Cotton Pest Management Guide 2015–16

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The Australian cotton industry's CottonInfo Team

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MONSANTO

MORE OPPORTUNITY TO PLANT BOLLGARD II® WITH THE PLANTING WINDOW PERMIT FOR 2015/16

The Bollgard II Planting Window permit (PER14808) approved by the APVMA for the 2014/15 season, extending the planting window across valleys in New South Wales and Queensland, is still valid for the 2015/16 season:

Region	**Overview of Permit Window**	**Resistance management strategies**
NSW and Southern QLD (including Darling Downs)	All Bollgard II must be planted by November 30 – an additional 15 days after the Resistance Management Plan (RMP) window close.	Bollgard II planted within the permit period (November 15–30) must be destroyed within 30 days of completion of harvest.
Central Queensland	An additional two weeks to be allocated adjacent to the current RMP window, at the discretion of the CGA (can be prior or following the current window or 1 week prior and 1 week after current window).	• Bollgard II planted within the permit period must be destroyed within 30 days of completion of harvest. • Bollgard II planted later than the current RMP window will require an additional 1% refuge area.

In order to take advantage of this permit, the RMP prescribed planting window cannot be varied. In the event that a variation notice is submitted and approved, this permit will no longer apply to the valley in question.

If you have any concerns or questions regarding Planting Windows or the RMP, please do not hesitate to contact your Regional Business Manager.

Roundup Ready FLEX COTTON

Bollgard II®

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Foreword

Susan Maas, Sally Ceeney, Ruth Redfern, CottonInfo

Welcome to the 2015-16 Cotton Pest Management Guide.

This Guide provides you with a comprehensive summary of the key cotton crop protection issues, and is brought to you by the Australian cotton industry's joint extension program, CottonInfo.

CottonInfo is an initiative of the Cotton Research and Development Corporation (CRDC), Cotton Australia and Cotton Seed Distributors Ltd, designed to connect you (our cotton growers and consultants), with research and provide you with information, when and where you need it.

CottonInfo integrates closely with the industry's best management practice program, *my*BMP, which sets the industry's best practice performance criteria and provides a framework by which growers can participate in, and be accredited in, best practice.

We hope you find this year's Cotton Pest Management Guide a valuable and informative reference. Remember, the CottonInfo team of regional development officers, technical specialists and *my*BMP experts are standing by to assist you with all your cotton information needs (you can find our contact details on the inside of the back cover).

You can also find information from the CottonInfo team online at our new website (www.cottoninfo.net.au), while best practice information for your farm is available at the *my*BMP website (www.myBMP.com.au).

In addition, the sister publication to the Cotton Pest Management Guide, the 2015 Australian Cotton Production Manual, contains additional information on spray application and integrated pest, weed and disease management and is available to download from the CottonInfo and CRDC websites (www.cottoninfo.com.au/publications or www.crdc.com.au/publications).

On behalf of CottonInfo, thank you to the team of authors, reviewers and contributors from across the cotton research community and the wider industry for their invaluable assistance with this publication.

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COVER PHOTOS: Melanie Jenson.

Key insects and mite pests of Australian cotton

Tracey Leven, Susan Maas, CRDC
Robert Mensah, NSW DPI
Moazzem Khan, Richard Sequeria, QLD DAF
Lewis Wilson, Sandra Williams, CSIRO

This chapter is presented as a guide to assist growers in planning their Integrated Pest Management (IPM) programs. 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
- Resistance status
- Overwintering habits
- Alternative hosts

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 has 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 the pests and beneficials present 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 and beneficial abundance and crop 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. Understanding how pests can survive, including knowing their resistance status and risks, overwintering habit and alternative hosts can help with good decision making for the long term.

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

Registration of a pesticide is not a recommendation 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.

Growers must also ensure that their insecticide program fits in with the Insecticide Resistance Management Strategy (see pages 57–64). Insecticides can be a costly part of cotton production. Ensure that industry thresholds (pages 40–41) are followed to prevent unnecessary spraying.

Important – avoid spray drift

For legal requirements and best practice information on reducing spray drift, refer to the Spray Application chapter page 134. Carefully follow all label directions.

ABBREVIATIONS USED IN TABLES 1–18

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

INSECT PEST	MANAGEMENT AND REGISTERED CHEMICALS
Helicoverpa spp.	Page 10
Aphids	Page 14
Plague locusts	Page 19
Mirids	Page19
Spider mites	Page 22
Whitefly	Page 27
Thrips	Page 31
Green vegetable bugs	Page 32
Pale cotton stainers	Page 34
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IMPORTANT – Use an integrated approach to pest management. For more information on Integrated Pest Management Guidelines for Australian cotton refer to Page 47.

TABLE 1: Seasonal activity plan for IPM

	Overwinter/Planning	Planting – first flower	Flower – first open boll	Open cotton – Harvest
Develop an IPM strategy	Review last season's IPM approach. Communicate IPM goals and chemical handling application management plan (CHAMP) for the coming season.	Good record keeping supports CHAMP, regulatory requirements and allows end of season assessment of IPM strategy.		
Know your enemy	Get the latest guides and IPM related information.	Participate in IPM training, field days, or workshops: Contact your local CottonInfo Regional Development Officer (RDO) (see inside back cover for contact details) to join mailing list or go to www.cottoninfo.com.au/subscribe		
Take a year round approach	Manage winter crops carefully to avoid disrupting beneficial populations. Plan ahead to ensure insecticides are available.	Consider lucerne (strips or block). Consider the summer cropping plan and pest risk.	Begin planning for rotation crops.	Reduce pest risk for next season by considering rotation crop type and location.
Think beyond the crop	Participate in Area Wide Management (AWM) all year round. Apply IPM to all crops. Consider rotation crops (type, location, and potential to host pests and disease). Establish and maintain communication with bee keepers in the region. Avoid spray drift. Consider native vegetation as part of pest management. Maximise its value by improving its health, linking patches of vegetation, controlling weeds and keeping it diverse for a range of species (including birds and bats).			
Have good on-farm hygiene	Zero tolerance to volunteer cotton in entire landscape all year. Ensure a host free period for pests and diseases. Keep farm weed free all year. Where practical remove weeds from native vegetation areas.	Consider pre-irrigation, to allow control of cotton volunteers and other weeds with non-glyphosate control prior to planting. Consider in-crop cultivation where necessary.	Continue to manage volunteer cotton in entire landscape (eg. fence lines, channels, perennial vegetation and pastures). Consider chipping	Conduct effective crop removal to prevent ratoons.
	Practice Come Clean Go Clean all year round			
Consider options to escape, avoid or reduce pests	When planning cotton, consider proximity to sensitive areas, pest hosts and beneficial habitats. Consider spring trap crop. Manage areas of vegetation to encourage beneficials. Consider lucerne (strips or block) in autumn. If planning to release Trichogramma, plan to sow other crops (eg sorghum) that will host *Helicoverpa spp.*	Assess risk of soil pests before planting to decide on control options. Use a suitable variety (consider okra leaf). Provide optimum planting conditions to promote healthy seedlings. Consider summer trap crop. Cultivate spring trap crops (following guidelines). Consider insecticide choice, food sprays or releasing beneficials to build beneficial numbers.	Monitor crop development to maintain a healthy crop. Maintain high beneficial numbers.	Slash and pupae bust last generation summer trap crop (following guidelines). Follow pupae busting guidelines for Bollgard II cotton. Practice Come Clean Go Clean to prevent spread of pests on, off and around farm.
Sample crops effectively and regularly	Remain up-to-date with key pests, beneficials, crop sampling and plant damage monitoring.	Sample for pests, beneficials, parasitism, fruit load and plant damage at least twice weekly throughout the season. Track pest trends. Use pest and damage thresholds and the beneficial to pest ratio.		
Grow a healthy crop	Consider the best rotation crop for your situation. Soil test to determine fertiliser requirements for cotton crop. Consider potential disease risks.	Provide optimum planting conditions to promote healthy seedlings that can outgrow damage. Monitor leaf and tip damage and development of first squaring node.	Monitor crop development, fruit retention, nodes above white flower and vegetative growth. Manage nutrition and irrigation to maintain a healthy crop.	Monitor crop development, nodes above cracked boll and percentage of open bolls for defoliation decisions. Manage nutrition and irrigation to avoid or reduce regrowth that may harbour pests.
Use established thresholds	Use thresholds and careful spray selection for all crops.	Use pest and damage thresholds relevant to region, time of season and sampling method. Consider the beneficial to pest ratio taking parasitism into account.		
Choose insecticides wisely	Use thresholds and careful spray selection for all crops.	Consider insecticide selectivity and impact on beneficials and bees. Avoid early season use of broad-spectrum (eg.OPs) sprays. Consider edge or patch spraying for aphids and mites. Avoid prophylactic sprays.	When choosing insecticides think about impact on beneficials and bees	Defoliation may be a late season alternative to an insecticide
Apply good resistance management principles	Complete pupae busting (following guidelines). Zero tolerance of ratoon and volunteer cotton in the entire landscape.	Adhere to refuge requirements. Consider choice of at-planting insecticides/seed dressings and implications for later sprays.	Ensure that Bollgard II refuges are attractive/effective.	Follow pupae busting guidelines for Bollgard II cotton.
		Use pest thresholds and follow your Insecticide Resistance Management Strategy for every spray		

TABLE 2: Impact of insecticides at planting or as seed treatments on key beneficial groups in cotton

		Main target pest(s)							Beneficial group				
Insecticides	**Rate (g ai/ha)**	**WW**	**Mite**	**Mir.**	**Aph.**	**Th**[5]	**Persistence**[6]	**Overall**[7]	**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%

TABLE 3: Impact of insecticides and miticides on predators, parasitoids and bees in cotton

Insecticides (in increasing rank order of impact on beneficials)	Rate (g ai/ha)	Target pest(s)							Beneficials																	Pest resurgence [12]			Toxicity to bees[14]
										Predatory beetles				Predatory bugs							Hymenoptera								
		Helicoverpa	Mites	Mirids	Aphids	Thrips	Silverleaf whitefly	Persistence[8]	Overall Ranking[10]	Total[1]	Red & Blue beetle	Minute 2—spotted lady beetle	Other lady beetles	Total[2]	Damsel bugs	Big—eyed Bugs	Other Predatory bugs	Apple Dimpling	Lacewing adults	Spiders	Total (wasps)	Eretmocerus[19]	Trichogramma	Ants	Thrips[22]	Mite	Aphid	Helicoverpa	
Bt[11]		√						very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL				VL
Nuclear Polyhedrosis 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		—
Chlorantraniliprole	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
Sulfoxaflor (very low)	24			√	√		21	medium	low	VL	L	VL	M	L	VL	L	L	H	L	VL	L	—	M	L	H	+ve		+ve	—
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 (very low)	8			√				medium	low	L	L	L	VL	L	M	—	L	M	L	M	L	—	—	VH	L	+ve			VH
Fipronil (very low + salt)	8			√				medium	low	L	L	L	VL	L	M	—	L	M	L	M	L	—	—	VH	L	+ve	+ve	+ve	VH
Indoxacarb	127.5	√		√				medium	low	H[13]	L	VH	VH	L	M	L	L	VH	M	VL	L	—	VL	VH	VL		+ve		H[14]
Cyantraniliprole	60	√			√[20]		√	long	moderate	M	M	VL	L	M	M	M	H	L	VH	M	VL	—	VL	VL	H	+ve			—
Sulfoxaflor (low)	48			√	√		21	medium	moderate	L	L	L	M	L	VL	L	M	VH	H	VL	M	—	M	H	H	+ve		+ve	—
Spirotetramat	96				√		√	medium	moderate	M	L	H	H	VL	VL	VL	VL	M	VH	M	M	—	M	M	M				—
Flonicamid (high)	70			√	√			medium	moderate	VL	VL	VL	VL	H	H	VH	H	H	VL	M	M	L	H	VL	H				—
Sulfoxaflor (mid)	72			√	√		21	medium	moderate	M	L	M	H	L	VL	L	M	VH	H	VL	M	M	H	H	H	+ve		+ve	—
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
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	VH	M	VH	VL			+ve	—
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	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
Sulfoxaflor (full)	96			√	√		21	medium	moderate	H	L	M	H	L	VL	L	M	VH	H	L	M	—	H	VH	H	+ve		+ve	—
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	—
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
OP's[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, bifenthrin, esfenvalerate, deltamethrin, lambda-cyhalothrin,
5. Organophosphates: omethoate, profenofos, chlorpyrifos, chlorpyrifos-methyl, methidathion, parathion-methyl, thiometon
6. *Helicoverpa punctigera* only.
7. Bifenthrin is registered for mite and silverleaf whitefly control; alpha-cypermethrin, 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 moderate for this group. PSO=Petroleum Spray Oil.
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 (eg. mites, some cotton aphid *(Aphis gossypii)* populations
19. Rankings for Eretmocerus based on data from Jamie Hopkinson in semi-laboratory replicated experiments (QDAF) and on ranking for *E. mundus* (P. De Barro, CSIRO, unpublished) and for *E. eremicus* (Koppert B.V., The Netherlands (http://side-effects.koppert.nl/#))
20. Suppression only
21. Sulfoxaflor (Transform) is registered for control of greenhouse whitefly.
22. Effects on thrips are for populations found on leaves. This is relevant to seedling crops, where thrips damage leaves, and to mid-late season when thrips adults and larvae help control mites by feeding on them as well as on leaf tissue. Note that flowers are a protected site, so live adult thrips may be found in flowers even after crops have been treated with products that would control them on leaves.

DISCLAIMER: Information provided is based on the current best information available from research data. Users of these products should check the label for further details of rate, pest spectrum, safe handling and application. Further information on the products can be obtained from the manufacturer.

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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 per cent of Bt cotton area may carry Helicoverpa larvae at or above the recommended threshold levels for a short period during peak to late flower. In Bt cotton, chewing damage is mostly confined to fruit and may lead to yield loss.

Sampling

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.

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 beneficial to pest ratio to be applied. Collect eggs to check for parasitism by *Trichogramma spp.* Only collect brown eggs as white eggs may have only recently been laid.

Frequency

Check at least 2 times/week in both conventional and Bt cotton crops.

Begin Helicoverpa sampling at seedling emergence. Cease sampling when the crop has 30–40 per cent open bolls.

Methods

Through the entire season, Helicoverpa are most accurately sampled using visual methods. Check at least 30 plants or 3 separate metres of row for every 50 ha of crop.

***H. armigera* larvae (left) have pale hairs compared to darker hairs on *H. punctigera* larvae (right).** (Hugh Brier, QLD DAF)

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 per cent early season, 25 per cent mid season and 40 per cent 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 per cent. 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

Bt cotton

Calculation of spray thresholds in Bt 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 Bt 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 beneficial to pest ratio

The beneficial to pest ratio can be applied in conventional and Bt cotton. The ratio is calculated as:

$$\frac{\text{Total beneficials*}}{\textit{Helicoverpa spp.}\ \text{(eggs – (\% parasitised) + VS + S larvae)}}$$

At least 30 plants or 3 to 4 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 beneficials **must only** include the key beneficial insects (marked with an asterisk in the list below). **At least** 3 of the key beneficial species need to be present.

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

The beneficial to pest ratio calculated incorporates parasitoids, particularly Trichogramma, in the calculation. The level of egg parasitism should be deducted from the number of Helicoverpa eggs before the beneficial 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 and how to use the beneficial to pest ratio refer to page 54.

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 sp*p., *Telenomus spp.*

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

Parasitoids of pupae – banded caterpillar parasite

*See ratio formula on page 10.

Selecting an insecticide

The insecticide products registered for the control of *Helicoverpa spp.* in cotton are presented in Table 4 on page 13. The use of more selective insecticide options will help to conserve beneficial insects. Refer to Table 3 on pages 8–9.

Be aware of resistance status and follow IRMS (pages 61–64).

Resistance profile

Conventional cotton

Widespread use of Bt cotton has reduced reliance on chemical insecticides. However large plantings of Bt cotton does not change the overall frequencies of resistance genes in the Helicoverpa population and is unlikely to influence the rate at which *H. armigera* will develop resistance to conventional insecticides if significant selection pressure is imposed. While resistance to indoxacarb (Steward), avermectins (Affirm), rynaxypyr (Altacor) and organophosphates (chlorpyrifos) are low, recent testing has identified that frequencies of resistance to Bifenthrin (SP) have increased to 40 per cent. This means that field failures are now likely for this product. Resistance to general pyrethroids has increased to 90 per cent. Therefore the use of conventional chemistries for control of *H. armigera* in conventional and Bt cotton crops should be used according to the relevant thresholds and the principles of the IRMS applied to all spray decisions (pages 57–64).

Pupae busting is another key tactic for mitigating resistance risk to all insecticides targeting *H. armigera*, including Bt cotton. Individuals that have survived seasonal selection by insecticides can be controlled before they have a chance to mate, thereby reducing carryover of resistant insects from one season to the next.

Pupae busting should be a priority post-harvest operation on all cotton farms. The IRMS recommends pupae busting as soon as possible after harvest. For Bt cotton crops, follow the pupae busting guidelines in the products' Resistance Management Plan.

OCCASIONAL DETECTION OF RESISTANCE	WIDESPREAD RESISTANCE
Indoxacarb emamectin benzoate chlorpyrifos (OP)	methomyl/thiodicarb (carbamate) (moderate frequency) general pyrethroids (high frequency) bifenthrin (SP) (moderate frequency)
CROSS RESISTANCE	
H. armigera resistance to Bifenthrin has increased. Field failures are likely.	

Bt 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 5 in 10,000. It is not cross-resistant to Cry2Ab or Vip3A 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 or Vip3A. In 2014–15 around 2 per cent of the *H. armigera* population carried the Cry2Ab resistance gene. A gene that confers high level resistance to Vip3A is present in field populations of *H. armigera*. This gene does not confer cross resistance to Cry1Ac or Cry2Ab. In 2014–15 around 3 per cent of the *H. armigera* population carried the Vip3A resistance gene. The continued efficacy of Bt cotton 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 Bt resistance genes in *H. armigera*, refer to the Preamble to the RMP for Bt cotton on page 65.

Over-wintering habit

H. armigera 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 zero per cent in late February to +90 per cent 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 per cent 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. *H. armigera* will attack flowering crops of sorghum and maize preferentially over most other crop hosts.

Further Information:

CSIRO Narrabri
Sharon Downes: (02) 6799 1576 or 0427 480 967.
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Lisa Bird: (02) 6799 2428.

Native budworm

Helicoverpa punctigera

Damage symptoms

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

Sampling

Refer to the section on sampling Helicoverpa on the previous page. It is not possible to visually differentiate the eggs or early larval stages of the *H. punctigera* from the *H. armigera*, hence it is appropriate that these pests be sampled as one.

Thresholds

Refer to the section on thresholds for Helicoverpa on the previous page. The thresholds for Helicoverpa *spp*. are based on the assumption of potentially mixed populations of *Helicoverpa armigera* and *punctigera*. .

Key beneficial insects

Refer to the section on Key Beneficial Insects for the Helicoverpa on the previous page. These beneficials and parasitoids also attack the native budworm.

Selecting an insecticide

The insecticide products registered for the control of *H. punctigera* in cotton in Australia are presented in Table 4 on page 13. The use of more selective insecticide options will help to conserve beneficial insects. Refer to Table 3 on pages 8–9.

Survival strategies

Resistance profile

Conventional cotton

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

***Helicoverpa armigera* & *punctigera* moths.** (Hugh Brier QLD DAF)

Bt cotton

A gene is present in field populations of *H. punctigera* that has the potential to confer resistance to Cry1Ac. Research suggests that this gene occurs at a low frequency which is probably less than 1 in 1,000. It is not cross-resistant to Cry2Ab or Vip3A and in certain environments is largely recessive.

A gene that confers high level resistance to Cry2Ab is present in field populations of *H. punctigera*. In 2014–15 around 1 per cent of the *H. punctigera* population carried a Cry2Ab resistance gene.

A gene that confers high level resistance to Vip3A is present in field populations of H. punctigera. This gene does not confer cross resistance to Cry1Ac or Cry2Ab. In 2014–15 around 1 per cent of the H. punctigera population carried the Vip3A resistance gene. The continued efficacy of Bt cotton 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 Bt resistance genes in *H. punctigera* refer to the Preamble to the RMP for Bt cotton on page 65.

Over-wintering habit

H. punctigera has the capacity to over-winter as pupae, but extensive research conducted in the early 1990s found that it is rarely observed to do so in cotton growing areas. However between 20–50 per cent 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 *H. punctigera* is not as closely associated with crop hosts as the *H. armigera*. The host range of the *H. punctigera* 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
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TABLE 4: 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 36 g/L EC	0.3 or 0.6 L/ha 0.15 or 0.3 L/ha	No	Use the higher rate alone or the lower rate with a suitable mixing partner. Some labels indicate control of *Helicoverpa punctigera* only. See IRMS.#
Alpha-cypermethrin	100 g/L EC 250 g/L SC	0.3, 0.4 or 0.5 L/ha 0.12, 0.16, or 0.2 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		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		Apply during egg lay to egg hatch. Best results are obtained from two sequential applications 6–7 days apart.
Bacillus thuringiensis	Btk SC	0.5–4.0 L/ha	No*	Use alone or with mixtures. Refer to relevant label for details. *See RMP preamble page 65.
Bifenthrin	100 g/L EC 250 g/L EC 300 g/L EC	0.6–0.8 L/ha 0.24–0.32 L/ha 0.20-0.267 L/ha	Yes	Time spray to coincide with egg hatch. DO NOT apply to larvae >5 mm.#
Chlorantraniliprole	350 g/kg WDG	0.090 or 0.150 kg/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 and to achieve longer residual control.
Chlorantraniliprole/ Thiamethoxam	200 g/kg/200 g/kg WDG	0.15–0.250 kg + non ionic surfactant	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 and to achieve longer residual control.#
Cyantraniliprole	100 g/L SE	0.6 L/ha + ethylated seed oil	No	Target eggs and neonates – 2nd instar.#
Cypermethrin	200 g/L EC 250 g/L EC 260 g/L EC	0.3–0.70 L/ha 0.3–0.5 L/ha 0.29–0.48 L/ha	Yes	See label for higher rate situations.
Deltamethrin	27.5 g/L EC	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. Use non-ionic surfactant as per label.#
Esfenvalerate	50 g/L EC	0.5–0.7 L/ha	Yes	Use low rate when larvae are small and pressure is low.#
Gamma–cyhalothrin	150 g/L CS	0.05 or 0.06, 0.07 L/ha	Yes	Ovicidal rate. Apply higher rate when egg lay is heavy and/or *H. punctigera* >10 mm and/or *H. armige*ra <5 mm.#
Indoxacarb	150 g/L EC	0.65 or 0.85 L/ha	No	Refer to label for rate selection criteria. Compatible with amitraz.#
Lambda-cyhalothrin	250 g/L ME	0.06, 0.07 or 0.085 L/ha	Yes	Ovicidal rate. Use low rate for newly hatched larvae.#
Helicoverpa NPV	2000 M-Obs/mL LC 5x109 M-Obs/mL LC	0.5 L/ha 0.5 L/ha		Alone or with compatible larvicide. See label for recommended additive. Target application to coincide with egg hatching.
Magnet		0.5L/100 m row (10–50 cm bands) in 72 m or 36 m		Use with insecticides as per label instructions
Methomyl	225 g/L AC, EC, LC, SC	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.#
Paraffinic oil	792 g/L	2% or 2L/100L of water		Use a minimum of 80 L/ha of water. Apply only by ground rig before crop closure.
Piperonyl butoxide	800 g/L EC	0.3–0.4 L/ha		Use as a synergist when applying synthetic pyrethroids. See label.
Thiodicarb	375 g/L SC 800 g/L WG	0.5–1.0 L/ha + Larvacide 2.0–2.5 L/ha 0.235–0.470 kg/ha + Larvacide 0.940–1.2 kg/ha	Yes	This product has ovicidal and larvicidal activity. See label for details.#
				#See label for instructions to minimise impact on bees.

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 and cowpea aphid are occasional pests of young cotton but both species decline as temperatures increase (generally early December).

