate	organophosphate	1B	400 g/L EC	Danadim	Ospray
			400 g/L EC	Dimethoate	ChemAg
			400 g/L EC	Dimethoate	Nufarm
			400 g/L EC	Dimethoate 400	4Farmers
			400 g/L EC	Dimethoate 400	Conquest
			400 g/L EC	Dimethoate 400	Farmoz
			400 g/L EC	Dimethoate 400	Halley
			400 g/L EC	Dimethoate 400	Gemax
			400 g/L EC	Dimethoate 400	Superway
			400 g/L EC	Dimethoate 400	Titan
			400 g/L EC	Rogor	Sipcam
			400 g/L EC	Saboteur	Crop Care
			400 g/L EC	Stalk	PCT Holdings
			400 g/L EC	Unidime 400	United Farmers Co-op
Disulfoton	organophosphate	1B	50 g/kg G	Disulfoton 50	David Grays
Emamectin benzoate	avermectin	6A	17 g/L EC	Affirm	Syngenta
Endosulfan	organochlorine	2A	350 g/L EC	Endosan	Crop Care
			350 g/L EC	Endosulfan 350 EC	Farmoz
			350 g/L EC	Endosulfan 350 EC	Nufarm
			350 g/L EC	Thiodan EC	Bayer CropScience
Esfenvalerate	pyrethroid	3A	50 g/L EC	Sumi-Alpha Flex	Sumitomo Chemicals
Ethion + zeta-cypermethrin	organophosphate + pyrethroid	1B + 3A	360 g/L + 20 g/L EC	Mustang	Crop Care, FMC
Etoxazole		10A	110 g/L SC	ParaMite	Sumitomo Chemicals
Fipronil	phenyl pyrazole	2C	200 g/L SC	Regent	Nufarm
Gamma-cyhalothrin	pyrethroid	3A	150 g/L CS	Trojan	Dow AgroSciences
				Trojan	Ospray
Helicoverpa NPV	nuclear polyhedrosis virus		2 x 10^9 PIB/mL* LC	Vivus	Ag Biotech
			5 x 10^9 PIB/mL** LC	Vivus Max	Ag Biotech
			2 x 10^9 PIB/mL*** LC	Vivus Gold	Ag Biotech
Imidacloprid	chloronicotinyl	4A	200 g/L AC	Annihilate	ChemAg
			200 g/L SC	Confidor 200 SC	Bayer CropScience
			200 g/L SC	Couraze 200 SC	Ospray
			200 g/L SC	Imidacloprid 200 SC	Genfarm
			200 g/L SC	Kohinor 200	Farmoz
			200 g/L SC	Nuprid 200SC	Nufarm
			200 g/L SC	Savage 200	Kenso
			200 g/L SC	Senator 200 SC	Agcare Crop Care
			200 g/L SC	Surefire Spectrum 200SC	PCT Holdings
Indoxacarb	oxadiazine	22A	150 g/L EC	Steward	Dupont
Lambda-cyhalothrin	pyrethroid	3A	250 g/L ME	Karate Zeon	Syngenta
			250 g/L ME	Kung Fu 250	ChemAg
			250 g/L ME	Matador Zeon	Crop Care
Methidathion	organophosphate	1B	400 g/L EC	Supracide 400	Syngenta
			400 g/L EC	Suprathion 400 EC	Farmoz
Methomyl	carbamate	1A	225 g/L EC	Electra 225	Farmoz
			225 g/L AC	Marlin	Dupont
			225 g/L AC	Methomyl 225	Ospray
			225 g/L AC	Sinmas	Sinon Australia
			225 g/L LC	Lannate L	Pinhead
			225 g/L LC	metholmyl 225	Crop Care
			225 g/L SC	Seneca	Ronic International
			225 g/L SL	Nudrin 225	Crop Care
Methoxyfenozide	benzoic acid, hydrazide	16A	240 g/L SC	Prodigy	Dow AgroSciences

Table 16. Insecticide trade names and marketers (continued)

Active ingredient	Chemical group	Insecticide group	Concentration and formulation	Trade name	Marketed by
Omethoate	organophosphate	1B	800 g/L SL 800 g/L SL	Folimat 800 Sentinel 800	Ayrsta Lifescience ChemAg
Paraffinic oil	petroleum spray oil (PSO)		792 g/L EC	Canopy	Caltex
Parathion-methyl	organophosphate	1B	500 g/L EC 500 g/L EC 500 g/L EC 450 g/L ME	Methyl Parathion 500 Parathion-Methyl 500 Parashoot 500 EC Parashoot CS	Crop Care Farmoz Ospray Ospray
Phorate	organophosphate	1B	100 g/kg G 100 g/kg G 100 g/kg G 200 g/kg G 200 g/kg G 200 g/kg G	Thiamet 100 Thiamet 100 Umet 100G Thiamet 200G Thiamet 200G Zeemet 200G	Nufarm BASF UPL Nufarm Barmac UPL
Piperonyl butoxide	synergist	synergist	800 g/L EC 800 g/L EC 800 g/L EC 800 g/L EC	Enervate PBO 800 EC Puppet Synergy	Nufarm Farmoz Imtrade Crop Care
Pirimicarb	carbamate	1A	500 g/kg WDG 500 g/kg WDG 500 g/kg WDG 500 g/kg WDG 500 g/kk WDG 500 g/kg WP	Aphidex WG Atlas WDG Pirimor WG Pirimicarb 500 Pirimicarb 500 WG Pirimicard 500 WP	Farmoz Titan Syngenta Ospray ChemAg 4Farmers
Pirimicarb	carbamate	1A	500 g/kg WDG 500 g/kg WDG 500 g/kg WDG 500 g/kg WDG 500 g/kk WDG 500 g/kg WP	Aphidex WG Atlas WDG Pirimor WG Pirimicarb 500 Pirimicarb 500 WG Pirimicard 500 WP	Farmoz Titan Syngenta Ospray ChemAg 4Farmers
Profenofos	organophosphate	1B	250 g/L EC/ULV 500 g/L EC/ULV	Prochem Duo 250 Prochem Elite 500	ChemAg Imtrade
Propargite	sulfite ester	14A	600 g/L EC 600 g/L EC 600 g/L EC 600 g/L EC 600 g/L EC	Bullet Comite Dyna-Mite 600 Mitigate Treble	Crop Care Chemtura Australia Farmoz United Phosphorous Nufarm
Pymetrozine	pymetrozine	9A	500 g/kg WDG	Fulfill	Syngenta
Pyriproxyfen	juvenile hormone mimic	7C	100 g/L EC	Admiral	Sumitomo
Rynaxypyr (chlorantraniliprole)	oxadiazine	22A	350 g/kg	Altacor	Dupont
Spinosad	spinosyn	5A	125 g/L ULV 480 g/L SC 800 g/L WP	Tracer II Tracer Entrust	Dow AgroSciences Dow AgroSciences Dow AgroSciences
Thiodicarb	carbamate	1A	375 g/L SC 375 g/L SC 800 g/kg WDG 800 g/kg WDG	Larvin 375 Showdown 375 Confront 800 WG Larvin 800 WG	Bayer CropScience Farmoz Imtrade Bayer CropScience

* contains 2 x 10^9 polyhedral occlusion bodies of the NPV of *Helicoverpa armigera.*
** contains 5 x 10^9 polyhedral occlusion bodies of the NPV of *Helicoverpa armigera.*
*** contains 2 x 10^9 polyhedral occlusion bodies of the NPV of *Helicoverpa armigera* with a minimum of 50% native isolate and 50% vivus isolate.

Use of beneficial insect attractants (food sprays) and spray additives

The application of food sprays in cotton crops enables beneficial insects (particularly predators) to be attracted retained and conserved in the crop. Food sprays cannot manage cotton pests alone but combined with other IPM compatible tools they can help manage cotton pests and minimise synthetic insecticide use without sacrificing yield.

There are two type of food spray. The yeast based food spray attract beneficial insects while the sugar based food spray help retain beneficials that are already present. For more information on the use of food sprays see page 37.

Table 17. Food sprays and spray additives

Active ingredient	Concentration and formulation	Application rate of product	Comments
Food concentrate (yeast based) sucrose, lactose, alkyl aryl sulfonate, sodium ligno sulfate	WP	2.5 kg/ha	Beneficial insect attractant. Apply prior to increase of pests. See labels of each product for notes on spray coverage.
Food flavouring (sugar based)	265 g/L WP	0.25 L/ha 0.5 L/ha	Ground application Aerial application Spray additive to improve acceptance of insecticides by pests. Encourages feeding of stomach ingested insecticides.

Table 18. Food sprays and spray additives trade names and marketers

Active ingredient	Concentration and formulation	Trade names	Marketed by
Food concentrate		Predfeed	Growth Agriculture
Food flavouring	265 g/L	Mobait	Nufarm (Agnova Technologies)

Integrated Weed Management (IWM) for Australian cotton

Graham Charles, Industry & Investment NSW and Tracey Farrell, formerly Industry & Investment NSW

WHAT IS IWM?

Integrated Weed Management (IWM) is the development and implementation of a plan that is made up of a range of weed management tactics. IWM aims to manage today's weed problems in a manner that reduces the potential for weed problems in the future. The main principle underlying IWM is preventing weeds from setting seed by:

- knowing the weed spectrum and considering the interaction between weeds and the farming system (plan).
- regularly examining the weed problem and the success or failure of recent practices (monitor).
- assessing the weed management system and developing economic and sustainable solutions (evaluation).
- implementing alternative management strategies to deal with any problems (response).

An IWM program uses a range of methods of weed control in combination (Figure 7), so that ALL weeds are controlled by at least one tactic in the weed management system. In short, IWM is about NOT relying on only one or two methods of weed control alone, and in particular it does not involve relying only on herbicides.

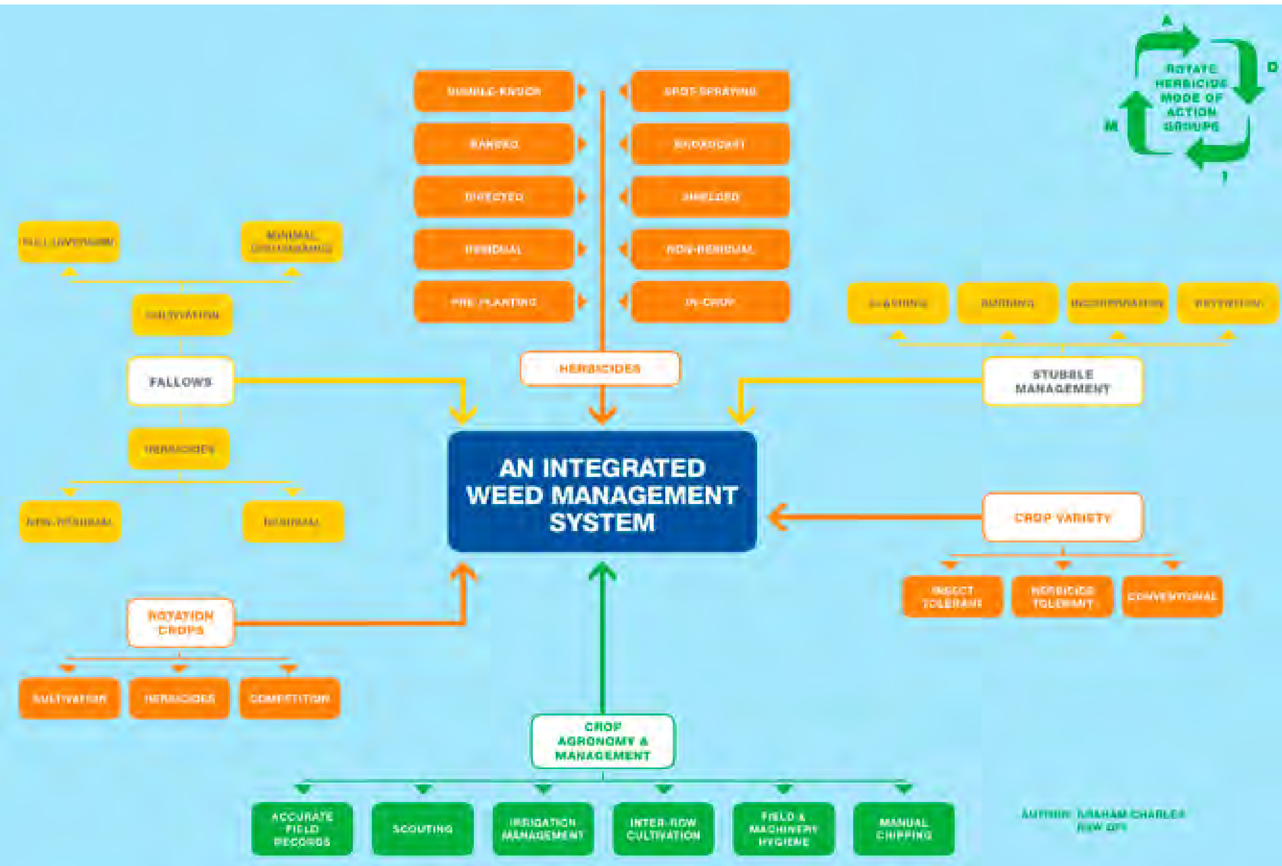
When developing an IWM program, think strategically about how you can best utilise all available weed control methods in cotton, in rotation crops and in fallows to give the best overall result. A short term approach to weed management may reduce costs for the immediate crop or fallow, but may not be cost effective over a five or ten year cropping plan. Over this duration, problems with species shift and the development of herbicide resistant weed populations are likely to occur where weed control has not been part of an integrated plan. Herbicide resistant weed populations are increasingly common in NSW and Queensland.

WHY USE IWM IN COTTON SYSTEMS?

Effectively managing weeds using an integrated program for the entirety of the cropping rotation will reduce:

- the rate of shift in the weed spectrum towards more herbicide tolerant weeds.
- the risk of selecting herbicide resistant weeds and so prolong the useful life of each herbicide.

Figure 7. An integrated weed management system relies on a large number of interrelated, complementary components. All inputs into the system are important.



Weeds

- the risk of herbicides accumulating in the soil and riverine systems.
- future weed control costs by reducing the number of weed seeds in the soil seed bank.
- the competitiveness of weeds and improve crop productivity each year.

Although all of these outcomes are important, reducing the risk of selecting herbicide resistant weeds is critical. This threat to cotton production has already had a major deleterious impact on many other cropping systems in Australia and elsewhere.

Throughout the world 185 weed species have developed resistance to different herbicides. Thirty-six weeds have developed resistance to herbicides in Australia. In northern NSW populations of 3 common grass weeds – awnless barnyard grass, liverseed grass and annual ryegrass – have resistance to glyphosate. Weeds with resistance to multiple herbicides is also occurring more frequently. The following tactics should be used to develop an integrated weed management strategy for your farm to help prevent the development of herbicide resistance.

IWM TACTICS IN COTTON

Know your weeds

Correct weed identification

Ensure that weeds are correctly identified before deciding upon a response. Similar species may respond differently to control measures. For example the strong seed dormancy mechanisms of cowvine (*Ipomoea lonchophylla*) make it less responsive to a tactic like the spring tickle than bellvine (*Ipomoea plebeia*) which has very little seed dormancy. Herbicide susceptibility can also differ between similar species. Yellow vine (*Tribulus micrococcus*) can be controlled by Staple® while caltrop (*Tribulus terrestris*) is naturally tolerant.

The *Weed Indentification and Information Guide* on the Cotton CRC website is a powerful tool to assist weed identification. Unknown weeds can be identified by scrolling through the collections of pictures and the supporting text. The picture collections include seedling, flowering and mature growth stages as well as close up images of seeds for over 80 of the weeds that commonly occur in cotton. Additional weeds and more detailed biology and ecology information are added to the collections as material becomes available.

Scouting

Scouting fields before weed control is implemented enables the weed control option to be matched to the species present. Soon after a control is implemented scouting should be repeated to assess efficacy. Weed audits are a requirement of growing Liberty Link®, Roundup Ready Flex® and Roundup Ready® cottons. See pages 103 and 106 for details. These auditing techniques can also be used to scout weeds in conventional cotton and rotation crops.

Timely scouting allows questions that affect the next weed control decision to be answered;

- Were the weeds damaged but have recovered?
- Has control been better in some parts of the field than others?
- Has there been good control but a subsequent germination?

For IWM strategies to be effective in preventing resistance, weeds that survive a herbicide must be controlled by another method before they are able to set seed. Weeds may need to be closely examined, as some are capable of setting seed while very small.

Identify and closely monitor areas where machinery such as pickers and headers breakdown. Weeds seeds are often inadvertently released when panels are removed from machines for repairs.

Weed scouting in non-crop areas of the farm is a valuable source of information for planning future weed management strategies. Non-cropping areas, such as roadways, channels, irrigation storages and degraded remnant vegetation can be a source of reinfestation and can provide oportunities for newly introduced weeds to build up significant seed banks. These can be moved into fields via water, wind and animals. Weed managers should always be on the lookout for new weeds.

Field records

For all fields, maintain records of weed control methods and their effectiveness after every operation. Consider the records from past years in this year's decisions, particularly in relation to rotating herbicide modes of action. Avoid relying too heavily on herbicides with the same mode of action. Repetitive use of the same mode of action group over time is closely associated with the evolution of herbicide resistance within weed populations.

The spring tickle

The spring tickle uses shallow cultivation in combination with a non-selective, knockdown herbicide. The aim of the spring tickle is to promote early and uniform germination of weeds prior to sowing to ease weed pressure in-crop. Some weed species are more responsive to the spring tickle than others. Highly responsive weeds include bellvine and annual grasses – liverseed grass and the barnyard grasses. Weeds that are less responsive include; cowvine, thornapple, noogoora burr and bathurst burr.

The shallow cultivation (1–3 cm) can be performed using implements such as, lillistons or go-devils. Best results are achieved when the cultivation follows a rainfall event of ≥ 20 mm. Adequate soil moisture is needed to ensure that weed germination immediately follows the cultivation. Where moisture is marginal, staggered germination may result in greater weed competition during crop establishment.

A number of non-slective, knockdown herbicides can be used to control the germinating weeds while they are young and actively growing. Glyphosate (Group M), Spray.Seed® and Gramoxone® (Group L), Pledge® and Hammer® (Group G), as well as some combinations of these herbicides can be used. Where cotton with Roundup Ready® technology is to be planted this is an excellent opportunity to rotate herbicide mode of action by using the Group L or Group G products at this time. These alternate mode of action products can also be used to control herbicide tolerant cotton volunteers. Depending on the weed spectrum, more selective products from other modes of action may be used. Refer to Table 24 page 110. For additional information regarding the plant back restrictions of these products for cotton, refer to Tables 19, 20 and 22 on pages 97 and 98.

The double-knock

The double-knock technique is a fallow weed control tactic that is being used widely in the southern states to manage hard to control weeds such as herbicide resistant annual ryegrass. When executed well (right rates, right timing, right application) the double-knock tactic will provide 100% control. In cotton systems there are several ways the technique can be applied to improve control of weeds such as flaxleaf fleabane and simultaneously reduce the risk of resistance developing in other key weed species such as liverseed grass and awnless barnyard grass.

Originally the technique was developed to maximise weed control at planting by using Spray.Seed® or Roundup CT® followed by the sowing operation. This has application at cotton planting time for effective management of volunteers.

More recently the double-knock has come to be the use of two herbicides. When using two herbicides, the basis of the double-knock is to apply a systemic herbicide, allow sufficient time for it to be fully translocated through the weeds, then return and apply a contact herbicide, **from a different mode of action group**, that will rapidly desiccate all of the above ground material, leaving the systemic product to completely kill the root system. Most comonly glyphosate is followed with a Group L product. The optimum time between the treatments is dependent on the weed targets. Small, rapidly growing grasses respond best when the second application occurs 3–5 days after the first. When slightly larger fleabane is the target, separate the applications by 7–10 days. Examples of double-knock treatments and their efficacy on flaxleaf fleabane compared to a standard fallow application of glyphosate are shown above.

Performance of double-knock strategies on flaxleaf fleabane, 6–10 leaf (7–8 cm wide)

Initial Treatment	Days	Follow-up Treatment	% Control*
Roundup CT® 2 L/ha		nil	55
Roundup CT® 2 L/ha	7	Spray.Seed® 1.6 L/ha	96
Roundup CT® 2 L/ha	14	Spray.Seed® 1.6 L/ha	96
Roundup CT® 2 L/ha	21	Spray.Seed® 1.6 L/ha	88
Roundup CT® 2 L/ha Surpass® 1.5 L/ha	7	Spray.Seed® 1.6 L/ha	100
Roundup CT® 2 L/ha Surpass® 1.5 L/ha	14	Spray.Seed® 1.6 L/ha	100
Roundup CT® 2 L/ha Surpass® 1.5 L/ha	21	Spray.Seed® 1.6 L/ha	96
Roundup CT® 2 L/ha Surpass® 1.5 L/ha	7	Spray.Seed® 2.4 L/ha	100
Roundup CT® 2 L/ha Surpass® 1.5 L/ha	14	Spray.Seed® 2.4 L/ha	100
Roundup CT® 2 L/ha Surpass® 1.5 L/ha	21	Spray.Seed® 2.4 L/ha	100

Source: Jeff Werth, DEEDI. These results are from a single trial conducted on the Darling Downs in October 2006.

* Control measured 28 days after the initial treatment was applied.

Encourage insect predation

Insects predation can contribute significantly to natural mortality in the weed seed bank. Seed theft by ants commonly causes failure of pasture establishment, so it is feasible that weed seed banks can be decreased by encouraging ants. A study in the WA wheatbelt showed ant predation reduced annual ryegrass seed by 81% and wild radish seed by 46% over a 3 month period. Reductions were greatest it situations close to refuge areas such as fencelines and remnant vegetation. For further information, refer to the Weed CRC publication, *Intergrated Weed Management in Australian Cropping Systems*. In central Queensland ant abundance in remnant vegetation has been shown to be favoured by vegetation diversity and the presence of leaf litter and fallen logs. Renmant areas need not be large to support rich diversity and abundance of ants.

Ants are affected by many of the insecticides registered for use in cotton. When possible, avoid using products with a high or very high impact on ants. Refer to Table 3 *Impact of insecticides and miticides on predators, parasitoids and bees in cotton*, page 40–41, for insecticide ratings.

In Bollgard II® cotton and unsprayed refuges feeding by the Datura leaf beetle, *Lema trivittata*, can prevent thornapples from setting seed.

Herbicide tolerant GM cotton varieties

Herbicide tolerant cottons allow the use of non-selective herbicides for summer weed control in-crop. Incorporating this tactic into the IWM strategy allows for more responsive, flexible weed management. Weeds need only be controlled if and when germinations occur meaning herbicide application can be timed to have maximium impact on weed populations. In relatively clean fields the reliance on residual herbicides for in-crop management is reduced. In fields known to have heavy weed burdens, using the non-selective together with residual herbicides can achieve very high levels of control. Avoid using the same herbicide to control successive generations of weeds.

Prevent weed establishment

Where cotton is grown in rotation with crops such as winter cereals or maize, retain stubble cover from these rotation crops for as long as possible. Stubble cover reduces weed establishment and encourages more rapid breakdown of weed seed on the soil surface.

Use field history records to match residual herbicides to the likely weed problems in the field. Applying residual herbicides in combination with other in-crop measures reduces the selection pressure for resistance on post emergent herbicides.

Protect yield potential

After planting, time weed control measures based on the critical periods for weed control to prevent yield loss. Young cotton is not a strong competitior with weeds. The critical times when weed competition can cause yield loss are provided in the Guide on this page for a range of weed densities and weed types. Irrespective of the type of weeds, early season control is critical to prevent yield loss. The higher the weed population, the longer into the season weed control is required. Preventing yield loss as well as preventing weed seed set ensures there is an economic return from weed control both today and in the future.

Control survivors and late germinations

Use a range of selective controls – inter-row cultivation, lay-by herbicide, chipping and spot spraying – to prevent seed set in weeds that survived early season tactics or have germinated late.

For a range of reasons, situations will occur when some weeds escape control by herbicides.

Guide to the critical period for weed control to prevent 2% yield loss.

Weed Type	Weed Density /10 m row	Cotton Growth Stage (day degrees) To prevent yield loss, control weeds			
		From		To	
Large broadleaf weeds such as; noogoora burr, thornapple, volunteer sunflower, sesbania	1	1–2 leaf	(145)	3 leaf	(189)
	2	1–2 leaf	(144)	5–6 leaf	(275)
	5	1–2 leaf	(143)	first square	(447)
	10	1–2 leaf	(141)	squaring	(600)
	20	1–2 leaf	(139)	squaring	(738)
	40	1–2 leaf	(131)	early flowering	(862)
Medium broadleaf weeds such as; bladder ketmia, mintweed, Boggabri weed	1	1–2 leaf	(145)	2–3 leaf	(172)
	2	1–2 leaf	(144)	4–5 leaf	(245)
	5	1–2 leaf	(143)	pre-squaring	(387)
	10	1–2 leaf	(141)	early squaring	(514)
	20	1–2 leaf	(139)	squaring	(627)
	40	1–2 leaf	(131)	squaring	(880)
Grass weeds such as; awnless barnyard grass, liverseed grass, Johnson's grass	20	–	–	–	–
	30	1 leaf	(122)	1–2 leaf	(139)
	40	1 leaf	(122)	2–3 leaf	(174)
	80	1 leaf	(122)	4–5 leaf	(248)
	160	1 leaf	(122)	7–8 leaf	(357)
	320	1 leaf	(122)	early squaring	(531)

Missed strips due to poor operation of equipment, insufficient coverage due to high weed numbers, applying the incorrect rate and interruptions by rainfall are just a few reasons why weeds escape control. If herbicide resistant individuals are present, they will be amongst the survivors. It is critical to the longer term success of the IWM strategy that survivors not be let to set seed.