Damage symptoms

Nymphs and wingless adults of cotton aphid feed on the undersides of leaves, in the terminals, on young stems and on developing fruit. Damage to leaves may cause stunting of the leaves and in severe cases portions of a damaged leaf's upper surface will turn red. Feeding on terminals and fruit can also cause stunting. Populations of aphids that develop early and increase quickly can inhibit photosynthesis and reduce yield. Cotton aphids have also been shown to transmit the disease Cotton Bunchy Top (CBT). CBT is described on page 116. Once bolls begin to open, the sugary 'honeydew' excreted by aphids can contaminate the lint. Green peach aphid causes similar but more severe damage to plant growth than similar densities of cotton aphid.

Sampling

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. As the different aphid species differ in their potential to damage cotton or spread CBT it is important to identify the species present.

Sample for Species and Population

Species: Verify which aphid species is present before implementing any management strategies. Aphid species can be distinguished by close examination with a hand lens. The distinguishing features for green peach are uniformly pale green colonies, the presence of tubercles (on the head between the antenna – which results in a deep 'U' shape), and the long siphunculi (tubes between the back legs). Cotton aphid and cowpea aphid don't have tubercles (the head is smooth between the antennae) and the siphunculi are very short. Adults of cowpea aphid are shiny black and nymphs are always dusky matt grey, while adults and nymphs of cotton aphid are matt and vary widely from yellow, green, brown to dull black. If you are unable to make a determination, or suspect both could be present, contact Lewis Wilson or Tanya Smith, CSIRO Agriculture Flagship at Narrabri, to arrange for a sample to be sent for identification. Contact details are provided at the end of this section.

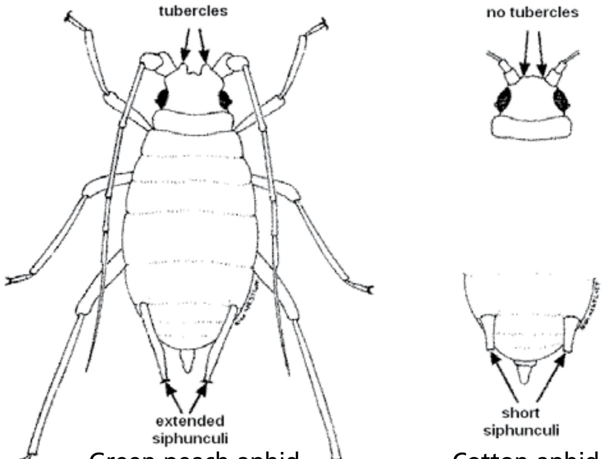
Population: Sample for non-winged adults and nymphs on the underside of mainstem leaves 3–4 nodes below the plant terminal. If a high proportion of plants have only the winged form, recheck within a few days to see if they have settled and young are being produced.

Frequency

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

Methods

Seedling to first open boll: Use a 0–5 scoring system based on the number of aphids/leaf. The protocols for scoring aphids are presented in full on pages 17–18.



Green peach aphid *Myzus persicae*

Cotton aphid *Aphis gossypii*

If hot spots of cotton aphid are found early season, monitor cotton in these areas 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 and Cotton Bunchy Top

Cotton aphid

From the seedling stage through until first open boll, thresholds are based on the potential for feeding damage of 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 (see the Aphid Yield Loss Estimator at www.cottassist.com.au). After first open boll the thresholds aim to protect the quality of the lint by avoiding contamination of open bolls with honeydew. As penalties for honeydew contamination are severe, thresholds aim to limit honeydew contamination to trace amounts.

There is also a risk that yield loss can occur through crop infection with CBT. These thresholds do not take into account the risk of yield loss due to CBT. Recent research has shown that risks of CBT spreading through crops

Aphids and mummies. (Lewis Wilson, CSIRO) and affecting yield are low unless significant populations of ratoon cotton or alternative weed hosts are neighbouring or within the field. If there are many hosts of CBT near the field and a large influx of aphids occurs from these hosts into the cotton crop, control of aphids in the cotton may be required to prevent spread of CBT.

In these situations the development and spread of aphids should be monitored intensively (at least twice weekly), and any hotspots checked for the presence of plants showing CBT symptoms. Mark aphid hotspot areas and return to them to check aphid survival. If it is low, then no action may be needed; but if populations are healthy, increasing and spreading, control may be required to prevent transmission of CBT within the crop. If control is needed choose a selective option to conserve beneficials. Removing cotton ratoons/volunteers and weeds in and around fields well before cotton planting will reduce winter survival of aphids and carryover of CBT in these hosts. Refer to page 117 for hosts of CBT.

SEEDLING TO FIRST OPEN BOLL	FIRST OPEN BOLL TO HARVEST
Calculate the Cumulative Season Aphid Score (page 18)	50% plants infested or 10% if trace amounts of honeydew present

Green peach aphid

This species can severely stunt young cotton plants. As it is more damaging than cotton aphid the threshold for control is lower. Populations can occasionally occur on seedling cotton. However as populations usually decline naturally when temperatures increase, it is unusual for control to be necessary.

SEEDLING TO FLOWERING	FLOWERING TO HARVEST
25% plants infested	Populations decline in hot weather. Highly unlikely to be present post-flowering.

Cowpea aphid

This species can occur on seedling cotton crops, sometimes in quite high numbers. However, populations usually decline quickly as temperatures increase. Control would only be needed if cowpea populations persisted (eg cooler temperatures) and plants were showing signs of damage and stunting.

Key beneficial insects

Predators – lady beetle adults and larvae, red and blue beetles, damsel bugs, big-eyed bugs, lacewing larvae, hoverfly larvae, silverfly 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 5 on page 16. If aphid control is required early season, use a selective option to help conserve beneficial populations, in accordance with the IRMS. These beneficials can assist in controlling any survivors from the insecticide.

Resistance profile

Aphids reproduce asexually. All the progeny of a resistant individual will be resistant. Once resistance is selected in a population it can quickly dominate and give rise to new, entirely resistant populations.

Resistance profile – Cotton aphid

WIDESPREAD, HIGH LEVELS OF RESISTANCE	WIDESPREAD, LOW/MOD LEVELS OF RESISTANCE
OCCASIONAL DETECTION OF LOW LEVELS OF RESISTANCE	
pyrethroids (SP) dimethoate (OP) omethoate (OP) profenofos (OP) pirimicarb (carbamate)	acetamiprid, clothianidin thiamethoxam, and imidacloprid (chloronicotinyl) chlorpyrifos-methyl (OP)
CROSS RESISTANCE	
Strong cross-resistance between omethoate, dimethoate and pirimicarb. Strong cross-resistance between phorate and pirimicarb. Strong cross-resistance between all the neonicotinoids. *If a phorate side dressing is used instead of a neonicotinoid seed dressing then do not use pirimicarb or dimethoate/omethoate as first foliar spray as there is cross resistance between them all. Dimethoate/omethoate use will select catastrophic pirimicarb resistance in aphids so do not use pirimicarb and dimethoate/ omethoate in the same field.*	

Neonicotinoid resistance was once widespread but is now trending down and is sporadic but there remains cross resistance between acetamiprid, thiamethoxam, imidacloprid and clothianidin. While there has been very low use of neonicotinoid insecticides against aphids during recent cotton seasons, resistance in cotton aphids to this insecticide group still persists.

Resistance is being inadvertently selected in two ways. The first has been through the widespread use of neonicotinoid seed treatments and the second is through the use of foliar applied products targeting mirids. Even when aphids are present at very low levels, resistance is being selected.

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 (currently all commercially treated seed includes a neonicotinoid, refer to table 2) or at-planting insecticide.

There is cross resistance in cotton aphid between pirimicarb and dimethoate/omethoate, and in the early 2000s this resistance rendered these compounds ineffective. Fortunately in recent years resistance to these compounds has declined dramatically and they again will provide effective control of aphids. However, re-selection of resistance is a risk, and the IRMS stipulates that omethoate/dimethoate should not be used in rotation with pirimicarb, or vice versa. Neonicotinoid resistance places strong pressure on pirimicarb and dimethoate/omethoate and attention should be paid to the effective management of these valuable products.

When choosing an aphicide, consider previous insecticide choices for mirids as well as for aphids and rotate chemical groups. It should be noted that if a phorate side dressing is used instead of a neonicotinoid seed dressing then do not use pirimicarb or dimethoate/omethoate as first foliar spray as there is cross resistance between them all. Dimethoate/omethoate use will re-select catastrophic pirimicarb resistance in aphids so do not use pirimicarb and dimethoate/omethoate in the same field.

Resistance profile – Green peach aphid

HIGH LEVELS OF RESISTANCE	LOW/MOD LEVELS OF RESISTANCE
dimethoate (OP) omethoate (OP) chlorpyrifos (OP)	pirimicarb (carbamate) profenofos (OP)

CROSS RESISTANCE (DIFFERENT TO COTTON APHID)
No cross-resistance between omethoate, dimethoate or 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, including cotton volunteers and ratoons.

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.

Cowpea aphid is more abundant in winter and has a broad host range. Populations in winter can be found on burr medic, marshmallow, dwarf amaranth, caustic weed, volunteer cotton and in summer on these hosts as well as hogweed, cathead, volunteer cotton, beggars ticks, datura, tarvine, small crumbleweed, paddy melon and sowthistle.

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 Agriculture Flagship, Narrabri
Lewis Wilson: (02) 6799 1550 or 0427 991 550.

NSW DPI, Camden
Grant Herron: (02) 4640 6471.

TABLE 5: Cotton aphid *Aphis gossypii* and Green peach aphid *Myzus persicae*

Active ingredient	Concentration and formulation	Application rate of product	*A. gossipii* resistance detected	Comments
Acetamiprid	200 g/L SC 225 g/L SL	0.055–0.113 L/ha 0.05–0.1 L/ha	Yes	Ensure good coverage. Use high rate under sustained heavy pressure. Do not use as first foliar if neonicotinoid seed treatment used.
Amitraz	200 g/L EC	2.0 L/ha		Suppression when used for controlling Helicoverpa.
Chlorantraniliprole/ Thiamethoxam	200 g/kg/200 g/kg WDG	0.250 kg + non ionic surfactant	No	Apply in early stages of population development. Do not use as first foliar if neonicotinoid seed treatment used.#
Chlorpyrifos	300 g/L EC 500 g/L EC	0.5–0.7 L/ha 0.3–0.4 L/ha	Yes	Use higher rates on heavy infestations
Clothianidin	200 g/L SC	0.125–0.25 L/ha + Maxx Organsilicone Surfactant 0.02 L/L of water	Yes	Apply when aphid numbers are low and beginning to build. Do not use as first foliar if neonicotinoid seed treatment used.
Cyantraniliprole	100 g/L SE	0.6 L/ha + ethylated seed oil	No	Suppression only#
Diafenthiuron	500 g/L SC	0.6 or 0.8 L/ha	No	Apply before damage occurs. Only use lower rate when spraying by ground rig.#
Dimethoate (Permit 13155)	400 g/L EC	0.5 L/ha	Yes	Do not use where resistant strains are present. Do not harvest for 14 days after application. Do not graze or cut for stockfood for 14 days after application.#
Flonicamid	500 g/kg WG	100–140 g/ha	No	Apply to an aphid population in the early stages of development before honeydew is evident or aphid damage occurs. Thorough spray coverage is essential.
Imidacloprid	200 g/L SC	0.25 L/ha	Yes	Add Pulse penetrant at 0.2% v/v (2 m L/L water). Do not use as first foliar if neonicotinoid seed treatment used.#
Omethoate	800 g/L SL	0.25 L/ha	Yes	Apply by ground or air. Refer withholding period #
Paraffinic oil	792 g/L 815 g/L	2% or 2 L/100 L of water, 2.5 L/ha		Apply by ground rig using a minimum of 80 L/ha of water. If populations exceed 20% per terminal use in a mixture with another aphicide.
Phorate	100 g/kg G	6.0 kg/ha	Yes	For short residual control at time of planting.
		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		
		5.5–8.5 kg/ha (NSW only)		For short residual control.
Pirimicarb	500 g/kg WDG, WP	0.5 or 0.75 kg/ha	Yes	Thorough spray coverage essential for best results.
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 organosilicone surfactant.
Spirotetramat	240 g/L SC	0.3–0.4 L/ha	No	Add Hasten Spray Adjuvant 1.0 L/ha. Use the higher rate when periods of high pest pressure or rapid crop growth are evident, when longer residual control is desired or when crops are well advanced. Do not re-apply within 14 days of a previous spray. Do not apply more than 2 applications per crop.
Sulfoxaflor	240 g/L SC	0.2–0.3 L/ha	No	Use higher rate for heavy infestations or when water volume is reduced, such as with aerial application.#
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. Do not use as first foliar if neonicotinoid seed treatment used.#

#See label for instructions to minimise impact on bees.

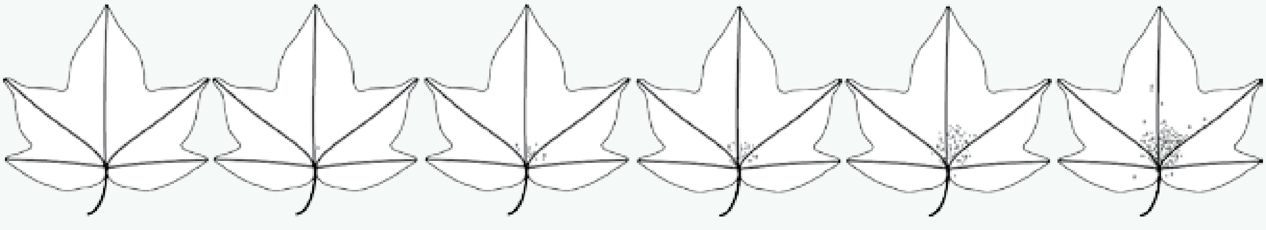
SAMPLING PROTOCOLS FOR COTTON APHID FOR USE UNTIL FIRST OPEN BOLL

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.

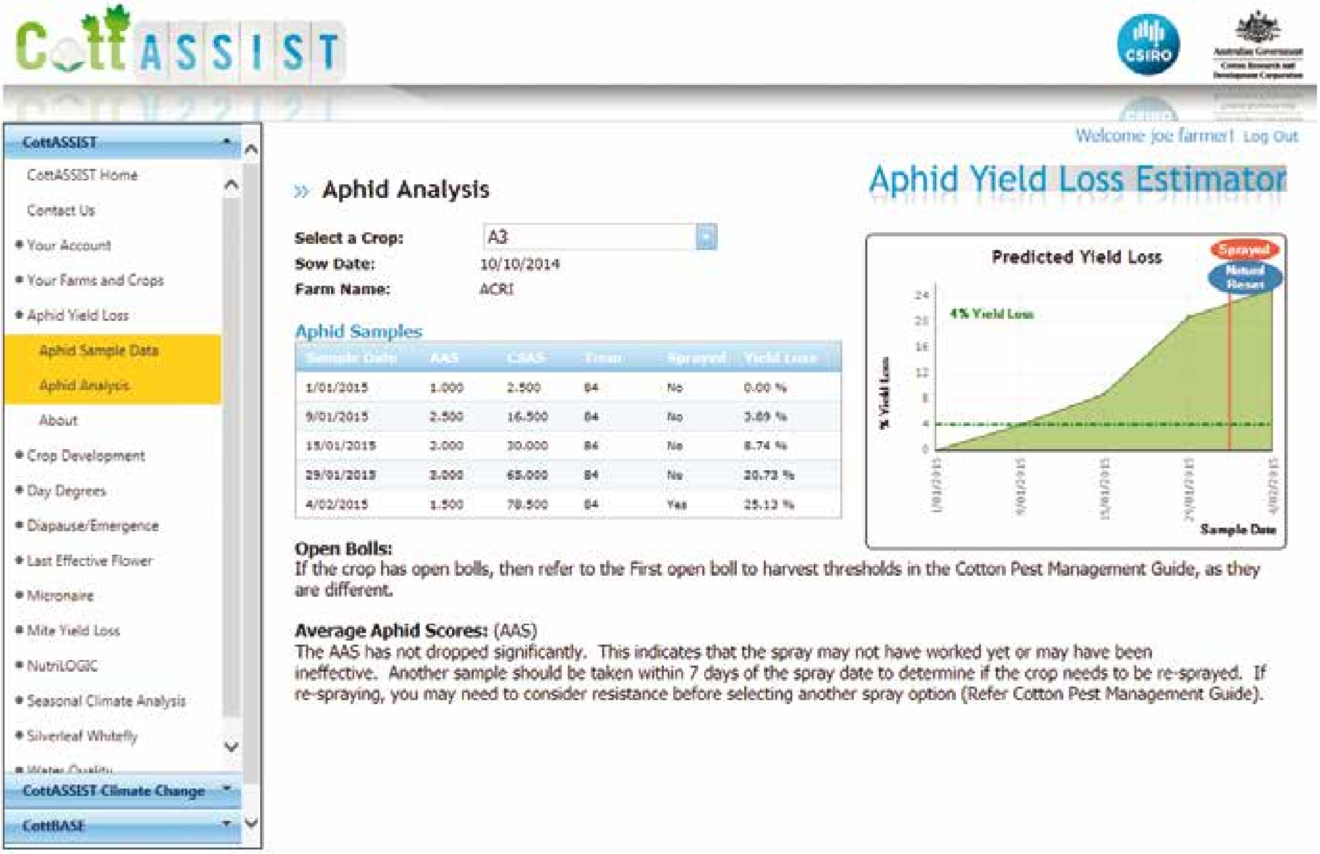


Score = **0**	Score =**1**	Score = **2**	Score = **3**	Score = **4**	Score = **5**
No aphids	1–10 aphids	11–20 aphids	21–50 aphids	51–100 aphids	> 100 aphids

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 Cumulative 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 at www.cottassist.com.au. Alternatively, the Scores can be calculated manually by following Steps 4 and 5 (over page).

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



» Aphid Analysis

Select a Crop: A3
Sow Date: 10/10/2014
Farm Name: ACRI

Aphid Samples

Sample Date	AAS	CSAS	[illegible]	Sprayed	Yield Loss
1/01/2015	1.000	2.500	84	No	0.00 %
9/01/2015	2.500	16.500	84	No	3.89 %
15/01/2015	2.000	30.000	84	No	8.74 %
29/01/2015	3.000	65.000	84	No	20.73 %
4/02/2015	1.500	78.500	84	Yes	25.13 %

Open Bolls:
If the crop has open bolls, then refer to the First open boll to harvest thresholds in the Cotton Pest Management Guide, as they are different.

Average Aphid Scores: (AAS)
The AAS has not dropped significantly. This indicates that the spray may not have worked yet or may have been ineffective. Another sample should be taken within 7 days of the spray date to determine if the crop needs to be re-sprayed. If re-spraying, you may need to consider resistance before selecting another spray option (Refer Cotton Pest Management Guide).

STEP 4: Manual calculation of the cumulative 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, and note that this does not take into account risks of yield loss from Cotton Bunchy Top disease. 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 per cent 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 per cent 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

Plague Locusts

Chortoicetes terminifera

Very rarely are plague locusts a problem for cotton, but large swarms of plague locusts during autumn can result in significant egg lays. Locusts are able to travel up to 500 km in a night on the winds so can be a threat even if not experienced locally in the previous season. Whilst cotton is not a preferred food source for locust there have been a number of instances in southern NSW where control has been required.

Threat of attack could be from bands of hatchlings for instance in adjacent areas or from swarms that fly in from elsewhere. Locusts can actually mow the cotton plants down and can cause significant damage especially when cotton is at the seedling stage.

Damage symptoms

Severe damage directly attributed to chewing.

Sampling

An important aspect of responding to the threat of locust plagues is surveillance and monitoring. In NSW, land managers have a legal obligation to report the prescence of locusts on their properties to their Local Land Services (LLS). In Queensland, landholders are asked to report the presence of locusts to Biosecurity Queensland (BQ), although there is no legal requirement. While high numbers will be seen very easily visually, it will pay to inspect the perimeters of fields to detect the occurrence of any banding of emerging locust as early as possible. These state authorities may also implement surveillance and monitoring programs to determine the extent of locust outbreaks in an area and evaluate the success of control methods.

Threshold

The threshold is based on plant damage. Locust can cause significant damage in a short period of time especially if the cotton is small.

Key beneficials

Birds do eat locusts yet there are no beneficials that could control the numbers present when swarming occurs.

Selecting an insecticide

In selecting control options it is essential to consider the risk of flaring secondary pests. Choosing an appropriate chemical that fits within the IRMS will be a challenge. As an occasional pest, there are few products registered for their control in cotton. Diazinon and chlorpyrifos are registered – check label for rates and further information. Cotton Australia have applied for a minor use permit for alternate chemistry in light of a predicted high pressure season for 2015–16.

In some states free insecticide may be available for locust control in certain circumstances. In NSW, the LLS coordinates locust control activities. The primary aim of this service is to protect crops and pastures, but the circumstances in which free insecticide may be provided may not be consistent with what is required to protect cotton crops. In NSW, free insecticide will only be provided to LLS rate payers once locust nymphs have banded. BQ coordinates locust control in QLD, and undertakes strategic aerial control of locusts.

Further Information

In NSW – contact your local Local Land Services Office. www.lls.nsw.gov.au

In QLD – contact your local Biosecurity Officer 132523

Australian Plague Locust Commission (APLC)
www.daff.gov.au/animal-plant-health/locusts

Mirids

Green mirid – *Creontiades dilutus*
Brown mirid – *Creontiades pacificus*

Both the green and brown mirids are similar in appearance, however brown mirids are slightly larger and carry more dark pigments. While the brown mirid can cause similar damage to green mirid at the boll stage, at the squaring stage they cause less damage than green mirids. Brown mirids are usually found in much lower numbers than the green mirids on cotton and they move into cotton crops later than green mirids.

Damage symptoms

Adults and nymphs cause early season damage to terminals 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.

Square loss depends upon where the mirids are feeding and size of the squares. If mirids feed directly on small or medium sized squares, targeting the ovules and anthers, they will be shed. However, if the mirids feed on leaves or

Green mirid. (P. Room, CSIRO)

stems near the squares this does not cause square loss. If mirids feed on large squares they are not shed but may develop into bolls with distorted growth. If >70 per cent anthers are damaged then one side of the boll usually has poor fertilization of ovules.

This results in poor or no seed growth so that side of the boll remains small, distorting the bolls shape, which is known as 'Parrot Beaking'. The different responses for different sized squares mean that mirid numbers and square loss do not always match. For this reason both fruit retention and mirid numbers should be considered when making a spray decision. The rate of mirid feeding varies with temperature, with highest rates of feeding between 27°C and 32°C. This suggests that temperature plays a role in the different rates of damage observed in the field for the same mirid density.

Bolls that are damaged during the first 10 days of development will be shed. Bolls damaged between 10-20 days old will be retained but their development will not be normal development and they may have one or more stunted, brown locks. This reduces boll weight and if too many bolls are damaged, yield loss will occur. Black, shiny spots on the outside of bolls indicate feeding sites. When damaged bolls are sliced open the areas beneath the black shiny spots will have warty growths and the immature lint will be discoloured. Bolls older than 20 days are generally too hard for mirids to feed on.

Sampling

Mirids are a very mobile pest and are easily disturbed so care must be taken during sampling, otherwise numbers will be underestimated (discussed below). Sample both adults and nymphs. It is important to include nymphs as 4th and 5th instars cause as much damage as 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

Regular sampling (weekly) is important in order to identify sudden changes in abundance which may indicate rapid influxes of mirid adults. The greatest risk from mirids is through the period of peak fruit production, from first flower until 60 per cent of bolls are 20 days old, so through this period it is advisable to sample more often (twice weekly).

Methods

The distribution of mirids is usually clumped (patches of higher density amongst areas of low density) so sample throughout the field to gain a more reliable estimate of overall density. There are three options for sampling: visual inspection of whole plants, using a beat sheet or using a sweep net. All methods give comparable estimates of mirid abundance when plants are young. Once the crop reaches 9–10 nodes the efficiency of whole plant visual sampling declines because the plants are too big to sample quickly and effectively without disturbing the mirids. From this stage onward sample using either the beat sheet or sweep net.

When beat sheeting, the beat sheet is placed against the base of a row of plants and draped across the furrow and up over the adjacent row. Each sample consists of the plants in a 1m section of row of plants being vigorously pushed 10 times with a 1m stick toward the area of beatsheet lying across the furrow. Quickly count the number of mirid adults and nymphs dislodged onto the beatsheet. Preliminary research has shown that the number of beatsheet samples required for a good estimation of mirid numbers is between 8–10 per field (approximately 50 ha).

When using a sweep net, a sample can consist of 20 sweeps along a single row of cotton using a standard (380 mm diameter) sweep net. Preliminary research has shown that at least 6 sweep samples are required per field (approximately 50 ha) to achieve a good estimation of mirid numbers.

It is essential to also monitor fruit retention and signs of fruit damage to assess if mirid damage is affecting the crop. Not all bolls that are damaged by mirids will be shed, so it is important to monitor bolls for mirid damage by cutting a sample of 20 open and checking for internal damage.

Thresholds

Yield loss due to mirid feeding varies with crop stage. Different thresholds apply at different times of the season, depending on the crops capacity to compensate for the damage incurred. The threshold is based on both mirid numbers and plant damage (fruit retention/boll damage). When applying the thresholds, always consider both the crop damage component and the mirid numbers.

The crop is most susceptible to mirid damage that can cause yield loss in the period from first flower until ~60 per cent of bolls are 20 days old. The crop has a greater capacity to recover from fruit loss during the early squaring stage, up to the stage where there is 1 flower per metre, provided plants do not suffer from other stresses such as water stress. That is why the threshold is higher during that stage. Once bolls are 20 days old the boll wall is hard enough to deter mirid feeding and minimal damage occurs. From 1 open boll per metre onwards there are no squares on plants so only the boll damage threshold is relevant.

Beatsheet sampling is recommended for estimating the numbers of mirid adults and nymphs present in the crop. From the start of squaring through until 1 open boll per metre, place the emphasis on fruit retention. From 1 open boll per metre onwards the proportion of the retained bolls that are damaged is 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 spiders, yellow night stalkers and jumping spiders 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 6. The use of more selective

		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	–
Adults or nymphs/sample				
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.

insecticide options will help to conserve beneficial insects (see Table 3 on pages 8–9). Research by QLD DAF and CSIRO entomologists has shown that salt mixed with a low rate of insecticide provides similar efficacy against mirid and stinkbug to the full rate alone but with reduced negative effects on beneficials. However, to date, only one chemical (Steward) has a registration to mix with salt. Early and mid-season use of dimethoate/omethoate for the control of green mirids will cross-select for pirimicarb resistance in cotton aphid, and also increase the risk of silverleaf whitefly and mite outbreaks.

Resistance profile

Mirids aren't known to have developed resistance to insecticides in Australian cotton. Currently there is limited (fipronil only) resistance monitoring for mirids. It is possible that resistance could develop and the principles underlying the IRMS should be followed in making mirid control decisions. Many of the products registered for mirid control in cotton are also registered for the control of other pests. It is critical that mirid control decisions also consider sub-threshold populations of other pests that are present in the field, as application against mirids will also select for resistance in these other pests.

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 *H. punctigera* (see section on Native Budworm, page 12).

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 their movement into cotton. Other crop hosts include soybeans, mungbeans, pigeon pea, safflower and sunflowers. It is assumed that mirids migrate between these crops. Weed hosts include turnip weed, noogoora burr, variegated thistle and volunteer sunflowers.

Further Information:
QLD DAF, Toowoomba, Moazzem Khan: (07) 4688 1310 or 0428 600 705
CSIRO, Narrabri, Mary Whitehouse: (02) 6799 1538 or 0428 424 205
NSW DPI, Narrabri, Robert Mensah: (02) 6799 1525 or 0429 992 087

TABLE 6: Control of mirids

Active ingredient	Concentration and formulation	Application rate of product	Comments
Mirids (Green mirid *Creontiades dilutus* and Yellow mirid or Apple dimpling bug *Campylomma liebknechti*)			
Acetamiprid	200 g/L SC 225 g/L SL	0.113 L/ha 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.
Alpha-cypermethrin	100 g/L EC	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.#
Bifenthrin	100 g/L EC 250 g/L EC	0.6–0.8 L/ha 0.24–0.32 L/ha	Apply at recommended threshold levels as indicated by field checks. Use the higher rate for increased pest pressure and longer residual control.#
Chlorantraniliprole/ Thiamethoxam	200 g/kg/200 g/kg WDG	0.250 kg + non ionic surfactant	Suppression only. Do not use as first foliar if neonicotinoid seed treatment used.#
Clothianidin	200 g/L SC	0.125–0.25 L/ha + Maxx Organsilicone Surfactant 0.02 L/L of water	Apply when numbers reach threshold levels requiring treatment
Deltamethrin	27.5 g/L EC	0.18 L/ha.	Suppression only.#
Dimethoate (Permit 13155)	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. Use non-ionic surfactant at label rate.#
Fipronil	200 g/L SC 800 g/kg WG	0.0625–0.125 L/ha 15.5–30 g/ha	Apply spray to achieve thorough coverage. Use higher rate under sustained heavy pressure.#
Flonicamid	500 g/kg WG	100–140 g/ha	Thorough spray coverage is essential.
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 m L/L water). Do not use as first foliar if neonicotinoid seed treatment used.#
Indoxacarb	150 g/L EC.	0.65 L/ha or 0.85 L/ha	Under high populations suppression only may be observed.#
Indoxacarb + Salt	150 g/L EC	0.3 or 0.4 L/ha + Salt (NaCl) at 5 g/L spray volume by ground (100 L/ha) or 10 g/L spray volume by air (30 L/ha).	For controlling green mirids ONLY. Use the higher rate on infestations exceeding economic spray threshold levels and/or large canopy crops.#
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 or 5 kg/ha	QLD only. Suppression only. Apply into seed furrow at planting
Sulfoxaflor	240 g/L SC	0.2–0.3 L/ha	Use lower rate when infestation is predominately nymphs.#
			#See label for instructions to minimise impact on bees.

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 do colonise cotton but seldom cause economic damage. Even in high numbers, *T. lambi* infestations still result in very low levels of damage. Historically, two-spotted spider mite was the dominant mite species, but in recent years it is less common and bean spider mite and strawberry spider mite are more common. These species differ in damage potential so correct identification of the species present is crucial for good decisions.

Damage symptoms

All three species feed on the underside of leaves but the damage symptoms are quite different.

Two-spotted mite – nymphs and adults cause damage that appears as brownish areas on the lower leaf surface, usually starting at the junction of the petiole and leaf blade or in leaf folds. These areas show reddening on the upper surface. If damage is allowed to continue leaves will become completely red and fall off.

Bean spider mite (adults of this species are red in colour) – damage results in white, intensively stippled areas on the leaf underside, but there is generally no reddening of the upper surface. Severe damage may result in some leaf shedding.

Strawberry spider mite – this species can be very abundant (> 90 per cent of plants infested) but rarely, if ever, affects yield. Damage is a light, sparse stippling or white dots on the underside of the leaf. There is generally no reddening of the upper leaf surface.

Sampling

Sampling protocols for mites in cotton are presented in full on page 24.

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 and is pale green with 3 dark green spots on either side. Strawberry mites cause very little damage.

Two spotted mite with egg (mite is 0.5 mm long).
(Lewis Wilson, CSIRO)

Frequency

Sample at least weekly. Begin at seedling emergence.

Sample more frequently if mite populations begin to increase, if conditions are hot and dry or if sprays which reduce natural enemy abundance 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 development to be seen at a glance.

Thresholds

Thresholds and yield loss charts and tools have been developed for two-spotted mites. These probably over-estimate yield loss for bean spider mite. No threshold is required for strawberry mite as it does not appear to reduce yield.

A general threshold of 30 per cent 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 7 on page 25 to determine whether the rate of increase warrants control.

Squaring to first open boll

Control if mite populations increase at greater than 1 per cent of plants infested per day in two consecutive checks, or if more than 30 per cent of plants are infested. Use Table 7 on page 25 for details.

First open bolls to 20 per cent open bolls

Control is only warranted if mites are well established (greater than 60 per cent plants infested) and are increasing rapidly (faster than 3 per cent of plants infested per day). Use Table 7 on page 25 for details.

Crop exceeds 20 per cent open bolls

Control is no longer warranted.

Mite Yield Loss estimator on the web

A simple relationship has been developed which allows prediction of yield loss from mites based on knowledge of the rate of increase in the population and the time remaining until defoliation. Record keeping and calculating can be simplified by using the Mite Yield Loss Estimator in CottASSIST on the web.

Examples of charts generated by this tool are presented on page 26.

Mite population percentage. This is the percentage of leaves infested with mites.

Average rate of change. This is an average of the rates of change recorded for successive mite samples. This is compared with the rate of change that you would expect if the yield loss from the mite population was 4 per cent. The value of 4 per cent is roughly when yield loss from mites would justify control, based on loss of revenue and cost of control. This may need to be adjusted for your particular situation.

Yield loss percentage. The yield loss calculation is based on the current percentage of plants infested with mites, the rate of change of the mite population and the number of days remaining in the season depending on the region. In general, zero or negative change in mite populations indicates that something has adversely affected population development such as mite spray, beneficials eating mites, heavy rainfall or a combination of these factors.

Mite yield reduction charts

As an alternative to the web tool, 'look-up' charts have been provided in Table 7, page 25 for areas with different season lengths:

Warmer – Bourke, Central Queensland, Macintyre Valley, St George, Mungindi and Walgett
Average – Dalby, Gwydir Valley, Lockyer Valley and Lower Namoi Valley
Cooler – Upper Namoi, Cecil Plains, Pittsworth, Macquarie Valley and Southern NSW

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 per cent of plants infested a week ago and 24 per cent infested now, this gives a rate of increase of 2 per cent of plants infested per day.

To use the charts

1. Select the chart appropriate for your region.
2. Go to the section that is closest to the current infestation level of the field ie. 10, 30 or 60 per cent.
3. Go to the column with the rate of increase closest to that of the mite population in the field.
4. 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 (eg. mite populations develop faster in hot dry conditions). Differences between the more mite resistant 'okra' leaf varieties and the normal leaf varieties are built into the charts. The effect of beneficials is also built-in as high predation on mites will result in lower rates of mite population growth and less risk of yield loss.

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, minute pirate bug, tangleweb spiders.

Selecting a miticide

The miticide products registered for the control of spider mites in cotton in Australia are presented in Table 8 on page 26. Amitraz, used for the control of *Helicoverpa spp.* early in the season, will 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, fipronil, and organophosphates (see Table 3 for information on this risk). This occurs because those sprays kill key beneficial species allowing mite populations to flourish.

Resistance profile – Two-spotted spider mite

WIDESPREAD, HIGH LEVELS OF RESISTANCE	WIDESPREAD, LOW/MOD LEVELS OF RESISTANCE
bifenthrin (SP)	abamectin
OCCASIONAL DETECTION OF HIGH LEVELS OF RESISTANCE	**OCCASIONAL DETECTION OF LOW LEVELS OF RESISTANCE**
	propargite

The two-spotted mite causes economic damage and has a long history of developing resistance to miticides. While current resistance levels are low for all products excluding OP's, abamectin and pyrethroids, resistance can be selected very quickly. Avoid consecutive sprays of the same miticide. If mite numbers rebuild after a miticide application, rotate to a product from a different chemical group. Once cotton is ~8-10 nodes, thrips cease to be a seedling pest and become important predators of mites. Where thrips are preserved, they can provide sustained suppression of mite populations at below damaging levels.

Abamectin resistance has occasionally been detected at high levels in two-spotted spider mite in horticulture, but not in cotton. The bifenthrin and chlorfenapyr resistance in mites occured largely due to the use of these compounds against other pests. When choosing a miticide, consider previous insecticide choices and avoid consecutive sprays from the same group.

There has been no research yet that relates bean spider mite abundance to yield loss. However, if populations build to the point that leaves begin to drop then yield loss is possible and populations should be controlled with a product registered for that use to prevent this occurring.

Overwintering habit

Mites mostly survive the winter in cotton growing areas as active colonies on a wide range of broad-leaf weeds. 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. Control of winter hosts on farms will reduce carry-over of mites between seasons.

Alternative hosts

Preferred winter weed hosts are turnip weed, marshmallow, deadnettle, medics, wireweed and sowthistle, although they can be found on almost any broad-leafed weed species. Alternative winter and spring host crops include safflower, faba beans and field peas.

Further Information:

CSIRO Agriculture Flagship, Narrabri
Lewis Wilson: (02) 6799 1550 or 0427 991 550

NSW DPI, Camden
Grant Herron: (02) 4640 6471

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 per cent of plants are infested it is also advisable to count the numbers of mites on plants, and to score the mite damage level (ie. estimate the percentage 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 per cent 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 per cent 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 per cent 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 (eg. Gwydir) ....

Collector's Name..

Phone No...

Fax No..

Email address ....

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

Comments eg. 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
NSW DPI,
Elizabeth McArthur Agricultural Institute,
Woodbridge Road,
Menangle NSW 2568. Phone: (02) 4640 6471

Sampling Tips

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.

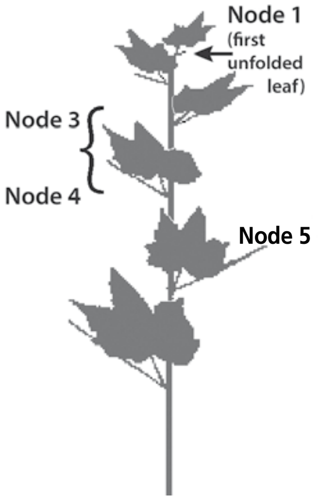


TABLE 7: Yield reduction caused by mites

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

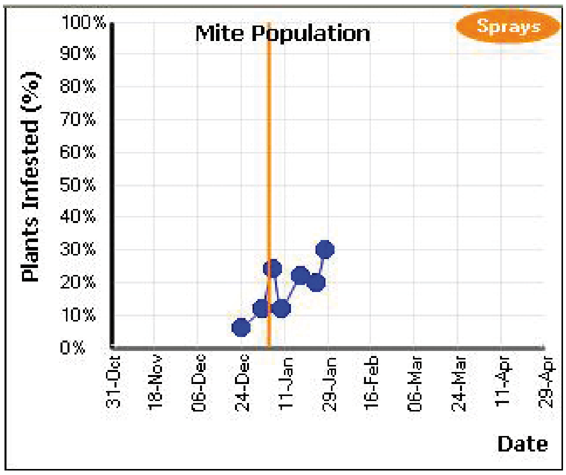
Days from planting	Current % plants infested with mites																				
	10							30							60						
	Observed rate of increase (%/day)							Observed rate of increase (%/day)							Observed rate of increase (%/day)						
	0.5	1	1.5	2	3	5	7	0.5	1	1.5	2	3	5	7	0.5	1	1.5	2	3	5	7
Warmer regions; planting 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. Upper Namoi, Boggabri, Breeza, Cecil Plains, Pittsworth, Trangie, Southern NSW																					
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

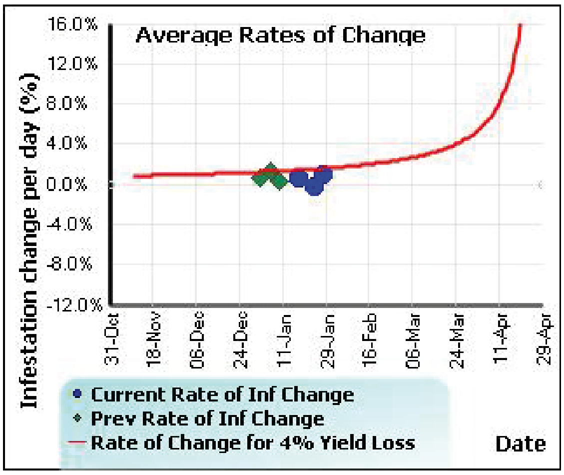
TABLE 8: Control of mites

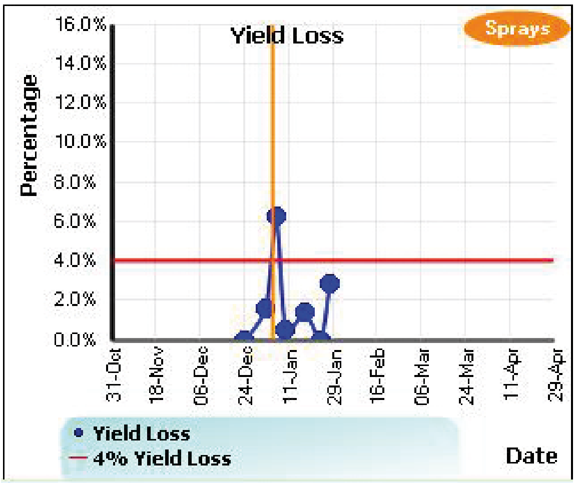
Active ingredient	Concentration and formulation	Application rate of product	Comments
Mite (*Tetranychus*) species			
Abamectin	18 g/L EC	0.3 L/ha	Best results will be obtained when applied to low mite populations. Do not use more than twice in one season.#
Amitraz	200 g/L EC	2.0 L/ha	Suppression when used for controlling Helicoverpa
Bifenthrin	100 g/L EC 250 g/L EC	0.6–0.8 L/ha 0.24–0.32 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 480 g/L EC	4.0 L/ha 2.0 L/ha	NSW registration only. Apply by ground rig at first appearance of mites before row closure.#
Dimethoate (Permit 13155)	400 g/L EC	0.5 L/ha.	Will not control organophosphate-resistant mites. Do not harvest for 14 days after application. Do not graze or cut for stockfood for 14 days after application.#
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	Good coverage is essential. Refer to label for no-spray zones and record keeping.Best 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 at time of planting.
		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 & WA registration only.
Propargite	600 g/L EC	2.5 L/ha	Apply as spray before mite infestations reach damaging levels as maximum efficacy is not reached until 2 weeks after spraying.

#See label for instructions to minimise impact on bees.

MITE YIELD LOSS ESTIMATOR CHARTS







Whitefly

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

SLW is a major pest due to contamination of cotton lint by honeydew and resistance to many insecticides. Greenhouse whitefly (Trialeurodes vaporiorum) and Australian Native whitefly (*Bemisia tabaci*) can be present in cotton but are not considered pests, as their honeydew secretions do not cause problems for textile processing, and they are both susceptible to many of the insecticides used to control other pests.

Damage symptoms

SLW adults and nymphs cause contamination of lint through their excretion of honeydew. Silverleaf whitefly honeydew is considered to be worse than aphid honeydew because the main sugar in SLW honeydew, trehalulose, has a lower melting point and during the processing stage, can cause machinery to gum up and overheat.

Sampling

Sample for Species and Population

Species: Verify which whitefly species are present before implementing any management strategies. Species composition may change rapidly during the season due to factors such as insecticide applications and climate. If large increases in population occur, this probably indicates the predominance of SLW. Consider insecticide application history for the crop as a clue to species composition – if the crop has been sprayed in the last few weeks then it is most likely the whitefly present are SLW.

Note absence of hairs on SLW nymph (left) compared to presence on Greenhouse whitefly (right). (Richard Lloyd, QLD DAF)

Greenhouse whitefly can be visually differentiated from Bemisia tabaci by comparing their wing shape in adults and the presence/absence of hairs on the nymphs (see photographs this page). The different biotypes of Bemisia tabaci cannot be distinguished by eye. Other biotypes of Bemisia tabaci such as Q-biotype have not been detected in widespread and yearly monitoring of Australian cotton.

To determine what species you have, use a hand lens to inspect adult whitefly on the undersides of leaves. To determine the species of nymphs collect a minimum of 50 fourth instar whitefly from cotton leaves across the whole sampling area (ie. do not collect nymphs from only 1 or 2 leaves) and inspect with a hand lens.

Population: Once you have confirmed the presence of SLW, effective sampling is the key to successful management.

Frequency

Sampling on cotton before flowering is not essential but can be helpful in making decisions about product selection for control of other pests – particularly to try to conserve beneficial species that may help delay build-up of SLW or other pests.

Sampling to decide if SLW justify control 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).

Note the gap between wings for SLW (left) compared with overlapping wings for Greenhouse whitefly (right). (Richard Lloyd, QLD DAF)

Species verification and resistance monitoring

Entomology staff at QLD DAF can provide assistance with species verification and they manage the industry's SLW resistance monitoring program which guides the resistance management strategies for SLW.

Sending collections to QLD DAF 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;

Jamie Hopkinson
QLD DAF
203 Tor Street, Toowoomba QLD 4350
Phone (07) 4688 1152 or 0475 825 340
Email: jamie.hopkinson@daf.qld.gov.au

Ensure samples are clearly labelled and include the following information:

Collector's Name..

Phone No. ....

Email address ....

Farm Name ....

Field .... Postcode ....

Region (eg. Gwydir) ....

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

Comments ....

....

....

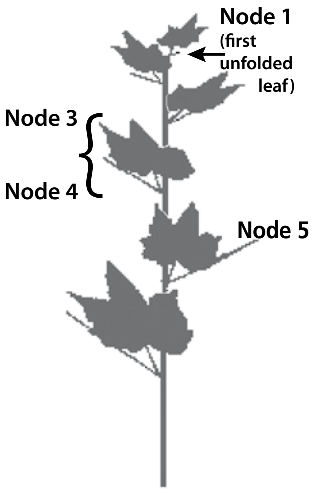
2. Choose a plant to sample

- 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 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.

Supporting information

There are a number of factors that affect SLW movement in the plant, and this can impact on the threshold. To better understand how the population is building, it can be informative to monitor the 8th, 9th or 10th node for large nymphs and adults as well as the 4th or 5th node up until about cut-out (~1450dd). If you are finding SLW at threshold on Nodes 3-5, the presence of large nymphs on leaves at lower nodes (6 – 10) provides further strong support that the SLW is following the predicted population growth that the threshold is based on.

Also monitor for the presence of honeydew on lower leaves, as if there is open cotton, this indicates some remedial action should be taken to prevent contamination of bolls.

Thresholds

A Threshold Matrix has been developed to assist in the interpretation of population monitoring data with the ultimate objective of minimising the risk of honeydew contamination on lint. The threshold matrix assists with management decisions that are appropriate for a range of whitefly density and crop stage situations. Thresholds are based on rates of population increase relative to the accumulation of day degrees and crop development.

The threshold matrix has been designed to manage populations that build gradually in the crop and provides a framework for using sampling information to (a) determine if intervention is required, and (b) make optimal use of currently registered products for population control (ie. intervention to bring a well-established population to low levels over a sustained period) or suppression (ie. early intervention to delay buildup). There are separate thresholds for early season suppression and for control. Frequent population monitoring is essential to use the Threshold Matrix effectively (see page 30).

The management of SLW in situations involving adult immigration into crops with open bolls and/or developmentally delayed crops with open bolls is not covered by the threshold matrix and associated guidelines. In these potentially hard-to-manage situations, new guidelines and management recommendations based on (a) expected time to defoliated leaf drop, (b) lint contamination level, and (c) SLW population growth rate have been developed. Once defoliant starts to take effect, adult SLW will generally leave the crop and falling leaves will take the nymphs with them. The likely efficacy and residual impact of insecticides also needs to be considered. Slower acting products with longer residuals such as an insect growth regulator (IGR) require up to 14 days to be fully effective, whereas knockdown products, provide quick but limited control. Where the risk from contamination is high, early defoliation can be considered. Finally, honeydew on leaves is a good indicator of potential lint contamination. Refer to the silverleaf whitefly fact sheet (available from the CottonInfo website) for more information, including considerations for managing populations that are not covered by the matrix.

In the worst case scenario, where cotton lint has been contaminated with honeydew, delaying harvest may assist in breaking down honeydew or expose the crop to rainfall that will remove most of the honeydew. However, if conditions remain dry any reduction in the amount of honeydew on bolls will be slow, and there is a risk that contaminated cotton may still have sufficient honeydew to result in substantial penalties if harvested.

Key beneficial insects

Several species of whitefly parasitoids and parasites have been observed in Australia including several species of *Encarsia* and *Eretmocerus*. Predators of nymphs include big-eyed bugs, pirate bugs, lacewing larvae and ladybeetles.