Inter-row cultivation
Inter-row cultivation can be used mid-summer to prevent succesive generation of weeds from being targeted by post-emergent herbicides. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the soil damage caused by tractor compaction and soil smearing from tillage implements.

Manual chipping
Manual chipping is ideally suited to dealing with low densities of weeds, especially those that occur within the crop row. It is normally used to supplement inter-row cultivation or spraying.

Spot spraying
Spot sprayers may be used as a cheaper alternative to manual chipping for controlling low densities of weeds in crop. Ideally, weeds should be sprayed with a relatively high rate of a herbicide from a different

herbicide group to the herbicides previously used to ensure that all weeds are controlled.

Crop rotations

Rotation crops enhance IWM by;

- introducing herbicide options not available in cotton,
- producing stubble loads that reduce subsequent weed germinations,
- varying the time of year non-selective measures can be used and the time of year that crop competition suppresses weed growth.

Rotation between summer and winter cropping provides opportunities to use cultivation and knockdown herbicides in-fallow at all times of the year. When summer crops such as maize are planted earlier than cotton, there is an opportunity to use crop competition and inter-row cultivation for cotton volunteer control rather than relying on herbicides, as is required when cotton follows cotton.

Bury seed of surface–germinating species

Use strategic cultivation to bury weed seeds and prevent their germination. Some weed species, such as common sowthistle (milk thistle) and flaxleaf fleabane, are only able to germinate from on or near the soil surface (top 20 mm). Time operations such as pupae busting, where full distrurbance of the soil is required, to assist in situations where these species have set seed. Burying the seed more than 20 mm below the surface will prevent its germination. This tactic is most successful when used infrequently as seed longevity of common sowthistle and flaxleaf fleabane will be extended from ~12 months to ~30 months.

Practice good farm hygiene

To minimise the entry of new weeds into fields, clean down boots, vehicles, and equipment between fields and between properties. Pickers and headers require special attention. Eradicate any new weeds that appear while they are still in small patches. Monitor patches frequently for new emergences.

Irrigation water can be a source of weed infestation with weed seeds being carried in the water. While it is not practical to filter seeds from the water, growers should be on the look out for weeds that gain entry to fields via irrigation. Give special consideration to water pumped during floods, as this has the greatest potential to carry new seeds. If possible flood water should be first pumped into a storage to allow weed seeds to settle out before being applied to fields. Control weeds that establish on irrigation storages, supply channels and head ditches.

CRITICAL SUCCESS FACTORS IN IWM

Timely implementation of tactics

Often the timeliness of a weed control operation has the largest single impact on its effectiveness. Herbicides are far more effective on rapidly growing small weeds, and may be quite ineffective in controlling large or stressed weeds. Cultivation may be a more cost-effective option to control large or stressed weeds, but additional costs can be avoided through being prepared and implementing controls at the optimum time.

Rotate herbicide groups

All herbicides are classified into groups based on their mode of action in killing weeds. Rotate herbicide groups whenever possible to avoid using the same group on consecutive generations of weeds. When this is unavoidable, use other methods of weed control in combination with the herbicide and ensure no weeds survive to set seed. The cotton industry is very fortunate to have registered herbicides in the majority of the mode of action groups.

Closely follow herbicide label recommendations

Herbicides are a principal component of most IWM strategies so it is important that they are used in the most effective manner possible. When reading the herbicide label check;

- that the rate you are about to use is right for the growth stage of the target weeds.
- whether a wetter or crop oil is required to maximise herbicide performance.
- that the application set up you are about to use is consistent with the label – water volume, droplet spectrums, operating pressure.
- for additional, specific information regarding appropriate weather conditions for spraying.

Herbicide efficacy is highly dependant of the use of correct application techniques. Always consider the suitablility of weather conditions. Using higher water volumes and coarse to very coarse droplet spectrums reduce the likelihood of product being lost off target.

Consider other aspects of crop agronomy

Most agronomic decisions for cotton have some impact on weed management. Decisions such as cotton planting time, pre-irrigation versus watering-up, methods of fertiliser application, stubble retention and in-crop irrigation management all have an impact on weed emergence and growth. The influence of these decisions should be considered as part of the IWM program. For example, modify the timing and method of applying pre-plant N to achieve a 'spring tickle' in the same operation.

Table 19. Herbicide plant backs from rotation crops to cotton

Trade name	Herbicide active ingredient	Registered for use in;	Plant back to cotton	Notes
Hotshot	aminopyralid + fluroxypyr	Cereal Crops: wheat, baley, oats, triticale Fallows	9 months	When rates up to 750 ml/ha are used. If is less than 100 mm in over a 4 month period, the plant back period may be significantly longer.
atrazine	atrazine	Cereal Crops: broom millet, maize, sorghum Legume Crops: lupins Other Field Crops: forage sorghum, potatoes, TT canola, sugarcane Pastures: lucerne, grass pastures	6 months	Where the maximum use of atrazine + smazine is 4 L/ha (500 g/L) on soils with pH ≤6.5.
			6 months	Where the maximum use of atrazine + simazine is 2 L/ha (500 g/L) on soils with pH ≥6.5.
			18 months	Where higher rates up to 6 L/ha are used.
Primextra Gold	atrazine + s-metolachlor	Cereal Crops: sorghum, maize Other Field Crops: sugarcane	6 months 18 months	When rates up to 3.2 L/ha are used. When rates above 3.2 L/ha are used.
Glean®	chlorsulfuron	Cereal Crops: wheat, barley, triticale, oats, cereal rye	18 months	Where soil pH is 6.6–7.5 and 700 mm of rain has fallen. For soil pH >7.5 only grow cotton after growing a test strip.
Lontrel®	clopyralid	Cereal Crops: wheat, barley, oats, triticale Other Field Crops: canola Pastures and Fallows	3 months 6 months 24 months	When rates up to 75 ml/ha are used. When rates of 75–300 ml/ha are used. When rates above 300 ml/ha are used. At least 100 mm rainfall during plant back period, including irrigation.
diuron	diuron	Cereal Crops: wheat, barley, oats, triticale, cereal rye Legumes: lupins Pastures: perrenial grass seed crops, lucerne	12 months	Plant back also applies from use in cotton.
Broadstrike®	flumetsulam	Cereal Crops: winter cereals, maize Legume Crops: chickpeas, field peas, lentils, soybeans Other Field Crops: peanuts, fenugreek, lathyrus Pastures: lucerne, serredella, clover, medic, Popany vetch	3 months	On deep, well drained soils.
Flame®	imazapic	Other Field Crops: sugarcane, peanuts	24 months	Also registered for use in fallows.
Balance®	isoxaflutole	Legume Crops: chickpeas Other Field Crops: sugarcane	7 months	350 mm rainfall between application and planting the subsequent crop. Do not include flood or furrow irrigation.
Tordon 75D®	picloram + 2,4-D	Cereal Crops: wheat, barley, oats, triticale, sorghum, maize Other Field Crops: sugarcane Pastures: Pastures	12 months	When rates up to 1 L/ha are used. Longer periods for higher rates.
Tordon 242®	picloram + MCPA			
simazine	simazine	Legume Crops: chickpeas, faba beans, lupins Other Field Crops: TT canola Pastures: lucerne, sub clover, perennial grasses	9 months	When up to 4.5 L/ha of 500 g/L formultions. Where higher rates are used, longer plant backs apply.
Logran®	triasulfuron	Cereal Crops: wheat, barley, oats	15 months	Soil pH ≤6.5 — 700 mm rainfall between application and sowing the plant back crop.
			15 months	Soil pH 6.6–7.5
			18 months	Soil pH 7.6–8.5
Grazon* Extra	triclopyr + picloram + aminopyralid	Fallow	18 months	During drought conditions (<100 mm rainfall in a 4 month period) the plant back is significantly longer.

Table 20. Plant backs to cotton for herbicides used in seedbed preparation

Herbicide active ingredient	2,4-D amine 625 g/L			2,4-D amine 300 g/L			dicamba 700 g/kg			fluroxypyr 200 g/L			triclopyr 600 g/L
Rate L or g/ha	0.56	1.1	1.7	0.35	0.7	1.1	140	200	400	0.375	0.75	1.5	0.080–0.100
Plant back[1] (days)	10	14	21	10	14	21	7	7	14	14	14	28	14

[1] If applied to dry soil, at least 15 mm rain is required before plant back period begins.

Table 21. Herbicides with unknown plant back periods to cotton

Trade name	Active ingredient	Registered for use in;
Spinnaker®	imazethapyr	Legume Crops: chickpeas, faba beans, field peas, mungeans, soybeans Other Field Crops: peanuts Pastures: lucerne, serradella, sub clovers
Raptor®	imazamox	Legume Field Crops: field peas, soybeans Other Field Crops: peanuts Pastures: lucerne, legume-based pastures
Midas®	imazapic + imazapyr + MCPA	Cereal Crops: Clearfield® wheat
Hussar®	mefenpyr-diethyl + iodosulfuron-methyl sodium	Cereal Crops: wheat
metribuzin	metribuzin	Cereal Crops: wheat, barley, oats Legume Crops: chickpeas, faba beans, lentils, vetch, lupins, field peas, soybeans (irrigated) Other Field Crops: potatoes
Ally®	metsulfuron methyl	Cereal Crops: wheat, barley, triticale Legume Crops: chickpeas (desiccant) Other Field Crops: Clearfield® canola
Harmony® M	metsulfuron methyl + thifensulfuron	Cereal Crops: wheat, barley, triticale
Atlantis®	metsulfuron methyl + mefenpyr-diethyl	Cereal Crops: wheat
Monza®	sulfosulfuron	Cereal Crops: wheat, triticale
Express®	tribenuron methyl	Fallows

Where fields have been treated with herbicides with no plant back recommendations to cotton, firstly determine the tolerance of cotton grown through to maturity on a smaller scale before sowing larger areas.

Table 22. Cotton herbicide plant backs to rotation crops Updated 2009

Herbicide active ingredient	Plant backs from cotton to rotation crops (months)																					
	Cereal grain crops							Legume crops											Other crops			
	Barley	Maize	Millet	Oats	Sorghum	Triticale	Wheat	Azuki bean	Chickpea	Cow pea	Fab bean	Field pea	Lab Lab	Lupin	Lucerne	Mungbean	Pigeon pea	Soybean	Canola	Safflower	Linseed	Sunflower
chlorthal dimethyl	8	8	8	8	8	8	8	8	8	8	8	8	8	8	FH	FH	8	FH	8	8	8	8
diuron	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
fluometuron	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
fluometuron + prometryn	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
halosulfuron-methyl	24	2	24	24	2	24	3	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
metolachlor	6	0	6	6	0[1]	6	6	6	6	6	6	6	6	6	6	6	6	0	6	6	6	0
norflurazon[2]	30	27	NI	30	27	30	30	NI	9	NI	30	NI	NI	NI	NI	27	NI	9	NI	12	9	27
pendimethalin	6	0[3]	12	12	12	FH	FH	FH	FH	FH	FH	FH	FH	FH	6	FH	FH	FH	6	FH	FH	FH
prometryn	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
pyrithiobac sodium	5	22	NR	5	22	NR	5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	22	NR	NR	NR	22
s-metolachlor	6	0	6	6	0[1]	6	6	6	6	6	6	6	6	6	6	6	6	0	6	6	6	0
trifloxysulfuron sodium	6	22	22	6	22	22	6	22	18	22	7	22	22	22	22	9	15	15	22	22	22	22
trifluralin	12	12	12	12	12	12	12	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH

1 Concep® II treated seed only.
2 For rates up to 3.5 kg/ha. Where higher rates, up to 4.2 kg/ha are used, increase plant back period by 6 months.
3 Maize can be resown immediately after use in a failed crop provided the seed is sown below the treated band of soil. Further information in Weed control in Summer and Winter Crop Publications from Industry & Investment NSW

FH = following cotton harvest
NR = not recommended
NI = no information
S = in the spring following application

Jeff Werth, Department of Employment, Economic Development and Innovation (DEEDI); David Thornby, DEEDI and Tracey Farrell, CRDC.

There are currently no reported cases of herbicide resistant weeds in cotton farming systems. This is largely due to the diversity of herbicides used and the regular inclusion of cultivation and hand chipping in weed management strategies. However the increasing use of glyphosate associated with Roundup Ready® technologies may increase the risk of resistance development.

The cotton growing regions are closely aligned with the northern grains region. Across this area, there are 16 weed species that have developed resistance to a least one herbicide mode of action. Most recently, liverseed grass with resistance to glyphosate has been confirmed for the first time. Table 23 summarises the herbicide resistance status of weeds in the north to each of the herbicide modes of action that are available for use in cotton. While none of the listed cases have occurred within the cotton system, the list clearly illustrates that if strategies used for weed management in cotton become overly reliant on herbicides, resistance can occur.

Development of herbicide resistant weed populations has been most strongly associated with cropping systems where there is minimal or no use of tillage and where there is only limited rotation between summer and winter cropping. The weeds considered to be at highest risk of developing resistance in the north are barnyard grass, liverseed grass, wild oats and sow thistle. These weeds are all able to germinate and establish over a wide range of temperatures and have very high capacities for seed production, meaning more than one generation can be exposed to herbicide selection pressure each season.

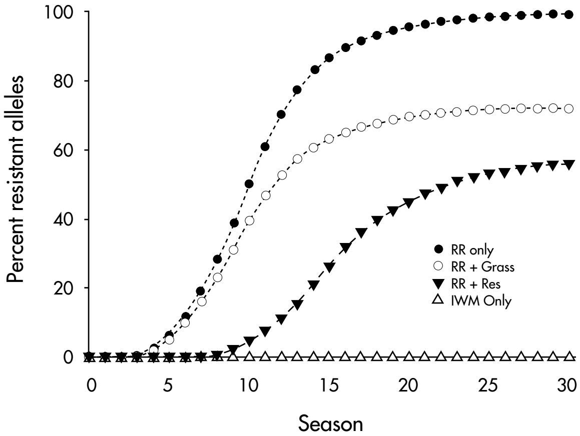
In a recent PhD study, the population dynamics of two key weed species, barnyard grass (*Echinochloa crus-galli*) and liverseed grass (*Urochloa panicoides*) were modelled under a range of weed management strategies. The model used the results from experiments investigating the seed producing capabilities of the two species and their responses to glyphosate.

Outputs from the model showed that the largest factor affecting resistance development was management. Shown in Figure 8, when a glyphosate-only approach to weed control was taken, resistance was highly likely to occur. Timeframes for resistance developing to the point of field control failures was in the vacinity of 12–17 years. When Roundup Ready® technology was used together with another herbicide option

Table 23. Australian weeds with resistance to the Mode of Action (MoA) groups used in cotton

Mode of Action Group		Examples of cotton herbicides with the MoA	Australian weeds with resistance to the MoA (not to specific herbicides)	NSW	Qld	Other States
A	fop	fluazifop-p, haloxyfop-r, propaquizafop	Annual ryegrass	✓		✓
			Barley grass	✓		✓
			Paradoxa grass			✓
			Wild oat	✓	✓	✓
	dim	butroxydim, clethodim, sethoxydim	Annual ryegrass	✓	✓	
			Barley grass			✓
			Paradoxa grass	✓		
			Wild oat	✓	✓	✓
B	sulfonylurea	halosulfuron-methyl, trifloxy-sulfuron sodium	Annual ryegrass	✓		✓
			Barley grass			✓
			Wild oat			✓
			Northern barley grass	✓		
			African turnip weed		✓	
			Black bindweed		✓	
			Charlock	✓		
			Common sowthistle	✓	✓	
			Dirty Dora	✓		✓
			Indian hedge mustard	✓	✓	✓
			Paterson's curse			✓
			Prickly lettuce			
			Turnip weed	✓	✓	
			Wild radish	✓		✓
			Wild turnip			✓
		imazapyr	Annual ryegrass	✓		✓
			Indian hedge mustard			✓
			Prickly lettuce			✓
			Wild radish			✓
		pyrithiobac sodium				
C	urea	diuron, fluometuron	Annual ryegrass			✓
			Liverseed grass		✓	
		prometryn				
D	dinitroaniline	pendimethalin, trifluralin	Annual ryegrass	✓		✓
	benzoic acid	clorthal dimethyl				
F		norflurazon				
G		carfentrazone ethyl, oxyfluorfen				
I	phenoxy	2,4-D	Indian hedge mustard			✓
			Wild radish			✓
		dicamba, triclopyr, fluroxypyr				
K		metolachlor, s-metolachlor	Wild oat	✓		
L		paraquat, diquat	Barley grass			✓
			Northern barley grass			✓
			Silver grass			✓
M		glyphosate	Annual ryegrass	✓	✓	✓
			Barnyard grass	✓		
			Liverseed grass	✓		
N		glufosinate-ammonium				
Q		amitrole + ammonium thiocyanate	Annual ryegrass			✓
Z		MSMA				

Figure 8. Simulated accumulation of glyphosate resistance alleles in a barnyard grass population under four weed management strategies.



resistance development was delayed. When it was used as part of a fully integrated weed management strategy, resistance did not develop over the 30 year period of the simulation. The weed management requirements of the Roundup Ready® Crop Management Plans (CMPs) are designed to ensure that Roundup Ready® is used in an integrated strategy. It is essential that the industry follows the CMPs and is proactive in preventing the development of herbicide resistance.

Looking for the early signs of resistance

Herbicide resistance is normally present at very low frequencies in weed populations before the herbicide is first applied. Using the herbicide creates the selection pressure that increases the resistant individuals' likelihood of survival. The underlying frequency of resistant individuals within a population will vary greatly with weed species and herbicide mode of action. Resistance can begin with the survival of one plant and the seed that it produces. Early in the development of a resistant population, resistant plants are likely to occur only in small patches. This is the critical time to identify the problem. Options are much more limited if resistance is first diagnosed over large areas.

Many of the symptoms of herbicide resistance can also be explained by other causes of spray failure. Evaluate the likelihood of other possible causes of herbicide failure. Start by taking the self assessment at the top of the page. The more questions to which you have confidently answered 'Yes', the more a further investigation of possible resistance is warranted. If you have answered 'Yes' to most of these questions, including questions 8–10 on field history, take action;

- Collect samples and send for testing.
- Remove surviving plants from the field to limit the amount of seed going into the soil seed bank.
- Develop a management plan for continued monitoring of the sites and the use of alternative weed control strategies.

Self Assessment – Likelihood of herbicide resistance		Y/N
1.	Was the rate of herbicide applied appropriate for the growth stage of the target weed?	
2.	Are you confident you were targeting a single germination of weeds?	
3.	Were the weeds actively growing at the time of application?	
4.	Having referred to your spray log book, were weather conditions optimal at the time of spraying so that herbicide efficacy was not compromised?	
5.	Are you confident the suspect plants haven't emerged soon after the herbicide application?	
6.	Is the pattern of surviving plants different from what you associate with a spray application problem?	
7.	Are the weeds that survived in distinct patches in the field?	
8.	Was the level of control generally good on the other target species that were present?	
9.	Has this herbicide or herbicides with the same mode of action been used in the field several times before?	
10.	Have results with the herbicide in question for the control of the suspect plants been disappointing before?	

Options for herbicide resistance testing

Testing a plant population for the presence of herbicide resistant individuals involves growing large numbers of plants in 'ideal' conditions then at particular growth stages applying the herbicide at a range of rates and observing the responses. Generally, seed is collected from the suspect plants and is sent for testing. However the dormancy mechanism in some species, such as barnyard grass, creates problems with this process. It is difficult to get sufficient quantities of seed to germinate uniformly in short time frames. An alternative sampling method is to collect actual plants out of the field for the Quick test. This process is limited to seedlings/ small plants as large numbers need to be collected and posted. Upon arrival they are potted and once re-established, herbicide treatments are applied. In mid-summer conditions plants are less likely to survive the trip than if collected in cooler times of the year. It is recommended to take seed samples from the surviving plants in summer and mark these sites to enable seedling collections in the following autumn or spring if they are needed.

The timeline for obtaining results from sending seed samples can be several months. Results are usually available by the end of April when samples are recievied before January. When plants are sent for Quick tests results are usually available within 4–8 weeks.

Sampling information sheet for herbicide resistance testing

Contact Details			
Farm Manager/Owner:		Address:	
Consultant:		Telephone:	
Preferred contact:	Manager/Owner / Consultant (details provided on right)	Email:	
		Fax:	

Sampling Details			
Weed species:		Sampled by:	
Field Name:		Sampling Date:	

Field History

Season	Crop	Herbicides	Timing	Control Level (good/average/poor)
2008				
2007/08				
2007				
2006/07				
2006				
2005/06				
2005				
2004/05				
2004				
2003/04				

Collecting seed samples:

- Collect 2000–3000 seeds from plants you suspect are resistant. Barnyard grass = 1 cup full. Wild oats = 5–6 cups full.
- If testing >3 modes of action, collect additional seed.
- Avoid collecting large amounts of seed from just a few large plants.
- Follow a 'W' shaped pattern stopping every ~20 m if survivors are widespread. If survivors are localised, collect from within this area.
- Bash seed heads into a bucket to ensure only ripe seed in collected.
- Store samples in a paper bag at room temperature, away from sunlight, moisture and heat. Post as soon as possible.

Collecting plant samples for the Quick test:

- For each mode of action to be tested: collect 50 plants/field from areas where you suspect resistance.
- Gently pull out plants and wash roots.
- Wrap in moistened paper towel.
- Place in waterproof plastic bag.
- Keep in fridge and Express Post on the next Monday.

Sending samples to resistance testing services

Follow the instructions above and send samples together with a completed information sheet to either of the testing services below.

Dr Peter Boutsalis (seed or Quick test)
Plant Science Consulting
22 Linley Avenue,
Prospect SA 5082
Phone: 0400 664 460
Email: info@plantscience consulting.com
Website: www.plantscienceconsulting.com

John Broster (seed test only)
Charles Sturt University
Herbicide Resistance Testing Service, PO Box 588
Wagga Wagga NSW 2678
Phone: (02) 6933 4001
Email: jbroster@csu.edu.au

Select Herbicide Modes of Action for Testing

Mode of Action	Example Herbicides	✔
Group A – fops	Topik, Wildcat, Verdict	☐
Group A – den	Axial	☐
Group A – dims	Sertin, Select, Achieve	☐
Group B – sulfonylureas	Ally, Glean, Logran, Hussar	☐
Group B – imidazolinones	Spinnaker, Midas, OnDuty	☐
Group B – triazolopyrimidines	Broadstrike, Eclipse	☐
Group C – triazines	Atrazine, Simazine	☐
Group D – dinitroanilines	Trifluralin (seed test only)	☐
Group F – nicotinanalides	Brodal, Jaguar, Tigrex	☐
Group I – phenoxys	2,4-D	☐
Group J – thiocarbamates	Avadex (seed test only)	☐
Group K – chloroacetamides	Dual Gold	☐
Group L – bipyridils	Paraquat, Diquat	☐
Group M – glycines	Glyphosate	☐
Cross Resistance		☐

These are 'user pays' testing services. Indicative prices; 1 MoA – $110; 2 MoA – $170; 3 MoA– $225; 4 MoA– $275; 5 MoA – $305. 4 MoA packages including cross resistance also available from $325.

Using Liberty Link® technology

Developed by Bayer CropScience in association with the Weeds Subcommittee of theTransgenic and Insect Management Strategies Committee of the Cotton Australia .

LIBERTY® 200 HERBICIDE MODE OF ACTION

In plants, the glutamine synthetase enzyme combines ammonium with glutamate to form glutamine which can then be used by plants in photosynthetic processes. The active ingredient of Liberty® 200 Hebricide, glufosinate-ammonium, inhibits the actions of the glutamine synthetase enzyme, stopping the plant from utilising ammonium. Soon after application of Liberty® 200 Herbicide, plant growth ceases and symptoms appear within a couple of days. Initially there is a general yellowing before damaged patches appear which enlarge as the plant wilts and collapses. Within 1– 3 weeks the plant dies from the combined effects of ammonia building up to toxic levels within the cells and the breakdown of photosynthesis.

Liberty® 200 Herbicide is a broad spectrum, post-emergent herbicide that is active against green plant tissue. It has no soil or residual activity. A range of broadleaf weed species are listed on the label. The label recommends weeds be targeted at 2–6 leaf growth stages. As there is only very limited systemic movement of the product through the plant, high water volumes of at least 100 L/ha should be used to ensure thorough coverage. Liberty® 200 Herbicide has shown activity on a number of other weeds including summer grasses, common thornapple, bathurst burr and common vetch. However further investigation is required before label claims could be made.

For resistance management purposes Liberty® 200 Herbicide is a Group N herbicide. This is the first Group N herbicide to be made available for use in cotton. When used in accordance with the label and the Crop Management Plan, weed populations are unlikely to develop resistance to Liberty® 200 Herbicide. The use of Liberty Link® technology in rotation with non-herbicide tolerant cotton and Roundup Ready® technology can help to reduce the selection pressure on weeds from currently used herbicides.

HOW DOES LIBERTY LINK® COTTON WORK?

Liberty Link® cotton contains the bar gene which allows it to expresses a protein that blocks the action of Liberty® 200 Herbicide. The protein, known as phosphinothricin acetyltransferase (PAT) attaches an acetyl group to the glufosinate ammonium molecules, rendering them ineffective. The expression of PAT allows Liberty Link® cotton to continue producing glutamine when glufosinate-ammonium is present. The *bar* gene is derived from the common soil bacterium, *Streptomyces hygroscopicus*.

HOW TOLERANT IS LIBERTY LINK® COTTON TO LIBERTY® 200 HERBICIDE?

Liberty Link® cotton is tolerant to repeated applications of Liberty® 200 Herbicide when used in accordance with label recommendations. A maximum of three over-the-top applications can be made each season. Applications can be made up until 10 weeks prior to harvest.