LATE SEASON SLW MASS IMMIGRATION SCENARIO DECISION CASE STUDY

Crop with low or no SLW experiences a mass immigration of SLW adults	>3 wks till leaf drop	Eggs may have time to develop to nymphs that could produce honeydew	Little or no honeydew on leaves in lower canopy	Monitor and timely defoliation
			Heavily speckled leaves in lower canopy	Control
	<2 weeks till leaf drop	Too little time for nymph population to develop so manage adults.	Little or no honeydew on leaves in lower canopy	Monitor
			Heavily speckled leaves in lower canopy	Salvage: Knockdown &/or defoliate early &/or delay picking for rain if bolls contaminated

Selecting an insecticide

Natural enemies can play a vital role in the successful management of whitefly. Avoid early season use of broad-spectrum insecticides, particularly synthetic pyrethroids and organophosphates. There are several products registered for the control of whitefly in cotton in Australia. The SLW threshold matrix identifies the optimium times for tactical use of these products.

Resistance profile – SLW

When silverleaf whitefly was first identified in Australia in 1994 it already possessed resistance to many older insecticide groups. Refer to the SLW Threshold Matrix, page 30, for industry recommendations on the best way to utilise these products with the lowest risk of developing resistance. The SLW Threshold Matrix is designed to minimise the need to intervene with chemical control as well as to delay the development of resistance. Currently there are low levels of resistance to pyriproxyfen and bifenthrin and no resistance to diafenthiuron and spirotetramat. Compliance with the IRMS will ensure the products available for SLW control will remain efficacious into the future. To delay the development of resistance, ENSURE ONLY A SINGLE APPLICATION OF PYRIPROXYFEN OCCURS WITHIN A SEASON.

WIDESPREAD, HIGH LEVELS OF RESISTANCE	WIDESPREAD, LOW/MOD LEVELS OF RESISTANCE
pyrethroids (SP)	Insect Growth Regulators (IGRs)
CROSS RESISTANCE	
There is cross-resistance between other pyrethroids and Bifenthrin.	

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 north of Biloela, 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: sowthistle, 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 alternative 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 and volunteer cotton, 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:

SLW Factsheet available: www.myBMP.com.au

QLD DAF, Toowoomba
Jamie Hopkinson: 07 4688 1152 or 0475 825 340.
Richard Lloyd: (07) 4688 1315.
Paul Grundy: (07) 4688 1533 or 0427 929 172

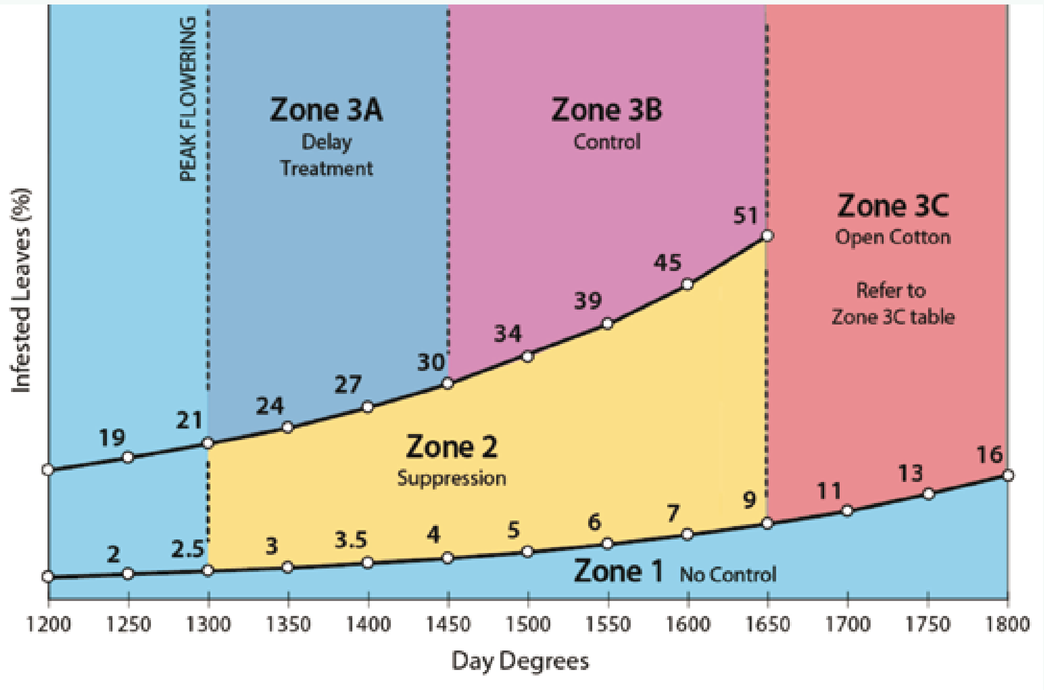
QLD DAF, Emerald
Richard Sequeria: (07) 4983 7410 or 0407 059 066.

TABLE 9: Control of silverleaf whitefly

Active ingredient	Concentration and formulation	Application rate of product	Comments
Silverleaf whitefly *Bemisia 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. IRMS recommends no more than 1 application per season.#
Cyantraniliprole	100 g/L SE	0.6 L/ha + oil	Target early developing populations. 2 consecutive applications of cyantraniliprole 10-15 days apart may be required.#
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. Note: The 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#
Paraffinic oil	792 g/L SC	2% V/V (min 2L per sprayed ha)	Most effective when targetting low, early season populations. Apply in a minimum of 100 litres per hectare for ground applications. Multiple applications are more effective.
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 once in a season.
Spirotetramat	240 g/L SC	0.3–0.4 L/ha + Hasten Spray Adjuvant 1.0 L/ha	Use the higher rate when periods of high pest pressure or rapid crop growth are evident, and when crops are well advanced. Do not re-apply within 14 days. Do not apply more than 2 applications per crop. Spirotetramat may not control silverleaf whitefly adults and eggs, however a decline in the total silverleaf whitefly population will occur over time as the juvenile stages are controlled.

#See label for instructions to minimise impact on bees.

SLW THRESHOLD MATRIX



NOTES	
Sampling protocol	Sample 20 leaves 3rd, 4th or 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.cottassist.com.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. Use IPM principles to conserve natural enemies which can play a vital role in successful management of SLW. Avoid early season use of broad spectrum insecticides.
Zone 2 **Suppression**	This Zone represents a wide window of opportunity for the most economic and low-risk control of SLW. Registered, non-insect growth regulator (IGR) type products can be used for suppression within a wide application window at lower population densities prior to boll opening (refer to lower density curve/line in matrix). Sustained low SLW populations can contribute to lint contamination. Where populations are maintained in Zone 2 over several weeks, consider applying a suitable 'Suppression' product, especially if a honeydew sheen is observed on lower leaves (see visual diagnostic images in SLW management factsheet). This tactic is best used in conjunction with the need to control other pests by the use of insecticides that will control the target pest but also have a significant suppressive effect on SLW. A number of products, including those with good knockdown efficacy (ie. give a quick reduction in SLW numbers) can be useful for population suppression when used early in this zone (see Product Selection section in SLW management factsheet). However, due to the potentially significant impact of suppressive/knockdown products on beneficial insect populations, subsequent re-treatment of resurgent SLW populations is a possibility that must be taken into consideration when utilising this tactic.
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 honeydew. Delay control until Zone 3B.
Zone 3B **Control**	Where populations are mid to high density, targeting an application when the crop is between 1450 and 1650 DD, (allowing the product to become active prior to the onset of boll opening), greatly reduces the risk of lint contamination and the need for further controls. IGR products such as pyriproxyfen, trade name Admiral, and non-IGR products such as Spirotetramat (trade name Movento), and Cyantraniliprole (trade name Exirel) are registered in this zone. Delaying IGR, such as Pyriproxyfen use beyond 50% infested leaves or 1650 DD can result in yield loss, lower efficacy of the IGR and significant lint contamination. If using Spirotetramat in this zone, use the higher rate for periods of high pest pressure or rapid crop growth are evident, when longer residual control is required or when crops are well advanced. In this zone use two consecutive applications of Cyantraniliprole 10-15 days apart.
Zone 3C **Open Cotton**	Once there is open cotton, the ideal period for control has passed and the risk of honeydew contamination is heightened. Management decisions should be based on: • time-to-defoliation • lint contamination level, and • population growth rate and size. This three-pronged approach is designed to support greater confidence in decision making in a range of situations including late maturing crops and those with an extended period of maturity. **Refer to the SLW management factsheet (available from the CottonInfo website) for details.**

Thrips

Tobacco thrips – *Thrips tabaci*
Tomato thrips – *Frankliniella schultzei*
Western flower thrips – *F. occidentalis*

Damage symptoms

Thrips larvae and adults cause early season damage to terminals, leaves and stems. The most obvious damage is crinkling and reduced area of young leaves which is very visible. The feeding damage is a visible 'silvering' on the undersides of leaves. Thrips can also kill the growing terminal, which delays the plant's growth until it can establish a new terminal, but this only occurs when they are present at very high densities.

In some seasons thrips can also build to high numbers in flowers and on leaves in the mid-late season. High numbers on leaves can lead to stunting and damage especially along leaf veins. While recognised as a pest, both adults and larvae of all three thrips species are a key predator of spider-mite eggs.

Sampling

Sample seedlings and count the number of thrips/plant. Check for the presence of thrips larvae as well as adults. The presence of larvae indicates that the population is actively breeding. This is important to establish as crops that have had an insecticide seed treatment or in-furrow insecticide treatment may have adult thrips, because these continue migrating into the crop from surrounding vegetation, but no larvae and little plant damage. This indicates that the insecticide is effectively controlling the thrips but the presence of larvae would indicate poor control.

Score the severity of damage to the seedlings by estimating the percentage reduction in leaf area. 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 thrips damage rarely justifies control.

Frequency

Sample weekly from seedling emergence and continue sampling seedlings until thrips abundance declines and plants begin to recover (usually by about 4-8 nodes, but sometimes up to 10 nodes). In the mid to late season monitor for the presence of thrips in flowers and on the undersides of leaves in the upper canopy. It is always worthwhile to look for thrips when sampling mites, as the presence of thrips adults and larvae in mite colonies is a good indicator of potential natural control of the mites.

Thrip damage to lower nodes with terminal showing new growth without damage. Plant is likely to recover however continue to monitor. **(Photo: Lewis Wilson, CSIRO)**

Methods

Use a hand lens to observe and count the number of adult and larval thrips on 20–30 separate plants for every 50 ha of crop. At the same time assess leaf damage. When assessing leaf damage, if the average size of damaged leaves is less than 1 cm squared, then leaf area reduction is usually greater than 80 per cent.

Check if thrips have killed the plant terminal. This is indicated by complete blackening of the embryonic leaves in the terminal. Thrips must be present in high numbers (>30/plant) for this to occur.

Thresholds

As thrips occur in cotton in most years the most effective management option is to use a seed treatment or an at-planting insecticide applied with the seed. This protects plants during the establishment phase and has the advantage of being less likely to negatively affect beneficial species (predators or parasites) than an insecticide applied to the crop after emergence.

Thrips damage to leaves (very common) can result in delayed maturity or yield loss if very severe. In northern and central regions with warmer climates, the risk of delayed maturity or yield loss is low because plants

TABLE 10: Control of thrips

Active ingredient	Concentration and formulation	Application rate of product	Comments
Thrips (Tobacco thrip *Thrips tabaci* and Tomato thrip *Frankliniella schultzei*)			
Dimethoate (Permit 13155)	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. Do not harvest for 14 days after application. Do not graze or cut for stockfood for 14 days after application.#
Fipronil	200 g/L SC 800 g/L WG	0.0625–0.125 L/ha 15.5–30.0 g/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 at time of planting.
		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.
			#See label for instructions to minimise impact on bees.

can outgrow and compensate for thrips damage and yield loss due to thrips damage is only likely one year in 10. In cooler shorter season areas (Downs, Upper Namoi, Macquarie) the risk of delayed maturity and/or yield loss is higher because there is less time to compensate and yield loss may occur one year in every two. In the newer southern regions (Hillston, Griffith, Hay) the effect of thrips on maturity and yield loss is not well understood.

In all instances a seed treatment or a planting insecticide applied with the seed should provide sufficient control for plants to establish. However, crops should be carefully monitored and if significant leaf damage continues past 6–8 nodes control may be required. Thrips populations will normally naturally decline in early December.

In some instances, populations of thrips will remain high and plant growth delayed by cool, wet weather. In these situations, seed treatments or at planting insecticides may run out and supplementary control necessary according to the thresholds below.

Western flower thrips is not controlled by the current seed treatments or at-planting insecticides, but this species is not normally abundant early season in cotton.

Thresholds

SEEDLING TO 6 TRUE LEAVES
80% reduction in leaf area + 10 thrips/plant (adults and larvae)

Thrips can also be found in cotton in the mid and late season. These are usually *Frankliniella spp*. Adult thrips can be found in flowers where they feed on pollen, but it is unlikely that they affect pollination or fruit set. Eggs are laid on leaves and the hatching larvae may cause damage to the undersides of leaves, resulting in distorted, smaller leaves. These larvae are also predatory and will eat spider mite eggs, often preventing mite outbreaks from developing. Research has shown that high levels of damage would be required to affect yield, and control should not be considered unless >30 per cent of leaf area is damaged in the top 6 nodes in pre-cut-out crops or more than 50 per cent of leaf area damaged after the crop has cut-out.

Key beneficial insects

Predators – minute 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 10, page 31. 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. **It should be noted that every western flower thrips tested in Australia since resistance screening commenced has been pyrethroid resistant, so that group must be avoided.**

Resistance profile – Western flower thrips

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)

In Australia, pyrethroid and OP resistance has been detected in some tobacco thrips associated with bulb onion but resistance in tomato thrips has not been detected.

Overwintering habit

Thrips prefer milder temperatures. Populations decline at temperatures greater than 30°C. Thrips are active and common through winter on a range of hosts.

Alternative hosts

Thrips continue to feed and reproduce on a range of weed hosts during winter and spring. Adult thrips may migrate from these weeds into flowering wheat crops but generally don't reproduce there. In spring, as weeds and wheat crops dry out large numbers of adults are forced to seek new hosts, and transfer to cotton. Cotton crops planted adjacent to cereal crops are particularly at risk of infestation by thrips.

Further Information:

CSIRO Agriculture Flagship, Narrabri – Lewis Wilson: (02) 6799 1550 or 0427 991 550.

NSW DPI, Camden – Grant Herron: (02) 4640 6471.

NSW DPI, Yanco – Sandra McDougall (02) 6951 2728

Green Vegetable Bug (GVBs)

Nezara viridula

Damage symptoms

Nymphs and adults cause dull to black shiny spots on the boll walls, warty growth inside the carpels and brown staining of lint in developing bolls. In severe cases, it is hard to peel the carpel off the damaged lint which may result in tight lock and yield loss. Damage symptoms cannot be distinguished from those caused by mirids. GVB damage varies with boll age, small bolls suffering more damage than old bolls. Bolls aged up to 7 days old are usually shed. Bolls eight to 24 days old are not shed but can suffer significant damage resulting in incomplete development of one or more sectors (locks) of the bolls, stained lint and reduced yield. Bolls aged 25 days or older will not suffer any damage.

Sampling

Sample adults and nymphs and monitor fruit retention. Smaller instars are less damaging than older instars so it is important to note the size of nymphs in order to use the thresholds correctly. A cluster (more than 10) of first and second instars causes as much damage as one adult. Third instars cause half the damage of adults, but fourth and fifth instars inflict the same amount of damage as adults.

GVB will use turnip weed as a host in spring. (Lewis Wilson, CSIRO)

Instar	Length (mm)	Description
1	1	Orange on hatching with 2-3 dark spots. They quickly darken to brown/black with 2-3 small lighter brown spots.
2	2	Black with 2-4 white shoulder spots and 4 or more orange to yellow abdomen spots. Two orange to yellow spots may develop on the edges behind the head.
3	4	Black/brown with 2 orange spots on each side of the thorax, 6 yellow/green spots in the centre of the abdomen and white spots around the perimeter of the abdomen.
4	7	Green/dark green with developing wing buds. Two orange spots on each side of the thorax, yellow/green spots in the centre of the abdomen and white and orange spots around the perimeter of the abdomen.
5	10	Light green body with obvious wing buds. Edge of the abdomen and thorax is orange/red, centre of the abdomen with 6 white spots on either side of 2 or 3 large red spots.
Adult	15	All green with wings

Frequency

Sample bugs and fruit retention at least weekly from the start of squaring, more often if numbers are close to threshold. The crop is most susceptible to damage from flowering through until one open boll/m.

Methods

GVBs are most visible early to mid morning. Visual sampling and beat sheets are equally effective checking methods from the start of squaring until flowering. From flowering onwards, when the crop is most susceptible to damage, beat sheeting is twice as efficient at detecting GVBs. 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 first and second instars tend to hide in the bracts and may be difficult to dislodge.

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.

GVB with 4 Trichopoda parasite eggs. (Hugh Brier QLD DAF)

Comparing damage between stinkbugs using GVB adult equivalents

There are 5 more stinkbugs occasionally occurring in cotton that cause damage similar to that of GVB. However, their damage potential is less than that of GVB so their counts need to be adjusted to GVB adult equivalents according to the table below:

Other Stink Bugs	Proportion of damage compared to GVB	Threshold (based on GVB adult equivalents)
green stinkbug (GSB)	1/2	2
red banded shield bug (RBSB)	1/3	3
cotton stainer bug (CSB)	1/3	3
brown stinkbug (BSB)	1/4	4
harlequin bug (HRLQB)	1/4	4

Key beneficial insects

Parasites – *Trissolcus* is a wasp which parasitises GVB eggs by inserting their eggs inside GVB eggs. After hatching, *Trissolcus* larvae remain inside the GVB egg and continue to feed and mature. *Trichopoda* is a fly which parasites later instar nymphs and adults of GVB. They lay eggs on the outside of bugs. The eggs hatch and Trichopoda larvae bore into the GVB, which dramatically reduces the bug's feeding, egg lay and ultimately kills them.

Selecting an insecticide

The insecticide products registered for the control of GVBs in cotton in Australia are presented in Table 11. Mid-season use of dimethoate for GVB control should be carefully considered as this compound also selects for organophosphate/carbamate resistance in aphids.

TABLE 11: Control of green vegetable bug

Active ingredient	Concentration and formulation	Application rate of product	Comments
Green vegetable bug *Nezara viridula*			
Dimethoate (Permit 13155)	400 g/L EC	0.34–0.5 L/ha	Apply when pests appear. Do not harvest for 14 days after application. Do not graze or cut for stockfood for 14 days after application.#
Fipronil	200 g/L SC	0.0625–0.125 L/ha	Apply when pests appear. Use higher rate when higher infestations are present.#
Clothianidin	200 g/L SC	0.125–0.25 L/ha + Maxx Organsilicone Surfactant 0.02 L/L of water	Use higher rate when heavy infestations is expected and longer control is required. Treated insects may still be on plant 2 or 3 days after application but will have stopped feeding.
			#See label for instructions to minimise impact on bees.

Resistance profile

No GVB resistance to insecticides has been detected in Australia.

Overwintering habit

A high proportion of GVB adults enter a dormant phase (bronze colour) 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. A small proportion will remain green and active and will feed on whatever hosts are available.

Alternative hosts

In QLD 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. Recent data has shown that blackberry nightshade (*Solanum nigrum*) is a good second generation weed host. GVB populations are usually much lower in mid summer, mainly due to a lack of suitable hosts. In NSW the two generations occur a little later compared to QLD.

Further Information:

QLD DAF, Toowoomba – Moazzem Khan: (07) 4688 1310 or 0428 600 705.
CSIRO, Agriculture, Narrabri – Tanya Smith: (02) 6799 2465

Pale cotton stainers

Dysdercus sidae

Damage symptoms

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

- Susceptibility to insecticides used for other pests, especially in conventional cotton;
- Inability to survive high temperatures (> 40°C); and,
- Need for free water to be present.

However in mild seasons Bt crops may be a favourable environment for cotton stainers and management may be required.

Pale cotton stainers are able to penetrate the boll wall of young and mature bolls to feed on cotton seeds and will also feed on seeds in open bolls. Seed weight, oil content and seed viability all decline as a result of cotton stainer feeding. Loss of seed viability should be a consideration in pure seed crops.

Damage to bolls up to 20 days old may cause warty growths on the inner boll wall. Damage to older bolls, 20 days old onwards, usually shows no external symptoms and only small dark marks will be seen on the inside of the boll wall. Most damage is to seeds, reducing their growth and sometimes lint production. 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 for adults and nymphs of the pest as both stages can cause similar amounts of damage. Where adults and nymphs are observed feeding, monitor the percentage of damaged bolls.

Frequency

Sample at least weekly once bolls are present, and more often if pale cotton stainer numbers approach threshold.

Usually cotton is infested by adults flying into fields around the time of first open boll. Sometimes however, 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 is likely to cause 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. Ensure sampling occurs at multiple sites spread throughout the field. The beat sheet is a suitable sampling method however as younger instars 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 that pale cotton stainer bug feeding causes small black marks on the outer surface of young bolls but almost no marking to older bolls. Similarly, 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. A week after damage 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

Juvenile pale cotton stainers are often found in aggregations low in the canopy. They will feed on developing bolls.
(Lewis Wilson, CSIRO)

Adult pale cotton stainers are often seen in maturing cotton, often as mating pairs. They can damage maturing bolls.
(Lewis Wilson, CSIRO)

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 green vegetable bugs. 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 per cent 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 (eg. 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 spp.* and other pests. Cotton stainers may be incidentally controlled when carbamates such as carbaryl or organophosphates such as dimethoate are used. Any decision to use broad spectrum insecticides such as pyrethroids should take into account their impact on beneficial insects and the subsequent risk of flaring whitefly and other secondary pests.

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.

Overwintering habit

As there is no resting stage in the cotton stainer's lifecycle, cultural controls, particularly of alternative hosts, between cotton seasons assist greatly in limiting population development.

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 and volunteer cotton is important for limiting cotton stainer's access to alternative food source.

Further Information:

QLD DAF, Toowoomba
Moazzem Khan: (07) 4688 1310 or 0428 600 705

CSIRO Plant Industry, Narrabri
Lewis Wilson: (02) 6799 1550

Solenopsis mealybug

Phenacoccus solenopsis

The solenopsis mealybug (*Phenacoccus solenopsis*) has been found in Burdekin, Central Queensland, Burnett and most recently Darling Downs cotton crops.

Damage symptoms

Nymphs and adults can affect plant growth at all stages of crop development. When infested during early development, plants exhibit distorted terminal growth, crinkled and bunchy leaves, and in severe cases plant death will occur. On older plants, mealybug can cause shedding of leaves, squares and small bolls as well as fewer, smaller and deformed bolls, and premature crop senescence. Heavy infestations (>500 mealybug in top 8 nodes at cut-out) has been found to have an 80 per cent reduction in harvestable bolls. Honeydew excreted by the insects onto the leaves and lint can promote the development of black sooty mould.

Sources and sampling

At low densities, mealybugs can be present anywhere on the plant.

Mealy bug predators cryptolaemus lady beetle larva (left) and lacewing lavae (right), can look very similar to mealy bugs.
(Zara Hall and Paul Grundy, QLD DAF)

Trials on mealybug distribution within the plant revealed that they like to aggregate on the underside of leaves and inside bracts of squares or bolls within the top 10 nodes. This suggests sampling for mealybug in the top half of the crop canopy in the field.

A number of weed species and volunteer cotton can be sources of mealybug within the crop. Volunteer cotton grows earlier than cultivated cotton and therefore attracts overwintering mealybug populations in the field. Mealybug populations from volunteer cotton and weeds are easily dispersed on to nearby cotton. Checking volunteer and adjacent cotton will help to detect early infestation in the field. Crop stress, such as waterlogging, may make cotton more susceptible to mealybug, so it is important to include stressed areas when checking eg. tail drains. Investigate patches of stunted or dead plants. As solenopsis mealybug has a very wide host range, also monitor surrounding vegetation including gardens.

If mealybugs are found, contact: Melina Miles (07) 4688 1369 or Moazzem Khan (07) 4688 1310 to arrange identification and to help track distribution of the species.