WEED MANAGEMENT WITH LIBERTY LINK®

Before growing Liberty Link® cotton, develop and document a weed control strategy for each field, including a rotation program for crop and herbicide useage. For fields with heavy weed burdens, or where there is not the capacity to treat all Liberty Link®cotton in a timely manner, Bayer CropScience recommends the use of residual herbicides prior to or at planting. Below are two example weed situations and suggested integration of Liberty Link® technology into the weed management strategies.

Weed situation	IWM strategy
Light infestation of broadleaf	– Glyphosate herbicide pre-plant – Liberty® 200 Herbicide applied over-the-top of the established Liberty Link® crop (1–3 applications) – Inter-row cultivation – Layby or selective herbicides if required
Heavy infestation of broadleaf weeds, especially peach vine, bladder ketmia and dwarf amaranth	– Residual herbicide incorporated pre or at planting – Liberty® 200 Herbicide applied over-the-top of the established Liberty Link® crop (1–3 applications) – Inter-row cultivation – Layby or selective herbicides if required

MANAGING LIBERTY LINK® VOLUNTEERS

Control of cotton volunteers is an important component of rotational flexibility and an essential component of farm hygiene. Cultivation and herbicides are the two most common methods of controlling volunteer cotton. Cultivation is an effective and efficient method of managing all types of volunteer cotton. Seedling, established and ratoon growth stages of conventional, Roundup Ready® and Liberty Link® varieties can be controlled with cultivation. Herbicides are only able to effectively control seedling volunteers. Liberty Link® seedling volunteers are susceptible to Roundup Ready® herbicide. Alternative herbicide options are Spray.Seed®, Hammer® and Pledge®.

Where Liberty Link® seedling volunteers are present in a Liberty Link® crop, the options for their control are the same as those for removing conventional cotton volunteers from conventional cotton. Refer to WEEDpak for strategies to control cotton volunteers.

AUDIT REQUIREMENTS IN THE LIBERTY LINK® CROP MANAGEMENT PLAN

Growers holding a Liberty Link® licence are required to conduct a weed audit in each field of Liberty Link® cotton that has been treated with Liberty® 200 Herbicide. The weed audit should take place prior to crop canopy closure and from 14–18 days after an application of Liberty® 200 Herbicide. The person conducting the audit is required to have undertaken the optional, additional module covering Weed Audits as part of successfully completing the Liberty Link® Cotton and Liberty® 200 Herbicide Accreditation Programme with Bayer CropScience.

To sample the field, use Audit Method A where the distribution of weeds within the field prior to applying Liberty® 200 Herbicide is known. Sample using Audit Method B where weed distribution prior to application is unknown. Methods A and B are presented below. Within the sample areas, identify surviving weeds and volunteers. For each survivor, rate the infestation severity. Complete a Liberty® Link Cotton Weed Management Audit form to capture the observations of the audit sampling, general comments on weed control and remidial action taken to control any surviving weeds prior to seed set. Return completed forms to Bayer CropScience by 31 December. Audit data will be collated and reported to the TIMS Weeds Subcommittee.

Sampling options when conducting weed audits in Liberty Link® cotton.

Audit Method A

Divide the field into quarters. Within each quarter, select 2 × 50 m linear row (≥ 20 m apart) that are representative of the weed burden prior to application. After application, assess these areas in at least three quarters of the field.

Audit Method B

Field Size	Sample size	Distance between each sampling site
<50 ha	4 x 100 m linear row	Minimum 100 rows
51–100 ha	6 x 100 m linear row	Minimum 100 rows
101–200 ha	8 x 100 m linear row	Minimum 100 rows
>200 ha	2 x 200 m linear row	Minimum 100 rows

APPLICATION GUIDELINES

The Liberty® 200 Herbicide is not significantly translocated as an active herbicide throughout the plant and therefore will only kill that part of the green plant that is contacted by the spray. Best results are achieved when applications are made to young weeds that are actively growing under warm, humid conditions. (e.g. temperatures below 33°C and relative humidity above 50%.)

Pre-plant paddock preparation

Control all existing weeds by cultivation or by using a knockdown herbicide such as glyphosate or paraquat.

Over-the-top applications

Liberty® 200 Herbicide can be applied over-the-top of Liberty Link® cotton from emergence through to 10 weeks prior to harvest. Application can only be made using a ground boom sprayer. Application volumes of at least 100 L water/ha through flat fan nozzles with droplet size of 200–300 microns are recommended for most situations. Up to 3 over-the-top applications can be made each season.

Tank mixes with Liberty® 200 Herbicide

Liberty® 200 Herbicide may be tank mixed with some other herbicides and insecticides. Check with your local Bayer CropScience representative for tank mixing compatabilities.

KEEPING GOOD FIELD RECORDS

It is essential that farmers keep records of the crops planted, the weeds present and the weed control methods each growing season. Such information is vital when planning crop and herbicide rotations to manage weeds, volunteers and herbicide resistance. Ensure good records are kept in relation to Liberty Link® cotton and can be made available to Bayer CropScience or the regulatory authorities as required. Keep records for at least 2 years after harvest.
As a minimum, maintain records of;

- Paddock History – crop rotation, weeds present, herbicide applications, the use of non-herbicide weed controls, other management practices influencing weed control.
- A farm map with field reference numbers and varieties sown.
- Seed bag labels and accompanying information, especially seed lot numbers.

FURTHER INFORMATION

Website: www.bayercropscience.com.au
Technical enquiries: 1800 804 479
Liberty® and Liberty Link® are Registered Trademarks of Bayer.

Roundup Ready Flex® technology

Craig McDonald, Monsanto Australia Limited, Bill Gordon, Bill Gordon Consulting, Graham Charles, Industry & Investment NSW

HOW DOES ROUNDUP READY FLEX® DIFFER FROM ROUNDUP READY® COTTON?

Roundup Ready Flex® cotton contains two copies of the CP4 EPSPS gene and a new promoter sequence resulting in expression in both the vegetative and reproductive parts of the plant. Roundup Ready Flex cotton is therefore able to tolerate applications of glyphosate in its vegetative (pre-squaring) and reproductive (squaring, flowering, boll development and maturation) stages. Roundup Ready herbicide may be applied over the top (OTT) of Roundup Ready Flex cotton up to four times between emergence and 22 nodes, while one application is allowed between 60% bolls open and harvest. However, the total amount of herbicide applied to any one crop must not exceed 6 kg/ha as illustrated in Figure 9. Crops that are intended for seed production must not have an application of Roundup Ready Herbicide past the 60% bolls open stage.

The full-plant glyphosate tolerance of Roundup Ready Flex means that applications of glyphosate can be made irrespective of the rate of crop growth or the number of days between applications.

HOW TOLERANT IS ROUNDUP READY FLEX® TO ROUNDUP READY® HERBICIDE?

Trials examining plant growth, development, yield and fibre quality were conducted in Australia by Monsanto as part of the phenotypic evaluation of Roundup Ready Flex cotton. These trials were conducted at eight locations over two seasons to assess whether Roundup Ready Herbicide applied to Roundup Ready Flex cotton at different growth stages altered the agronomic characteristics of the plant when grown under Australian conditions. Very high levels of crop safety were observed. There were no significant differences in first position fruit retention, yield, micronaire or fibre length between unsprayed Roundup Ready Flex, unsprayed conventional cotton and Roundup Ready Flex cotton treated with up to three times the registered quantity of herbicide. A new formulation of Roundup Ready Herbicide is now registered for use in Roundup Ready Flex and Roundup Ready cotton. The new formulation contains Plantshield®, a crop safener for improved performance in humid conditions. Roundup Ready Herbicide with Plantshield will be available during the 2009–10 cotton season. The new formulation contains the same quantity of active ingredient (690 g/kg), as the previous formulation and has been extensively tested over several seasons and at multiple locations to ensure maximum crop safety and efficacy.

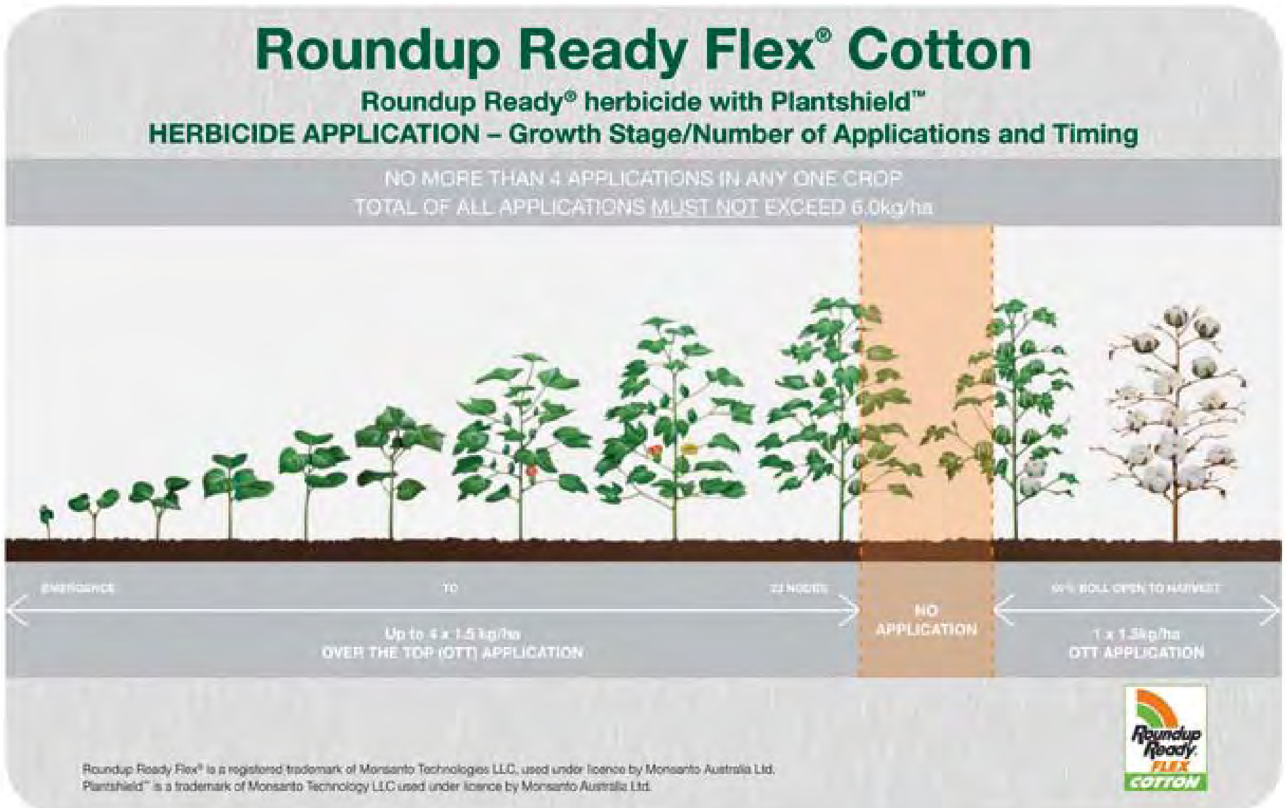


Figure 9. Application windows for over the top Roundup Ready Herbicide.

Weeds

WEED MANAGEMENT IN ROUNDUP READY FLEX® CROPS

Roundup Ready Flex cotton offers growers an increased margin of crop safety, a more flexible window for OTT applications of Roundup Ready Herbicide, and the potential to improve the efficacy of weed control. However Roundup Ready Flex cotton should be viewed as a component of an Integrated Weed Management (IWM) system, not as a solution to all weed management scenarios. Weeds species with natural tolerance to glyphosate will be selected for with repeated glyphosate applications, resulting in species shift. The most effective, economic and sustainable weed management system for growers will, therefore, be achieved using an integrated (IWM) approach.

Know your field history

A combination of the relative effectiveness of previous herbicide programs and other agronomic practices employed on a farm is likely influence the weed species present in any field. The correct identification and a basic understanding of the biology and ecology of the weeds present in a field are essential elements in the design of a successful weed management program. It is critical that the correct herbicide and herbicide rate is chosen for the target weed species. By knowing field history, growers can determine which weed control tools they should use and at what time they should be employed to achieve the best results.

Pre-plant knockdown

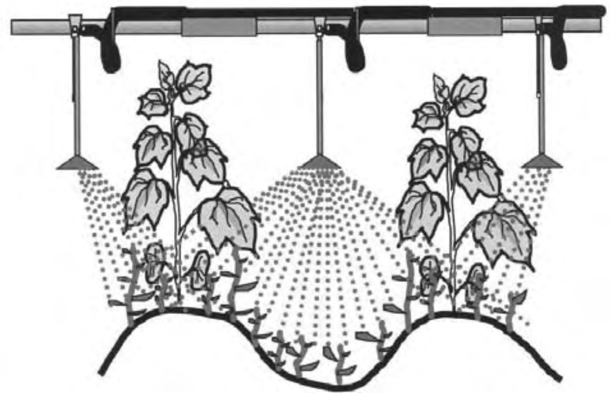
Starting the crop 'clean' gives seedling cotton good conditions to emerge and develop unhindered by the competitive effects of weeds. Pre-plant weed control can be achived using tillage and/or appropriate registered herbicides. Using glyphosate tank mixes or herbicides with other modes of action is encouraged at this stage to strengthen the IWM program. It is important to consider the control of cotton volunteers at this stage.

The role of residual herbicides

Residual herbicides should be used where appropriate in the Roundup Ready Flex weed control system. The nature of pre-emergence residual herbicides often requires that they be applied in anticipation of a weed problem. Consideration for the use of residual herbicides in a weed control program for any given field should be determined based on the knowledge of the fields history.

The first OTT (over-the-top) application

Cotton is a very poor competitor and is sensitive to early season weed competition. The longer OTT window with Roundup Ready Flex may tempt growers to delay the first OTT application of Roundup Ready Herbicide in the hope that multiple weed germinations can be controlled with a single spray. Whilst competitive affects will vary according to weed species and weed density, it is commonly recognised that good weed control in the first 6-8 weeks following crop emergence maximises cotton yield potential. Delaying the initial OTT application may result in growers having to target weeds later in the season that are beyond the growth stage for optimum control.



Directed application between 16 and 22 nodes targets weeds along the plant line.

Monsanto Australia Ltd. Roundup Ready Flex® cotton Technical Manual. Version 1 – August 2006.

There are no label recommendations for any tank mixtures with Roundup Ready® Herbicide OTT of Roundup Ready Flex® cotton.

Subsequent OTT applications

After the first OTT application, the use of subsequent OTT applications (maximum of four), should be made according to the presence of new weed germinations. In any field, a mix of weed species will commonly exist. Correct identification of weeds is very important as this will have a direct impact on the rate selection and application timing chosen. Select the timing and application rate of Roundup Ready Herbicide based upon the most difficult to control weed species in each field.

Inter-row cultivation

Inter-row cultivation is a relatively cheap and non-selective method of weed control. In irrigated cotton, it also assists in maintaining furrows to facilitate efficient irrigation. In a Roundup Ready Flex crop, inter-row cultivation contributes to the diversity of weed control methods being employed and, as such, is a valuable component of an IWM strategy.

Lay-by residual application

Growers and their advisors are encouraged to scout fields prior to row closure and to combine these observations with their historical knowledge of individual fields to ascertain the need for a lay-by herbicide application. A lay-by application should be used on fields where there is an expectation of a significant emergence of weeds later in the season.

Pre-harvest application

One application of Roundup Ready Herbicide may be made OTT between 60% boll open and harvest. In most circumstances, good weed control earlier in the crop should render the pre-harvest application redundant. However, if late season weeds are present, a pre-harvest application can be used to reduce seed set and improve harvest efficiency. Pre-harvest applications of glyphosate will not provide regrowth control in Roundup Ready Flex cotton.

AUDIT REQUIREMENTS IN THE ROUNDUP READY FLEX® CROP MANAGEMENT PLAN

A legal requirement of the approved release of Roundup Ready Flex cotton is that all persons growing and managing Roundup Ready Flex cotton crops comply with the Crop Management Plan (CMP). Within the CMP, there are the requirements for a Planting Audit and a Weed Management Audit.

Planting Audit

The Technology Service Provider (TSP) is responsible for completion of the planting audit by no later than December 15, as set down in the Technology User's Agreement (TUA). The information required includes;

- Number of hectares sown,
- Location of Roundup Ready Flex cotton on the farm unit, and
- Date/s of sowing.

Weed Management Audit

Only accredited TSPs will be able to conduct the Weed Management Audit.
The Weed Management Audit must be completed by the TSP and provided to Monsanto prior to January 15.(Except the Burdekin region)
Details required for Roundup Ready Flex cotton include:

- Assessment of all weeds remaining 10 to 14 days after an 'over the top' (OTT) application of Roundup Ready Herbicide at a minimum of 6 nodes of crop growth, and not exceeding 16 nodes. The table below outlines how to assess the field for the presence of surviving weeds;

Field Size	Assessment of Surviving Weeds
< 50 ha	4 x 100 metres linear row
51–100 ha	6 x 100 metres linear row
101–151 ha	8 x 100 metres linear row
> 150 ha	8 x 200 metres linear row

The minimum distance between each assessment (i.e. each 100 metres linear row) must be 100 rows. In addition to the assessment of surviving weeds, the TSP is required to record;

- any remedial action taken to stop seed set of surviving weeds. Weeds identified to have survived Roundup Ready Herbicide applications must be controlled by an alternative management strategy in order to prevent those weeds from setting seed.
- Comments about the level of weed control achieved in Roundup Ready Flex cotton, including the efficacy of remedial actions undertaken.
- Adverse event reporting. Growers and TSPs are required to report any adverse event, such as suspected weed resistance, to Monsanto as soon as it is identified.

Monsanto will discuss the data collected with relevant industry weed scientists and any findings will be reported to the TIMS Herbicide Tolerant Crop Technical Panel.

MANAGING ROUNDUP READY FLEX VOLUNTEERS

A major consideration in the development of an IWM plan for Roundup Ready Flex is the management of herbicide tolerant cotton volunteers. Plans need to be made to use cultural control options and herbicides with alternate modes of action in fallows and subsequent crops to control volunteers.

Cultural controls

Minimising the presence of lint/seed from last year's crop on this year's plant line will assist in managing cotton volunteers. Operations such as moisture seeking, bed renovation and fertiliser application all assist in redistributing cotton lint away from the plant line and into the furrow where inter-row cultivation and/or shielded spraying can be used for control.

Pre-watering stimulates volunteer germination and emergence prior to crop establishment, providing the opportunity to target volunteers with broad spectrum herbicides.

Herbicide options

Currently there are four registered herbicide options for the control of volunteer cotton;

1. Paraquat/Diquat (Spray.Seed®, Revolver®)
2. Bromoxynil (Bromicide® 200)
3. Carfentrazone ethyl (Hammer® 240 EC)
4. Paraquat/Amitrole- (Alliance®)

These options are all effective in controlling volunteer cotton, however the following points should be considered;

- The effectiveness of these herbicides on conventional, Roundup Ready and Roundup Ready Flex cottons is generally limited to volunteers no more than 4–6 leaf. The size of the volunteers needs to be assessed before a herbicide selection is made.
- Larger plants will be more difficult to control with a single pass.
- Using the recommended water volumes for application is imperative for effective control.
- Other weeds within the field should be taken into consideration when making a herbicide selection.
- Bromoxynil and Carfentrazone ethyl can be mixed with glyphosate, which may assist when a range of other weeds is also present.
- It is important to read all labels to confirm the correct application timings and rates. Label directions must be followed.

Ratoon Cotton

Ratoon or 'stub' cotton is cotton that has 're-grown' from root stock still in the ground from the previous season. Ratoon cotton is more common in minimum tillage systems. These plants are inherently difficult to control with herbicide due to their large root mass and often relatively small leaf area. Ratoon conventional, Roundup Ready and Roundup Ready Flex cotton plants will not be controlled by Roundup Ready Herbicide or glyphosate products. The most effective means of controlling ratoon cotton is achieved through effective root cutting of cotton stalks, followed by 'centre-busting'. Care needs to be taken that during 'centre-busting' to ensure the tool does not run off the bed centre and miss stalks that may regrow in the following spring.

OTHER SOURCES OF INFORMATION

Roundup Ready Flex® Cotton Technical Manual, Version 1 – August 2006, Monsanto Australia Ltd.

CSD website: www.csd.net.au

APPLICATION GUIDELINES

Timing options

The Roundup Ready Herbicide label permits;

- Applications in fallow, prior to sowing the Roundup Ready Flex crop, with the maximum rate applied dependent on the targeted weed/s. Application may be made by ground rig sprayer or by aircraft.
- Up to four applications of Roundup Ready Herbicide between crop emergence and 22 nodes of crop growth, with a maximum of 1.5 kg/ha being applied in any single spray event.
- An option for a pre-harvest application, alone or in tank mix with Dropp®, once the crop is 60% open and immature bolls cannot be cut with a sharp knife. The maximum herbicide rate for pre-harvest use is 1.5 kg/ha. Application may be made by ground rig sprayer or by aircraft.
- Not more than four applications and 6.0 kg of Roundup Ready Herbicide may be applied through all growth stages of Roundup Ready Flex cotton in any one growing season.

Over-the-top applications

Before an over-the-top application, it is absolutely essential to thoroughly decontaminate the sprayer of any products which might damage the crop, particularly sulfonylurea and phenoxy herbicides. **For ground rig sprayers**, the use of flat, tapered fan nozzles or low drift nozzles is recommended. Operate the sprayer at pressures up to 250 kPa with a spray output of up to 80 L/ha. Avoid spraying a fine mist. Aim for a minimum VMD 300 microns plus. Select nozzle types that produce a minimum Coarse spray quality (ASAE S572)For **aerial application**, use CP nozzles with the appropriate reduced swath width for the aircraft type and apply in appropriate conditions to produce a VMD of 300 microns or greater. Use a minimum spray volume of 40 L/ha. Do not apply Roundup Ready herbicide by aircraft at temperatures above 30°C or if relative humidity falls below 35%.

Air Induction Nozzles

If using air induction nozzles to produce a coarse spray quality or larger, the nozzle must operated in such a way as to include adequate air inclusion with in the droplets which will assist with retention of the herbicide mix on the target.

Low Pressure Air Induction Nozzles

To ensure adequate air inclusion typically requires operating low pressure air induction nozzles at approximately 3–4 bar (provided they can achieve a coarse spray quality or larger at that pressure), and if operating these nozzles with an automatic rate controller, not allowing the pressure to drop below 2 bar (hence, careful selection of nozzle size is required to ensure overdosing does not occur when speed is reduced, if a minimum pressure setting/ hold is used).

High pressure air induction nozzles

These should typically be operated at approximately 5-6 bar (provided they can achieve coarse droplets at that pressure), and if operating an automatic rate controller, not allowing the pressure to drop below 3-4 bar (hence, careful selection of nozzle size is also required to ensure overdosing does not occur when speed is reduced).

Preventing off-target drift

Drift can be influenced by incorrect droplet sizing, spray tip height, operating speed, wind velocity, air temperature and humidity. Drift can be successfully prevented by adhering to the above recommendations and waiting for appropriate weather conditions. Be prepared to stop spraying if conditions change and become unsuitable. Refer to SPRAYpak for detailed information on choosing the appropriate spray equipment and determining low risk weather conditions. Communication between growers, neighbours, consultants, farm workers and applicators is also essential for preventing spray drift damage to sensitive crops and vegetation.

Consider using an on-site weather station to continually monitor conditions during spraying and cease spraying if conditions become unsuitable. Always keep accurate records of the prevailing conditions during spraying.

Plants without the Roundup Ready technology will be destroyed or seriously damaged if Roundup Ready Herbicide comes in contact with them.

Other Sources of Information

Roundup Ready® Cotton Technical Manual, Monsanto Australia Ltd.

WEEDpak a guide for integrated weed management in cotton, Australian Cotton CRC.

SPRAYpak cotton grower's spray application handbook 2nd Edition, Cotton Research and Development Corporation.

Suspension of 2,4-D High Volatile Ester (HVE) products

Based on the APVMA's 'Notice of continued suspension of products containing 2,4-D ethyl, butyl and isobutyl esters and all associated label approvals.'

The APVMA has taken the decision to continue the suspension of registration and label approvals of products containing high volatile ester (HVE) forms of 2,4-D, namely the ethyl, butyl and isobutyl esters. These suspensions are in effect until 30 April 2010. This suspension does not affect the availability of 2,4-D low volatile ester or 2,4-D amine formulations.

DURING THE PERIOD OF SUSPENSION

During the period of suspension new instructions for use apply to all products containing 2,4-D HVEs. Where the new instructions are inconsistent with the label instructions on the container, the new instructions in the Notice must be followed.
A summary of the new directions for use are below.

Directions for use: for products containing 2,4-D ethyl, butyl or isobutyl ester.

RESTRAINTS:

This is a PHENOXY HERBICIDE that can cause severe damage to native vegetation and susceptible crops such as cotton, grapes, tomatoes, oilseed crops and ornamentals.

DO NOT apply this product between 1 September and 30 April. Use only within the SPRAY WINDOW between **1 May and 31 August.**

DO NOT apply this product by air.

DO NOT apply this product

- in aquatic situations
- to sugar cane
- to rights of way
- as a harvest aid / salvage spray

DO NOT apply more than 800 g 2,4-D active equivlents per hectare (1L/ha).

DO NOT apply if crop or weeds are stressed due to dry or excessively moist conditions.

DO NOT use unless wind speed is more than 3 km /hour and less than 15 km /hour as measured at the application site.

DO NOT apply with smaller than **Coarse to Very Coarse spray quality** according to the ASAE S572 definition for standard nozzles.

DO NOT use if rain is likely within 6 hours.

Within 24 hours of completing a 2,4-D HVE application all users must make and **keep a record of each application.** The details required include;

- Information about the farm owner and applicator, notification of neighbours and area treated.
- Crop situation and pest details.
- Weather conditions at the application site, such as temperature, humidity, wind speed and direction at the beginning and end of the application.
- Application details including details of the equipment used, ground speed, product rate and application volumes and the use of spray additives.
- A statement saying the information on this record is accurate and correct, followed by the signature of the user.

For convienience, a 2,4-D record-keeping form can be obtained from the APVMA website – www.apvma.gov.au/chemrev/downloads/2_4_d_sprayrecord.pdf

BUFFER ZONES:

There must be a buffer zone of 100m between field edges and downwind water bodies, native vegetation and sensitive crops.

PERMISSIBLE DATES OF APPLICATION OF 2, 4-D VOLATILE ESTERS:

Application of 2, 4-D ethyl ester, butyl ester or isobutyl ester must only take place during a spray window between **1 May and 31 August.**

Victoria, Western Australia, Tasmania and Queensland currently have mechanisms whereby the use of specific chemicals (including 2,4-D_ is restricted to geographical areas and/or time zones due to the higher risk for adverse off-target crop or environmental effects. These state restriction on 2, 4-D use may place additional requirements on users within this spray equipment. Users must consult their local authority or department of agriculture to ensure they meet state requirements.

WHY HAVE 2,4-D HVEs BEEN SUSPENDED?

The high volatile ester forms of 2,4-D have been suspended because they are likely to have unintended harmful effects on non-target vegetation (crops and native vegetation) and/or aquatic organisms. During the suspension the APVMA required active consituent approval holders to provide new data on the physio-chemical properties of high volatile (short chain) esters. The APVMA has assessed the data provided and has decided to extend the suspension period. Registrants are now required to generate and provide additional environmental fate and environmental effects data for assessment.

IS VOLATILISATION THE SAME AS DRIFT?

No. The concepts are often confused. Spray drift refers to the physical movement of spray droplets (and their dried remnants) through the air from the nozzle to any off-target site *at the time of application.* Volatilisation is a process whereby chemical is applied to a target site but evaporates *at the time of application* or enters the air stream as a vapour. Once in the airstream, the vapour can be blown in the wind and settle on crops and vegetation many kilometres away.

ARE THERE ALTERNATIVES TO 2,4-D HVEs?

The APVMA recognises that the availability of alternatives is important to users. There are many other herbicides registered for the same uses as the HVEs including several other forms of 2,4-D. The APVMA has been advised that the HVEs are generally cheaper than the alternatives, however the cost benefit of chemicals is not a criterion on which the APVMA can make a decision.

Cotton Weed Control Guide – Registered chemicals as at 15 October 2009

Tracey Farrell, formerly Industry & Investment NSW

Registration of a herbicide is not a recommendation from I&I NSW for the use of a specific herbicide in a particular situation. Growers must satisfy themselves that the herbicide they choose is the best one for the crop and weed. Growers and users must also carefully study the container label before using any herbicide, so that specific instructions relating to the rate, timing, application and safety are noted. This publication is presented as a guide to assist growers in planning their herbicicide programs.

IMPORTANT— AVOID SPRAY DRIFT

Take every precaution to minimise the risk of causing or suffering spray drift damage by:

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions near property boundaries. Make it clear that you expect the same courtesy from them.
- Carefully following all label directions.
- Paying particular attention to wind speed and direction, air temperature and time of day before applying pesticides using buffer zones as a mechanism to reduce the impact of spray drift or overspray.
- Keeping records of chemical use and weather conditions at the time of spraying.

SPRAY LOG BOOKS

To assist in record keeping for pesticide applications, Spray Log Books can be purchased from:

DEEDI, cost $6.60 plus postage and handling. Contact DEEDI inToowoomba – 07 4688 1415 or in Dalby – 07 4669 0800 to place an order.

I&I NSW, cost $12.00 plus postage and handling. Contact I&I NSW, Yanco – 1800 138 351.

ABBREVIATIONS USED IN THE TABLES 24–30

AC	= Aqueous concentrate	L	= Liquid	SP	= Soluble powder
DF	= Dry flowable granule	SC	= Suspension concentrate	WDG	= Water dispersible granule
EC	= Emulsifiable concentrate	SolC	= Soluble concentrate	WP	= Wettable powder

Table 24a. Control of weeds in dry channels

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
Amitrole + ammonium thiocyanate	F	250 g/L + 220 g/L SC	0.28–4.5 L/100 L water	Controls a wide range of plants from seedling grasses, at low water rates, to perennial grasses, at high rates. Controls some young broadleaf weeds.
Diuron	C	500 g/L SC 500 g/L SC 900 g/kg DF, WDG	72–144 L/ha 20–40 L/ha 22 kg/ha (Qld) 40 kg/ha (NSW)	QLD registration. NSW registration. Channels must be flushed after application.
Glyphosate	M	360 g/L AC, L, SC 450 g/L AC 510 g/L AC 540 g/L AC 680 g/kg WDG	0.5–9.0 L/ha 1.6–7.2 L/ha 0.34–1.9 L/ha 1.32–5.855 L/ha 1.0–4.5 kg/ha	Controls most weeds. Low rates for annual grasses. High rates for perennials and broadleaf weeds. Mix only as directed on the label. Check label for details.
Imazapyr + glyphosate	B + M	150 g/L + 150 g/L SC	5.0 L/ha	For best results apply in early autumn with minimal weed growth. Allow six weeks before channel is re-used.
Pendimethalin	D	330 g/L EC 440 g/L AC	4.5–9.0 L/ha 3.4–6.75 L/ha	If 25–50 mm rain has not fallen within 14 days flush channel (1 day) and drain off.

Table 24b. Control of weeds around aquatic areas

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
Glyphosate	M	360 g/L AC 500 g/L AC, EC 540 g/L AC	3.0–9.0 L/ha 1.44–8.48 L/ha 1.3–6.0 L/ha	Rate varies with species present. Choose a glyphosate product that has a specific aquatic weed control registration. See label for details for application around aquatic areas.

Table 25. Weed control before planting

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
2,4-D as the iso-propylamine salt	I	225 g/L AC 300 g/L AC	0.8–3.6 L/ha 0.66–2.7 L/ha	For use with glyphosate at recommended rates. Check label for details.
Amitrole + paraquat	Q + L	250 g/L + 125 g/L	2–4 L/ha	Sowing can occur immediately after application.
Bromoxynil	C	200 g/L EC	1.4–2.1 L/ha	Controls peachvine, climbing buckwheat and cotton volunteers. Spray volumes above 50 L/ha are recommended. Complete coverage is essential.
Carfentrazone-ethyl	G	240 g/L EC	0.025–0.1 L/ha	Apply as a tankmix with glyphosate or products containing paraquat.
Dicamba	I	500 g/L AC 700 g/kg WDG	0.16–0.56 L/ha 0.115–0.4 kg/ha	Up to 14 days plant back period.
Fluometuron	C	900 g/kg DF, WDG	1.5–3.1 kg/ha	Controls many broadleaf weeds. Apply just prior to incorporation. High rate for heavier soils. Will require further band application on top of hill immediately after planting. See label.
Fluometuron + prometryn	C	250 g/L + 250 g/L AC, SC 440 g/kg + 440 g/kg DF, WDG	2.5–5.0 L/ha 1.4–2.9 kg/ha	Controls many annual grasses and broadleaf weeds. Incorporate to 5 cm. Will require further band application on top of hill immediately after planting.
Flumioxazin	G	500 g/kg WDG	30 g/ha + tank mix parner 45 g/ha	Addition to knockdown products will increase the speed of activity and may improve final control. For control of volunteer cotton. Always apply with a recommended adjuvant.
Fluroxypyr	I	200 g/L EC	0.75–1.5 L/ha	Controls certain broadleaf weeds post-emergent. See label for details of mixtures with glyphosate and plant back restrictions.
Glyphosate	M	360 g/L AC, EC, L, SC 450 g/L AC 470 g/L AC 480 g/L AC 500 g/L AC, EC 510 g/L AC 540 g/L AC 570 g/L AC 680 g/kg WDG	2.0–3.0 L/ha 0.4–2.4 L/ha 0.38–1.5 L/ha 0.37–2.25 L/ha 0.33–2.16 L/ha 0.34–1.4 L/ha 0.32–2.0 L/ha 0.322–1.27 L/ha 0.265–1.6 kg/ha	Controls most annual grasses and broadleaf weeds. Refer to label for rates on specified weeds and recommendations.
		690 g/kg WDG	0.265–1.5 kg/ha	In Roundup Ready® cotton and Roundup Ready Flex® cotton only.
Metolachlor	K	720 g/L EC	2.0 L/ha	Controls certain annual grasses and Wandering Jew. Rain or irrigation needed within 10 days of application or incorporate mechanically.
Norflurazon	F	800 g/kg DF	2.3–4.2 kg/ha	Controls many annual grasses and broadleaf weeds including nutgrass. Refer to label for plant back period.
Oxyfluorfen	G	240 g/L EC	0.075 L/ha	Use with glyphosate at recommended rates.
Paraquat	L	250 g/L SC	1.6–2.4 L/ha	Controls many annual grass and broadleaf seedlings.
Paraquat + diquat	L	135 g/L + 115 g/L SC	1.2–2.4 L/ha	Controls most annual grasses and broadleaf weeds.
Pendimethalin	D	330 g/L EC 440 g/L 455 g/L AC	3.0 L/ha 2.25 L/ha 2.2 L/ha	Controls annual grasses and some broadleaf weed seedlings. Incorporate within 24 hours. Check label for details.
Prometryn	C	500 g/L AC, SC 900 g/kg DF, WDG	2.2–4.5 L/ha 1.2–2.5 kg/ha	Apply as pre-emergent treatment onto bare, moist soil or as an early post-emergent treatment to weeds after cultivation. Use low rate for short-term weed control.
s-Metolachlor	K	960 g/L EC	1.0 L/ha	Rain/irrigation needed within 10 days of application or incorporate mechanically. Controls most annual grasses.
Triclopyr	I	600 g/L EC	0.08–0.16 L/ha	Melon weed control. 14 days plant back for cotton.
Trifluralin	D	480 g/L EC 500 g/L EC	1.2–2.3 L/ha 1.1–2.25 L/ha	Rate is soil type dependent. Incorporate within 4 hours. Controls seedling and annual grasses and some broadleaf weeds. See label for additional options for winter fallow control.

Table 26. Weed control at planting

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
Chlorthal dimethyl	D	900 g/kg WDG	5.0–12.5 kg/ha	Apply at time of planting. Use higher rate for areas under irrigation.
Diuron	C	900 g/kg DF, WDG	1.0–2.0 kg/ha	Controls many broadleaf weeds and annual grasses. Plant injury can occur if heavy rain follows application. Do not apply more than once per season.
Fluometuron	C	500 g/L AC, SC 900 g/kg DF, WDG	1.8–3.6 L/ha 0.945–2.0 kg/ha	Controls many broadleaf weeds and annual grasses. Apply just prior to incorporation. Use in conjunction with pre-plant application. Apply as a band (minimum band width 40 cm) or blanket application. Use higher rate on heavier soils. Check label for details.
Fluometuron + prometryn	C	250 g/L + 250 g/L AC, SC 440 g/kg + 440 g/kg DF, WDG	3.0–5.0 L/ha 1.7–2.9 kg/ha	Controls many broadleaf weeds and annual grasses. Apply just prior to incorporation. Use in conjunction with pre-plant applicaton. Apply as a band (minimum band width 40 cm) or blanket application. High rate on heavier soils. Check label for details.
Metolachlor	K	720 g/L EC	2.0 L/ha	Controls certain annual grasses and Wandering Jew. Rain or irrigation needed within 10 days of application or incorporate mechanically.
Paraquat + diquat	L	135 g/L + 115 g/L SC	0.8–2.4 L/ha	Controls most annual grasses and broadleaf weeds.
s-Metolachor	K	960 g/L EC	1.0 L/ha	Controls most annual grasses. Rain or irrigation needed within 10 days of application or incorporate mechanically.

Table 27. Weed control after planting and before crop emergence

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
Diuron	C	500 g/L SC 900 g/kg DF, WDG	1.8–3.5 L/ha 1.0–2.0 kg/ha	Controls many broadleaf weeds and annual grasses. Plant injury can occur if heavy rain follows application. Avoid light soils. Do not apply more than once per season. Spray immediately after planting.
Fluometuron	C	500 g/L AC, SC 900 g/kg DF, WDG	4.5–7.2 L/ha 2.4–4.0 kg/ha	Controls many broadleaf weeds and annual grasses. Minimum band width 40 cm. Apply to moist soil or significant rain or irrigation required within 3–5 days of application. Severe plant injury may result if heavy rain occurs between sowing and emergence. High rates apply to heavier soils.
Fluometuron + prometryn	C	250 g/L + 250 g/L AC, SC 440 g/kg + 440 g/kg DF, WDG	3.0–5.0 L/ha 1.7–2.9 kg/ha	Controls many broadleaf weeds and annual grasses. Apply to moist soil, significant rain or irrigation required within 3–5 days of application. Severe plant injury may result if heavy rain occurs between sowing and emergence. Do not use on light sandy soils or soils with low organic content. Check label for details.
Metolachlor	K	720 g/L EC	2.0 L/ha	Controls certain annual grasses and Wandering Jew. Rain or irrigation needed within 10 days of application or incorporate mechanically.
Paraquat	L	250 g/L SC	1.2–2.4 L/ha	Controls most annual grasses and broadleaf weed seedlings.
Paraquat + diquat	L	135 g/L + 115 g/L SC	0.8–2.4 L/ha	Controls most annual grasses and broadleaf weeds.
Pendimethalin	D	330 g/L EC 440 g/L EC 455 g/L AC	4.5 L/ha 3.4 L/ha 3.3 L/ha	Controls annual grasses and certain broadleaf weeds. Use when incorporation prior to sowing is impractical and where the seedbed tilth is fine and free of large stones and trash. Apply within 48 hours after sowing.
Prometryn	C	500 g/L AC, SC 900 g/kg DF, WDG	3.3–4.5 L/ha 1.8–2.5 kg/ha	Controls many broadleaf weeds and thins annual grasses. Apply onto bare moist soil or irrigate within three days after application.
s-Metolachlor	K	960 g/L EC	1.0 L/ha	Controls most annual grasses. Rain or irrigation needed within 10 days of application or incorporate mechanically.

Table 28. Weed control after crop emergence (includes layby)

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
Butroxydim	A	250 g/kg WDG	0.12 kg/ha or 0.18 kg/ha	Low rate for grass seedlings pre-tillering and high rate for 2–3 tillers. Always add the recommended spray adjuvant.
Chlorthal dimethyl	D	900 g/kg WDG	(6.0–11.0 kg/ha)	Layby only. Do not apply after bolls open.
Clethodim	A	240 g/L EC	0.25–0.375 L/ha	Apply at 2–5 leaf stage. Read label for details.
Diuron	C	500 g/L SC 900 g/kg DF, WDG	1.8–3.5 L/ha 1.0–2.0 kg/ha	Controls many broadleaf weeds and annual grasses. Cotton should be at least 30 cm high. Use as a directed spray. Avoid spray drift. Do not apply more than once per season.
Fluazifop-p	A	212 g/L EC	0.75–1.0 L/ha	High rate for actively growing weeds, 5 leaf – early tillering.
Fluometuron	C	500 g/L AC, SC 900 g/kg DF, WDG	1.3–2.8 L/ha (2.8–5.6 L/ha) 0.72–1.5 kg/ha (1.5–3.0 kg/ha)	Controls many broadleaf weeds and annual grasses. Rates in brackets for lay-by spraying. Crop should be more than 15 cm high. Weeds should be less than 5 cm high for early directed spraying and less than 8 cm high for lay-by treatments. Use with recommended surfactant.
Fluometuron + prometryn	C	250 g/L + 250 g/L AC, SC 440 g/kg + 440 g/kg DF, WDG	1.5–2.5 L/ha (2.0–3.5 L/ha) 0.855–1.4 kg/ha (1.1–1.9 kg/ha)	QLD registration only for low rate, early spray. Rates in brackets for lay-by spraying. Controls many broadleaf weeds and annual grasses. Crop should be 30–50 cm high, weeds not more than 8 cm. Use as a directed spray with recommended surfactant.
Flumioxazin	G	500 g/kg WDG	60 or 90 g/ha	Apply as a shielded spray. Do not contact cotton foliage.
Glufosinate-ammonium	N	200 g/L SC	3.75 L/ha in 100 L water	Only apply to Liberty Link® cotton varieties. Maximum 2.25 kg a.i./ha/season (3 applications). As a contact herbicide coverage is critical to effectiveness.
Glyphosate	M	360 g/L AC, EC, L, SC 450 g/L AC, L 490 g/L AC 480 g/L AC 500 g/L AC, EC 510 g/L AC 540 g/L AC 570 g/L AC 680 g/kg WDG	2.0–3.0 L/ha 0.4–2.4 L/ha 0.35–2.0 L/ha 0.375-2.25 L/ha 0.33–2.16 L/ha 0.34–1.4 L/ha 0.32–2.0 L/ha 0.322–1.27 L/ha 0.265–1.6 kg/ha	Apply with shielded sprayer. Do not apply in cotton less than 20 cm high.
		690 g/kg WDG	0.52–1.5 kg/ha	Only apply over-the-top to Roundup Ready® cotton varieties up to 4 leaf stage and to Roundup Ready Flex® cotton varieties up to 16 node stage of growth.
Halosulfuron–methyl	B	750 g/kg DF 750 g/kg WDG	65–130 g/ha	Shielded srayer application in irrigated cotton only. Apply in crops at least 20 cm high but before first flower. Contact with cotton may cause severe injury. See label for details.
Haloxyfop-r	A	130 g/L EC 520 g/L EC	0.4–0.6 L/ha 0.1–0.15 L/ha	Actively growing seedling grasses from 2 leaf to tillering up to 15 cm. Always use the recommended spray oil.
MSMA	Z	720 g/L L, SC 800 g/L L, SC	3.1 L/ha 2.8 L/ha	Controls Nutgrass, Xanthium burrs and Johnson grass. Apply as a band or as a directed spray after cotton is 7 cm high but before first flower opens.
Paraquat	L	250 g/L AC, SC	1.2–2.4 L/ha	Inter-row weed control, shielded spray. Use low rates for seedling weeds. Use high rates for mature stages.
Prometryn	C	500 g/L AC, SC 900 g/kg DF, WDG	1.1–2.2 L/ha (2.2–4.4 L/ha) 0.61–1.2 kg/ha (1.2–2.5 kg/ha)	Controls many broadleaf weeds and thins annual grasses. Rates in brackets are for lay-by spraying. Weeds should be less than 8 cm high. Use as a directed spray with recommended surfactant.
Propaquizafop	A	100 g/L EC	0.2–0.9 L/ha	Apply when weeds are actively growing. Always apply with an adjuvant. Refer to label for further details.
Pyrithiobac sodium	B	850 g/kg SP	0.03–0.12 kg/ha 0.06–0.09 kg/ha	Ground application only. Aerial application for a salvage treatment for sesbania pea. NSW (Macintyre Valley) and QLD registration only.
Sethoxydim	A	186 g/L EC	1.0 L/ha	Apply when most grass weeds are in the 2–6 leaf stage and are actively growing. Refer to label for details.
Trifloxysulfuron sodium	B	750 g/kg WDG	0.015 kg/ha or 0.03 kg/ha	Controls certain broadleaf weeds and suppresses Nutgrass. Use the low rate for over-the-top application from 2–8 leaf stage or as a directed spray until row closure. Apply the high rate as a directed application only.

Table 29. Weed control pre harvest

Active ingredient	Mode of Action Group	Concentration and formulation	Application rate of product	Comments
Chlorthal dimethyl	D	900 g/kg WDG	6.0–11.0 kg/ha	Controls some annual grasses and a wide range of broadleaf weeds. The higher range is recommended for heavier soil types. Refer to label.
Glyphosate	M	360 g/L AC, EC, SC, L 450 g/L AC, L 480 g/L AC 500 g/L AC, EC 540 g/L AC 570 g/L AC 680 g/kg WDG	1.25–2.5 L/ha 1.0–2.0 L/ha 0.375–2.25 L/ha 0.33–2.16 L/ha 0.32–2.0 L./ha 0.725–1.6 L/ha 0.66–1.30 kg/ha	Controls Bathurst burr, Noogoora burr, winter annual weeds. Use higher rates for Nutgrass control. May be applied alone or with harvest aid. Apply when 60% bolls are open.
		690 g/kg WDG	0.71–1.42 kg/ha	Registered for use in Roundup Ready® cotton and Roundup Ready Flex® cotton. Apply when 60% bolls are open. For nutgrass supression use high rate only.
		510 g/L AC	0.34–1.4 L/ha	Not registered for the control of Nutgrass.

Table 30. Herbicide trade names and marketers – Registered chemicals as at 15 Oct 2009

Active ingredient	Mode of Action Group	Concentration and formulation	Trade name	Marketed by
2,4-D present as the isopropylamine salt	I	225 g/L AC	Aminoz	Sanonda
		225 g/L AC	Smash	ChemAg
		300 g/L AC	2,4-D 300	Ospray
		300 g/L AC	2,4-D Amine 300	United Farmers Co-op
		300 g/L AC	2,4-D IPA 300	Halley
		300 g/L AC	2,4-D IPA 300	Rygel
		300 g/L AC	2,4-D IPA 300	Tradelands
		300 g/L AC	Amine 300	Conquest
		300 g/L AC	Amine 300	Sipcam
		300 g/L AC	Amine 300	Titan
		300 g/L AC	Amine 300	Genfarm
		300 g/L AC	Abound	Dow Agrosciences
		300 g/L AC	Cobber	Crop Care
		300 g/L AC	Crown 2,4-D IPA	Pacific Agrisciences
		300 g/L AC	Glymate 300	Generex
		300 g/L AC	Inca 300	Proterra
		300 g/L AC	Ken-Star 300	Kenso
		300 g/L AC	Mate 300	Growchoice
		300 g/L AC	Pura Amine 300	Hextar
		300 g/L AC	Rodamine 300	Rotam
		300 g/L AC	Smash 300	Imtrade
		300 g/L AC	Surpass 300	Nufarm
		300 g/L AC	Weeds Out 300	Biotis
		300 g/L AC	Zulu 300	Farmoz
Amitrole + ammonium thiocyanate	Q	250 g/L + 220 g/L SC	Amitrole T	ChemAg
		250 g/L + 220 g/L SC	Amitrole T	Nufarm
		250 g/L + 220 g/L SC	Weedeath	Cyndan
Amitrole + paraquat	Q + L	250 g/L + 125 g/L	Alliance	Crop Care
Bromoxynil	C	200 g/L EC	Bromo 200	Agriwest
		200 g/L EC	Bromicide 200	Nufarm
		200 g/L EC	Bromox 200	ChemAg
		200 g/L EC	Bromoxynil 200	4Farmers
		200 g/L EC	Bromoxynil 200	Accensi
		200 g/L EC	Bromoxynil 200	Genfarm
		200 g/L EC	Bromoxynil 200	Titan
		200 g/L EC	Firefighter	Ozspray
Butroxydim	A	250 g/kg WDG	Factor WG	Crop Care

Table 30. Herbicide trade names and marketers (continued)

Active ingredient	Mode of Action Group	Concentration and formulation	Trade name	Marketed by
Carfentrazone-ethyl	G	240 g/L EC	Hammer	Crop Care
		240 g/L EC	Task	Nufarm
Chlorthal dimethyl	D	900 g/kg WDG	Dacthal 900 WG	Crop Care
Clethodim	A	240 g/L EC	Blade 240	United Farmers
		240 g/L EC	Cleodim	Grow Choice
		240 g/L EC	Cletho 240	Sanplus
		240 g/L EC	Cletho 240 EC	Kenso Agcare
		240 g/L EC	Clethodim	Chemforce
		240 g/L EC	Clethodim	Generex
		240 g/L EC	Clethodim	Rygel
		240 g/L EC	Clethodim	Whitestar Ag Product Services
		240 g/L EC	Clethodim 240	Genfarm
		240 g/L EC	Clethodim 240 EC	4Farmers
		240 g/L EC	Clethodim 240 EC	Agri West
		240 g/L EC	Clethodim 240 EC	Agroshine
		240 g/L EC	Clethodim 240 EC	Nisso BASF
		240 g/L EC	Clethodim 240 EC	Crop Smart
		240 g/L EC	Clethodim 240 EC	Innova
		240 g/L EC	Clethodim 240 EC	Ospray
		240 g/L EC	Clethodim 240 EC	Titan
		240 g/L EC	Grasidim	Sipcam
		240 g/L EC	Innova	Syngenta
		240 g/L EC	Nissodim	Nisso BASF
		240 g/L EC	Nitro 240	Conquest
		240 g/L EC	Platinum	Farmoz
		240 g/L EC	Select	Sumitomo Chemicals
		240 g/L EC	Sequence	Nufarm
		240 g/L EC	Status	Sumitomo
		240 g/L EC	Uproot	UPL
Dicamba	I	500 g/L AC	Cutlass 500	Farmoz
		500 g/L AC	Conquesta 500 AC	Conquest
		500 g/L AC	Dicamba 500	Accensi
		500 g/L AC	Dicamba 500	ChemAg
		500 g/L AC	Dicamba 500	Choice
		500 g/L AC	Dicamba 500	Genfarm
		500 g/L AC	Dicamba 500	Kenso Agcare
		500 g/L AC	Dicamba 500	Ospray
		500 g/L AC	Dicamba 500	Titan
		500 g/L AC	Kamba 500	Nufarm
		700 g/kg WDG	Cadence	Syngenta
		700 g/kg WDG	Cambagran	Tradelands
		700 g/kg WDG	Dicamba	Titan
Diuron	C	500 g/L SC	various for multiple proucts	various for multiple products
		900 g/kg DF	Diuron 900 DF	4Farmers
		900 g/kg DF	Diuron DF	Nufarm
		900 g/kg WDG	various for multiple products	various for multiple products
Fluazifop-p	A	128 g/L EC	Fusilade Forte	Syngenta
		212 g/L EC	Flazz	Agriwest
		212 g/L EC	Fluazifop	Genfarm
		212 g/L EC	Fuziler	Ospray
		212 g/kg WDG	Fluazifop-P	Tradelands
Fluometuron	C	500 g/L SC	Cotoran SC	Farmoz
		500g/L SC	Fluometuron 500 SC	CMStrade
		500 g/kg WDG	Fluometuron 500 WG	CMStrade
		900 g/kg WDG	Cotoran 900 WG	Farmoz
		900 g/kg WDG	Fluometuron 900 WDG	Farmoz
		900 g/kg DF	Nu-Tron 900 DF	Nufarm
Fluometuron + prometryn	C	250 g/L + 250 g/L AC	Bandit Liquid	Crop Care
		250 g/L + 250 g/L AC	Convoy	Nufarm
		250 g/L + 250 g/L SC	Flupromix 500	Sipcam
		250 g/L + 250 g/L SC	Cotogard SC	Farmoz
		440 g/L + 440 g/L WDG	Bandit WG	Crop Care
		440 g/L + 440 g/L DF	Convoy DF	Nufarm
		440 g/L + 440 G/L WDG	Cotogard WG	Farmoz
		450 g/L + 450 g/L WDG	Flupromix	Sipcam
Flumioxazin	G	500 g/kg WDG	Pledge	Sumitomo Chemicals