Thresholds

Damage thresholds have been assessed, however it is important to note that there are no insecticides registered for the control of mealybugs and insecticides are not expected to be the main means of control. Trials on mealybug damage revealed that damage varies depending on which crop stage they commence establishment. The earlier they establish the more damage they cause. Establishment of mealybug up to early boll set stage causes significant yield loss. The damage thresholds of 25, 110 and 150 mealybugs per plant for seedling, squaring and early boll stages respectively, have been calculated. Once populations reach these points economic yield loss is expected.

Management strategy

There are a number of management options that can reduce the size of infestations, and the overall impact of this pest. Minimise the buildup of mealybug in volunteers, ratoons and weeds, particularly in fallows where cotton will be planted. Ensure effective crop destruction and continue to monitor fields post cotton for potential hosts. Natural enemies have proven to be very effective at reducing high mealybug populations, and minimising the build up of populations in crops. Avoiding early season use of broad spectrum insecticides will help preserve natural enemies that may contribute to the control of mealybug infestations.

Once mealybug are known to be in an area, consider increasing thresholds for other pests, and review all insecticides for their impact on mealybug predators prior to use.

Key beneficial insects

Predators – Three banded ladybird beetles, white collared lady beetles, lacewings, cryptolaemus, smudge bugs, earwigs and native cockroaches.

Aenaisus bamabwalei, a parasitoid of solenopsis mealybug was reasonably wide spread during the 2012–13 season. Parasitoids are reportedly very effective in suppressing populations in India and Pakistan.

Survival

Key factors that contribute to solenopsis mealybug being a pest:

- All stages of mealybug can cause damage.
- They have a high reproductive rate. One female can produce hundreds of offspring. Eggs hatch out within an hour.
- They shelter in protected positions on the cotton plant; in squares, bracts and under surfaces of leaves. The waxy coating on mealybugs is water repellent, making insecticide contact more difficult.
- They can be spread in the field by wind, surface water runoff, rain splash, birds, people and farm equipment. Mealybugs disperse as first instar ‘crawlers’.
- Adults and large nymphs can survive for long periods without a host. QLD DAF research found that the crawler stage can live for up to 6 days, and the third instar stage for up to 50 days without food or water.

Over-wintering

Mealybugs, usually at the small and large nymph stage, can be found throughout winter on the root zone of weed hosts. During a severe winter they go under soil, loose soil and ant's nests on the ground help them to do so. Once the weather begins to warm, breeding and dispersal begins.

Alternative hosts

The solenopsis mealybug has a wide host range, and in Pakistan it has been recorded on 154 plant species including field crops, vegetables, ornamentals, weeds, and trees. In Australia, solenopsis mealybug has been recorded from a range of common weed species on-farm such as pigweed, sowthistle, bladder ketmia, native rosella, vines (cow, bell and potato), crownbeard, stagger weed, marshmallow, verbena, raspweed, and volunteer cotton.

Further information:

QLD DAF, Toowoomba
Melina Miles (07) 4688 1369
Paul Grundy (07) 4788 1533
Moazzem Khan (07) 4688 1310

Best practice…

- **Monitor for presence of mealybug along with other pest monitoring. Include areas that are under stress where populations may develop first.**
- **Monitor abundance of adults, nymphs and natural enemies over time, this will provide a picture of whether the mealybug population is building up, stable or declining.**
- **Consider release of cryptolaemus and/or lacewings in hotspots.**
- **Be mindful of spreading infestations with machinery and passage of people through hotspots.**
- **Put into practice the industry Come-Clean-Go-Clean protocols to minimise the spread of mealybug.**

Soil pests at plant establishment

True Wireworms *Agrypnus sp* and False Wireworms *Gonocephalum spp.* and *Pterohelaeus spp*
Black Field Earwig *Nala lividipes*
Symphyla *Hanseniella spp*

Damage symptoms

Soil pests can reduce plant establishment, row density and vigour. Symptoms can be confused with other establishment problems, and may be worse if seedling development is slow due to climate or other factors such as allelopathy or soil constraints. See below for symptoms associated with specific pests.

Sampling

Sampling for soil insects is best conducted using a baiting technique. Soil digging can also be used for detecting presence of symphylans (see section below) however is ineffective for earwigs and wireworms.

Grain baiting for soil insects can be conducted following planting rain or irrigation:

1. Soak insecticide-free crop seed in water for at least two hours to initiate germination.
2. Bury a dessertspoon full of the seed under 1 cm of soil at each corner of a 5x5 m square at five widely spaced sites per 100 ha.
3. Mark the position of the seed baits as high populations of soil insects can completely destroy the baits.
4. One day after seedling emergence, dig up the plants and count the insects.

The type of seed used makes no noticeable difference when it comes to attracting soil-dwelling insects. Recent research has shown that medium sized potatoes cut in half and buried in the same manner with the cut side facing down will produce comparable results to grain baits.

Soil pest cultural aspects

Tillage and farm management practices can influence the composition and abundance of pest species. For example weedy fallows encourage the abundance of soil pests whereas clean fallows generally cause pest insect numbers to decline due to a lack of food.

The influence of field stubble is contentious as high stubble loads within fields will promote the abundance of soil pests however, stubble can also provide a diversionary food source as well as increase the diversity of soil fauna such as predatory beetles (carabidae), centipedes and earthworms. The incorporation of grains stubble prior to planting cotton may increase the damage potential of black field earwig populations as it can cause them to switch feeding activity from stubble to seedlings. Wireworms are found under a range of cultivation and stubble retention regimes.

A Symphylan (left) is very similar in appearance to a Dipluran (right), but has legs all along its body like a millipede and lacks the Dipluran's long rear appendages. **(Paul Grundy QLD DAF)**

True and False Wireworms

Damage symptoms

Larvae attack germinating seeds, the hypocotyl, roots and at the surface of young cotton plants resulting in seedling death, young plant 'felling' and patchy plant stands. The adult beetles can also damage seedlings by chewing at or just above ground level.

Threshold

Conduct bait sampling prior to planting to determine the abundance of wireworm. Although there are no specific thresholds for wireworms in cotton, densities of one or more larvae per baiting site are considered damaging for summer grain crops.

Management

Wireworm larvae are unlikely to be controlled with standard seed treatments, so where populations are high, an in-furrow insecticide treatment at planting should be considered. Importantly, infestations of wireworm larvae detected after crop emergence cannot be controlled with baiting or surface spraying. Therefore this pest must be detected before planting for control actions to be effective.

Black Field Earwigs

Damage symptoms

Black field earwigs are an occasional pest of seedling cotton, predominantly feeding on germinating seed and seedling roots, resulting in poor establishment.

Threshold

Conduct bait sampling prior to planting to determine the presence of black field earwigs. No thresholds for black field earwigs have been defined for cotton. Thresholds used for maize and sorghum suggest that control maybe warranted when more than 50 earwigs are found across 20 baits or 2–3 earwigs per bait sample.

Management

If earwig numbers are high the application of insecticide treated grain baits at the time of sowing may offer protection. Notably the use of in-furrow insecticide treatments have been found to be generally ineffective for the protection of newly sown grain crops where dense populations are present. The efficacy of seed dressings for black field earwig control is unknown.

Symphylans

Symphyla are white, soft-bodied "millipede-like", soil inhabiting arthropods, 3-7 mm long with 12 pairs of legs and a pair of antennae. Symphyla are sensitive to light and are very active when exposed. Symphyla are relatively common in most soils where they generally feed on decomposing organic matter.

Symphyla have been associated with crop establishment issues in some fields within the Theodore irrigation district and recently fields west of Moree and Dalby. However, whether crop damage is solely attributable to Symphyla or a broader complex of soil pests and disease is unclear.

Damage

Symphyla may feed on rootlets and root hairs. Continuous surface grazing can result in a characteristic 'witches broom' root system or a general lack of lateral root expansion. Symphyla activity is more common in well structured soils that enable easier movement through the profile. As feeding is confined to root tips and hairs, dry soil conditions will exacerbate the severity of damage symptoms by inhibiting root exploration of the soil profile. Typically Symphyla feed on the roots where the soil is moist and as the profile dries out, the continuous tip pruning of the roots can leave plants stranded in the top 10–15 cm of drier soil upon an otherwise full profile. Symphyla are very active and will move up and down in the soil profile to reported depths of up to 1 metre.

Symphyla damage in establishing cotton crops may first appear as plant patches showing slight symptoms of moisture stress and reduced vigour. Over time symptoms become more pronounced even though the subsoil moisture is adequate.

Sampling

The detection of Symphyla prior to planting is difficult as distribution within a field is generally patchy.

Where plants are showing symptoms of damage, conduct a basic soil survey to confirm the presence of Symphyla. Insert a shovel to full depth at the plant line on the hill and carefully lever the soil out so that it can be inspected more closely. Symphyla are delicate soft bodied creatures so avoid overly compacting the soil while sampling. Start with the soil from the bottom of the shovel, as Symphyla may be more common in the deeper, wetter part of the soil profile. Holding a soil clod in one hand, use your other hand to careful break the soil apart while keeping a close eye on the inner surfaces for the movement of Symphyla. Symphyla are fast moving and will rapidly shift to avoid sunlight.

It is important not to confuse Symphyla with other soil organisms such as Diplurans or collembolan (springtails). Diplurans closely resemble Symphyla but are distinguishable by their smaller size, more rapid movement and having legs confined to the upper body. Symphyla have legs along the entire body much like a millipede. Collembolans are more easily distinguished from Symphyla having more of a curved body and the capacity to jump when disturbed.

Symphyla thresholds & management strategies

There is no definitive information regarding the density at which Symphyla are likely to cause crop damage. However, recent crop surveys and pot trials suggest that Symphyla are unlikely to be the lone cause of crop establishment issues. Fields with establishment problems and high numbers of Symphyla have also been found to host high numbers of other soil pests such as wireworm and earwigs. Conditions in these fields were also suboptimal in terms of unfavourable temperatures and a drier than optimal soil profile which slowed plant development and by default increased the period whereby young plants were more susceptible to root feeding and damage. A fair conclusion from these fields would be that Symphyla exacerbated poor establishment but were not the primary driver for the poor plant stands observed. In the absence of other soil pests and diseases or more optimal field conditions the impact of Symphyla may have been minimal.

There are no recommended chemical control options for Symphyla. The in-furrow application of insecticide at planting will not provide protection for establishing seedlings as Symphyla are active to depths of up to one metre and will easily avoid exposure. Standard seed dressings were used in nearly all surveyed fields where establishment issues have been recently recorded which suggests that these products offer limited protection when high densities of soil pests are present.

For fields where Symphyla have been known to be abundant near Theodore, a useful strategy has been to plant these areas last so that the warmer conditions aid more rapid establishment. Plant roots that grow deeper into the profile more quickly are less likely to become stranded in dry soil through the root pruning by Symphyla feeding. If plants show signs of moisture stress where Symphyla are present, a quick flush with irrigation may assist plants that may have root systems that are becoming stranded in the drier surface profile due to root pruning. Irrigation can also decrease Symphyla activity in the upper profile for about 7–14 days which may also assist crop recovery.

If establishment is so poor to warrant replanting, consider alternate fibrous rooted crops such as maize or sorghum that are less susceptible.

Other soil pests

Cutworms (*Agrotis sp*) can be a pest of emerging cotton but the incidence of this pest causing economic damage to cotton fields has been rare. This pest is typically found along field margins that adjoin pastures or where cotton has been sown into recently sprayed out weedy fallows.

Whitegrubs which are the larvae of Scarabaeidae beetles have been found to feed on the roots of crops where they cause a loss of vigour and lodging. Damage in cotton is rare and likely only if sown into fields that were previously a weedy fallow or a summer sorghum crops.

Other pests

TABLE 12: Control of armyworm and cutworm

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 observed. Apply in a minimum of 100 L of water.#
			#See label for instructions to minimise impact on bees.

TABLE 13: Control of wireworm

Active ingredient	Concentration and formulation	Application rate of product	Comments
Wireworm *Aprypriius variabilis* and False wireworm *Pterohelaeus* spp.			
Bifenthrin	100 g/L EC 250 g/L EC	0.375 L/ha 0.15 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. Rate is based on 1m furrows.#
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.
			#See label for instructions to minimise impact on bees.

TABLE 14: Control of cotton leafhopper

Active ingredient	Concentration and formulation	Application rate of product	Comments
Cotton leafhopper (jassids) *Amrasca terraereginae*			
Chlorantraniliprole/ Thiamethoxam	200 g/kg/200 g/kg WDG	0.250 kg + non ionic surfactant	Suppression only. Do not use as first foliar if neonicotinoid seed treatment used.#
Clothianidin	200 g/L SC	0.125–0.25 L/ha + Maxx Organsilicone Surfactant 0.02 L/L of water	Apply when numbers reach threshold levels requiring treatment.
Dimethoate (Permit 13155)	400 g/L EC	0.35 L/ha	Do not harvest for 14 days after application. Do not graze or cut for stockfood for 14 days after application.#
Gamma- cyhalothrin	150 g/L CS	0.05 L/ha	Apply at recommended threshold levels as indicated by field checks.#
Lambda-cyhalothrin	250 g/L	0.06 L/ha	Apply at recommended thresholds 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 and WA registration only.
			#See label for instructions to minimise impact on bees.

TABLE 15: 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	100 g/L EC 250 g/L SC	0.3 or 0.4 L/ha 0.12 or 0.16 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.#
Cypermethrin	200 g/L EC 250 g/L EC 260 g/L EC	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.#
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
			#See label for instructions to minimise impact on bees.

TABLE 16: 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	WA & 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	2.5–3.5 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.#
			#See label for instructions to minimise impact on bees.

TABLE 17: 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** No egg threshold during pre-flowering due to high natural mortality. **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.
Brown eggs/m	–	5	5	5	
Total larvae/m	2	2	3	5	
Medium and large larvae/m	1	1	1	2	
Helicoverpa Tip damage (% of plants affected)	100–200% (100% of plants tipped once or twice)	– –	– Helicoverpa control can cease at 30–40% bolls open.	–	
***Helicoverpa spp.* in Bollgard II cotton**					
	All season				
White eggs/m	–				
Brown eggs/m	–				
Total larvae/m (excluding larvae < 3 mm)	2/m over 2 consecutive checks				
Medium and large larvae/m	1/m on the first check				
Green mirids					
Adults and nymphs/m					The relative importance of the % fruit retention and % boll damage reverses as the season progresses. From the start of squaring through until cut-out, place the emphasis on fruit retention. Not all bolls that are damaged by mirids will be shed, so after cut-out it is important to monitor bolls for mirid damage. If only the terminal is blackened, damage could be considered light. If the terminal plus one or more true leaves are blackened, damage could be considered heavy.
cool region – visual	0.7	0.5	–		
warm region – visual	1.3	1.0	–		
cool region – beatsheet	2	1.5	–		
warm region – beatsheet	4	3	–		
Fruit retention	< 65%	< 65%	–		
Boll damage		20%	20%		
Tip damage (% of plants affected)					
(heavy)	20%	–	–		
(light)	50%	–	–		
Cotton aphid (check species)					
Presence of adults and nymphs	Calculate Cumulative Season Aphid Score*	Calculate Cumulative Season Aphid Score	50% infestation		Until 1% of the bolls are open calculate the Cumulative Season Aphid Score to determine the threshold. * 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.
Honeydew presence	–	monitor for the presence of honeydew	10% infestation if honeydew present		Once open bolls are present in the crop, use 50% infestation. When 1% of bolls are open and honeydew is present, the aphid threshold is reduced to 10% infestation. Check field borders and spray them separately where necessary. 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.
Mites					
% of leaves infested	30% Normally suppressed by predators. Use the table on page 26.	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 26 to base thresholds on potential yield loss or use the Mite Yield Loss Estimator at www.cottassist.com.au. Yield loss is estimated using time of infestation and rate of population increase.

TABLE 17: Insect pest and damage thresholds (continued)

Insect pest	Planting to flowering (1 flower/m)	Flowering to 1 open boll/m	1 open boll/m to harvest		Comments
			Up to 15% open	After 15% open	
Thrips					
Adults and nymphs/plant	10	–	–		Control is justified if there are 10 thrips/plant plus the reduction in leaf area due to thrips is greater than 80% (roughly leaves <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 nymphs (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	–	–	–	Bollgard II cotton provides moderate control of armyworm.
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		Bollgard II cotton provides good control of cotton loopers.

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2015*

Active ingredient	Chemical group	Insecticide group	Concentration & formulation	Trade name	Marketed by
Abamectin	avermectin	6	18 g/L EC	ABA	Genfarm Landmark
				Abachem	Imtrade
				Abacin	Farmalinx
				Abaken	Kenso
				Abamect	Nufarm
				Abamectin 18	4Farmers, Accensi, Apparent, Chemtura, eChem, Macro Protect, Mission Bell, Pacific, Rainbow, Titan
				Abamix	Hextar
				Abasect	Conquest
				Ac Whistler	Axichem
				Acarmik	Rotam
				Agrimec	Syngenta
				Agrocn	Shanghai Agrochina
				Announce	Agri West
				Biomectin	Jurox
				Catcher	Sinon
				Gremlin	Sipcam
				Kill-A-Mite	Nulife
				Mite Terminator	Rosmin
				Stealth	Cropro
			18 g/L EW	Vantal EW	Cheminova
Acetamiprid	neonicitinoids	4A	200 g/L SC	Cobra	Aako
				Primal	ADAMA
			225 g/L SL	Acetam	eChem
				Intruder	Agnova
Alpha-cypermethrin	pyrethroid	3A	100 g/L EC	Agvantage Duo	Landmark
				Alf	Agri West
				Alpha	Biotis Life Science
				Alpha C	Ozcrop
				Alpha Duo	Conquest, Genfarm Landmark, Opal, Titan
				Alpha Duop	Grow Choice
				Alpha-Cyp	Acp, eChem
				Alpha-Cyp	eChem
				Alphacyper	Farmalinx, WSD
				Alpha-cypermethrin Duo 100	4Farmers, Apparent, Chemforce, Cheminova, Country, Grass Valley, Halley, Mission Bell, Rainbow, Sabakem
				Alpha-Scud Elite	ADAMA
				Alphasip Duo	Sipcam
				Antares	Campbell
				Astound Duo	Nufarm
				Buzzard	Cropro
				Chieftain Duo	Sinon
				Dictate Duo	Imtrade
				Dominex Duo	Fmc
				Ken-tac	Kenso Agcare
				Mascot Duo	Crop Care
				Unialphacyper	Ravensdown
				Unichoice	UPL
Alpha-cypermethrin	pyrethroid	3A	250 g/L SC	Alpha cypermethrin 250SC	Genfarm Landmark
				Alpha Forte	Conquest, Rygel
				Googly Alpha-Duo	Genfarm Landmark
Amitraz	triazapentadiene	19	200 g/L EC	Amitraz	eChem, Imtrade, Jurox
				Amitraz Duo	Genfarm Landmark
				Amitraz Elite	ADAMA
				Hitraz	Rotam
				Mitra	UPL
				Opal Duo	Nufarm
				Ovasyn Options	Arysta

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2015* (continued)

Active ingredient	Chemical group	Insecticide group	Concentration & formulation	Trade name	Marketed by
Amorphous silica	not a member of any chemical group		450 g/L SC	Abrade Abrasive Barrier	Grow Choice
Bacillus thuringiensis	Bt microbials	11	Btk* HD1** SC	Biocrystal Kurstaki	Grevillia Ag
				DiPel SC	Sumitomo Chemical
* *Bacillus thuringiensis* subspecies KURSTAKI. ** Strain type.					
Bifenthrin	pyrethroid	3A	100 g/L EC	Agfen	Agri West
				Akostar	Aako
				Arrow	Conquest
				Astral	Crop Care
				Beast	Axichem
				Bifendoff	Grow Choice
				Bifenthrin 100EC	4Farmers, Accensi, Cheminova, David Gray&Co, eChem, Genfarm Landmark, Imtrade, Kenso Agcare, Ravensdown, Sabakem, Superway, Titan
				Bifentin 100EC	Farmalinx
				Bisect Duo	UPL
				Bi-thrin	Kdpc
				Compel	Amgrow
				Disect	UPL
				Fenstar	Biotis Life Science
				Fenthrin	Sipcam
				Killzone	Freezone
				Out of Bounds	Barmac
				Sarritor	Nuchem
				Surefire Bent	PCT
				Tal-ken	Kenso Agcare
				Talstar	Fmc
				Termighty	Willobri
				Venom	ADAMA
			250 g/L EC	Astral	Crop Care
				Bifenthrin 250EC	Cheminova, Enviromax
				Stockade	Apparent
				Talstar	Fmc
			300 g/L EC	Bifenthrin Ultra	Imtrade
Chlorantraniliprole	diamides	28	350 g/kg	Altacor	DuPont
Chlorantraniliprole/ Thiamethoxam	Diamides/Neo-nicotinoids	28/4A	200 g/kg/200 g/kg WDG	Voliam Flexi	Syngenta
Chlorpyrifos	organophosphate	1B	500 g/L EC	Chemicide	Hextar Pty Ltd
				Chlorban	UPL
				Chlorpros	Farmalinx
				Chlorpyrifos	4Farmers, Accensi, Agkare, Agro-Alliance, Agrocn, Agvantage, Chemforce, Conquest, Country, Crop Smart, Cutter, David Grays, Ezycrop, Fmc, Fortune, Genfarm Landmark, Halley, Imtrade, Macphersons, Mission Bell, Novaguard, Nufarm, Ozcrop, Rainbow, Ravensdown, Sabakem, Sabero, Spalding, Titan, Wsd,
				Chop	Axichem
				Cuft	Agri West Pty Limited
				Cyren	Cheminova Australia Pty Limited
				Dingo	Apparent
Clothianidin	neo-nicotinoids	4A	200 g/L SC	Shield	Sumitomo Chemical
Cyantraniliprole	Diamides	28	100 g/L SE	Exirel	DuPont

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2015* (continued)

Active ingredient	Chemical group	Insecticide group	Concentration & formulation	Trade name	Marketed by
Cypermethrin	pyrethroid	3A	200 g/L EC	Boom	Genfarm Landmark
				Cypermethrin 200 EC	Halley, United Farmers, Titan, Wsd
				Cypershield 200	Imtrade
				Cyrux 200	UPL
				Scud Elite	ADAMA
			250 g/L EC	Arrivo	Fmc
				Cyper Plus	Genfarm Landmark
				Cypermethrin 250 EC	Accensi
				Cyrux 250	UPL
			260 g/L EC	Cypermthrin 260 EC	4Farmers, Agriwest;
Deltamethrin	pyrethroid	3A	27.5 g/L EC	Ballistic Elite	ADAMA
				Decis Options	Bayer CropScience
				Delta-Duo	Imtrade
				Deltamethrin Duo	Apparent
				Deltamethrin Duo	Halley, eChem
				Dicast	Sinon
				D-Sect	Cropro
				Surefire Deltashield	PCT
Diafenthiuron	organotonin miticides	12B	500 g/L SC	Aphinox	Sumitomo Chemical
				Detonate	Farmalinx
				Diafenthiuron	eChem
				Pegasus	Syngenta
				Receptor	ADAMA
Dicofol	organochlorine	UN	240 g/L EC	Miti-Fol EC	ADAMA
			480 g/L EC	Kelthane MF	Cropcare
Dimethoate (See permit 13155)	organophosphate	1B	400 g/L EC	Danadim	Cheminova
				Dimethoate	4Farmers, ADAMA, Agrogill, Agriwest, Apparent, Conquest, Farmalinx, Halley, Imtrade, Nufarm, Sinon, Superway, Titan
				Rover	Sipcam
				Saboteur	Crop Care
				Stalk	Cropro
Emamectin benzoate	avermectin	6	17 g/L EC	Affirm	Syngenta
Esfenvalerate	pyrethroid	3A	50 g/L EC	Sumi-Alpha Flex	Sumitomo Chemical
Etoxazole	Etoxazole	10B	110 g/L SC	ParaMite	Sumitomo Chemical
				Swoop	Nufarm
Fipronil	phenyl pyrazole	2B	200 g/L SC	Albatross	ADAMA
				Ancestor	Crop Culture
				Cannonball	Farmalinx
				Emporium	Axichem
				Fipronil 200SC	Enviromax, Landmark, Sherwood, Titan
				Flak	Agri West
				Kaiser	Campbell
				Maestro	Nufarm
				Onslaught	Apparent
				Regent 200SC	BASF
				Seeker	Sinochem
				Vista	Surefire PCT
Fipronil	phenyl pyrazole	2B	800 g/L WG	Brutus	Kenso
				Fipronil 800 WG	4Farmers, Gharda, Mission Bell
				Regal	Imtrade
				Regent 800WG	BASF
Flonicamid	pyridine carboxamide	9C	500 g/kg WG	MainMan	UPL Australia
Gamma-cyhalothrin	pyrethroid	3A	150 g/L CS	Trojan	Dow Agrosciences, Cheminova