Table 30. Herbicide trade names and marketers (continued)

Active ingredient	Mode of Action Group	Concentration and formulation	Trade name	Marketed by
Fluroxypyr	I	200 g/L EC	Acclaim	Sipcam Pacific
		200 g/L EC	Comet 200	Nufarm
		200 g/L EC	Decoy 200	Crop Care
		200 g/L EC	Flagship 200	Farmoz
		200 g/L EC	Fluroken 200	Kenso Agcare
		200 g/L EC	Fluroxypyr 200	Genfarm
		200 g/L EC	Fluroxypyr 200	Innova
		200 g/L EC	Fluroxypyr 200	Ospray
		200 g/L EC	Fluroxypyr 200	Titan
		200 g/L EC	Neon 200	Conquest
		200 g/L EC	Prostas	Proterra
		200 g/L EC	Restrain	Grow Choice
		200 g/L EC	Staroxy 200	eChem
		200 g/L EC	Uni-Rane	UPL
		333 g/L EC	Starane Advanced	Dow AgroSciences
		400 g/L EC	Comet 400	Nufarm
Glufosinate–ammonium	N	200 g/L SC	Liberty 200	Bayer CropScience
Glyphosate	M	360 g/L AC, EC, L, SC	various for multiple products	various for multiple products
		450 g/L AC, L	various for multiple products	various for multiple products
		470 g/L AC	Glyphosate 470	4Farmers
		480 g/L AC	Ripper	Dow Agrosciences
		490 g/L AC	various for multiple products	various for multiple products
		500 g/L AC	Ken-Up Gold 500	Kenso Agcare
		500 g/L EC	Touchdown Hitech	Syngenta
		510 g/L AC	various for multiple products	various for multiple products
		540 g/kg AC	various for multiple products	various for multiple products
		570 g/ka AC	Eradicator Power	Chemag
		680 g/kg WDG	Ken-up Dry	Biotis
		680 g/kg WDG	Klin-Up	Biotis
		680 g/kg WDG	Roundup Dry	Nufarm
		680 g/kg WDG	Wynca	Biotis
		690 g/kg WDG	Roundup Ready Herbicide	Nufarm
Halosulfuron–methyl	B	750 g/kg DF	Nut-buster	agVantage
		750 g/kg DF	Sempra	Nufarm
		750 g/kg WDG	Nutgrass Killer	ChemAg
		750 g/kg WDG	Halo 750 WG	ChemAg
		750 g/kg WDG	Halosulfuron	Gullf Ag
Haloxyfop-p		520 g/L EC	Halomac	Macspread
		520 g/L EC	Haloxyfop 520	ChemAg
		520 g/L EC	Haloxyfop 520	Grow Choice
		520 g/L EC	Haloxyfop 520	Generex
		520 g/L EC	Haloxyken 520	Kenso
		520 g/L EC	Harpoon	Agriwest
		520 g/L EC	Inquest	Sipcam
Haloxyfop-r	A	130 g/L EC	Asset	Nufarm
		520 g/L EC	Haloxyfop 520	4Farmers
		520 g/L EC	Haloxyfop 520	Chemforce
		520 g/L EC	Haloxyfop 520 EC	Ospray
		520 g/L EC	Recon 550	Conquest
		520 g/L EC	Verdict 520	Dow AgroSciences
Imazapyr + glyphosate	B + M	150 g/L + 150 g/L AC	Arsenal Xpress	Nufarm
Metolachlor	K	720 g/L EC	Chaser	Ospray
		720 g/L EC	Clincher	Farmoz
		720 g/L EC	Bouncer	Nufarm
		720 g/L EC	Metal 720	ChemAg
		720 g/L EC	Metoken 720	Kenso Agcare
		720 g/L EC	Metolachlor 720	4Farmers
		720 g/L EC	Metolachlor 720	Chem force
		720 g/L EC	Metolachlor 720	Conquest
		720 g/L EC	Metolachlor 720	Grow Choice
		720 g/L EC	Metolachlor 720	United Farmers Co-op
		720 g/L EC	Spruka 720	Proterra
		720 g/L EC	Strada	Sipcam
		720 g/L EC	Forge	Genfarm
		960 g/L EC	Clincher Plus	Farmoz
		960 g/L EC	Metolachlor 960	Titan

Table 30. Herbicide trade names and marketers (continued)

Active ingredient	Mode of Action Group	Concentration and formulation	Trade name	Marketed by
MSMA	Z	720 g/L EC	MSMA	Barmac
		800 g/L L	Daconate	Crop Care
		800 g/L L	Megalith	Agriwest
		800 g/L SC	MSMA	ChemAg
MSMA	Z	720 g/L EC	MSMA	Barmac
		800 g/L L	Daconate	Crop Care
		800 g/L L	Megalith	Agriwest
		800 g/L SC	MSMA	ChemAg
Norflurazon	F	800 g/kg DF	Zoliar DF	Syngenta
Oxyfluorfen	G	240 g/L EC	Convert 240 EC	Ospray
		240 g/L EC	Cavalier	Farmoz
		240 g/L EC	Encore 240	Conquest
		240 g/L EC	Goal	Dow AgroSciences
		240 g/L EC	Govern	Sipcam Pacific
		240 g/L EC	Ox 240	Kenso Agcare
		240 g/L EC	Oxen	Chemag
		240 g/L EC	Oxxel	Agriwest
		240 g/L EC	Oxy 240 EC	CMStrade
		240 g/L EC	Oxyfluorfen 240 EC	4 Farmers
		240 g/L EC	Oxyfluorfen 240 EC	Genfarm
		240 g/L EC	Oxyfluorfen 240 EC	Innova
		240 g/L EC	Oxyfluorfen 240 EC	Ospray
		240 g/L EC	Oxyfluorfen 240 EC	OzCrop
		240 g/L EC	Oxyfluorfen 240 EC	Titan
		240 g/L EC	Oxyfluorfen 240 EC	Accensi
		240 g/L EC	Oxyfluorfen 240 EC	United Farmers Co-op
		240 g/L EC	Point	Kendon Chemicals
		240 g/L EC	Striker	Nufarm
Paraquat	L	250 g/L SC	Biotis	Biotis Life Science
		250 g/L SC	Explode 250	Conquest
		250 g/L SC	Gramoxone 250	Syngenta
		250 g/L SC	Inferno	Sipcam Pacific
		250 g/L SC	Nuquat 250	Nufarm
		250 g/L SC	Para-Ken 250	Kenso Agcare
		250 g/L SC	Paraquat 250	4 Farmers
		250 g/L SC	Paraquat 250	ChemAg
		250 g/L SC	Paraquat 250	Chem Force
		250 g/L SC	Paraquat 250	Farmcochem
		250 g/L SC	Paraquat 250	Forward Australia
		250 g/L SC	Paraquat 250	Genfarm
		250 g/L SC	Paraquat 250	Grow Choice
		250 g/L SC	Paraquat 250	Halley
		250 g/L SC	Paraquat 250	Summit Agro
		250 g/L SC	Paraquat 250	Ospray
		250 g/L SC	Paraquat 250	Rygel
		250 g/L SC	Paraquat 250	Titan
		250 g/L SC	Paraquat 250	United Farmers
		250 g/L SC	Quash	Hextar
		250 g/L SC	Sinmosa	Sinon Australia
		250 g/L SC	Shirquat 250	Crop Care
		250 g/L SC	Sprayquat 250	Kendon
		250 g/L SC	Spraytop 250 SL	Farmoz
Paraquat + diquat	L	135 g/L + 115 g/L AC	Revolver	Nufarm
		135 g/L + 115 g/L AC	Spray.Seed 250	Syngenta
		135 g/L + 115 g/L AC	Spraykill 250	Chem Ag
		135 g/L + 115 g/L AC	Sprayout 250	Ospray
		135 g/L + 115 g/L AC	Di–Par 250	Genfarm
		135 g/L + 115 g/L SC	Combik 250	Sinon Australia
		135 g/L + 115 g/L SC	Brown Out 250	4Farmers
		135 g/L + 115 g/L SC	Di–Par 250	Genfarm
		135 g/L + 115 g/L SC	Alarm	Sipcam Pacific
		135 g/L + 115 g/L SC	EOS	Titan Ag
		135 g/L + 115 g/L SC	Paradym 250	Ronic Internationsl
		135 g/L + 115 g/L SC	Premier 250	Halley
		135 g/L + 115 g/L SC	Rygel Pre-Seed	Rygel
		135 g/L + 115 g/L SC	Scorcher 250	Conquest
		135 g/L + 115 g/L SC	Speedy 250	Kenso
		135 g/L + 115 g/L SC	Spray & Sow	Farmoz
		135 g/L + 115 g/L SC	Uni-Spray	United Phosphorus Limited
		135 g/L + 115 g/L SC	Wildfire	United Farmers

Table 30. Herbicide trade names and marketers (continued)

Active ingredient	Mode of Action Group	Concentration and formulation	Trade name	Marketed by
Pendimethalin	D	330 g/L EC	Charger 330 EC	Conquest
		330 g/L EC	Cyclone 330	ChemAg
		330 g/L EC	Panida Grande	Sipcam Pacific
		330 g/L EC	Pendi 330	Kenso Agcare
		330 g/L EC	Pendimethalin 330 EC	4 Farmers
		330 g/L EC	Pendimethalin 330 EC	Allfire
		330 g/L EC	Pendimethalin 330 EC	Halley
		330 g/L EC	Pendimethalin 330 EC	Ospray
		330 g/L EC	Pendimethalin 330 EC	Rallis India
		330 g/L EC	Pendimethalin 330 EC	Summit Agro
		330 g/L EC	Pendimethalin 330 EC	Titan
		330 g/L EC	Pendimethalin 330 EC	United Farmers
		330 g/L EC	Pendimethex	Farmoz
		330 g/L EC	Rifle 330	Nufarm
		330 g/L EC	Stomp 330 EC	Crop Care
		440 g/L EC	Cyclone 440	ChemAg
		440 g/L EC	Rifle 440	Nufarm
		440 g/L EC	Stomp 440	Crop Care
		455 g/L AC	Stomp*Xtra	Crop Care
Prometryn	C	500 g/L SC	Gesagard 500 SC	Syngenta
		500 g/L SC	Promesip 500	Sipcam
		500 g/L SC	Prometrex 500 SC	Farmoz
		500 g/L SC	Prometryn 500	Farmoz
		500 g/L SC	Prometryn 500	Ospray
		500 g/L SC	Prometryn 500 SC	CMStrade
		900 g/kg DF	Prometryn 900 DF	Nufarm
		900 g/kg WDG	Gesagard 900 WG	Syngenta
		900 g/kg WDG	Prometrex 900 WDG	Farmoz
		900 g/kg WDG	Proton 900 WG	Crop Care
Propaquizafop	A	100 g/L EC	Correct 100 EC	Bayer CropScience
Pyrithiobac sodium	B	850 g/kg SP	Staple	DuPont
Sethoxydim	A	186 g/L EC	Sertin 186 EC	Bayer CropScience
s-Metolachlor	K	960 g/L EC	Dual Gold	Syngenta
Triclopyr	I	600 g/L EC	Garlon 600	Dow AgroSciences
		600 g/L EC	Grando 600	Crop Care
		600 g/L EC	Hurricane 600	ChemAg
		600 g/L EC	Invader 600	Nufarm
		600 g/L EC	Maca 600	Conquest
		600 g/L EC	Melon 600	Agronomics
		600 g/L EC	Pyrmac	Macspread
		600 g/L EC	Triclon 600	Grow Choice
		600 g/L EC	Triclopyr 600	4Farmers
		600 g/L EC	Triclopyr 600	Chemforce
		600 g/L EC	Triclopyr 600	Crop Smart
		600 g/L EC	Triclopyr 600	Generex
		600 g/L EC	Triclopyr 600	Halley
		600 g/L EC	Triclopyr 600	Innova
		600 g/L EC	Triclopyr 600	Kenso Agcare
		600 g/L EC	Triclopyr 600	Ospray
		600 g/L EC	Triclopyr 600	Superway
		600 g/L EC	Triclopyr 600	Titan
		600 g/L EC	Triclopyr 600	United Farmers
		600 g/L EC	Trident 600	Genfarm
Trifloxysulfuron sodium	B	750 g/kg WDG	Envoke	Syngenta
Trifluralin	D	480 g/L EC	Treflan 480	Crop Care
		480 g/L EC	various names for multiple products	various names for multiple products
		500 g/L EC	Triflur xcel	Nufarm

Herbicides

Integrated Disease Management

Stephen Allen, Cotton Seed Distributors; Linda Scheikowski, Cherie Gambley, Murray Sharman and Susan Maas, Department of Employment, Economic Development and Innovation, Queensland

These pages are a brief version of Integrated Disease Management for Cotton published by the Australian Cotton CRC. For more details on any of the following pages please contact the Technology Resource Centre at the Australian Cotton Research Institute or see the Cotton CRC website.

INTRODUCTION

A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. When a virulent pathogen is dispersed onto a susceptible host and the environmental conditions are suitable then a plant disease develops and symptoms become evident.

Disease control strategies must therefore focus on the **host**, the **pathogen** and/or the **environment**. 'Integrated Disease Management' involves the selection and application of a harmonious range of control strategies that minimise losses and maximises returns. Each of the disease control strategies by itself is not able to provide adequate control. However, when several such strategies are used in combination then acceptable control is achieved.

Effective disease management must be integrated with management of the whole farm. The absence of symptoms does not indicate an absence of disease. Basic strategies should be implemented regardless of whether or not a significant disease problem is evident. These basic strategies should focus on the host, the pathogen and the environment.

THE HOST

A particular plant may be immune, resistant or susceptible. Breeders also use the term 'tolerance' to imply good performance (yield) despite the presence of the disease. Examples of disease control strategies that focus on the host include:

The use of resistant varieties

Australian upland cotton varieties are completely resistant to Bacterial blight. Some have good resistance to Verticilium wilt and some have some resistance to Fusarium wilt. Use varieties with good seedling vigour. When the Black root rot pathogen is present, use the more indeterminate varieties that have the capacity to catch up later in the season. Avoid growing susceptible varieties in fields that contain infected residues.

Balanced crop nutrition

A healthy crop is more able to express its natural resistance to disease. Adopt a balanced approach to crop nutrition, especially with nitrogen and potassium. Both deficiencies and excesses provide better conditions for the development of diseases such as Verticillium and Alternaria. For more information on cotton nutrition see NUTRIpak available from the Cotton CRC.

Replanting

Replanting decisions should be made on the basis of stand losses, not on the size of the seedlings.

THE PATHOGEN

A pathogen must be present in the area, capable of surviving the inter-crop period and adapted for effective dispersal between host plants if a disease is to occur. Disease control strategies that focus on the pathogen include:

Monitoring

Be aware of what diseases are present, where they are present and whether or not the incidence is increasing. Do your own disease survey in November and February of each season. Train farm staff to be observant and report back on possible disease occurrences.

Practice good farm hygiene

Minimise the movement of pathogens onto and off your farm, and between fields within your farm. Clean down machinery and vehicles of mud, crop and weed residues between fields and farms. Minimise movement of crop residues in tailwater recirculation systems. Encourage all visitors to 'COME CLEAN' and 'GO CLEAN'. For more information refer to the Farm Hygiene booklet in the BMP Guidelines manual.

Use rotation crops that are not hosts

Develop a sound crop rotation strategy. Successive crops of cotton can contribute to a rapid increase in disease incidence – especially if susceptible varieties are used. Use rotation crops that are not hosts for the pathogens present. The Verticillium wilt pathogen has a large host range and most legume crops are hosts of the Black root rot pathogen.

Control alternative hosts and volunteers

The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, Tabacco Streak Virus and Alternaria leaf spot can also infect common weeds found in cotton growing areas. Control alternative hosts to prevent build up of inoculum and carry over of disease from one season to the next.

Cotton volunteers and cotton ratoons can significantly increase the risk of disease carry over between seasons. Ensure weed management strategies for fallows and rotation crops consider the need for volunteer control, particularly in systems where herbicide tolerant crops are grown. Manage cotton stubble to avoid the occurrence of ratoon cotton as herbicides are rarely cost effective or highly efficacious.

Crop residues

Manage crop residues to minimise carryover of pathogens into subsequent crops. The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, boll rots, seedling disease and Alternaria leaf spot can all survive in association with crop residues. Incorporate cotton crop residues as soon as possible after harvest, except where Fusarium wilt is present. Where Fusarium is present residues should be slashed and retained on the surface for at least one month prior to incorporation.

The Fusarium wilt pathogen can also survive and multiply on the residues of non-host crops such as cereals. Currently recommendations are that residues should be buried or baled as soon as possible after harvest.

Application of fungicides

Examples include seed treatments for seedling disease control and foliar sprays for the control of Alternaria leaf spot on Pima cotton. For more details see Tables 31 and 32 on page 129 and 131.

Biofumigation

In addition to fixing substantial quantities of nitrogen, vetch has a biofumigation effect against Black root rot. As the vetch breaks down in the soil, ammonia is released in sufficient quantities to kill spores of the Black root rot pathogen. In contrast, vetch residues can increase the activity of Fusurium wilt in the following cotton crop.

The success of biofumigation depends on the growth of the biofumigant crop and good incorporation (at least 4 weeks before planting). Biofumigant crops can been grown and incorporated a year before planting the following cotton crop.

Control of insect vectors

Diseases caused by a virus or phytoplasma can often be prevented by controlling the vector that carries the pathogen.

Cotton Bunchy Top (CBT) can be transmitted by aphids feeding on infected plants then migrating to healthy plants. Transmission of Tobacco Streak Virus (TSV) to plants relies on the virus from infected pollen entering plant cells through the feeding injury caused by thrips. Many species of thrips are potentially capable of transmitting TSV. For more information on these diseases, see the following section. Aphid and thrip thresholds can be found on pages 22–23.

THE ENVIRONMENT

Pathogens have optimum temperature, relative humidity, leaf wetness and/or soil moisture content requirements for infection to occur and for the disease to spread and multiply in the host plant. When environmental conditions are not optimal then the rate of disease development is reduced.

It may appear difficult to manipulate the environment but it can be achieved by altering row or plant spacing, irrigation method or frequency or by changing the sowing date. Possible disease control strategies that focus on the environment include:

Good bed preparation

Plant into well prepared, firm, high beds to optimise stand establishment and seedling vigour. Carefully position fertiliser and herbicides in the bed to prevent damage to the roots. Fields should have good drainage and not allow water to back-up and inundate plants.

Irrigation scheduling

Applying water prior to planting provides better conditions for seedling emergence than watering after planting.

Watch for signs of water stress early in the season if the root system has been weakened by disease (eg. Black root rot) and irrigate accordingly. Avoid waterlogging at all times, but especially late in the season when temperatures have cooled. Irrigations late in the season can result in a higher incidence of Verticillium wilt.

Agronomic management

High planting rates can compensate for seedling mortality however a dense canopy favours development of bacterial blight, Alternaria leaf spot and boll rots. Avoid rank growth and a dense canopy with the use of growth regulators. Manage irrigations, nutrition and insects for early maturity as many pathogens are favoured by cool conditions at the end of the season.

In fields where Fusarium wilt is present avoid inter row cultivations after seedling stage as mechanical damage to the roots provide a site for infection by the pathogen.

Sowing date

Delay sowing as late as possible within the planting window to avoid cool, wet conditions that favour disease. Sowing when the soil temperature is above 20°C would be best for reducing cotton's susceptibility to disease, but generally this is not practical. Time planting to coincide with soil temperatures of at least 16°C and rising.

Soil health

Fields where soil borne pathogens cause chronic disease in cotton are not 'unhealthy' as healthy cereal crops could be grown in the same field. These diseases are not present because the soil has been mistreated, the presence of the pathogen creates a problem with the health of the plants but not a problem with the health of the soil.

Common Diseases of Cotton

Stephen Allen, Cotton Seed Distributors; Linda Scheikowski, Cherie Gambley, Murray Sharman and Susan Maas, Department of Employment, Economic Development and Innovation, Queensland

Seedling Diseases

There have been over 30 species of fungi isolated from dying cotton seedlings. Death of seedlings is often referred to as 'damping off' but is mainly caused by

Rhizoctonia solani
***Pythium* spp.**
***Fusarium* spp. (not Fusarium wilt)**

Symptoms

Pre-emergent seed rots. Post emergent wilting, collapse and death (damping off). Slow early season growth, small cotyledons and reddened hypocotyls, lesions on roots.

Favoured by

Anything that slows down germination and seedling growth favours infection by seedling disease. This includes cool and/or wet weather, poorly formed beds, compaction, waterlogging, incorrect planting depth, fertiliser under the plant line, excessive rates of planting herbicide, movement of herbicide into root zone (ie by rain) and infection by other pathogens.

Host range

These pathogens have wide host ranges and can survive on residues of many crops and weeds.

IDM tactics

- Use a variety with good seedling vigour.
- Use effective seed treatment fungicides.
- Avoid freshly incorporated rotation crop residues.
- Plant into well prepared, high, firm beds.
- Carefully position fertiliser away from the plant line.
- Plant into moisture.
- Delay planting until temperatures are optimum.
- Take care with use of herbicides at planting.

Black Root Rot

Thielaviopsis basicola

Symptoms

Affected crops appear to be slow growing or stunted, especially during the early part of the season. The disease causes destruction of the root cortex (outer layer), seen as blackening of the roots. Some roots may die but *T. basicola* does not kill seedlings by itself. Severe black root rot opens the root up for infection by *Pythium* or *Rhizoctonia*. Plants that are badly affected early in the season may not continue to show symptoms later in the season as the dead cells of the root cortex are sloughed off when growth resumes in warmer weather.

Host range

The host range of *T. basicola* includes all varieties of cotton, most legumes including faba bean, soybean, cowpea, field pea, chickpea, mung bean, lablab and lucerne. Datura weeds (thornapple, caster oil) are also hosts, but little is known about other weeds.

Non hosts include all the cereal crops, sunflower, canola and vetch.

IDM tactics

- Choose varieties that can 'catch up'.
- Use Bion seed treatment.
- Prepare beds well ('high and firm' not 'low and loose')!
- Pre-irrigate and/or plant into moisture.
- Delay planting if possible.
- Rotate with non-hosts for up to 3 years.
- Avoid legumes and control weeds.
- Effective biofumigation with vetch or mustard,
- Minimize your tailwater.
- Always practice good farm hygiene.
- Summer flooding if possible.

Verticillium Wilt

Verticillium dahliae

Symptoms

Leaf mottle – yellowing between the veins and around the leaf margins, vascular discolouration or browning extending throughout the stem and into the petioles, root system otherwise healthy, some defoliation may occur if cool.

Internal symptoms can be checked by cutting the stem. The vascular tissue of an infected plant will reveal flecking brown discolouration extending throughout the stem and into the petioles. Under Australian conditions with Australian strains of the pathogen, all plants with vascular symptoms will also display foliar symptoms,

The discolouration is similar to that of Fusarium wilt but usually appears as flecking rather than continuous browning. Severe cases often need to be tested by a pathologist to determine whether the pathogen is *Fusarium* or *Verticillium*.

The root system appears otherwise healthy.

Favoured by

Resistance to the disease is temperature sensitive. Varieties that are resistant at 25°–27°C are susceptible at 20°–22°C. The disease is most severe during extended wet weather and/or waterlogging and in late maturing crops. The disease is favoured by excessive use of nitrogen which results in late season growth and also by potassium deficiency.

Host range

Verticillium wilt has a large host range which includes sunflower, soybean, noogoora and bathurst burr, saffron thistle, thornapple, caustic weed, bladder ketmia, burr medic, black bindweed, pigweed, devils claw, turnip weed, mintweed, blackberry nightshade and others.

Non host crops include sorghum and cereals.

IDM tactics

- Choose varieties with V.ranks over 100.
- Manage for earliness.
- Avoid late season irrigations.
- Incorporate cotton residues soon after harvest.
- Rotate with non-hosts such as cereals or sorghum.
- Control alternative weed hosts.
- Minimize your tailwater.
- Always practice good farm hygiene.

Fusarium Wilt

Fusarium oxysporum* var. *vasinfectum (FOV)

Symptoms

External symptoms include stunted growth and dull and wilted leaves followed by yellowing or browning of the leaves and eventual death from the top of the plant. Some affected plants may reshoot from the base of the stem. External symptoms can appear in the crop at any stage. Most commonly they become apparent in the seedling phase when plants are beginning to develop true leaves, or after flowering during boll fill. Symptoms can appear as only a few, individual plants or as a small patch, often but not always in the tail drain or low-lying areas of the field.