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2015* (continued)

Active ingredient	Chemical group	Insecticide group	Concentration & formulation	Trade name	Marketed by
Helicoverpa NPV	nuclear polyhedrosis virus		2x109 OBS	Gemstar	Sipcam
			7.5x109 OBS	Helicovex	Organic Crop Protectant
			2x109 OBS	Heliocide	Bioflexus
			5x109 OBS	Vivus Max + Optimal	Agbitech
Imidacloprid	neonicitinoids	4A	200 g/L SC	Couraze	Cheminova
				Imidacloprid 200SC	4Farmers, Agro-Alliance, Apparent, eChem, Enviromax, Landmark, Mission Bell, Pacific Agriscience, Profeng, Superway, Titan
				Intersect	Sinochem
				Kohinor	ADAMA
				Komondor	Crop Culture
				Nuprid	Nufarm
				Savage	Kenso
				Sindor	Sinon
				Spectrum	PCT
			350 g/L SC	Couraze Classic	Cheminova
				Kohinor	ADAMA
				Nuprid 350SC	Nufarm
			700 g/L WG	Nuprid 700WG	Nufarm
				Senator	Crop Care
Indoxacarb	oxadiazine	22A	150 g/L EC	Steward	DuPont
Lambda -cyhalothrin	pyrethroid	3A	250 g/L CS	Cyhella	Zelam
				Flipper	Sherwood
				Kung Fu	Imtrade
				Lambda 250CS	Conquest, Easyfarm, Ezycrop, Novaguard
				Lambda-Cyhalothrin 250CS	4Farmers, Chemtura, Macro Protect, Mission Bell, Rainbow
				Limit	Sinochem
			250 g/L ME	Karate Zeon	Syngenta
				Matador Zeon	Crop Care
Magnet	UN	UN		Magnet	Ag Bitech
Methidathion	organophosphate	1B	400 g/L EC	Ridacide	Aako
			400 g/L EC	Suprathion 400 EC	ADAMA
Methomyl	carbamate	1A	225 g/L AC	Marlin	DuPont
				Methomyl 225	Cheminova ; Hextar
				Sinmas 225	Sinon
			225 g/L EC	Electra 225	ADAMA
			225 g/L LC	Landrin	Conquest
				Lannate L	Crop Care
				Mayhem	Axichem
				Methomyl 225	Fmc; Imtrade; Kenso Agcare, Mission Bell
				Nudrin 225	Crop Care
			225 g/L SC	Metho	Kd Plant Care
				Methomyl 225	Acp, Easyfarm, Ezycrop; Novaguard; Rainbow; Titan
				Seneca	Macphersons
Omethoate	organophosphate	1B	800 g/L SL	Fokus	Hextar
				Folimat 800	Ayrsta Lifescience
				Sentinel	Imtrade
Paraffinic oil	petroleum spray oil (PSO)		792 g/L EC	Canopy	Caltex
			815 g/L EC	Biopest	Sacoa
Phorate	organophosphate	1B	100 g/kg G	Thimet 100 g	Barmac
				Umet 100 g	UPL
			200 g/kg G	Thiamet 200 g	Barmac
				Umet 200 g	UPL
Piperonyl butoxide	synergist	synergist	800 g/L EC	PBO 800 EC	ADAMA, Agkare, Sipcam
				Puppet	Imtrade
				Synergy	Crop Care

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2015* (continued)

Active ingredient	Chemical group	Insecticide group	Concentration & formulation	Trade name	Marketed by
Pirimicarb	carbamate	1A	500 g/kg WDG	Aphidex	ADAMA
				Atlas	Titan
				Piri-ken	Kenso
				Pirimicarb 500WG	4Farmers, Apparent, Cheminova, Farmalinx, Imtrade, Landmark, Ozcrop, Rainbow,
				Pirimidex	Conquest
				Pirimor	Syngenta
			500 g/kg WP	Aphidex 500 WP	ADAMA
				Pirimicarb 500 WP	4Farmers
Propargite	propargite	12C	600 g/L EC	Bullet	Crop Care
				Comite	Chemtura
				Dyna-Mite 600	ADAMA
				Mitigate	UPL
				Propamite	Sipcam
				Propargite 600	Sabakem
				Treble	Nufarm
Pymetrozine	pymetrozine	9B	500 g/kg WDG	Fulfill	Syngenta
Pyriproxyfen	pyriproxyfen	7C	100 g/L EC	Admiral	Sumitomo Chemical
				General 100EC	Aalio Australia
Spirotetramat	spirotetramat	23	240 g/L SC	Movento	Bayer CropScience
Sulfoxaflor	Sulfoximines	4C	240 g/L SC	Transform	Dow Agrosciences
Thiamethoxam	Neo-nicotinoids	4A	250 g/kg wdg	Actara	Syngenta
Thiodicarb	carbamate	1A	375 g/L SC	Larvin 375	Bayer CropScience
			375 g/L SC	Showdown 375	ADAMA
			800 g/kg WDG	Confront 800 WG	Imtrade
			800 g/kg WDG	Thiodicarb 800 WG	Mission Bell

(*Some products that are registered but no longer commercially available have been omitted; Due to space limitations some trade names and marketers names have been shortened/abbreviated. Refer to www.apvma.gov.au for updates and more information)

TABLE 19: Insecticide seed treatment trade names and marketers – Registered chemicals as at June 30, 2015

Active ingredient	Chemical group	Insecticide group	Concentration and formulation	Trade name	Marketed by
Imidacloprid*	4A	Neo-nicotinoids	600 g/L FS	Gaucho	Bayer
				Genero	eChem
Imidacloprid + Thiodicarb	4A/1A	Neo-nicotinoids/Carbamates	350 + 250 g/L FS	Amparo	Bayer
Thiamethoxam	4A	Neo-nicotinoids	350 g/L FS	Cruiser 350 FS	Syngenta
	4A	Neo-nicotinoids	600 g/L FS	Cruiser Extreme 600 FS	Syngenta

*There are multiple other registrations for Imidacloprid, however these are currently not commercially available through CSD.

Integrated Pest Management (IPM) in cotton

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Introduction

Successful pest management aims to keep pest populations to levels that do not cause economic damage, to maintain profitability year after year and to preserve a healthy environment.

The key challenge is to prevent over-reliance on chemical control of pests that will lead to insecticide resistance and render insecticidal control options ineffective. Insecticide resistance can destroy an industry and the collapse in 1975 of the cotton industry in the Ord River Irrigation Area in Western Australia is testament to this. History has shown that reliance on a single pest control tactic will result in resistance problems, and the cotton industry in eastern Australia has been seriously challenged by insecticide resistance in its 50 year history.

What is IPM?

Integrated Pest Management (IPM) is a concept developed in response to problems with managing pests, insecticide resistance and environmental contamination. The basic concept of IPM is to use knowledge of pest biology, behaviour and ecology to implement a range of tactics throughout the year in an integrated way that suppresses and reduces their populations. This approach considers tactics to suppress or avoid pests across the farm and surrounding areas, and tactics to manage pest and beneficial insect populations in the crop, including the responsible use of insecticides.

Because all pests have other animals that eat them, such as predators or parasites (known as beneficials or natural enemies), building and conserving populations of beneficials is at the heart of IPM. To conserve natural enemies, a pest management decision needs to be well informed, supported by good sampling, valid control thresholds and knowledge of the beneficials present and their activity. Finally, if insecticides are required, they are selected based on the Insecticide Resistance Management Strategy (to avoid resistance), how effective they are on the pest (to ensure adequate control) and their risk (soft) to the beneficial population (so beneficials can be conserved).

The outcome of an effective IPM system is long term stable management of pests and beneficials, reducing the risk of resistance, so that economic losses of crop yield and quality and threats to human health and the environment can be minimised. Elements of best practice IPM are::

1. Know your enemy and your friends.
2. Take a year round approach.
3. Think of the farm and surrounding vegetation as a whole system.
4. Have good on-farm hygiene.
5. Consider options to escape, avoid or reduce pests.
6. Sample crops effectively and regularly.
7. Aim to grow a healthy crop.
8. Evaluate pest abundance against established thresholds.
9. Choose insecticides wisely to conserve beneficials.
10. Apply good resistance management principles.

Developing an IPM strategy

As part of your plan to grow cotton, identify your in-crop risks and identify how different tactics will be applied in-crop for different pest scenarios. Identify what your overall IPM goals will be, some examples include:

- Start each cotton season with low/no pest populations.
- Avoid unnecessary insecticides especially early season.
- Follow the cotton industry's IRMS for all insecticides.
- Make non-crop areas more productive for beneficials.
- Avoid pest outbreaks that are generated within the farm.
- Minimise impact on bees and beneficials.
- Participate in Area Wide Management.

Communicate your IPM goals and planned tactics with your entire farming team and neighbouring farmers.

As insecticides still play an important role in an IPM system, develop and implement a chemical handling application management plan (CHAMP), formerly PAMP, to minimise the risks associated with a pesticide application specific to your farm. A CHAMP will help to establish good communication with everyone involved and interested in the application of pesticides, both pre-season, and during the season, as well as ensuring appropriate application techniques and procedures are used and that sufficient record keeping is kept. For more information and assistance in developing a CHAMP go to the *my*BMP website (www.mybmp.com.au).

What can I do to avoid or suppress pests on my farm?

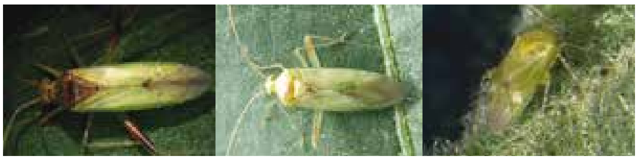
Upfront tactics

1. Know your enemy and your friends

'The enemy of your enemy is your friend!' Knowledge of pest species, and their damage, and beneficials and the pests they feed on is critical in evaluating the potential for economic loss.

Knowledge of pest ecology can identify sources of potential infestation and non-insecticidal management strategies to control the pest before problems develop. For instance, management of weed hosts may reduce pest abundance. Understanding the ecology of key beneficial insect species and their preferred prey is also valuable. It is equally important to recognise signs of parasitic activity, as many parasitoids are too tiny and secretive to find in a field check. For example, whitefly parasitoids, *Encarsia* and *Eretmocerus* lay their eggs into whitefly nymphs. These small wasps complete their development by using (and eventually killing) the whitefly. The pale yellow/green Whitefly nymphs will turn brown or black (*Encarsia*) or yellow/brown (*Eretmocerus*) when parasitised.

Consider how your IPM strategy can target different mechanisms of pest



Brown mirid (L), green mirid (centre) and apple dimpling bug are known to damage squares to varying degrees and apple dimpling bug is generally regarded more as a predator of heliothis eggs and mites. (Photos 1, 2 M Khan, QLD DAF; 3 C. Mares, CSIRO) survival. For information about key pests and mites of Australian cotton go to page 5. Refer to the Australian Cotton Production Manual and the 'Guide to Pests and Beneficials in Australian Cotton Landscapes' for more information.

If you would like to participate in workshops or training on IPM, contact your CottonInfo Regional Development Officer (see inside back cover).

2. Take a year round approach

Seasonal conditions and farming practices during the winter months can have a big influence on summer pest populations. Divide the year up into logical phases and consider what actions could be taken in each phase to reduce overall risk, refer to the IPM calendar pages 6–7.

Take into account factors such as;

- Crop history – for some pests if a field had a problem with that pest last year it may be more prone to the same pest next year (mites are an example).
- Crop sequences – can encourage build up and movement of the same pest between crops (eg late soybeans will inherit silverleaf whitefly populations from nearby maturing cotton), management of weeds in fallows and crops.

Seasonal conditions are a major driver of outbreaks of pests. For example, a wet winter and spring will increase the risk of a number of key cotton pests because they are able to survive on hosts (often weeds) that grow on the unseasonal rainfall. Conversely, a wet summer in southern regions of Australia may promote the likelihood of winter pest outbreaks. Being aware of how the conditions may influence pest pressure will help assess the risk of pest outbreak.

3. Think of the farm and surrounding vegetation as a whole system

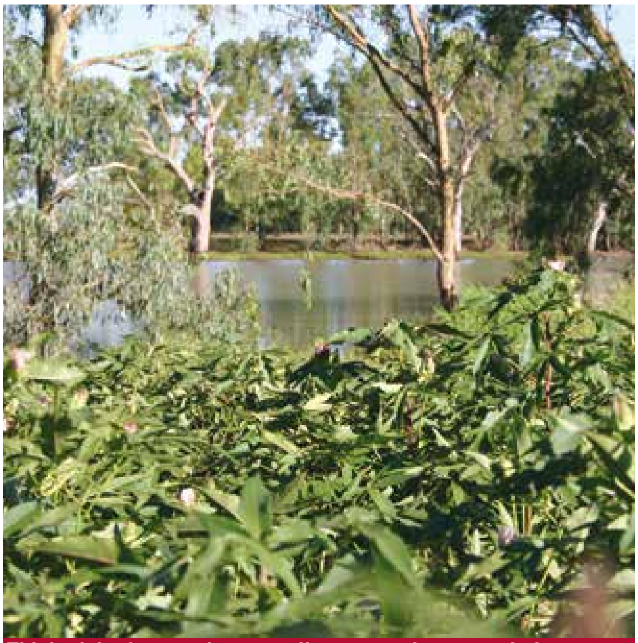
Insects live in landscapes, not on farms. Management across farms can impact on both pests and beneficials. This extends beyond cropping land, as areas of complex, perennial vegetation can be an important host for beneficials.

Consider this situation – if you were to spray all of the fields on your property at once with a disruptive insecticide there will be a large decline in the abundance of predators and parasites in those fields. This places those fields at risk because other secondary pests not controlled by the insecticide may then increase without being controlled by beneficials. Also pests which enter the crop after a disruptive insecticide application will survive better and potentially cause more economic damage. If beneficials are disrupted, where will new beneficials come from to re-establish in the crop?

One source of beneficials could be unsprayed crops on the farm or nearby farms – reinforcing the notion that it is only sensible to control pests in the fields where they warrant control. This 'site-specific' management means unsprayed fields will harbour beneficials and are a source of beneficials to re-colonise sprayed fields. To build beneficials across the farm, apply IPM principles to manage all crops, not just cotton.

Another source of beneficials is native vegetation both on farms and in the region. When it comes to pest management, 'Veg is Valuable' as an important source of beneficials. This is especially so because these areas are permanent and usually complex, with a range of species and layers, and so provide continuous prey as well as habitat for beneficials year round, whereas cropped fields may be fallow for long periods. When looking to enhance IPM value of areas of vegetation consider the following:

- Managing for groundcover and diversity
- Prioritise connectivity
- Enhance habitat with water ways
- Control pest hosts, especially volunteer cotton.



Think of the farm and surrounding vegetation as a whole system. (Photo: Greg Kauter, formerly Cotton Australia)

The Cotton Pest and Beneficial Guide and the Australian Cotton Production Manual provide more information on enhancing natural assets to improve IPM values.

Area Wide Management (AWM) acknowledges that insects are mobile and that the management regimes used on one farm can have implications for the surrounding locality. Sharing your strategies and coordinating tactics with neighbouring cotton growers as well as other farmers will increase the success in implementing IPM. These may include weed management, conserving beneficials, delaying use of disruptive insecticides, reducing the risk of drift between farms, shared adherence to IRMS, planting windows, maintenance or enhancement of local native vegetation areas 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.

4. Have good on-farm hygiene

Many cotton pests rely on weed hosts and cotton volunteers prior to migrating into cotton fields.

Pests that gain the greatest advantage from weeds are those that are unable to hibernate/over winter when conditions are unfavourable, such as spider mites, cotton aphids, mirids and silver leaf whitefly. Some weeds and cotton volunteers or ratoons can also act as a reservoir for plant viruses such as Cotton Bunchy Top disease which can cause significant loss of yield. Weed hosts should be managed in non-crop areas such as field borders, roadways, irrigation channels and in perennial vegetation and pastures, as well as in fallows. Refer to pages 5–37 for details of hosts of key insect and mite pests of Australian cotton.

Cotton volunteers are the worst weeds in terms of pest risk. A 'zero tolerance' approach to cotton volunteers throughout the year is required – refer to page 119 for more information.


UPL. A great growth story.

5. Consider options to escape, avoid or reduce pests

Pre-season planning to reduce pest risks can help to identify upfront opportunities to suppress or avoid the incidence of pests throughout the season.

Field selection

Consider proximity to other host crops, as well as sensitive areas such as watercourses, pastures and buildings, relative to the prevailing wind direction. Growing Bt crops maybe most appropriate for fields adjacent to sensitive areas. Conventional cotton may benefit from being embedded amongst Bt cotton and rotation crops. In this situation pest loads are diluted across all the crop area. The conventional crops may gain some protection by Bt crops intercepting some of the Helicoverpa population, and surrounding 'low spray' Bt crops can act as sources for the re-entry of beneficials into conventional crops if sprays are required. Bt crops adjacent to conventional cotton crops may also suffer boll damage from large Helicoverpa larvae (4-6 instar) unaffected by Bt toxin, migrating from conventional crops. Conventional crops (particularly unsprayed refuge) and Bt crops should be separated by at least a 20 m buffer or should not be planted side by side on the same field.

As part of field selection, stubble loads and soil pest activity should be monitored in the lead up to planting. There are no insecticidal control options for symphyla or nematodes – field selection is an important component of managing the rare but serious risks associated with these pests. Refer to page 37 for more information about soil dwelling pests.

Also worthy of consideration is whether the intended location of cotton fields creates 'stepping stone' linkages between areas of crops and vegetation to enable movement of beneficials through the landscape.

Varietal selection

Select a variety that suits the growing region in terms of season length. The okra leaf shape reduces the rate at which silverleaf whitefly and two spotted spider mite populations are able to increase in cotton.

Bt crops are ideally suited to IPM as the level of control of *Helicoverpa spp.* provided by the plant reduces the need to spray for those pests. This in turn increases beneficial numbers, which naturally suppresses populations of other pests.

Seed treatment

Seed treatments provide prophylactic protection against early season/establishment pests. In general they are less disruptive to beneficial populations than spraying the crops with a foliar insecticide because most options available are not very selective. Prior to using a seed treatment, refer to the current Insecticide Resistance Management Strategy (IRMS) for your region for more information on insecticide use when seed treatments are used.

Seed bed preparation and strategic planting time

Vigorous, healthy, early growth enables crops to recover from what can at the time appear to be significant early season damage from soil dwelling pests such as wireworm, mealy bug and symphyla. Planting during optimal temperatures for germination, contributes to this early vigour, and can reduce the need for prophylactic insecticidal seed treatments, as well as improve tolerance towards seedling disease and herbicides.

Very late planted crops which have delayed maturity can be susceptible to influxes of pests such as whitefly at the end of the season. See page 27 for further information on late season whitefly control.

Create a diversion

Summer trap cropping aims to concentrate a pest population into smaller less valuable areas by providing the pest with a host crop that is more preferred and attractive than the crop you are aiming to protect, for example lucerne can be used as an effective trap crop for mirids. In Central Queensland, pigeon pea is used as a summer trap crop as part of the RMP for Bollgard II cotton.

Spring trap cropping with chickpeas is designed to attract *H. armigera* adults as they emerge and reduce the first generation through strategic crop destruction. It is important to ensure that the chickpea crop does not become a nursery for multiple generations of moths.

Pupae busting

In NSW and Southern Qld, cultivation of cotton fields through winter, kills diapausing *H. armigera* pupae in the soil, and has proven to assist in the management of resistance. Pupae busting is required following harvest of Bollgard II cotton (see page 73) and is recommended by the industry's IRMS for all cotton (page 61).

Build bigger populations of beneficials

Careful farm management and planning can enhance beneficial populations and increase their contribution to controlling pests. The abundance of beneficials in a cotton crop is affected by food resources, mating partners, proximity to other sources of habitat, climatic conditions and insecticide sprays. In addition to enhancing opportunities to build beneficials in nearby habitat, such as rotation crops and perennial vegetation, tactics to attract and build beneficials early in the crop should be considered.

The application of food sprays in cotton crops attracts and retains beneficial insects. There is currently only one type of food spray commercially available for use in cotton. Predfeed is a yeast based food spray that attracts beneficial insects and should be applied when a cotton field does not have enough beneficial insects.

The abundance of beneficial species can be increased through purchase and release of predators and/or parasitoids in the crop. While this practice is widespread in other industries, this has not been demonstrated as effective in cotton. The *Trichogramma* spp. wasp (parasite of *Helicoverpa spp.* eggs) has been successfully released to help control Helicoverpa. 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 the very short life cycle.

TABLE 20: Food sprays and spray additives

Active ingredient	Formulation	Application rate of product	Trade name	Marketed by	Comments
Food concentrate (yeast based)	WP	2.5 kg/ha	Predfeed	Growth Agriculture	Beneficial insect attractant. Apply prior to increase of pests. See label for notes on spray coverage.


POISON
MainMan
500 WG INSECTICIDE
UPL

What can I do to manage pests in my crops?

Active tactics

6. Sample crops effectively and regularly

Regularly sample and correctly identify pest and beneficial populations. Observe beneficial activity (eg thrips in mite colonies, parasitized aphid mummies, ladybirds, hoverfly, lacewing larvae in aphid colonies).

Ensure you can identify key pests, beneficials, signs of parasitism and types of plant damage. This information forms the backbone for making pest control decisions. A key resource is the 'Cotton Pest and Beneficials in Australian Cotton Landscapes'. This is available through www.cottoninfo.net.au or by contacting your regional CottonInfo team member. Some insects are difficult to see with the naked eye – a 10X power hand lens in your pocket is an invaluable tool to quickly and simply check pest species. These are available from Australian Entomological Supplies. Some species, such as greenhouse whitefly and SLW cannot be differentiated in the field. Refer to the relevant insect and mite pest section (pages 5–37) for industry contacts on who can help with identification.

If you suspect you have an exotic pest or disease on your farm, immediately contact the Exotic Plant Pest Hotline 1800 084 881.

How to sample for pests and beneficials

There is a range of sampling techniques available. Make sure you familiarise yourself with these techniques and use those that are appropriate for the pests, beneficials and threshold.

DECISION MAKING PROTOCOL (beneficial to pest ratios)

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 (PSO)
< 0.4	> threshold	Selective insecticide.

Bollgard II crops

The beneficial 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, mix PSO with soft chemical and apply to crop

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 www.myBMP.com.au

Visual sampling: This involves looking at the entire plant, including under leaves, along stems, in squares and around flowers and bolls. Check at least 30 plants or 3 to 4 separate metres of cotton per 50 ha.

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. Preliminary studies indicate that at least 8–10 metres are required per field (~50 ha).

D-vac sampling is more common as a research tool, however, can be used as an additional method when sampling 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 mirid adults, and each sample consists of 20 sweeps along a single row of cotton using a standard (380 mm) sweep net. Preliminary studies indicate that at least 6 sweep net samples are required per field (~50 ha).

Sampling specific pests: Aphids, Spider mites and Whitefly have specialised sampling methods. See their relevant pest section to find out more.

Fields are rarely uniform in crop growth and attractiveness to insects. For example mealybugs are more likely to build up in areas of plant stress, such as water-logged tail drains, while other pests may be more likely to lay eggs in areas of lush growth. Awareness of such areas and their size helps you to determine how many sample points are required in a crop.

Note: Increasing the number of samples will increase the level of accuracy.

Monitoring predators and levels of parasitism provides useful detail for IPM decision making. Where high levels of beneficials are recorded, this can provide confidence in delaying an insecticide. Refer to Table 21 'Friends in the field' for which beneficials target what prey.

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 beneficial to pest ratio to be determined.

Guidelines for the beneficial to pest ratio

Beneficial to pest ratio for sucking pests have not been determined. However, the ratio for *Helicoverpa spp.* has been determined and given below for both conventional and Bollgard II cotton crops. The most common predators found in cotton farms feed on a wide range of pests and are therefore classified as general predators. Therefore, the beneficial to pest ratio calculated for *Helicoverpa spp.* may also be enough to manage other secondary pests.

TABLE 21: Friends in the field

	Heliothis	Aphid	Mealybug	Spider Mites	SLW	Green Mirid	Jassids	Thrips	Notes
Red and blue beetle	X	X							Red and blue beetles are also predators of slow moving insects. The larvae feed on small worms and other soil organisms.
Lady beetles	X	X	X	X	X		X		Lady beetles also feed on scale insects.
Apple dimpling bug (yellow mirid)	X			X	X				ADB can also cause damage, but threshold is 5 times greater than green mirids. Monitor fruit retention.
Damsel bug	X	X		X		X			
Big Eyed bug	X			X	X				
Brown smudge bugs	X		X	X	X				
Glossy shield bug	X								Also predators of other caterpillars.
Predatory shield bug	X								Also predators of other caterpillars.
Minute pirate bugs				X	X			X	
Assassin bug	X					X			Also predators of other caterpillars.
Lacewings	X	X	X	X				X	Lacewing larvae is the predator.
Spiders	X			X	X	X	X		Spiders can eat both good and bad insects.
Parasitoids	X	X	X		X				Species of parasitoid are specific in pests targeted. Monitor for parasitized pests.
Hoverfly larvae and Silverfly larvae		X							The adult will lay on your crop when there are aphid colonies.
Thrips				X	X				Can be an early season pest.

Calculation of the beneficial to pest ratio per metre for *Helicoverpa spp*:

The beneficial to pest ratio is calculated as –

$$\text{Ratio} = \frac{\text{beneficials}}{(\textit{Helicoverpa spp.}\ \text{eggs} - (\%\ \text{parasitised}) + VS + S)}$$

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 larger life stages.

Total beneficials per metre (visual check) should be used in calculating the beneficial to pest ratio. However, to be confident in the ratio, at least three insects of the most common beneficials (ladybird beetle, red and blue beetle, damsel bug, big eye bug, assassin bug, brown shield bug and lacewings) should be present. The beneficial to pest ratio calculation includes parasitoids as *Trichogramma spp.* wasps can be important in controlling *Helicoverpa spp.* in crops. To monitor egg parasitism by *Trichogramma spp.* Collect brown eggs and keep them at room temperature (about 25°C) until they hatch (healthy) or turn black (parasitised). From this procedure, the calculation of the percentage of parasitised eggs can be used in the beneficial to pest ratio. Collecting white eggs gives an underestimate of parasitism because they may have just been laid and not had sufficient time to be found by *Trichogramma* spp.

7. Aim to grow a healthy crop

A healthy cotton crop will be more able to recover from pest damage and reach its yield potential. 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.

Growing a healthy cotton crop optimises its yield potential, fibre quality and capacity to compensate for pest damage. While yield (and quality) potential will largely be determined by a range of factors, IPM provides a strategy to help manage the risk of economic losses due to pests, in the current season, as well as future crops.

Monitoring crop as well as insects

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 have a significant ability to recover from damage, especially early season damage with no reduction in yield or delay in maturity. Plant monitoring in conjunction with regular insect monitoring allows an assessment of the effects of 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.

Damage monitoring should be conducted as frequently as pest sampling and includes:

- Leaf area loss or discoloration;
- Tip damage;
- Fruit retention or fruiting factor; and,
- Boll damage.

Refer to 'Key Insects and Mites of Cotton Section' for pest specific damage thresholds. 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.

Cotton development can be predicted using daily temperature data (day degrees). Monitoring crop vegetative and reproductive growth compared to a potential rate of growth and development enables crop managers to determine when growth is not optimal and manage accordingly.

The CottASSIST Crop Development Tool (CDT) is a web based tool that helps to determine whether the rate of crop development is meeting its potential. Using the CDT, the development of nodes, vegetative growth rate, square and boll 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, and the tool accesses local climate data to calculate accumulated day degrees (DD) for that location. The tool displays this in graphical and tabular formats alongside theoretical potential or optimum development. 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. CottASSIST can be accessed at www.cottassist.com.au

What to monitor?

Leaf damage

Research on seedling cotton (up to 6 nodes) has found that loss of leaf area did affect maturity, but only treatments with more than 80 per cent loss of leaf area were affected.

Tip damage

Tip damage caused by thrips appears as extensive crumpling and blackening of the edges of the small leaves within the terminal. If only the terminal is blackened, damage could be considered light. If the terminal plus one or more true leaves are blackened, damage could be considered heavy. Tip damage caused by *Helicoverpa spp.* larvae in conventional cotton is more evident as the terminal will normally be completely destroyed. In many cases, the secondary terminal will also be damaged or destroyed. Tip damage caused by the cotton tipworm in conventional cotton is also obvious as larvae will often be still entrenched or burrowed into the terminal.

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. 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. Squaring node development can be tracked using the CottASSIST Crop Development Tool.

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 CottASSIST Crop Development Tool'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.

Nodes above white flower (NAWF)

At the time of first flower, there should be about 8 nodes above the first position white 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 allocating resources to the developing fruit, the rate at which the crop can produce more squaring nodes is in decline.

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. NAWF can also be tracked using the CottASSIST Crop Development Tool.

Vegetative Growth Rate (VGR)

VGR is the industry recommended approach for identifying excessive growth. The VGR tracks the rate of change in plant height relative to the rate of node development.

VGR is calculated using the following equation:

$$\text{VGR (cm/node)} = \frac{\text{This week's height (cm)} - \text{Last week's height (cm)}}{\text{This week's node number} - \text{Last week's node number}}$$

Measurements of height and nodes should start as the crop approaches first flower and continue whilst squaring nodes are being produced. VGR can be tracked using the CottASSIST Crop Development Tool. In making a decision as to whether Mepiquat Chloride can help, it is important to consider causes behind any excessive growth.

Refer to the Australian Cotton Production Manual for more information.

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 and effective way to estimate early signs of pest damage.

Percentage of first position fruit retention =

$$\frac{\text{Count first position fruit (either top five or all fruiting branches)}}{\text{Count total fruiting branches}}$$

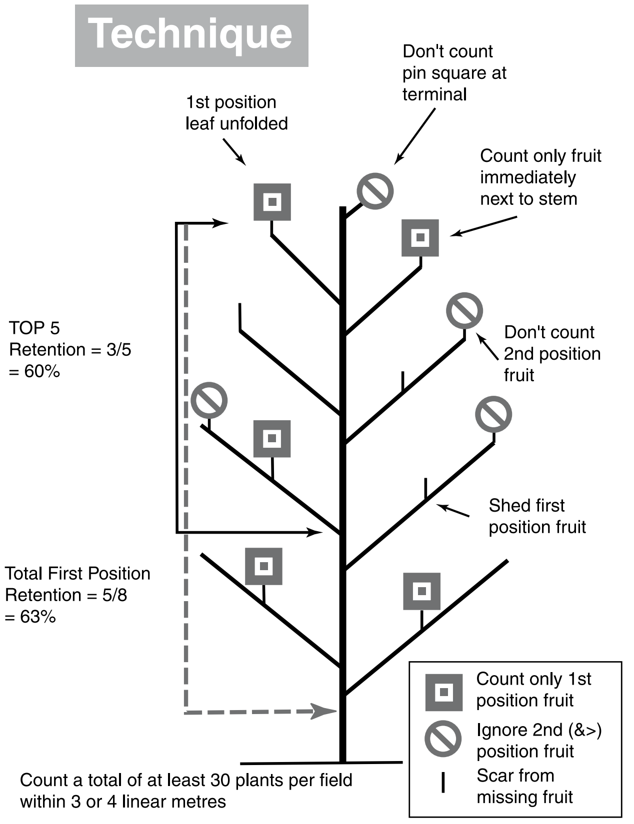
Monitor both tipped and non-tipped plants using the dominant stem, not vegetative branches.

Aim to have first position fruit retention of 50–60 per cent by first flower. Low retention (<50 per cent) increases the risk that yield or crop maturity will be affected. However, very high fruit retention, in excess of 80 per cent may also be associated with premature crop cut-out. For the first five fruiting branches on the plant, first position fruit retention can be as low as 30 per cent without affecting yield or maturity, however such levels should trigger close monitoring and a reduction in thresholds. Refer to Figure 1 below.

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 per cent of all possible fruiting sites. First position retention will vary from 50–70 per cent. Cotton variety and boll size will also affect final yield.

FIGURE 1: A technique for checking fruit retention



Fruiting factor

Fruiting factors allow total fruit load to be monitored throughout the season. Fruiting factors should be used when first position retention falls below recommended levels (ie. 50–60 per cent), to 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 per cent 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 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.

8. Evaluate pest abundance against established thresholds

Economic thresholds based on research, are available for most major pests in cotton. These thresholds should be used in conjunction with information on forecast, crop stage, plant damage and beneficial abundance to make decisions about the need to spray.

Economic thresholds are usually derived from experiments where pest densities are manipulated so that the relationship between pest abundance or amount of damage and yield can be established. Once this is known it is possible to determine the pest density or damage level at which control must be implemented to prevent economic loss. Thresholds should be considered in context of other factors that may influence the need to spray.

For instance, if pest abundance is just over threshold but damage is low and beneficial populations are high it is practical to delay control several days. This is a low risk strategy to allow time for beneficials to manage the pests to below threshold levels, thereby avoiding a potentially disruptive spray and reducing insecticide costs and selection for resistance. Conversely, if pest damage is high and there are low numbers of beneficials (perhaps due to an earlier spray) then immediate control with an insecticide may be the best option. In cotton a 'beneficial to pest ratio' has been developed for *Helicoverpa spp.* to assist these decisions by indicating a ratio above which the pest is likely to be effectively controlled by the beneficial population.

Ensure that the threshold used is appropriate for the crop stage, sampling method and region. For example the mirid threshold accounts for the reduced ability to compensate for damage in cool regions, variation in yield loss due to crop stage and differences in effectiveness of different sampling techniques. The mirid threshold also provides crop damage levels that need to be considered in conjunction with pest and beneficial population.

Thresholds for cotton aphid, two-spotted mite and silverleaf whitefly are based on cumulative population changes, and require comparison of multiple samplings to determine if action thresholds have been reached. CottASSIST provides threshold tools that support management decisions.

Knowledge of the pest and the environment is important in determining whether a spray is warranted. For example two spotted mite populations can be suppressed by cool conditions, however will increase rapidly when it is hot and dry, and so consideration of the forecast conditions should be part of the decision. While some thresholds only require monitoring of one lifecycle stage, it can be useful to be aware of all life stages. For example, the silverleaf whitefly threshold is based on presence/absence of adult whitefly, however monitoring nymphs can help to identify if a population has built up within the crop, or has migrated in recently.

9. Choose insecticides wisely to conserve beneficials

IPM strategies aim to balance the contribution of beneficials with the need to protect the crop from significant loss. Where insecticide control is warranted, use the most selective effective insecticide (soft on beneficial insects), adhere to the IRMS and consider a reduced rate mixed with either salt or spray oils.

Selecting an insecticide

Spraying is often the final resort in an IPM program, however product choice will have a large impact on the strategy for the remainder of the season. When choosing an insecticide (or miticide) in addition to the efficacy against the targeted pest, it is very important to consider the 'selectivity'. Some insecticides are very selective and have very little impact on beneficial insects (often referred to as 'soft') while others are highly disruptive to beneficial populations ('broadspectrum' or 'hard'). The relative selectivity of all insecticides available for use in cotton can be found in Table 3 pages 8–9. Refer also to the IRMS (see pages 61–64)

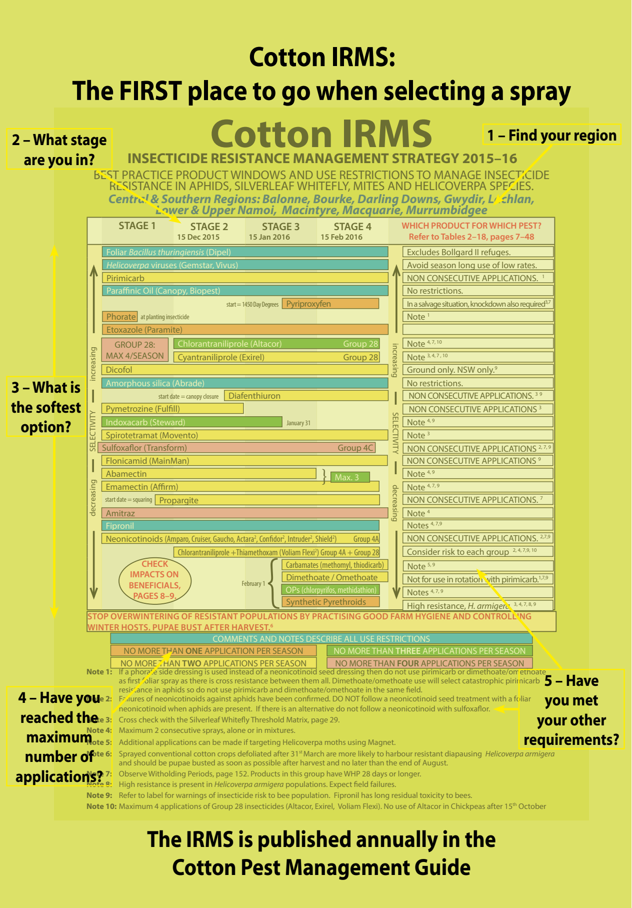
The selectivity of the insecticide helps to assess the risk that following its use, populations of other pests may 'flare' (increase rapidly). For example, where a mirid population has increased above threshold during flowering and an insecticide is required, the best choice depends not only on your budget, but the product's selectivity relative to the types of beneficials you have and want to conserve. Within the IRMS there are several options available at this time with differing selectivity profiles. According to Table 3, pages 8–9, the newer neonicotinoid product, clothianidin (tradename Shield), will reduce populations of lady beetles (aphid predators) and Eretmocerus wasps (whitefly parasitoids) but conserve predatory bugs and thrips (mite predators). In contrast the low rate of fipronil (multiple tradenames such as Regent) with salt will reduce predatory bug populations, and conserve lady beetles, but have an unknown impact on the key wasp parasitoids of whitefly. It is important to note that for many products Table 3 (pages 8–9) considers rate as well as product. Lower registered rates of a product may provide sufficient efficacy against the target pest, while minimising impact on beneficials.

Increases in populations of non-target pests such as aphid, mite and whitefly may follow insecticide applications if the beneficial populations keeping them in check are disrupted.

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 direct contact with foraging bees occurs during the application. This occurs if foraging bees carry residual insecticide back to the hive after the application or when insecticide drifts over hives or neighbouring vegetation which is being foraged by bees. Always look for and follow label directions regarding impact on bees and refer to page 141 for more information on how to manage the risk to bees.

Consider alternatives

Consider the use of reduced rates of synthetic insecticides mixed with either salt or petroleum spray oils. In some instances this will provide greater selectivity and better efficacy.



Cotton IRMS:
The FIRST place to go when selecting a spray

Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2015–16

BEST PRACTICE PRODUCT WINDOWS AND USE RESTRICTIONS TO MANAGE INSECTICIDE RESISTANCE IN APHIDS, SILVERLEAF WHITEFLY, MITES AND HELICOVERPA SPECIES.

Central & Southern Regions: Balonne, Bourke, Darling Downs, Gwydir, Lachlan, Lower & Upper Namoi, Macintyre, Macquarie, Murrumbidgee

STAGE 1 | STAGE 2 15 Dec 2015 | STAGE 3 15 Jan 2016 | STAGE 4 15 Feb 2016	WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2–18, pages 7–48
Foliar *Bacillus thuringiensis* (Dipel)	Excludes Bollgard II refuges.
Helicoverpa viruses (Gemstar, Vivus)	Avoid season long use of low rates.
Pirimicarb	NON CONSECUTIVE APPLICATIONS. ^{1}
Paraffinic Oil (Canopy, Biopest)	No restrictions.
start = 1450 Day Degrees Pyriproxyfen	In a salvage situation, knockdown also required^{3,7}
Phorate at planting insecticide	Note ^{1}
Etoxazole (Paramite)	
GROUP 28: MAX 4/SEASON Chlorantraniliprole (Altacor) Group 28	Note ^{4,7,10}
Cyantraniliprole (Exirel) Group 28	Note ^{3,4,7,10}
Dicofol	Ground only. NSW only.^{9}
Amorphous silica (Abrade)	No restrictions.
start date = canopy closure Diafenthiuron	NON CONSECUTIVE APPLICATIONS. $^{3\ 9}$
Pymetrozine (Fulfill)	NON CONSECUTIVE APPLICATIONS ^{3}
Indoxacarb (Steward) January 31	Note ^{4,9}
Spirotetramat (Movento)	Note ^{3}
Sulfoxaflor (Transform) Group 4C	NON CONSECUTIVE APPLICATIONS ^{2,7,9}
Flonicamid (MainMan)	NON CONSECUTIVE APPLICATIONS ^{9}
Abamectin } Max. 3	Note ^{4,9}
Emamectin (Affirm)	Note ^{4,7,9}
start date = squaring Propargite	NON CONSECUTIVE APPLICATIONS. ^{7}
Amitraz	Note ^{4}
Fipronil	Notes ^{4,7,9}
Neonicotinoids (Amparo, Cruiser, Gaucho, Actara^{2}, Confidor^{2}, Intruder^{2}, Shield^{2}) Group 4A	NON CONSECUTIVE APPLICATIONS. ^{2,7,9}
Chlorantraniliprole + Thiamethoxam (Voliam Flexi^{2}) Group 4A + Group 28	Consider risk to each group ^{2,4,7,9,10}
February 1 { Carbamates (methomyl, thiodicarb)	Note ^{5,9}
Dimethoate / Omethoate	Not for use in rotation with pirimicarb.^{1,7,9}
OPs (chlorpyrifos, methidathion)	Notes ^{4,7,9}
Synthetic Pyrethroids	High resistance, *H. armigera* ^{3,4,7,8,9}

CHECK IMPACTS ON BENEFICIALS, PAGES 8–9.

STOP OVERWINTERING OF RESISTANT POPULATIONS BY PRACTISING GOOD FARM HYGIENE AND CONTROLLING WINTER HOSTS. PUPAE BUST AFTER HARVEST.^{6}

COMMENTS AND NOTES DESCRIBE ALL USE RESTRICTIONS

🟧 NO MORE THAN **ONE** APPLICATION PER SEASON

🟨 NO MORE THAN **TWO** APPLICATIONS PER SEASON

🟩 NO MORE THAN **THREE** APPLICATIONS PER SEASON

🟥 NO MORE THAN **FOUR** APPLICATIONS PER SEASON

Note 1: If a phorate side dressing is used instead of a neonicotinoid seed dressing then do not use pirimicarb or dimethoate/omethoate as first foliar spray as there is cross resistance between them all. Dimethoate/omethoate use will select catastrophic pirimicarb resistance in aphids so do not use pirimicarb and dimethoate/omethoate in the same field.

Note 2: Failures of neonicotinoids against aphids have been confirmed. DO NOT follow a neonicotinoid seed treatment with a foliar neonicotinoid when aphids are present. If there is an alternative do not follow a neonicotinoid with sulfoxaflor.

Note 3: Cross check with the Silverleaf Whitefly Threshold Matrix, page 29.

Note 4: Maximum 2 consecutive sprays, alone or in mixtures.

Note 5: Additional applications can be made if targeting Helicoverpa moths using Magnet.

Note 6: Sprayed conventional cotton crops defoliated after 31st March are more likely to harbour resistant diapausing *Helicoverpa armigera* and should be pupae busted as soon as possible after harvest and no later than the end of August.

Note 7: Observe Witholding Periods, page 152. Products in this group have WHP 28 days or longer.

Note 8: High resistance is present in *Helicoverpa armigera* populations. Expect field failures.

Note 9: Refer to label for warnings of insecticide risk to bee population. Fipronil has long residual toxicity to bees.

Note 10: Maximum 4 applications of Group 28 insecticides (Altacor, Exirel, Voliam Flexi). No use of Altacor in Chickpeas after 15th October

1 – Find your region

2 – What stage are you in?

3 – What is the softest option?

4 – Have you reached the maximum number of applications?

5 – Have you met your other requirements?

The IRMS is published annually in the Cotton Pest Management Guide

The use of biopesticides such as NPV (Gemstar, Helicovex, Heliocide and Vivusmax) foliar Bt, petroleum spray oils (PSOs) or semiochemicals, such as the moth attractant Magnet to manage Helicoverpa and other sucking pests can help to conserve beneficial insects, minimise insecticide use and make it less likely to flare other pests.

Late season pest problems can sometimes be avoided by a successful defoliation. The silverleaf whitefly matrix illustrates that control of whitefly to protect crop yield and quality is required between peak flowering and 60 per cent open bolls. As the crop approaches the point where it can be defoliated, the reliance on insectide intervention declines.

Application

Ensure spray applications are accurate, timely and triggered by pest thresholds. Always follow label directions. Understanding how different insecticides work, can help when considering how efficacious they will be in a given situation. For example 'contact' insecticides, must be absorbed by the pest, and so application method (eg nozzle selection, higher water rates and use of ground rig) may improve impact on the pest. Systemic pesticides can be moved (translocated) throughout the plant where they kill chewing or sucking insects.

Some insecticides only target particular stages of a pest lifecycle. For example the insect growth regulators, pryiproxifen (tradename Admiral), does not kill adult silverleaf whitefly, however prevents egg hatching and progression from larval to adult stage, as well as sterilising of adult female insects. As this means it takes a while for the population to decline (maybe 10–14 days) before long term effective control of all life stages is achieved, this should be factored in, both in terms of managing honey dew risk from silverleaf whitefly, as well as assessing spray efficacy.

Pests such as aphids and mites often infest the edges of a field, not the entire field area. Consider whether it is possible to manage this type of infestation by only spraying the field borders. This may enable beneficial populations to keep pace with the remainder of the pest population in the field.

10. Apply good resistance management principles

Resistance management strategies and IPM strategies are complimentary. IPM aims to support resistance management by reducing the need to spray. Similarly, resistance management supports IPM by ensuring that the key insecticides as well as traits that are needed, to control pests remain effective.

In cotton, where insecticide resistance has been a major problem there are well defined industry sanctioned Insecticide Resistance Management Strategies (IRMS) (pages 61–64). Responsible stewardship of Bt cotton is also important. Refer to the Resistance Management Plan (pages 65–76).

These guidelines are based on: Integrated Pest Management in Cotton – a commonsense approach and Integrated Pest Management Guidelines for Australian Cotton II.

Insecticide Resistance Management Strategy (IRMS) for 2015–16

Lisa Bird and David Larsen, NSW DPI
Sharon Downes and Lewis Wilson, CSIRO
Melina Miles, QLD DAF
Tracey Leven, CRDC

The use of pesticides selects for resistance in pest populations. The cotton industry IRMS seeks to manage the risk of resistance in aphids, mites and *Helicoverpa spp.*, both in conventional and Bt cotton. Additional resistance management requirements are also in place for managing the risk of *Helicoverpa spp.* developing resistance to Bt cotton (pages 72–76). 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. The resistance risk management for silverleaf whitefly is built into the Silverleaf Whitefly Threshold Matrix (page 30).