Internal symptoms can be checked by cutting the stem. An affected plant will reveal continuous brown discolouration of the stem tissues running from the main root up into the stem. The discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecking.

Favoured by

Use of susceptible varieties. Stresses in the crop such as waterlogging, root damage through cultivation and cool, wet growing conditions. Spores surviving in soil and on crop residues can be spread by overland flows, in irrigation water and attached to people and machinery.

Host range

The FOV pathogen is specific to cotton but can live of the residues of most non host crops. Known alternative weed hosts include bladder ketmia, sesbania pea and dwarf amaranth, however there are possibly more.

IDM tactics

- Plant a high F.rank variety with Bion seed treatment.
- Delay planting to the end of October.
- Avoid cultivating with knives.
- Retain cotton residues on the surface for 60 days.
- Bare fallow rotation is best.
- If using a cereal rotation then bury, bale or burn cereal residues ASAP.
- Minimize your tailwater.
- Always practice good farm hygiene.
- Summer flooding if possible.

Alternaria Leaf Spot

Alternaria macrospora
Alternaria alternata

Most commercial varieties of cotton are relatively resistant to *Alternaria* and the impact of the disease on yield is insignificant, unless the crop is severely affected with premature senescence associated with potassium deficiency. Pima cotton is very susceptible.

Symptoms – *A. macrospora*

Brown, grey brown or tan lesions 3–10 mm in diameter on lower leaves, sometimes with dark or purple margins. Circular dry brown lesions on bolls. Pima varieties can defoliate rapidly when the environment favours the disease.

Symptoms – *A. alternata*

Purple specks or small lesions with purple margins on bolls and leaves.

Favoured by

Heavy dews or extended periods of wet weather resulting in long periods of free moisture on the leaf. Suppressed by hot dry weather. Nutritional stress can favour development. Pima varieties are quite susceptible.

Host Range

Cotton, bladder ketmia, sida and anoda weed.

Boll Rots

Phytophthora boll rot is the most common, while Sclerotinia boll rot and Fusarium boll rot (not Fusarium wilt) are usually only seen in very rank crops.

PHYTOPHTHORA BOLL ROT

Phytophthora nicotianae* var. *parasitica

Symptoms

Infected bolls quickly turn brown and become blackened before opening prematurely. Symptoms most prevalent on the lower bolls.

Favoured by

Heavy rainfall on exposed soil that splashes soil up onto low bolls enables infection. Low mature bolls and lodged plants are at highest risk of infection.

Host range

Safflower, some horticultural and many ornamental plants.

Tobacco Streak Virus

Tobacco streak virus (TSV)

Symptoms

Symptoms included dark purple or necrotic, spreading lesions on leaves, sometimes forming numerous diffuse ring spots. On plants with numerous necrotic lesions the upper leaves sometimes also display chlorotic mottle and deformed, down-curled leaves. Symptoms in young cotton crops are generally mild and consist of single, diffuse necrotic lesions on one leaf of infected plants.

Favoured by

TSV disease is favoured by climatic conditions which enable high thrips populations to develop, and large amounts of infective pollen to be produced by host plants such as parthenium. These conditions generally occur during warmer months and is highly dependant on rainfall and weed growth patterns.

Host Range

Cotton, sunflower, mung beans, chickpeas, soybean and peanuts. Weed hosts include parthenium, native jute, native rosella, milk weed, thornapple, ground cherry, rattle pods, crownbeard and Noogoora burr.

Cotton Bunchy Top (CBT)

CBT is viral disease that is relatively new to Australian cotton being first observed in the 1998/99 season. The disease has since been reported from the Macquarie Valley in the south to the Emerald region in the north. CBT is spread by the cotton aphid (*Aphis gossypii*, Glover).

Symptoms

Symptoms include; reduced plant height, leaf size, petiole length, internode length and boll size. Leaf symptoms are usually an angular pattern of pale green margins and darker green centres. These darker leaves have a leathery and sometimes glossy texture when compared to leaves on healthy plants. Typically, the pale angular patches turn red as leaves age. Bolls are often less than half the size of healthy bolls. Symptoms are also evident on roots. These include the formation of small knots on the secondary root branches. The roots also appear hairy and dark brown in comparison to the light yellow-brown colour of healthy roots.

Usually a period of 3–8 weeks lapses between when the infection occurs and when symptoms are first observed. The severity of symptoms expressed by infected plants depends on their age at the time of infection. After the plant is infected, new growth is also characterised by small leaves, short internodes and small bolls. This is usually limited to growth that occurrs after infection; growth before this stage may appear normal. When plants become infected very early, as seedlings, the growth of the whole plant is affected and the crop takes on a compact, stunted, 'climbing ivy' appearance.

Infections early in the season have the greatest potential to reduce yield. However the extent to which yield is affected also depends on the proportion of plants infected. If the proportion is low, then uninfected neighbouring plants will often compensate and make up any yield loss. Often the CBT-infected plants will become obscured by their neighbours. If the proportion infected is high (>50%), yield may be reduced, but this level of infection rarely occurs.

Plants showing symptoms of the disease are often found in circular patches in association with prolonged aphid activity. These are most likely to occur;

- on field margins, where aphids carrying the disease have moved from other hosts into the cotton crop; or
- in portions of the field where there has been survival of CBT-affected cotton ratoons from the previous season.

Favoured by

Fields at highest risk of CBT are those in close proximity to ratoon cotton. When cotton plants are infected with CBT late in the season, there may not be sufficient time for symptoms to be expressed. However when such plants ratoon, the new growth will be strongly affected. Ratoons act as both a preferred host for the aphids and a resevoir for the disease, creating a source of infection in the new season.

Disease spread is favoured by climatic conditions which are suitable for aphid reproduction, feeding and spread. The risk from CBT is probably higher after wetter winters and lower after dry winters. The presence of weed hosts allow larger aphid populations to overwinter, increasing the likelihood of aphids moving into cotton early in the season when there is sufficient time for infection to result in the development of severe symptoms.

Even when there is a source of CBT in close proximity to a cotton field, the spread of the disease is also highly dependent on the size and movement of the aphid population. CBT is more easily trasmitted when plants are colonised by many infected aphids. If just one CBT-infected aphid colonizes a plant, the transmission rate is ~5% (1 in 20 plants become infected). If there are three or more infected aphids the transmission rate increases to ~40%.

There is a 'latent' period that also slows down the rate of transmission through a field. When a CBT-infected aphid feeds on a cotton plant, transmission will happen within half a hour if it is going to occur. A latent period then passes. Over the next 10–14 days young aphids produced by the infected female can feed on the newly infected plant and not pick up the disease. They move on to nearby plants to start new colonies before becoming carriers of the disease. When the young aphids do pick up CBT from the original plant before moving to the next plant there will again be a latent period in that plant. This is compounded by the low transmission rate when a single aphid colonizes a plant. Many colonization events do not result in successful transmission. This scenario is often seen in commercial fields where at the centre of an aphid hotspot a single CBT infected plant will be found, while the nearby plants are disease free.

Host Range

The most critical alternative host plant is ratoon cotton. Ratoon plants are often large, with a deep tap root. They are able to survive through periods of low rainfall and often retain leaves and active growth through winter, supporting infected aphid populations from one season to the next.

Pima cotton (*Gossypium barbedense*) is a symptomless host. Even if plants become infected when they are very young disease symptoms will not be expressed. Aphids that feed on infected plants can become infected and transfer CBT to upland cotton (*G. hirsutum*) which will then express disease symptoms.

The cotton aphid has a broad host range, including many weeds common in cotton growing areas. At this stage only marshmallow has been confirmed to be an alternative host for CBT. However it is possible that other weeds are also hosts. Weed hosts may not express disease symptoms, similarly to pima cotton. For a comprehensive list of the cotton aphid's alternative hosts, refer to the Cotton CRC Information Sheet 'Managing Aphids in Cotton', available from the Cotton CRC website.

IDM tactics

- Manage cotton stubble to prevent ratoons.
- Control farm weeds that are aphid hosts, particularly marshmallow.
- Consider cotton volunteer management when making weed control decisions for fallows and rotation crops.
- Monitor cotton fields regularly from crop emergence for the presence of aphids.
- Check aphid hot spots for sypmtoms of CBT.
- If CBT symptoms are present early season, consider rouging infected plants or selectively controlling aphids in compliance with the IRMS.

Cotton Pathology Survey 2008/09

SJ Allen[1], CMT Anderson[2], PA Lonergan[2], LJ Scheikowski[3] and LJ Smith[4], Cotton Catchment Communities CRC

Commercial cotton crops across NSW and Queensland were inspected in November–December 2008 and March–April 2009. The incidence and severity of those diseases present were assessed and field history, ground preparation, cotton variety, planting date and seed rate were recorded for each of the 73 and 55 fields that were surveyed in NSW and Queensland respectively. This represents the 26th consecutive season of quantitative disease surveys of cotton in NSW and the 7th consecutive season of cotton disease surveys in Queensland.

Most cotton production areas experienced near average seasonal conditions with the following notable exceptions. Cotton crops in the Burdekin received over 1.5 metres of rainfall during the season. The Emerald area experienced only 49% of the average number of days with temperatures >35°C and rainfall 25% higher than the seasonal average. In contrast Mungindi (+78%), Gunnedah (+44%), Hillston (+39%) and Griffith (+30%) received an above average number of days with temperatures >35°C. Rainfall recorded at Walgett, Bourke and Moree was 64%, 50% and 33% higher than the seasonal average. The number of day-degrees accumulated during the season at Hillston and Griffith was 13% and 14% above average.

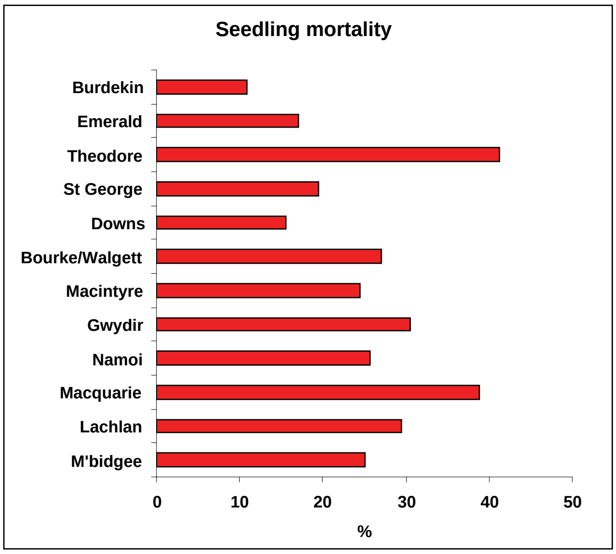
Cotton Industry Biosecurity Plan – Crop Surveillance for Priority Pests

During these surveys particular attention was given to the detection of Cotton Leaf Curl Virus, Blue disease, Phymatotrichopsis root rot, the hypervirulent strains of the bacterial blight pathogen, the defoliating strains of the Verticillium wilt pathogen and exotic strains of the Fusarium wilt pathogen. None of these pathogens were observed.

SEEDLING MORTALITY

As part of the disease survey an estimate of the number of seeds planted per metre is compared to the number of plants established per metre. This comparison produces an estimate of seedling mortality which includes the impact of seedling disease (Rhizoctonia and Pythium etc.) as well as seed viability, the activity of soil insects such as wireworms, physical problems such as fertiliser or herbicide burn and the effects of adverse environmental conditions.

Figure 10. Seedling mortality of cotton in the 2008/09 season was relatively low in the Burdekin, Emerald, St George and Darling Downs areas and particularly high in the Macquarie Valley and Theodore area.



Mean seedling mortality (Figure 10) for the crops inspected in Queensland and NSW was 24.9% and 28.8%, respectively, (19.5% and 31% in 2007–08; 22.5% and 28.9% in 2006–07). The highest seedling mortality was observed in the Theodore area (41.2%) and in the Macquarie valley (38.8%) The low incidence of seedling mortality in crops on the Darling Downs (15.6%) reflects the warmer conditions for establishment that resulted from the later planting window. The very low incidence of seedling mortality in crops in the Burdekin (10.9%) results from planting dates in December. The warmer than normal seasonal conditions in the Lachlan and Murrumbidgee valleys plus the inclusion of several fields relatively new to cotton production, resulted in lower than normal seedling mortality in this area.

FUSARIUM WILT

There were no new reports of Fusarium wilt from either NSW or Queensland this season. A fresh sample of affected plants was collected from a property near Mungindi. The results of tests on the original sample had indicated a possible new strain of the Fusarium wilt pathogen. The QPI&F diagnostic service at Indooroopilly are completing the tests.

[1] Cotton Seed Distributors, PO Box 17, Wee Waa NSW.
[2] Industry & Investment NSW, Locked Bag 1000, Narrabri NSW.
[3] Queensland Primary Industries and Fisheries, 203 Tor Street, Toowoomba, Qld.
[4] Queensland Primary Industries and Fisheries, 80 Meiers Road, Indooroopilly, Qld.

Figure 11. The average incidence and distribution of Fusarium wilt of cotton in the 2008/09 season. The average incidence declined in crops in the St George and Darling Downs areas but increased in crops in the Gwydir and Macintyre valleys.

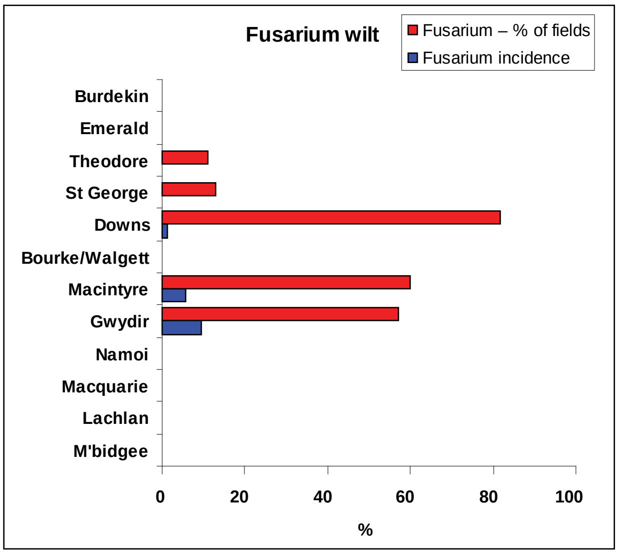
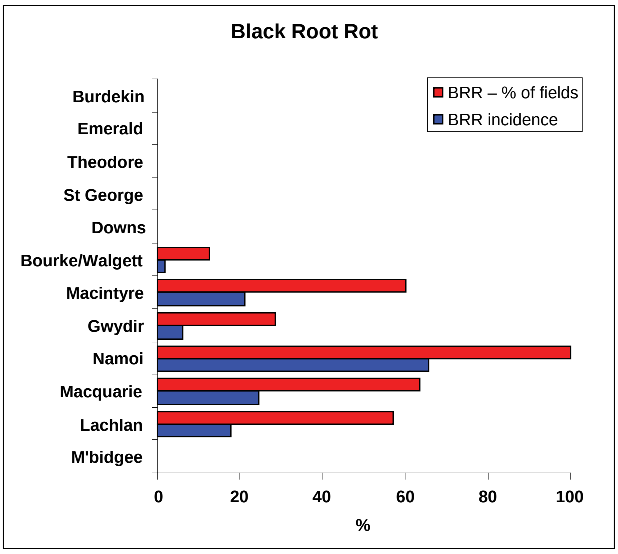


Figure 12. The incidence of black root rot of cotton in the 2008/09 season was highest in the Namoi Valley in NSW. Black root rot was not observed in cotton production areas of Queensland.



Fusarium wilt was most common in crops on the Darling Downs of Queensland where the disease was found in 9 of the 11 crops inspected. However, the average incidence of fusarium wilt was reduced to only 1.4% of plants affected compared to 11.4%, 3.1% and 7.4% for the previous three seasons. Similarly, at St George, the average incidence of fusarium wilt was reduced to only 0.01% of plants affected compared to 1.9% and 3.2% in the last two seasons. In contrast, the average incidence of Fusarium wilt in the Gwydir and Macintyre valleys increased to 9.4% and 5.7% respectively.

Several factors could be responsible for contributing to these observed trends. Previous research has shown that delaying the sowing of the crop by just a couple of weeks can reduce disease incidence by up to 24% by avoiding the cooler spring conditions. More than half of the fields surveyed on the Darling Downs were planted in late October and early November. whereas, all of the surveyed fields in the Gwydir valley were planted in September and early October. Other factors could include the more widespread use of the new more resistant varieties and the more widespread use of the BION seed treatment in Queensland cotton production.

The BION seed treatment, which provides some control of black root rot and Fusarium wilt, was applied to 42% of cotton seed planted in Queensland and 23% of cotton seed planted in NSW. Use of the product in NSW would have been mainly directed at black root rot while use in Queensland would have been almost all directed at Fusarium wilt.

Though Fusarium wilt is known to be present and widespread in the Macquarie valley, upper Namoi valley and Bourke areas it was not detected in the 2008/09 disease survey.

It is important that growers and consultants confirm and declare if the disease is present in an area. The Fusarium wilt diagnostic service provided by the QPI&F is funded by the cotton industry and is free to growers. The majority of samples submitted return a negative result and some growers who are withholding samples could be worried unnecessarily. Early detection of the disease and establishment of a control program has proven to be the best approach.

BLACK ROOT ROT

Black root rot (Figure 12) has been recorded in all production areas of Queensland and NSW. The disease was observed in 65% of fields and 32% of plants surveyed in the major valleys in NSW (Macintyre, Gwydir, Namoi and Macquarie); compared to 58% and 14% respectively in the previous year. The Namoi valley was again the worst affected with black root rot present in all fields inspected and the mean incidence estimated to be 66% of plants affected.

The average incidence of black root rot continued to increase in most areas. The disease incidence exceeded 90% of plants affected in the worst affected fields growing in the Namoi, Macquarie and Lachlan valleys!

Figure 13. The incidence of Verticillium wilt in March 2008/09 was greatest in the Namoi Valley where it was found in 93% of the fields inspected.

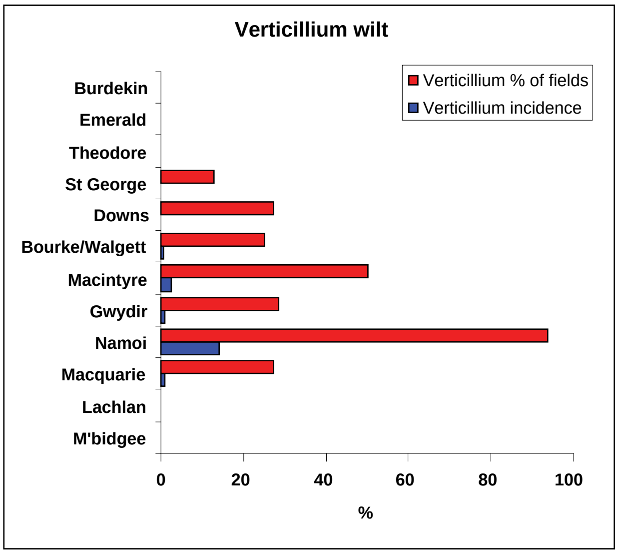
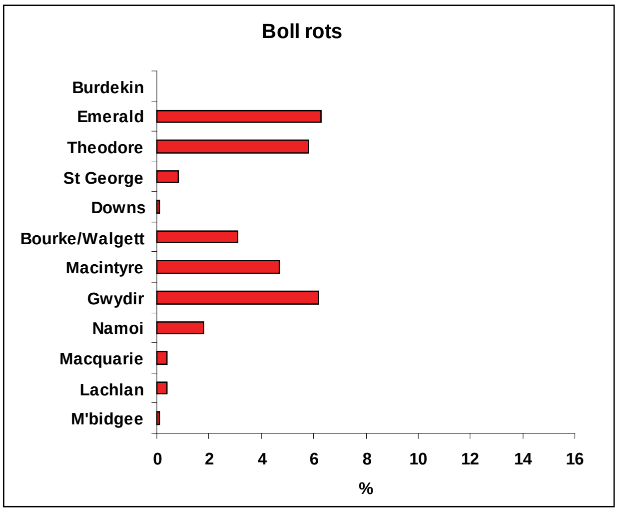


Figure 14. The incidence of boll rots, including those caused by Phytophthora and other fungi, in 2008/09 as assessed at time of survey. The incidence of boll rots is influenced by the timing of boll opening and periods of wet weather.



Black root rot was not observed during surveys in Queensland production areas in the 2008/09 season. The disease has only been rarely observed in the Emerald and Theodore areas over the last six seasons. The late planting window was probably a significant factor for crops in the St. George and Darling Downs areas where many fields were planted in late October and early November.

VERTICILLIUM WILT

In March–April 2009, the average incidence of Verticillium wilt across NSW (Figure 13) was found to be 3.8% (11.2%, 4.9% and 3.4% in the previous three seasons). Verticillium wilt was present in 94% of fields inspected in the Namoi valley where the average incidence of the disease was 14% of plants affected (28.9%, 10.4% and 10.1% in the previous three seasons). Symptoms were present in 31% and 50% of plants in the worst affected fields.

Verticillium wilt was present in 50% of fields inspected in the Macintyre valley where the average incidence of the disease was 2.6% of plants affected. Although present in several other areas the incidence was < 1% of plants affected.

BOLL ROTS AND TIGHT LOCK

Boll rots involve the complete collapse of the boll –'boll wall and all' – and result from fungal infection that is sometimes assisted by insect damage. Tight lock describes the failure of locks to 'fluff out' when bolls open and is also caused by microbial infection that is sometimes assisted by insect damage. These microbes include both bacteria and fungi and can be introduced to the lock by rain splash from the soil, airborne spores from other plants or by insects feeding through the boll wall before the boll opens. Severe boll rot and tight lock occur when there is a coincidence of wet weather, maturing bolls and the appropriate fungi that can thrive on pure cellulose.

The average incidence of boll rots in NSW and Queensland cotton crops was estimated to be 2.7% and 1.9% respectively. Wet weather prior to harvest in the Emerald and Theodore areas of Queensland and in the Gwydir and Macintyre valleys contributed to mean incidences of 6.3%, 5.8%, 6.2% and 4.7% respectively with up to 25% of bolls affected in individual crops. (Figure 14)

Phytophthora boll rot develops when low bolls are inundated with flood or irrigation water or when soil is splashed up onto low bolls as they approach maturity. Boll rots caused by other pathogens tend to be more frequent in crops with tall dense canopies. Phytophthora boll rot was the most common boll rot observed in NSW production areas (2.6%).

ALTERNARIA LEAF SPOT

The pathogen that causes Alternaria leaf spot survives on crop residues from the previous season. Its survival is favoured by dry winter conditions and the retention of cotton crop residues on the soil surface. Alternaria leaf spot was observed in trace amounts in many, but not all, crops surveyed throughout NSW and Queensland in February–March 2009, with the mean severity (percentage of leaf area infected) estimated to be 0.8% in both the

Macintyre valley and the Emerald area. One crop in the Emerald area had 2% of the leaf area affected with some defoliation.

COTTON BUNCHY TOP

Symptoms of cotton bunchy top include small bolls, small leaves and short internodes, usually accompanied by a distinctive light-green angular mottle occurring around the margins of the leaves (the leaf mottle may be masked if infestation by aphids or mites is severe), and usually confined to a few plants or a distinct patch. Bunchy top was observed in crops near Theodore and on the Darling Downs. Symptoms were observed in 7% of crops inspected in Queensland and the average incidence of bunchy top in these crops was <0.1%. Bunchy top was observed in 11% of fields inspected during the NSW surveys where the average incidence was 0.2% of plants with symptoms. The incidence of bunchy top in three crops in the Lachlan Valley was found to be 5%, 4% and 1%.

OTHER DISEASES AND DISORDERS

Tobacco Streak Virus (TSV)

TSV was observed in 7 of 14 crops inspected in November and in 6 of 9 crops inspected in February in the Emerald area. It was not observed on cotton in any other area. However, it was detected in the weed, 'crown beard' (*Verbesina encelioides*) that was collected along the roadside just west of Theodore. The incidence of TSV varied from 0 to 50% in the November survey and from 0 to 2% in the February survey. In all affected crops the symptoms were limited to just one or two lesions per plant.

Seed Rot

In recent years there has been an increasing awareness of a seed rot caused by pathogens transmitted by sucking insect pests, feeding on developing seed, within young developing bolls. These bolls either drop off the plant or open prematurely with affected locks failing to fluff out properly and lint surrounding the affected seed discoloured. Overseas research has suggested that a Pantoea sp. could be one of the pathogens involved. Seed rot was observed in 11.7% of crops inspected in NSW and Queensland. It was particularly noticeable in crops in the Burdekin valley, the Darling Downs and the Lachlan/Murrumbidgee area.

The Burdekin Valley

The Burdekin valley is unique because of its tropical environment with high rainfall and the common rotation with sugar cane. A leaf spot with symptoms similar to 'wet weather blight' caused by *Ascochyta* sp. was observed on the cotyledons of seedlings and on the lower leaves of adult plants. Premature senescence was pronounced in some fields and accompanied by Alternaria leaf spot. The survey was too early to get an assessment of boll rots.

ACKNOWLEDGMENTS

This research was made possible with the financial support of the Cotton Research and Development Corporation, Cotton Catchment Communities CRC, Cotton Seed Distributors Ltd., Industry & Investment NSW and Queensland Primary Industries and Fisheries.

Cotton Disease Control Guide – Registered chemicals as at 15 October 2009

Tracey Farrell, formelry Industry & Investment NSW.

Registration of a pesticide is not a recommendation from I&I NSW for the use of a specific pesticide in a particular situation. Growers must satisfy themselves that the pesticide they choose is the best one for the crop and disease. Growers and users must also carefully study the container label before using any pesticide, so that specific instructions relating to the rate, timing, application and safety are noted. This publication is presented as a guide to assist growers in planning their pesticide programs.

If there is any omission from the list of chemicals, please notify the authors.

IMPORTANT— AVOID SPRAY DRIFT

Take every precaution to minimise the risk of causing or suffering spray drift damage by:

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Carefully following all label directions.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions

SPRAY LOG BOOKS

To assist in record keeping for pesticide applications, Spray Log Books can be purchased from:

DEEDI, cost $6.60 each plus postage and handling. Contact DEEDI inToowoomba – Natalie Fletcher 07 4688 1460 or Rebecca Simmons 07 4688 1360 or in Dalby – 07 4669 0800 to place an order.

I&I NSW, cost $12.00 each plus postage and handling. Contact I&I NSW, Yanco – 1800 138 351.

ABBREVIATIONS USED IN THE TABLES 31–32

EC = Emulsifiable concentrate
FC = Flowable concentrate
SC = Suspension concentrate
WDG = Water dispersible granule
WP = Wettable powder

Table 31. Control of Cotton Diseases

Active ingredient	Fungicide chemical group	Concentration and formulation	Application rate of product	Comments
Alternaria leaf spot				
mancozeb	Y	750 g/kg WG	2.5 kg/ha	Pima varieties only. Do not apply before flowering. Begin applications as soon as disease symptoms appear and before each infection period. DO NOT apply more than 4 sprays per season.
Rhizoctonia solani **(Damping off)**				
quintozene	Y	750 g/kg WP	5.0 kg/ha	Apply over seed and surrounding soil at planting.
tolclofos-methyl	X	500 g/L SC	0.12 L/ha or 0.12 L/10km row	QLD and NSW only. Apply as an in-furrow spray or by water injection at time of planting.
		500 g/kg WP	0.12 kg/ha or 0.12 kg/10 km row	QLD and NSW only. Apply as an in-furrow spray or by water injection at time of planting.
Pythium **spp. and** ***Phytofthora*** **spp. (Damping off)**				
metalaxyl-m	D	350 g/L EC	0.1 L/100 kg seed	Commercial application recommended.
		350 g/kg WP	0.085 g/100 kg seed	Apply as a dust or slurry before sowing.
Rhizoctonia solani **and** ***Pythium*** **spp.**				
azoxystrobin + metalaxyl-m + fludioxonil	K D L	75 g/L SC 37.5 g/L SC 12.5 g/L SC	0.2 L/100 kg seed	Commercial application recommended. This seed treatment should be used as part of an integrated strategy to control seedling disease.
Fusarium Wilt				
acibenzolar-s-methyl		500 g/L FC	1.2 mL/100 kg seed	Seed treatment for suppression of Fusarium wilt and Black root rot.
metalaxyl-m	D	350 g/L	0.043 L/100 kg seed	For Fusarium wilt disinfection. Commercial application recommended.

Sending a Sample for Diagnosis by a Pathologist – Attach a completed form to each sample

Collected/Submitted by: (e.g. Cotton Extension Officer)	Address/Email/Fax/Telephone:
Property name and field number:	Date collected:
Grower/Agronomist	Grower's address or area/locality:

Mark (X) as appropriate

SYMPTOMS	DISTRIBUTION	INCIDENCE/SEVERITY	CROP GROWTH STAGE
❑ Poor emergence or seedling depth	❑ One field only	❑ All plants	❑ Irrigated
❑ Leaves: spots or dead areas	❑ In several fields	❑ Scattered single plants	❑ Dryland/rain-grown
❑ Leaves: discoloured	❑ In all fields	❑ Scattered patches of plants	❑ Seedling stage
❑ Leaves: mottled	❑ One variety only	❑ In a large patch (>5 m)	❑ Setting squares
❑ Leaves or shoots: distorted or curled	❑ Several varieties affected	❑ In a small patch (1–5 m)	❑ Early flowering
❑ Plants stunted	❑ Some rows more affected	❑ In a small patch (<1 m)	❑ Peak flowering
❑ Plants wilting	❑ On lighter soil types	❑ Plants dead	❑ First bolls open
❑ Premature plant death	❑ On heavier soil types	❑ Plants defoliating	❑ Defoliated
❑ Bolls: spots or dead areas	❑ In poorly drained area(s)	❑ One to a few plants only	❑ Ready to pick
❑ Roots: discoloured, bent, pruned, etc.	❑ Other: (please specify)		

OTHER INFORMATION

- Cultivar..
- Paddock History..
- Nearby crops..
- Rainfall in last 10 days..
- Average temperature range over the last 10 years..
- Date of last irrigation..
- Date of last cultivation..

Please contact your Cotton Industry Development Officer or District Agronomist to determine the appropriate Pathologist and address for submitting sample

ALL SAMPLES WHERE FUSARIUM WILT IS SUSPECTED MUST BE SENT TO INDOOROOPILLY

When sending samples:

- Send multiple samples (e.g. more than 1 leaf, stem or plant).
- If possible include a healthy plant as well as the diseased plant material.
- It is better to despatch samples early in the week rather than just before the weekend.
- Never wrap samples in plastic. Dry or slightly dampened newspaper is better.
- When collecting seedlings – dig them up rather than pull them out. Include some soil.
- Several sections of stem (10–15 cm long) are usually adequate for wilt diseases.
- Keep the sample cool and send as soon as possible.

Table 32. Fungicide trade names and marketers

Active ingredient	Concentration and formulation	Trade name	Marketed by
acibenzolar-s-methyl	500 g/L FC	Bion Plant Activator	Syngenta
azoxystrobin +	75 g/L SC	Dynasty	Syngenta
metalaxyl-m +	37.5 g/L SC		
fludioxonil	12.5 g/L SC		
mancozeb	750 g/kg WDG	Dithane Rainshield Neo Tec	Dow AgroSciences
	750 g/kg WDG	Mancozeb 750 WG	Ospray
	750 g/kg WDG	Manfil	Runge Agrichems
	750 g/kg DF	Innova Mancozeb 750	Syngenta
	750 g/kg DF	Mancozeb 750 DF	Sabero
	750 g/kg DF	Mancozeb 750 DF	Titan Ag
	750 g/kg DF	Manzate DF	Dupont
	750 g/kg DF	Penncozeb 750 DF	Arkema
	750 g/kg DF	Unizeb	United Phosphorus Limited
metalaxyl-m	350 g/L ES	ApronXL 350	Syngenta
quintozene	750 g/kg WP	Quintozene 750	Barmac
	750 g/kg WP	Terraclor Soil	Chemtura
	750 g/kg WDG	Chloroturf	Barmac
tolclofos-methyl	500 g/kg WP	Rizolex	Sumitomo Chemicals
	500 g/L SC	Rizolex liquid	Sumitomo Chemicals
	500 g/L SC	Tolex	Genfarm

Tracey Farrell, formerly Industry & Investment NSW.

Growth regulators

Excessive vegetative growth is a problem because it reduces the retention of fruit and delays maturity and results in reduced efficacy of insecticides due to poor penetration of the canopy. To determine if growth regulators are required see Cotton Seed Distributors' website (www.csd.net.au) to calculate vegetative growth rates.

Defoliation

The safe timing of defoliation is when the youngest boll expected to reach harvest is physiologically mature. This usually occurs when 60–65% of bolls are open. The other method of assessing physiological maturity is when there are 3–4 nodes of first position bolls above the highest cracked first position boll (last harvestable boll), known as nodes above cracked boll (NACB).

Registration of a chemical is not a recommendation from I&I NSW for the use of a specific chemical in a particular situation. Growers must satisfy themselves that the chemical they choose is the best one for the crop and situation. Growers and users must also carefully study the container label before using any chemical, so that specific instructions relating to the rate, timing, application and safety are noted. This publication is presented as a guide to assist growers in planning their agronomy programs.

If there is any omission from the list of chemicals, please notify the authors.

IMPORTANT— AVOID SPRAY DRIFT

Take every precaution to minimise the risk of causing or suffering spray drift damage by:

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions near property boundaries. Make it clear that you expect the same courtesy from them.
- Carefully following all label directions.
- Paying particular attention to wind speed and direction, air temperature and time of day before applying pesticides using buffer zones as a mechanism to reduce the impact of spray drift or overspray.
- Keeping records of chemical use and weather conditions at the time of spraying.

ABBREVIATIONS USED IN THE TABLES 33–36

AC	= Aqueous concentrate	SC	= Suspension concentrate
L	= Liquid	WDG	= Water dispersible granule
LC	= Liquid concentrate		

Table 33. Plant growth regulators

Active ingredient	Concentration and formulation	Application rate of product	Comments
Mepiquat	38 g/L AC	0.25–0.6 L/ha 0.25–1.0 L/ha	Pre flowering rate. Post flowering rate. Apply no more than 1.5 L/ha in total. See label for application times.
		0.75–2.0 L/ha	Single application rate. Use high rate where crop growth is excessive, between 1st flower and cut out. Check label.

Table 34. Plant growth regulators trade names and marketers

Active ingredient	Concentration and formulation	Trade name	Marketed by
Mepiquat	38 g/L AC	Adjust 38	Rotam
	38 g/L AC	Chemquat 38	ChemAg
	38 g/L AC	Mepiquat	Ospray
	38 g/L AC	Mepiquat 38	Accensi
	38 g/L AC	Mepiquat 38	eChem
	38 g/L AC	Mepiquat 38	Conquest
	38 g/L AC	Mepiquat 38	Genfarm
	38 g/L AC	Mepiquat 38	Kenso Agcare
	38 g/L AC	Mepiquat Chloride 38	Generex
	38 g/L AC	PiQme 38	United Phosphorus
	38 g/L AC	Pix	Nufarm
	38 g/L AC	Reign	Bayer CropScience
	38 g/L AC	Reward	Farmoz
	38 g/L AC	Roquat 38	Rotam

Table 35. Cotton defoliation products

Active ingredient	Concentration and formulation	Application rate of product	Comments
Cotton seed oil	860 g/L L	2 L/ha	Apply in combination with thidiazuron as specified on the label.
Diquat	200 g/ L AC	2.0–3.0 L/ha	See critical comments on label. May damage green bolls.
Ethephon	720 g/L AC	1.3 L/ha 2.0–3.0 L/ha	Pre-conditioning. Defoliation.
Ethephon + AMADS	275 g/L + 873 g/L AC	0.5–1.0 L/ha 1.3–2.6 L/ha 4 L/ha	Defoliation and accelerated boll opening. Defoliation. Boll opening.
Ethephon + cyclanilide	720 g/L + 90 g/L SC	0.33–0.67 L./ha 1.3–2.5 L/ha	Enhancement of defoliation. Must have minimum 30 L water/ha. Acceleration of boll opening and enhancement of defoliation.
Flumiclorac–pentyl	100 g/L	0.6–0.9 L/ha + 360 gai/ha ethephon 0.45 L/ha + 1440 gai/ ha ethephon	Defoliation, first application once natural senecence has commenced and 60% open bolls. Apply with 2.0 L/ha DC Tron Cotton Spray Oil. Apply 4–10 days later. Apply when canopy is suitably open to allow good penetration of ethephon.
Paraffinic oil	582 g/L L 598 g/L EC 792 g/L EC 815 g/L EC 830 g/L EC	0.5 L/100 L water 0.5 L/ha 0.5 L/ha 2 L/100 L 2 L/100 L	Compatible with thidiazuron and ethephon. Apply in combination with defoliants such as Dropp and Prep. Apply with Dropp Ultra® or Dropp® WP in accordance with their labels. Apply in combination with thidiazuron defoliant. Apply in combination with thidiazuron defoliant.
Paraquat + diquat	135 g/L + 115 g/L AC	1.2–1.6 L/ha	Apply to cotton in dryland situation only. OPM 0005 (NRA) Can damage immature green bolls.
Petroleum oil	839 g/L L 844 g/L 846 g/L EC 859 g/L L 861 g/L	2 L/ha 2 L/ha 2 L/ha 2 L/100 L water 2 L/ha	Apply in combination with thidiazuron as specified on the label. Apply with Dropp defoliant Apply with Dropp Ultra. Apply in combination with Dropp defoliant as apecified on the label. Apply with Dropp Ultra in accordance with the Drop Ultra label.
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	0.08 L/ha	Always apply as a tank mixture with ethephon (1–2 L/ha) and D-C-Tron (2 L/ha). Apply when the last harvestable boll is physiologically mature.
Sodium chlorate	300 g/L AC	11.0–22.0 L/ha	Apply when 60–65% bolls are open. Apply 2–3 weeks before anticipated picking dates. Apply when temperatures are high and soil moisture moderate.
Thidiazuron	490 g/kg WDG or 500 g/L SC	0.05–0.1 kg/ha 0.1–0.15 L/ha 0.15–0.2 L/ha	Ideal conditions. Good conditions. Average conditions. Do not apply under cold conditions. } plus 2.0 L/ha cotton spray oil
Thidiazuron + Diuron	120 g/L + 60 g/L SC	0.15–0.2 L/ha 0.2–0.25 L/ha 0.25–0.3 L/ha 0.3–0.4 L/ha	Ideal conditions. Good conditions. Average conditions. Cold conditions. } plus 2.0 L/ha cotton spray oil

Table 36. Defoliation products trade names and marketers

Defoliant	Concentration and formulation	Trade name	Marketed by
Cotton seed oil	860 g/L L	Intac Cotton Spray Oil	Nipro
Diquat	200 g/ L AC	Reglone	Syngenta
	200 g/L AC	Diquat 200	Chem Ag
	200 g/L AC	Sanction 200	Conquest
	200 g/L SC	Diquat 200	Kenso
Ethephon	720 g/L AC	Ethephon	eChem
	720 g/L AC	Ethephon 720	ChemAg
	720 g/L AC	Ethephon 720	Conquest
	720 g/L AC	Ethephon 720	Genfarm
	720 g/L AC	Ethephon 720	Ospray
	720 g/L AC	Ethephon 720	Runge
	720 g/L AC	Ethephon 720 SL	Tradelands
	720 g/L AC	Galleon	Nufarm
	720 g/L AC	Prep 720	Bayer CropScience
	720 g/L AC	Promote 720	Farmoz
Ethephon + AMADS	275 g/L + 873 g/L AC	CottonQuik	Dupont
Ethephon + cyclanilide	720 g/L + 90 g/L SC	Finish 720	Bayer CropScience
Flumiclorac–pentyl	100 g/L	Resource	Sumitomo
Paraffinic oil	582 g/L L	Uptake Spraying Oil	Dow AgroSciences
	598 g/L EC	Enhance Spray Adjuvant	Sacoa
	792 g/L SL	Canopy Insecticide	Caltex Australia
	815 g/L EC	Biopest Paraffin Oil	Sacoa
	815 g/L EC	Bioclear	Caltex
	830 g/L EC	Trump	Victorian Chemicals
Paraquat + diquat	135 g/L + 115 g/L AC	Revolver	Nufarm
	135 g/L + 115 g/L AC	Spray.Seed 250	Syngenta
	135 g/L + 115 g/L AC	Spraykill 250	Chem Ag
	135 g/L + 115 g/L AC	Sprayout 250	Ospray
	135 g/L + 115 g/L AC	Di–Par 250	Genfarm
	135 g/L + 115 g/L SC	Combik 250	Sinon Australia
	135 g/L + 115 g/L SC	Brown Out 250	4Farmers

Table 36. Defoliant trade names and marketers (continued)

Defoliant	Concentration and formulation	Trade name	Marketed by
Paraquat + diquat (continued)	135 g/L + 115 g/L SC	Di–Par 250	Genfarm
	135 g/L + 115 g/L SC	Alarm	Sipcam Pacific
	135 g/L + 115 g/L SC	EOS	Titan Ag
	135 g/L + 115 g/L SC	Paradym 250	Ronic Internationsl
	135 g/L + 115 g/L SC	Premier 250	Halley
	135 g/L + 115 g/L SC	Rygel Pre-Seed	Rygel
	135 g/L + 115 g/L SC	Scorcher 250	Conquest
	135 g/L + 115 g/L SC	Speedy 250	Kenso
	135 g/L + 115 g/L SC	Spray & Sow	Farmoz
	135 g/L + 115 g/L SC	Uni-Spray	United Phosphorus Limited
	135 g/L + 115 g/L SC	Wildfire	United Farmers
Petroleum oil	839 g/L L	D-C-Tron	Caltex
	844 g/L	Sacoa Summer	Sacoa
	846 g/L EC	Broadcoat	Caltex
	859 g/L L	Cottoil	Sacoa
	861 g/L	Empower	Innovative Chemical Services
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	ETee	Sipcam Pacific
Sodium chlorate	300 g/L AC	Total Ag Leafex	Total Ag
Thidiazuron	500 g/L SC	Dropp Liquid	Bayer CropScience
	500 g/L SC	Escalate 500	Farmoz
	500 g/L SC	Mace	Conquest
	500 g/L SC	Reveal Liquid	Nufarm
	500 g/L SC	Thidiazuron 500	Genfarm
	500 g/L SC	Thidiazuron 500 SC	eChem
	500 g/L SC	Thidiazuron 500 SC	Kenso Agcare
	500 g/L SC	Tradewyns Thidiazuron 500	Ospray
Thidiazuron + Diuron	120 g/L + 60 g/L SC	Do-away	Ospray
	120 g/L + 60 g/L SC	Dropp Ultra	Bayer CropScience
	120 g/L + 60 g/L SC	Escalate Ultra	Farmoz
	120 g/L + 60 g/L SC	Thi-Ultra	eChem
	240 g/L + 120 g/L SC	Dropp UltraMAX	Bayer CropScience

Best Practices for Aerial and Ground Spray Applications to Cotton

By Andrew Hewitt, Centre for Pesticide Application and Safety, University of Queensland; James Hill, NSW Industry and Investment; Tracey Farrell, CRDC; and Bill Gordon, Bill Gordon Consulting Pty ltd.

Acheiving maximum efficacy from dollars invested in products to control weeds and insects in cotton requires the careful consideration of many factors. The aim of spray application is to transfer the active ingredient of the product through the atmosphere to the target in an effective manner with minimal off-target losses. To do this the application process needs to be matched to the local target and weather conditions. Movement of spray beyond the target area is undesirable. It represents wastage of product and exposure of non-target sensitive areas to potentially damaging materials.

This chapter provides guidance on factors to be considered in optimizing the spray application process. It should be noted that new technologies and information are continually becoming available, so this is meant as a summary guide only. Readers should consult additional information where available.

Plan ahead

The development of a comprehensive pesticide application management plan (PAMP) is an important part of the Best Management Practice (BMP) program in cotton. The PAMP for farming enterprises should be completed prior to the season and should cover;

- Farm layout
- Identification of sensitive areas, potential hazards and awareness zones
- Communications procedures
- Pesticide Management Guidelines
- Accident and emergency procedures.

Having a PAMP in place helps to ensure that everyone involved in pesticide application has a clear understanding of their responsibilities.

MEET LEGAL OBLIGATIONS

Always read and follow the label when handling and applying chemicals and be aware of federal and state regulations pertaining chemical application. Staff responsible for handling and applying pesticides must be qualified according to state and federal requirements for the handling and application of chemicals. Keep records of chemical storage and applications including conditions during and following the application. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or not made in this publication.

New approaches to chemical labels

The APVMA is applying a spray drift risk assessment to all new registered products, and progressively to those existing products that have been subject to review. To access or download the APVMA document that explains this approach, check the APVMA website; apvma.gov.au

NOTIFY NEIGHBOURS OF SENSITIVE AREAS AND SPRAY INTENSIONS

Prior to spray application and product selection, check the proximity of susceptible crops and sensitive areas such as houses, schools, waterways and riverbanks. It is good practice to notify neighbours of your spray intentions, regardless of label requirements. By doing this, sensitive crops or areas that you may be aware of can be accounted for.

To assist in communicating with neighbours the location of cotton fields, a mapping tool is now available for all cotton growing districts. Maps can be found at www.cottonmap.com.au

Add your own cotton fields to your district map as soon as planting decisions are made. This gives others in your region the best chance of identifying the surrounding sensitive crops to be considered when planning spray applications. Share the maps with your neighbours.

Open communications with neighbours is critical due to herbicide tolerant cottons. Herbicide drift onto fields of non-tolerant cotton can result in serious yield losses.

No spray zones

Some pesticide product labels may refer to a mandatory no spray zone. This is the downwind distance between the sprayed area and the property boundary or a sensitive area. The no spray zone CANNOT BE SPRAYED when the wind is towards the sensitive area (which may be a residence, water body, pasture, native vegetation or another susceptible crop).

Always check the label to see of a no spray zone is required, and how wide the no spray zone has to be for the product you wish to apply.

Keep accurate records

It is always best practice to maintain accurate spray records.

Under the Records Regulations of the NSW Pesticides Act, when spraying you must record the weather and relevant spray details. An example form is presented on page 69 of this book in the Chemical Use section.

It is always best practice to maintain accurate records of every spray application made on your property. These records provide a valuable management tool for comparing spray applications and identifying factors that may have contributed when an application does not perform as well as expected. Accurate records can also assist in identifying issues such as the onset of resistance and sensitivity of the target to particular products or tank mixes.

Spray log books

Spray log books can be purchased from DEEDI for $6.60 each plus postage and handling.

In Toowoomba – contact Natalie Fletcher 07 4688 1460 or Rebecca Simmons 07 4688 1360.
In Dalby – phone 07 4669 0800.

Spray log books are also available from I&I NSW, Yanco for $12.00 each plus postage and handling.

Phone 1800 138 351.

ENHANCE VEGETATIVE BUFFERS

Vegetative buffers tend to be more effective than bare ground in intercepting spray that moves off target during spray application. Good buffers can reduce drift by as much as 60 to 90 percent.

Farm planning should consider where the protection of sensitive areas can be improved by enhancing vegetative buffers. Effective buffers are comprised of a mixture of tree and shrub species with foliage all the way to the ground. The planting arrangement and density allows for air to partly flow through the barrier. Barriers without airflow act like impermeable walls. The wind containing the spray drift is deflected up and over the top of the barrier which increases the effective release height and increases the far-field drift potential. Do not position barriers where airflow will be obstructed by adjacent objects such as turkey's nests.

The optimum height for a buffer is 1.5 times the release height of the spray. Trees and shrubs are able to act as an effective barrier for ground applied sprays from early in their development. Most guidelines suggest that the optimum width of the barrier is 20 m with a 10 m maintenance strip on either side.

BE ABLE TO MONITOR WEATHER CONDITIONS

Since sprays are released into the atmosphere, weather conditions at the time of application will have an effect on spray transport and deposition. Monitor weather conditions regularly during spray applications (this means at least every 20–30 minutes).

Handheld equipment is one option for monitoring weather conditions before and during spray applications.
Photo: Graham Betts

Every grower should use an electronic weather meter to measure meteorological data at the site of application. This can be done with handheld equipment (e.g. Kestrel 3000, 3500, 4000 etc). Alternatively there are on board weather stations available utilising GPS input to provide weather information and logging whilst spraying (such as the Topcon or Watchdog systems).

Growers can also subscribe to websites that provide forecasts of conditions for spraying up to 10 days in advance. These sites evaluate all of the following factors to produce tables indicating times that would be suitable for spraying. You can access the websites at either Spraywisedecisions.com.au or Syngenta.com.au for more information.

MAINTAIN SPRAY EQUIPMENT

Calibrate spray equipment

- The output of each nozzle should be checked pre-season and regularly during the season. Nozzles that vary more than 10% from the manufacturer's specifications should be replaced.
- Regularly check wheel sensors and flow meters for accuracy.
- Check pressure across the boom for evenness.
- Cross check total spray volumes used against sprayed areas on your GPS logs to monitor whether application accuracy may have changed since your last calibration.

Decontaminate spray equipment

Application equipment that has been used to apply herbicides should be thoroughly decontaminated before being used to apply any product to a susceptible crop. Strictly follow the method of decontamination recommended on the label. No matter how much time is spent decontaminating the equipment there is always a risk of herbicides residues causing a problem.

UNDERSTAND THE INFLUENCE OF WEATHER CONDITIONS

Wind Speed

Wind speed affects the distance that a droplet will travel before deposition, impaction or evaporation. Wind speeds of 3–15 km /h are recommended (8–10 km /h are ideal) for spraying with a ground rig.

Higher wind speeds usually pose greater risk that product will evaporate quicker or be blown off target. At wind speeds of 11–15 km /h, use low drift nozzles or higher application volumes. Avoid spraying when wind speeds exceed 4.5 m /s or 16 km /h.

Scandinavian studies have suggested that an increase in wind speed from ~5 km /h to ~16 km /h at an air temperature of 10°C will require a 25% increase in buffer zone size for herbicide applications.

Mandatory wind speed range

Some pesticide labels already have a mandatory wind speed range, such as those on products containing 2,4-D, which state… 'wind speeds must be above 3 km /h and less than 15 km /h as measured at the site of application.'

This approach will be applied to all new labels, with the wind speed range varying depending on the level of risk associated with each product, and the method of application. In many cases the wind speed range will also be linked to the size of a no spray zone.

Temperature and humidity

Water-based sprays should not be applied under conditions of high temperature and low relative humidity (RH). Spraying should occur when the delta T (the difference between the wet bulb and dry bulb) is more than 2 and less than 10°C. For example, spraying can be carried out if the temperature is;

- 20°C and RH ≥24%
- 25°C and RH ≥33%
- 30°C and RH ≥40%
- 35°C and RH ≥45%.

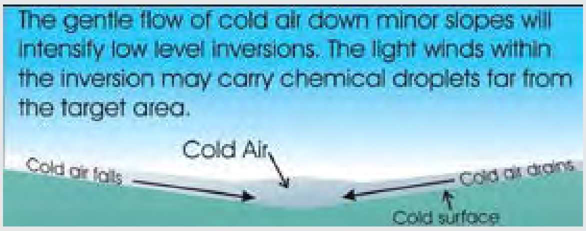
Higher ambient air temperatures and lower relative humidity conditions increase evaporation rates. Since droplet size of water-based sprays decreases rapidly with higher evaporation rates, drift tends to increase. Studies have shown that an increase in air temperature from 10°C to 20°C may require an increase of a few percent to over 100% in buffer zone size, depending on the accompanying wind speed.

When using coarse sprays at high water volume rates, evaporation may be lower, allowing application to continue in marginal delta T conditions.

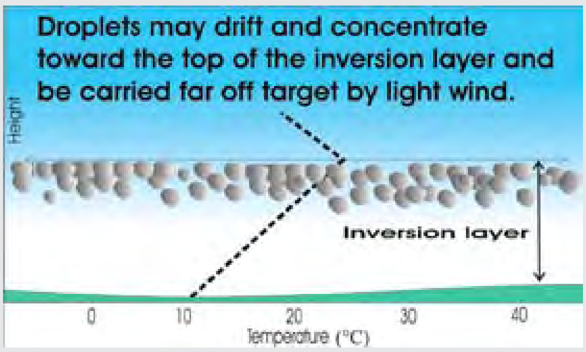
High humidity increases the drift hazard under inversion conditions – the more humid the air, the longer the life of small droplets (less than

What is an inversion layer?

An inversion exists when temperature increases with altitude instead of decreasing.



Inversions are the most hazardous atmospheric conditions for spray applications. **Do not spray in inversion conditions.**



Inversions usually occur on clear, calm nights and persist into the morning, until sufficient wind causes the air to mix, breaking the inversion layer.

100 microns). When spraying occurs in inversion conditions, droplets suspended within the inversion layer tend to travel parallel to the ground. The cool air drains to the lowest point in the landscape, carrying with it chemical that remains suspended.

Windy or turbulent conditions prevent inversion formation. Smoke generators can be used to detect inversion conditions. Under an inversion smoke will not continue to rise, but will drift along at a constant height under the inversion 'blanket'. **Do not spray in inversion conditions.**

Thermals are updrafts during the heat of the day cause rapidly shifting wind directions. Also avoid spraying in these conditions.

WIND SPEED AT NIGHT AND INVERSIONS

Still conditions or very light and variable winds greatly increase the risk of spray movement away from the target and so should be avoided for spray applications. Such conditions may indicate local surface inversion layers. Spray Drift that occurs under these conditions may travel long distances, often damaging large areas, with very uniform symptoms.

Figure 15. Effect of atmospheric stability on the dispersion of sprays in the atmosphere. Source: Bureau of Meteorology.

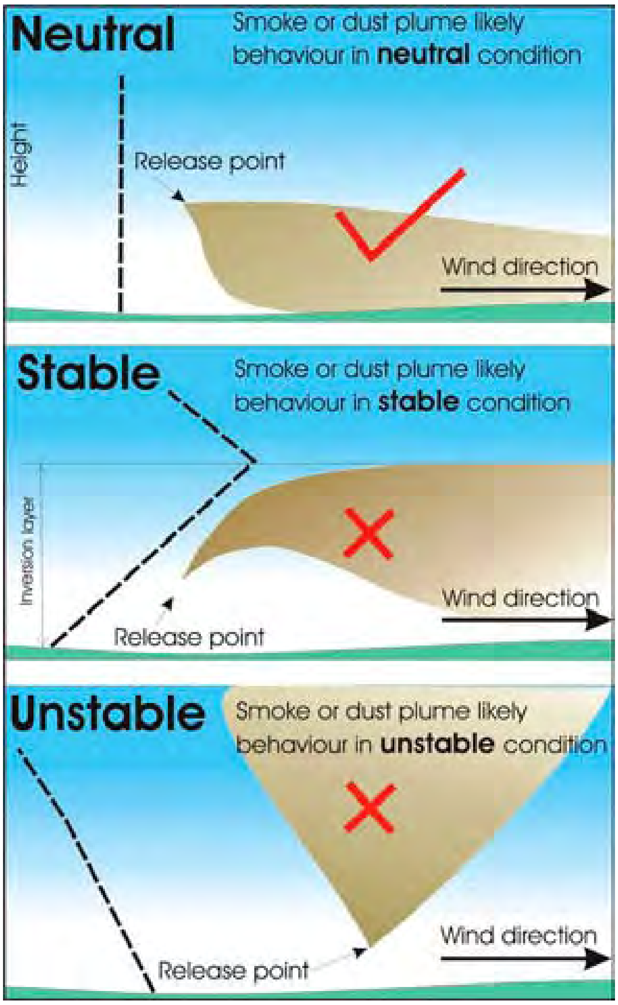


Figure 15 below shows the effect of atmospheric stability on the dispersion of sprays in the atmosphere. The behaviour of smoke or dust under various stability conditions may assist with selection of the preferred spraying conditions. Neutral atmospheric stability conditions (e.g. morning with a light cool breeze) are best for most applications.

Equipment to maximise efficacy

SET THE SPRAY RELEASE HEIGHT

The amount of chemical left in the air may double as nozzle height increases from 50 cm to 70 cm above the target or by a factor of 10 times as nozzle height increases from 50 cm to 1 m above the target. It is important to set the height of the boom at the minimum practical height to achieve the correct spray pattern for the nozzles.

Vertical movement of the spray boom should be minimised. Limit vertical movement by tuning the boom suspension and matching travel speed to release height. Alternatively consider fitting auto boom height.

Auto boom height devices use ultrasonic sensors to detect the height of the boom above the target. These adjust the boom hydraulically to maintain the nozzles at a constant height above the target. Generally these systems will require a machine with good hydraulic capacity. These systems allow the machine to maintain boom height at travel speeds up to 28 km /h.

FACTOR IN RISKS ASSOCIATED WITH TRAVEL SPEED

While the capacity of ground spraying equipment has improved significantly in recent years allowing more spraying to be carried out per unit of time, air velocity still has the same affect on the deposition of droplets onto the target. Increased operating speeds can cause spray to be diverted back into upward wind currents and vortexes behind the spray boom. Special care should be taken when using high speed, high clearance sprayers and some 'floaters' whose tires may become more like fans when driven at high speeds. Small droplets can become trapped in these air patterns and contribute to loss of product away from the target. Speeds above 15 km /h have been shown to increase the risk of drift for boom spraying and speeds above 10 km/h increase the risk from shielded sprayers.

OPERATE IN THE RECOMMENDED PRESSURE RANGE

Only ever operate nozzles within the pressure range recommended by the manufacturer. Higher or lower than recommended pressures changes the droplet spectrum and the spray pattern, affecting both the risk of drift and the efficacy of the spray application.

Be aware that many air induction nozzles will require slightly more pressure than the minimum indicated on the manufacturers spray chart. Always assess the spray pattern at various pressures, to determine an appropriate minimum operating pressure.

Where automatic rate controllers are fitted to the machine, carefully consider the true range of speeds the machine is likely to operate, from the slowest field to the fastest field. Identify what the pressure at the nozzle will be at your lowest speed and your fastest speed and identify a nozzle that will produce the required spray quality across that range of speeds.

Operating at recommended pressures can also minimise wear and tear on nozzles.

MATCH THE WATER VOLUME TO THE PRODUCT AND USE PATTERN

Always follow label recommendations for application water volumes. Typically in-crop applications to cotton will require application volumes of 100 L/sprayed hectare or more.
For fallow spraying with translocated herbicides (such as glyphosate and the phenoxys) equivalent efficacy has been shown for medium, coarse and even extremely coarse spray qualities at 50 L /ha.
For products with minimal translocation, such as Spray.Seed®, equivalent efficacy has been shown for medium, coarse and even extremely coarse spray qualities at 70 L /ha and greater.

When using coarser than a medium spray quality for translocated products, increasing water rate does not necessarily increase efficacy, and in some situations may actually reduce performance in the field. When a marginal rate of product is used, when water quality may be marginal or where diluting the adjuvants included in the product, higher water rates can reduce the performance of translocated products.

Describing nozzle size spectrums

Spray nozzles produce a range of droplet sizes called the droplet size spectrum. Nozzle manufacturers now use internationally recognised classifications for droplet size spectrums for nozzles. These are Very fine, Fine, Medium, Coarse, Very coarse and Extremely coarse. This classification system aims to provide an all-purpose description of the droplet size spectrum produced by the nozzle.

SELECT NOZZLES THAT ARE SUITED TO THE SPRAY SITUATION

For most farming enterprises it will not be possible to optimise the application of all pesticides to all crop and fallow situations using the same set of nozzles.

The droplet size spectrum from the nozzle influences the time it takes droplets to land on the target. Small droplets do not have as much mass to sustain their direction toward the target, so are more readily carried by horizontal and vertical winds, or in the vortices associated with sprayer wakes.

An increasing number of nozzle designs are available on the market that are specifically designed to produce less fine droplets and more droplets in the Medium and Coarse spectrums. They should be evaluated as part of your enterprise's BMP process and fitted if they are cost effective and result in better spraying.

Achieving coarse spray quality

Increasingly pesticide labels will state the specific spray quality (e.g. coarse) required for product application. Achieving compliance with the label with regards to spray quality is a function of nozzle selection and operating pressure.

Mandatory spray qualities

Some pesticide labels already have a mandatory spray qualities, such as those on products containing 2,4-D, which state… 'spray quality must not be smaller than a coarse to very coarse spray quality according to the ASAE Standard S-572'.

All new labels are likely to have a requirement for either a medium spray quality or a coarse to very coarse spray quality. This will be linked to a wind speed range and other measures for mitigating spray drift risk.

The spray quality produced by a particular nozzle can be manipulated by changing the operating pressure. For example, if a coarse spray quality is required when Turbo TeeJet® TT11002 nozzles are being used, reducing the operating pressure from ~4 bar to ~2 bar would change the droplet spectrum of the nozzle from medium to coarse and enable compliance with the label. However this strategy has implications for the application volume per hectare and operating speed, particularly if an automatic rate controller is being used. In the above example, if 50 L /ha was the desired output, at 4 bar the travel speed would be 22 km /h, while at 2 bar travel speed needs to be reduced to ~15.5 km /h to still be applying 50 L /ha. If an automatic rate controller is being used in the sprayer then variation in the travel speed, from ~15.5 km/h to 18 km/h during the operation would change the droplet spectrum back to medium. Where automatic rate controllers are being used, it is best to select a nozzle that produces coarse and very coarse spectrums over a range of operating pressures so that as the sprayer slows down to turn around or increases speed along straight runs, droplets are consistently being produced within the intended spectrum.

High pressure air induction nozzles such as AI Teejets, Hardi Injets and Agrotop Turbodrop TDs are types of nozzles that can produce coarse to very coarse droplet spectrums over wide range of pressures. Not all spray equipment however, has the capacity to consistently run at the high pressures required for these nozzle types. Most centrifugal pumps will struggle to operate consistently in the 5–8 bar range. Nozzles should only ever be operated within the manufacturer's recommended pressure range. When nozzles are operated at pressures below the recommended range, the fan angle may collapse and air flow into air induction nozzles is likely to be poor, leading to reduced pesticide efficacy and possible nozzle blockages.

'02' nozzles that will produce a coarse droplet spectrum over a range of operating pressures to achieve a spray output of 50 L/ha.

Nozzles		Operating Pressure (bar)						
		2.0	2.5	3.0	3.5	4.0	4.5	5.0
Type	Description	Travel Speed (km/h)						
		15		19		22		27
Hardi ISO Minidrift	Minidrift 02	C	C	C	C	C	C	C
Agrotop Airmix	TDAM11002	VC	C	C	C	C/M	M	M

Source: Nufarm 2008.

For a given nozzle, there are significant differences in the droplet spectrum data provided by Nufarm and some nozzle manufacturers. Nufarm data was generated in an independent wind tunnel facility in the UK in accordance with the ASAE S572 standard required by the APVMA, so can be used to make nozzle selection decisions.

Several nozzle types able to produce coarse and very coarse spectrums over a wide range of relatively low pressures include; AIC Teejet, Teejet AIXR, Hardi ISO Minidrifts and Agrotop AirMix® nozzles. If a desired spray volume of 50 L /ha for fallow weed control is required, then an '02' or '025' nozzle is the nozzle most likely to provide a coarse to very coarse droplet spectrum over a range of travel speeds and relatively low pressures. Examples of two nozzles are provided in the table below. If a different spray output (L /ha) is desired, then the required operating pressures and travel speeds need to be adjusted so as to produce coarse or very coarse droplets.

Consider specialised nozzle technologies

When ground spraying adjacent to sensitive areas, application to the crop can be improved by using off-center nozzles at the ends of spray booms. These emit the spray toward the crop only, i.e. pointing inwards as a half-plume only. This can avoid application beyond the edge of the field.

Controlled Droplet Application (CDA) and some ground spraying rotary atomizers can be used to reduce the range of droplet sizes in a spray. If used properly, such equipment can reduce the proportion of the spray contained in driftable small droplets.

Sometimes a trade-off will exist in choosing the nozzle option with the lowest drift potential. Wide angle (110°) flat fan nozzles will produce more fine droplets than those with a narrower angle (80°), but have the advantage of allowing the boom to be set at a lower height above the target. Optimum spray height is 75 cm above the target for 80° spray tips and 50 cm above the target for 110° spray tips for standard 50 cm nozzle spacings.

Interpreting information about spray nozzles

Nozzle manufacturers provide information on the droplet size spectrum performance of nozzles and atomizers under specific operating conditions. Most nozzle catalogues only provide such

Influence of droplet spectrum on time to deposition and distance travelled in a typical aerial application with a release height of 3 m.

Droplet spectrum category*	$Dv_{0.5}$ at emission (µm)	Time to deposition (s)	Distance travelled (m)	$Dv_{0.5}$ at deposition (µm)
Very Fine	100	25	80	30
Fine	200	5	20	185
Medium	300	3	12	295
Coarse	400	2	10	395
Very Coarse	500	2	7	496
Extremely Coarse	600	2	6	597

* Droplet size classifications are based on British Crop Protection Council specifications and are in accordance with the American Society of Agricultural Engineers (ASAE S-572)

information for applications of water underground spraying conditions. Real tank mixes may produce different spectrums than those suggested in nozzle catalogues. Tank mixes with lower surface tension and viscosity than water will tend to favour greater production of smaller droplets.

In aerial applications sprays tend to be much finer than the ground-based nozzle catalogue data would suggest. This is primarily due to air shear. Models are available for some nozzles and atomizers to indicate the droplet size classification under aerial conditions. A comprehensive set of such models and tables of droplet size information are available from the United States Dept. of Agriculture at http://apmru.usda.gov/downloads/downloads.htm and, for aerially-applied 2,4-D sprays, from wind tunnel droplet size research from www.aerialag.com.au

The table on previous page shows an example of the distance that water droplets from each of the droplet size spectrums would travel prior to deposition following release from a 3 m height in a typical aerial application. The example was generated using the AgDRIFT® model.

ADDITIONAL CONSIDERATIONS FOR AERIAL APPLICATIONS

Boom Length

The forces that provide lift and flight of aircraft also produce wake and vortex effects of the air into which spray droplets are released. If droplets become entrained in these airflows, their trajectory and path can change. To minimise this effect, boom length should not exceed 65 to 75% of the wingspan.

The strength of vortices tends to increase when a slower flight speed or greater weight is used and when the lift increases, for example when the aircraft climbs at the end of a flight line. Therefore, spray should not be applied when the aircraft is climbing, but only when the aircraft is level over the target. Also, if helicopters are flown very slowly, the airflow behaviour can cause droplets to be carried up by the rotor vortices, with an increase in spray drift potential.

Air Shear

The production of small droplets that may be more prone to drift can be reduced by minimizing air shear at the nozzle tip where the liquid meets the airblast from the aircraft motion. Reducing flight speed (e.g. using slower helicopters rather than higher speed fixed wing aircraft) can reduce this shear, but may affect productivity rates and optimal operation. Reducing the nozzle angle is an effective way to reduce air shear. In the case of deflector nozzles, the nozzle angle and the deflector angle can be reduced to provide minimal air shear conditions. The lowest air shear occurs for nozzle angles which are 0° straight back.

Pressure

The relative velocity of the air and liquid is important in affecting droplet size. For most nozzles, lower liquid pressure produces coarser sprays, within the optimal operating range for the nozzle. However, with very narrow angle sprays such as those from solid stream and narrow angle flat fan nozzles, higher pressure generally produces coarser sprays. Consult nozzle manufacturer information for specific recommendations on pressure range settings for optimal droplet size and application criteria.

Rotary Atomizers

Some rotary atomizer manufacturers provide models for predicting droplet size with their equipment based on operational parameters such as rotation rate, flight speed and liquid flow rate for specific product types.

Coarser droplets can be produced by increasing the drag on the atomiser to lower the rotation rate. Using windmill blade-driven atomizers allow selection of rotation rate through changing the blade angle. Droplet size also tends to increase with higher flow rates. There may be a change in the mode of atomization from direct droplet through ligament and sheet breakup as flow rate increases, each of which tend to produce progressively coarser sprays.

Special Aerial Equipment

Some spray equipment allows in-flight optimization of application conditions. For example,

- booms can sometimes be lowered after take-off, allowing spray release height to be reduced with lower drift potential;
- chambers are being developed for reversing the venturi effect where the nozzle can be positioned in a relatively lower airstream velocity reducing the number of small droplets;
- wing tip modification devices can reduce vortices and modify wake effects to prevent spray from drifting, but under some circumstances could also affect aircraft handling and airframe lifetimes;
- electrostatic spraying systems may help with droplet wrap-around onto lower leaf surfaces, but drift reduction will ultimately depend more

on droplet size than forces such as electrostatic charge. 'Spray Drift Management Principles, Strategies and Supporting Information'.

PRODUCT TYPE

The selection of product may affect the tank mix physical properties, which can affect droplet size and likelihood of off-target losses.

The impact of a given amount of drift off-target will depend on the product's toxicity to what is present in the affected areas. Alternative pest control methods (e.g. cultural, mechanical, biological) may allow pesticides to be avoided or used at lower rates in conjunction with other methods. Where chemicals are used, preference should be given to products which offer the lowest effects on non-target organisms and the environment. To compare the relative toxicities of insecticides to non-target insect species such as beneficials and bees, refer to Table 3, page 40.

(HL5) Herbicides with volatile active ingredients

If using volatile herbicide products, special care must be taken to avoid vapour drift issues. Vapours may arise directly from the spray or from the target surface after the spray has been deposited. Volatilisation from the target surface can occur hours or days after the herbicide is applied. The risk of vapour drift can be avoided by choosing active ingredients with low volatility. The ester forms of 2,4-D and MCPA have high volatility while the amine and salt forms have low volatility. However the propensity for a product to volatilise is influenced by temperature. High ground temperatures in summer can increase the risk of volatilisation. Additionally, active ingredients with low volatility are still susceptible to droplet and particle drift. Some examples of vapour drift risk from some different products are shown in the table on this page.

Specific Testing and Calibration

Sprayers should be operated according to the manufacturer instructions and be calibrated for proper performance. Sprays should be observed for correct appearance and uniformity of coverage.

Nozzles need to be checked regularly for possible wear or leaks. Nozzles that vary more than 10% from the manufacturer's specifications should be replaced. Replacement of warn nozzles prevents undue wastage of chemical and prevents changes in the spray discharge patterns and droplet size spectra that could reduce efficacy or increase the risk of drift.

RELATIVE HERBICIDE VOLATILITY

Active Ingredient	Product Example
HIGH VOLATILITY*	
2,4-D ethyl ester	Estercide® 800
2,4-D isobutyl ester	2,4-D Ester® 800
2,4-D n-butyl ester	AF Rubber Vine Spray®
SOME VOLATILITY	
MCPA ethylhexyl ester	LVE MCPA
MCPA isooctyl ester	LVE MCPA
2,4-D isooctyl ester	Low Volatile Ester 400
triclopyr butoxylethyl ester	Garlon® 600
picloram isooctyl ester	Access®
LOW VOLATILITY	
MCPA dimethyl amine salt	MCPA 500
2,4-D dimethyl amine salt	2,4-D Amine 500
2,4-D diethanolamine salt	2,4-D Low Odour 500
2,4-D isopropylamine salt	Surpass® 300
2,4-D triisopropylamine	Tordon® 75-D
2,4-DB dimethyl amine salt	Buttress®
dicamba dimethyl amine salt	Banvel® 200
triclopyr triethylamine salt	Tordon® Timber Control
picloram triisopropylamine	Tordon® 75-D
picloram triethylamine salt	Tordon® Granules

From Mark Scott, Agricultural Chemicals Officer, Industry & Investment NSW.

* The APVMA has taken the decision to continue to suspend the registration of products containing high volatile ester forms of 2,4-D, namely the ethyl, butyl and isobutyl esters. Refer to page 108 for more information.

Types of drift

Sprayed pesticides can drift as droplets and particles or as vapours.

Droplet and particle drift

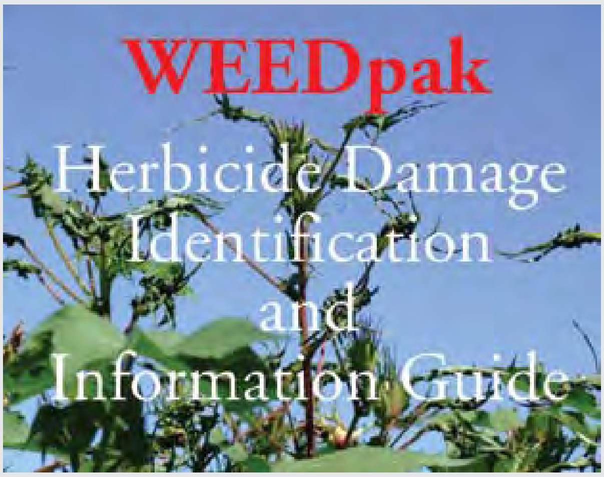
Droplet and particle drift is the most common cause of off-target damage from pesticides. It is particularly obvious where herbicides drift onto susceptible crops.

It occurs when any form of pesticide is applied in unsuitable weather conditions and/or with inappropriate application parameters. Water in the spray droplets evaporates resulting in finer droplets and particles of herbicide. As the size of the droplet declines, so too does their rate of fall towards the ground. Smaller droplets remain airborne longer and hence are susceptible to further evaporation and drift away from the intended target. Herbicide particle drift damage to susceptible crops has been reported up to 30 km from the spray source.

Droplet and particle drift is the easiest form of drift to prevent. Under good spraying conditions, droplets are carried down by air turbulence and gravity to collect on the intended plant surfaces.

Vapour drift

Vapour drift is the movement of volatile components of herbicides in air currents during or after application. Volatility refers to the likelihood that the herbicide will turn into a gas. Vapours may arise directly from spray or from the target surface after droplet deposition. Volatilisation from the target surface can occur hours or days after application. The risk of vapour drift can be avoided by choosing active ingredients with low volatility. The ester forms of 2,4-D and MCPA have high volatility, while the amine and salt forms have low volatility. Actives with low volatility are still susceptible to droplet and particle drift. Some examples of vapour drift risk from some different products are shown in the table in above.



When herbicide drift occurs, sensitive crops may be up to 10,000 times more sensitive to the herbicide than the crop being sprayed. For information about the impact of herbicide damage on subsequent growth and yield of cotton, visit the Cotton CRC web site. Herbicide damage images have been generated by applying a known rate of herbicide over-the-top of cotton at a given growth stage and recording the impact of the herbicide on the crop grow.

www.cottoncrc.org.au/content/Industry/Publications/Weeds/Herbicide_Damage_Identification_and_Information.aspx

Where possible, validate the chosen spray setup in field conditions. Field testing can verify the on-target performance as well as recognise where off-target losses are ocurring. A good technique available to farming groups or individuals is the use of water or oil sensitive papers. These can be placed in and beyond the spray swath and analyzed using camera/ scanner/ image analysis and software packages such as Stainalysis.

CONSIDER THE INFLUENCE OF ADJUVANTS ON DROPLET SIZE

More can be done to manipulate droplet size with nozzle selection, than with the addition of an adjuvant.

Some adjuvants can increase droplet size, but care should be taken in assuring that there is a decrease in small driftable droplets with diameter below 100–200 µm, and not just an increase in the average or volume median diameter of the spray.

When considering adjuvants, compatibility with the tank mix and spraying system should also be considered, since some adjuvants do not perform as well with some combinations of other factors. For example, many polymers cause a decrease in spray angle from cone nozzles which may adversely affect spray formation and coverage. Emulsion-based adjuvants often perform better for reduction in small droplets than solution-based adjuvants for the same surface tension. However, actual performance is specific to the conditions.

MONITOR TANK MIX TEMPERATURE

Recent research has shown that the temperature of the tank mix relative to the air may have an effect on the droplet size spectrum produced at atomization. Often a temperature difference where the liquid is greater than 6°C warmer than the ambient air can reduce the small droplet proportion of the spray.

FURTHER INFORMATION

'Spray Drift Management Principles, Strategies and Supporting Information', www.publish.csiro.au/pid/3452.htm

SPRAYpak – Cotton Growers' Spray Application Handbook, 2nd Edition, available from CRDC.

Spraywise – Broadacre Application Guide – Available through Croplands Distributors.

The spray drift model 'AgDRIFT', is available for free download from www.agdrift.com. Fact sheets on droplet size classification, and drift management in aerial and ground applications are also available at this website.

For more information about using vegetative barriers in spray drift management, see the *Queensland guidelines: Anon (1997) Planning Guidelines: Separating Agricultural and Residential Land Uses. Dept of Natural Resources, Queensland and Dept of Local Government and Planning, Queensland. DNRQ 97088.* Available for free download at www.nrm.qld.gov.au/land/planning/pdf/public/plan_guide.pdf

Comprehensive information about droplet spectrums of nozzles under aerial application conditions is available from the United States Dept. of Agriculture at http://apmru.usda.gov/downloads/downloads.htm. For aerially-applied 2,4-D sprays, from wind tunnel research, see www.aerialag.com.au

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