Checklist

- Use recommended thresholds for all pests to minimise insecticide use and reduce resistance selection. Refer to Table 17 pages 40–41.
- Monitor first position fruit retention at flowering and aim to retain at around 60 per cent or alternatively maintain a fruiting factor of between 1.1 and 1.3. Refer to IPM section page 47.
- Avoid repeated applications of products from the same insecticide group, including Bt products, even when targeting different pests. Rotate between groups. Consider seed treatment as a 'spray' and do not apply a first foliar spray from the same insecticide group as the seed treatment.
- Do not exceed the maximum recommended use limits indicated on the Insecticide Resistance Management Strategy charts for cotton (see pages 61–64).
- Do not respray an apparent failure with the same product or another product from the same insecticide group. Rotate to a different group.
- For all pest species, aim to use the most selective insecticide options first, delaying the use of broad spectrum insecticides for as long as possible. On the IRMS charts the options are arranged from top to bottom in order of selectivity. Using the most selective option helps conserve beneficial insects, reducing the chance of mite, aphid and silverleaf whitefly outbreaks.
- Monitor mite populations regularly after seedlings emerge. If established mite populations are present (5–10 per cent of plants infested) avoid using broad-spectrum insecticides to control other pests. Instead use selective options or options that also control or suppress mites, either alone or in mixtures as required.
- Avoid early season use of omethoate or dimethoate. When targeting mirids, avoid early season dimethoate/omethoate use as it will select catastrophic pirimicarb resistance in aphids.
- Control weeds and volunteer cotton on farm to minimise alternative hosts for mites, aphids and silverleaf whitefly through winter and particularly in the lead up to cotton planting.
- Cultivate cotton and residues of alternative host crops as soon as possible after harvest to destroy overwintering *H. armigera* pupae, particularly if crops are defoliated after 9 March (Northern Regions) and 31 March (Central and Southern Regions). In Bt cotton fields, cultivation must be completed before the end of July.
- 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 2015–16 IRMS decided?

The development of the IRMS is driven by the Transgenic and Insect Management Strategies (TIMS) Committee as advised by the TIMS Insecticide Technical Panel. TIMS is a part 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.

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. The genes remain rare until they are selected for by a toxin, either from an applied pesticide or from within Bt cotton. 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.

On the IRMS chart, what do the colours for the various products represent?

In the IRMS charts, the different colours for the various products correspond to maximum usage restrictions. Abamectin and Emamectin (Affirm) can individually have maximum of two applications however a maximum of three applications is allowed from these two products. In addition to colours please be aware of additional restrictions at side and footnoted. Insecticide groups are listed on page 64. Rotate to an insecticide from a different mode of action 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 and aphids

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.

Mirids

Mirids aren't known to have developed resistance to insecticides in Australian cotton. However it is possible that resistance could develop and the industry has begun resistance monitoring in mirids. As the IRMS includes all insecticides registered for use in cotton, the principles behind the IRMS are applied to mirids. Many of the products registered for mirid control in cotton are also registered for the control of other pests. It is critical that mirid control decisions also consider sub-threshold populations of other pests that are present in the field. Using dimethoate/omethoate for the control of mirids can inadvertently select for both dimethoate/omethoate and pirimicarb resistance in aphids. Use of clothianidin (Shield) for mirid control can inadvertently select for neonicotinoid resistance in aphids. Do not apply a first foliar spray from the same insecticide group as the seed treatment (4A). When selecting an insecticide for mirid control, consider the options that are left open for subsequent aphid control, in case the need arises.

Does the IRMS seek to manage resistance in Silverleaf Whitefly (SLW)?

The IRMS has now been modified to include all commercially available products registered for use in cotton, including SLW. Inclusion is based on the SLW threshold matrix which is designed to minimise the need to intervene with chemical control as well as to delay the development of resistance.

Refer to the SLW Threshold Matrix, page 30, for additional industry recommendations on the best way to utilise the available products with the lowest risk of developing resistance.

How do refuges help manage resistance to Bt in Bt cotton, and do they help manage resistance to insecticides in Helicoverpa?

Growing refuge crops is a pre-emptive resistance management strategy that is implemented to retard the evolution of field-scale resistance to Bt cotton. The success of the refuge strategy depends on the majority of the general population being susceptible (SS) to the toxins in Bt-cotton. 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 Bt cotton.

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

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 (RS) 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.

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.

Why is there a Northern, and Southern/Central IRMS?

The IRMS has always accounted for pest movement among different cotton growing regions. For example several field studies have shown that *Helicoverpa spp.* moths can travel large distances. Recently, some genetic work showed that mirids move long distances between regions. Insecticide resistance in one region can therefore spread to other regions by pest migration. The TIMS Committee designs the IRMS to reduce the chance that pests moving 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 two strategies accommodate the different growing seasons from central Queensland through to southern NSW.

Will the large uptake of Bt cotton reduce the population sizes of *Helicoverpa spp.*?

H. armigera is closely linked with cropping regions and the widespread use of Bt cotton may be affecting the size of natural populations of this pest. In most seasons, the majority of moths are locally generated, so Bt cotton may be acting as a 'sink' and influencing the overall population size. However, this species uses hosts other than cotton, so even with widespread use of Bt cotton, population sizes are likely to also 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. In this case, as moths are generated in other environments, Bt cotton 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 in inland areas and stop over points along the way, which is largely determined by rainfall and degree of land degradation. Years where inland areas receive little rainfall may produce few migrating moths, and even large populations may be prevented from migrating to cropping regions if suitable habitat along the way is absent.

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

Whenever insecticides are used there is selection pressure for resistance. In Bt cotton, aphids, mites, mirids and silverleaf whitefly are no longer secondary pests. More often than not, it is this range of pests that require intervention with foliar insecticides to protect cotton yield and quality and as such there is a risk of resistance developing in these populations. The IRMS chart seeks to directly manage the risk of resistance in pests as well as reduce risk of inadvertant selection of pests that are not the primary target of the insecticide.

Large areas of Bt cotton 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 Bt cotton. Hence the likelihood of resistance development to foliar and soil applied insecticides remains the same, even if the overall size of the Helicoverpa population is reduced. Continuing to follow the IRMS will ensure that the industry retains the ability to control Helicoverpa effectively with insecticides on conventional cotton both now and in the future The IRMS should always be consulted when making a spray decision, even in Bt cotton.

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 (eg. 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 (eg. 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 (ie. 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. The pupae busting guidelines for sprayed conventional cotton are based on 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 CotASSIST. The model was developed from field research conducted on the Darling Downs by QLD DAF and has broad application to farming systems in eastern Australia. The web tool predicts the timing of diapause.

Post Harvest Pupae Destruction statement

Sprayed conventional cotton crops defoliated after 9 March (Northern Region) and 31 March (Central & Southern Region) 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. 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; and,
- 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 (eg. amitraz and methomyl) in sprays to take the pressure off larvicides. When targeting sprays against eggs and very small larvae, do not expect 100 per cent 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. 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 (www.croplife.org.au/industry-stewardship/resistance-management/). The repeated use of any insecticide with different mix partners will also increase selection for resistance.

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.

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 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 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 (eg. 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, Lisa Bird (02) 6799 1500.**
- **For mites and aphids, Grant Herron (02) 4640 6333.**
- **For whitefly, Jamie Hopkinson (07) 4688 1152.**

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.

TIMS TROUBLESHOOTING COMMITTEE CONTACTS 2015–16

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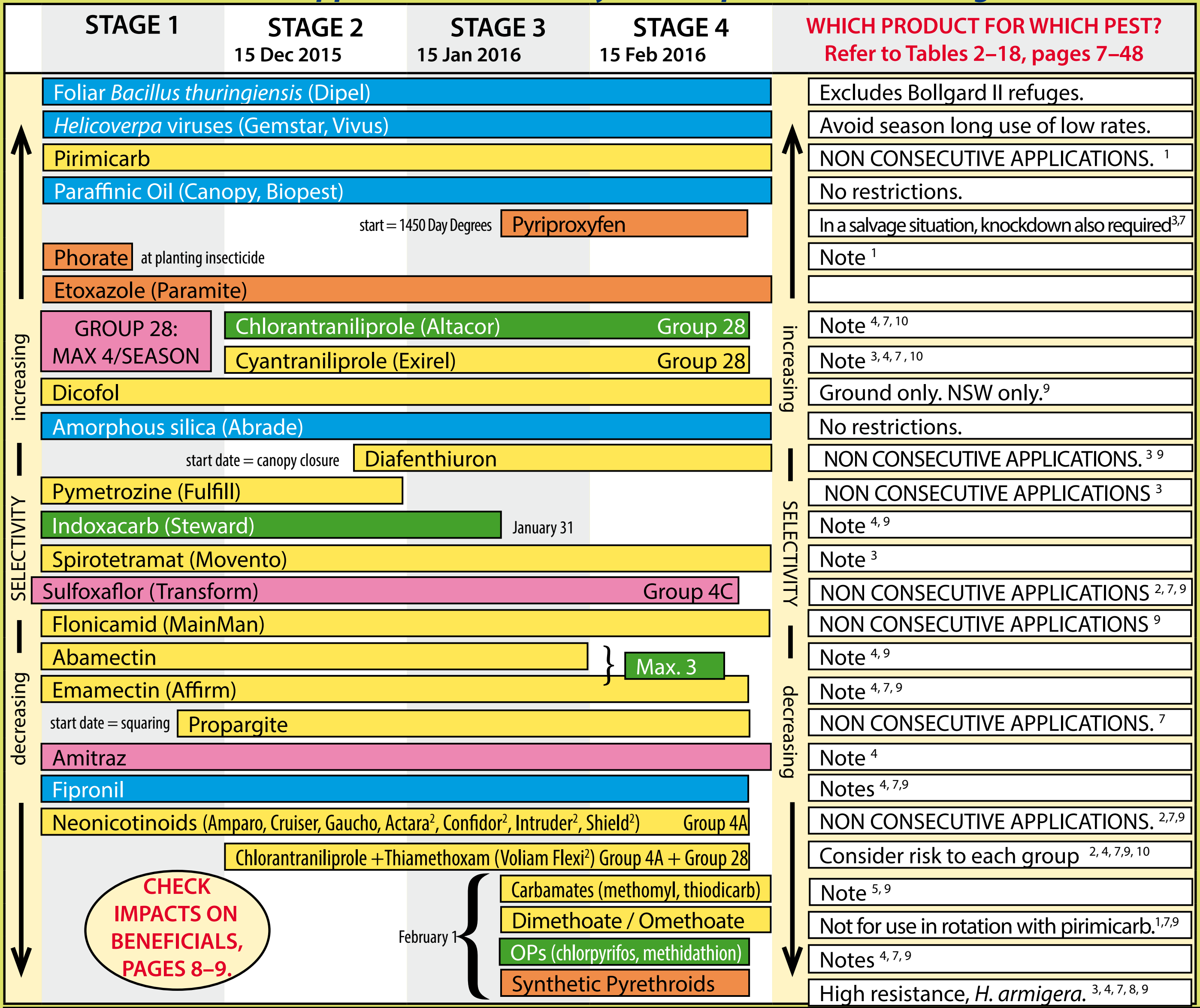
Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2015–16

BEST PRACTICE PRODUCT WINDOWS AND USE RESTRICTIONS TO MANAGE INSECTICIDE RESISTANCE IN APHIDS, SILVERLEAF WHITEFLY, MITES AND HELICOVERPA SPECIES.

Central & Southern Regions: Balonne, Bourke, Darling Downs, Gwydir, Lachlan, Lower & Upper Namoi, Macintyre, Macquarie, Murrumbidgee



	WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2–18, pages 7–48
Foliar *Bacillus thuringiensis* (Dipel)	Excludes Bollgard II refuges.
Helicoverpa viruses (Gemstar, Vivus)	Avoid season long use of low rates.
Pirimicarb	NON CONSECUTIVE APPLICATIONS. [1]
Paraffinic Oil (Canopy, Biopest)	No restrictions.
start = 1450 Day Degrees Pyriproxyfen	In a salvage situation, knockdown also required[3,7]
Phorate at planting insecticide	Note [1]
Etoxazole (Paramite)	
Chlorantraniliprole (Altacor) Group 28	Note [4, 7, 10]
Cyantraniliprole (Exirel) Group 28	Note [3, 4, 7, 10]
Dicofol	Ground only. NSW only.[9]
Amorphous silica (Abrade)	No restrictions.
start date = canopy closure Diafenthiuron	NON CONSECUTIVE APPLICATIONS. [3 9]
Pymetrozine (Fulfill)	NON CONSECUTIVE APPLICATIONS [3]
Indoxacarb (Steward) January 31	Note [4, 9]
Spirotetramat (Movento)	Note [3]
Sulfoxaflor (Transform) Group 4C	NON CONSECUTIVE APPLICATIONS [2, 7, 9]
Flonicamid (MainMan)	NON CONSECUTIVE APPLICATIONS [9]
Abamectin	Note [4, 9]
Emamectin (Affirm)	Note [4, 7, 9]
start date = squaring Propargite	NON CONSECUTIVE APPLICATIONS. [7]
Amitraz	Note [4]
Fipronil	Notes [4, 7, 9]
Neonicotinoids (Amparo, Cruiser, Gaucho, Actara[2], Confidor[2], Intruder[2], Shield[2]) Group 4A	NON CONSECUTIVE APPLICATIONS. [2,7,9]
Chlorantraniliprole + Thiamethoxam (Voliam Flexi[2]) Group 4A + Group 28	Consider risk to each group [2, 4, 7, 9, 10]
Carbamates (methomyl, thiodicarb)	Note [5, 9]
Dimethoate / Omethoate	Not for use in rotation with pirimicarb.[1,7,9]
OPs (chlorpyrifos, methidathion)	Notes [4, 7, 9]
Synthetic Pyrethroids	High resistance, *H. armigera*. [3, 4, 7, 8, 9]

STOP OVERWINTERING OF RESISTANT POPULATIONS BY PRACTISING GOOD FARM HYGIENE AND CONTROLLING WINTER HOSTS. PUPAE BUST AFTER HARVEST.[6]

🟦 COMMENTS AND NOTES DESCRIBE ALL USE RESTRICTIONS

🟧 NO MORE THAN **ONE** APPLICATION PER SEASON

🟩 NO MORE THAN **THREE** APPLICATIONS PER SEASON

🟨 NO MORE THAN **TWO** APPLICATIONS PER SEASON

🟪 NO MORE THAN **FOUR** APPLICATIONS PER SEASON

Note 1: If a phorate side dressing is used instead of a neonicotinoid seed dressing then do not use pirimicarb or dimethoate/omethoate as first foliar spray as there is cross resistance between them all. Dimethoate/omethoate use will select catastrophic pirimicarb resistance in aphids so do not use pirimicarb and dimethoate/omethoate in the same field.

Note 2: Failures of neonicotinoids against aphids have been confirmed. DO NOT follow a neonicotinoid seed treatment with a foliar neonicotinoid when aphids are present. If there is an alternative do not follow a neonicotinoid with sulfoxaflor.

Note 3: Cross check with the Silverleaf Whitefly Threshold Matrix, page 29.

Note 4: Maximum 2 consecutive sprays, alone or in mixtures.

Note 5: Additional applications can be made if targeting Helicoverpa moths using Magnet.

Note 6: Sprayed conventional cotton crops defoliated after 31st March are more likely to harbour resistant diapausing *Helicoverpa armigera* and should be pupae busted as soon as possible after harvest and no later than the end of August.

Note 7: Observe Witholding Periods, page 152. Products in this group have WHP 28 days or longer.

Note 8: High resistance is present in *Helicoverpa armigera* populations. Expect field failures.

Note 9: Refer to label for warnings of insecticide risk to bee population. Fipronil has long residual toxicity to bees.

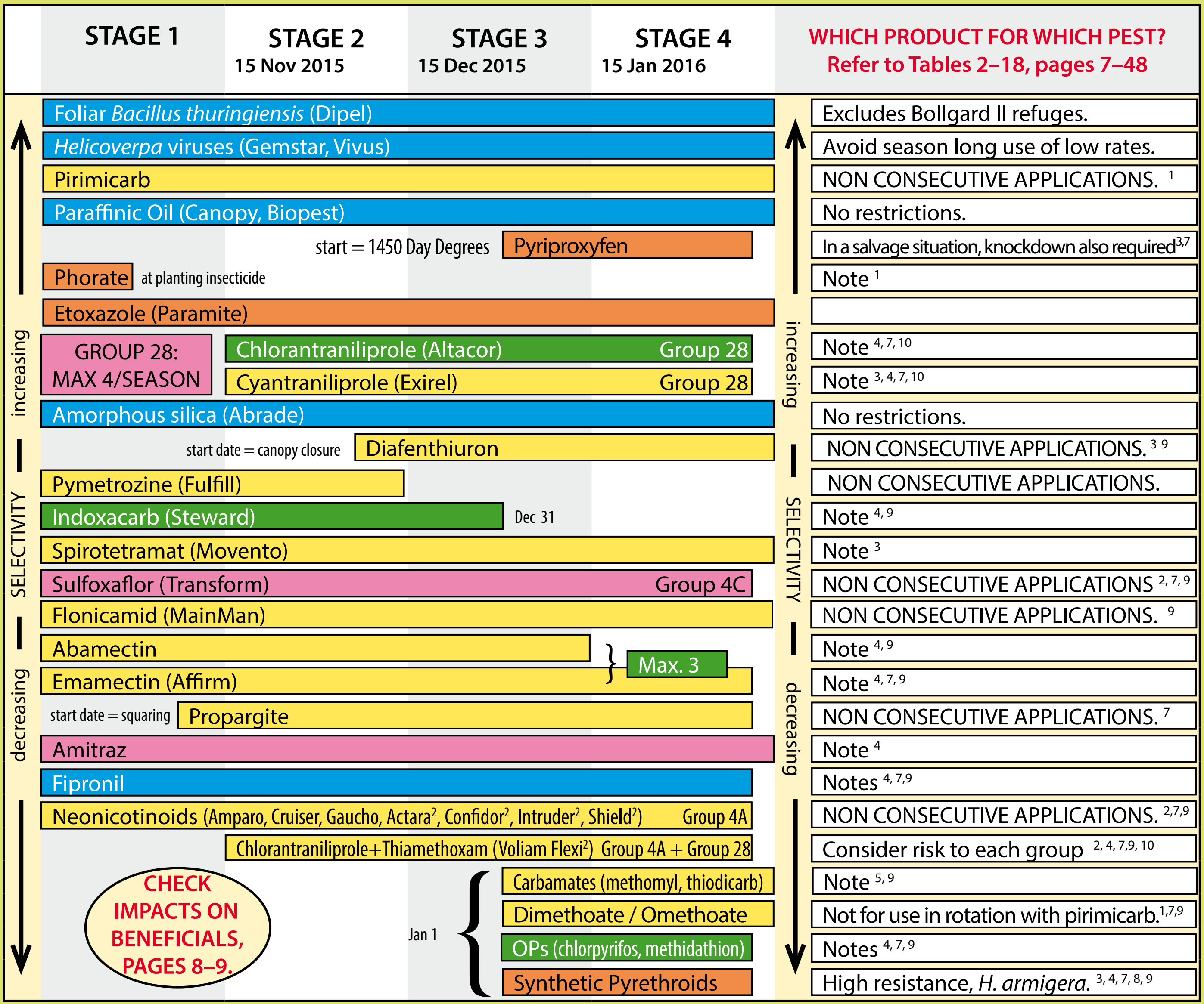
Note 10: Maximum 4 applications of Group 28 insecticides (Altacor, Exirel, Voliam Flexi). No use of Altacor in Chickpeas after 15th October.

Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2015–16

BEST PRACTICE PRODUCT WINDOWS AND USE RESTRICTIONS TO MANAGE INSECTICIDE RESISTANCE IN APHIDS, SILVERLEAF WHITEFLY, MITES AND HELICOVERPA SPECIES.

Northern Region: Belyando, Callide Central Highlands, Dawson



STAGE 1	STAGE 2 15 Nov 2015	STAGE 3 15 Dec 2015	STAGE 4 15 Jan 2016	WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2–18, pages 7–48
Foliar *Bacillus thuringiensis* (Dipel)				Excludes Bollgard II refuges.
Helicoverpa viruses (Gemstar, Vivus)				Avoid season long use of low rates.
Pirimicarb				NON CONSECUTIVE APPLICATIONS. [1]
Paraffinic Oil (Canopy, Biopest)				No restrictions.
	start = 1450 Day Degrees	Pyriproxyfen		In a salvage situation, knockdown also required[3,7]
Phorate at planting insecticide				Note [1]
Etoxazole (Paramite)				
GROUP 28: MAX 4/SEASON	Chlorantraniliprole (Altacor) Group 28			Note [4, 7, 10]
	Cyantraniliprole (Exirel) Group 28			Note [3, 4, 7, 10]
Amorphous silica (Abrade)				No restrictions.
	start date = canopy closure	Diafenthiuron		NON CONSECUTIVE APPLICATIONS. [3 9]
Pymetrozine (Fulfill)				NON CONSECUTIVE APPLICATIONS.
Indoxacarb (Steward)		Dec 31		Note [4, 9]
Spirotetramat (Movento)				Note [3]
Sulfoxaflor (Transform) Group 4C				NON CONSECUTIVE APPLICATIONS [2, 7, 9]
Flonicamid (MainMan)				NON CONSECUTIVE APPLICATIONS. [9]
Abamectin			} Max. 3	Note [4, 9]
Emamectin (Affirm)				Note [4, 7, 9]
start date = squaring	Propargite			NON CONSECUTIVE APPLICATIONS. [7]
Amitraz				Note [4]
Fipronil				Notes [4, 7,9]
Neonicotinoids (Amparo, Cruiser, Gaucho, Actara[2], Confidor[2], Intruder[2], Shield[2]) Group 4A				NON CONSECUTIVE APPLICATIONS. [2,7,9]
	Chlorantraniliprole+Thiamethoxam (Voliam Flexi[2]) Group 4A + Group 28			Consider risk to each group [2, 4, 7,9, 10]
CHECK IMPACTS ON BENEFICIALS, PAGES 8–9.		Jan 1 {	Carbamates (methomyl, thiodicarb)	Note [5, 9]
			Dimethoate / Omethoate	Not for use in rotation with pirimicarb.[1,7,9]
			OPs (chlorpyrifos, methidathion)	Notes [4, 7, 9]
			Synthetic Pyrethroids	High resistance, *H. armigera*. [3, 4, 7, 8, 9]

STOP OVERWINTERING OF RESISTANT POPULATIONS BY PRACTISING GOOD FARM HYGIENE AND CONTROLLING WINTER HOSTS. PUPAE BUST AFTER HARVEST.[6]

🟦 COMMENTS AND NOTES DESCRIBE ALL USE RESTRICTIONS

🟧 NO MORE THAN **ONE** APPLICATION PER SEASON

🟩 NO MORE THAN **THREE** APPLICATIONS PER SEASON

🟨 NO MORE THAN **TWO** APPLICATIONS PER SEASON

🟪 NO MORE THAN **FOUR** APPLICATIONS PER SEASON

Note 1: If a phorate side dressing is used instead of a neonicotinoid seed dressing then do not use pirimicarb or dimethoate/omethoate as first foliar spray as there is cross resistance between them all. Dimethoate/omethoate use will select catastrophic pirimicarb resistance in aphids so do not use pirimicarb and dimethoate/omethoate in the same field.

Note 2: Failures of neonicotinoids against aphids have been confirmed. DO NOT follow a neonicotinoid seed treatment with a foliar neonicotinoid when aphids are present. If there is an alternative do not follow a neonicotinoid with sulfoxaflor.

Note 3: Cross check with the Silverleaf Whitefly Threshold Matrix, page 29.

Note 4: Maximum 2 consecutive sprays, alone or in mixtures.

Note 5: Additional applications can be made if targeting Helicoverpa moths using Magnet.

Note 6: Sprayed conventional cotton crops defoliated after 9th March are more likely to harbour resistant diapausing *Helicoverpa armigera* and should be pupae busted as soon as possible after harvest and no later than the end of August.

Note 7: Observe Witholding Periods, page 152. Products in this group have WHP 28 days or longer.

Note 8: High resistance is present in *Helicoverpa armigera* populations. Expect field failures.

Note 9: Refer to label for warnings of insecticide risk to bee population. Fipronil has long residual toxicity to bees.

Note 10: Maximum 4 applications of Group 28 insecticides (Altacor, Exirel, Voliam Flexi). No use of Altacor in Chickpeas after 15th September.

Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2015–16

Explanatory notes for all regions

IRMS Guidelines

In every population of every pest species there is a small proportion of individuals with resistance to an insecticide. The use of insecticides selects against survival of non-resistant individuals, leaving these resistant individuals. Over-reliance on an insecticide can lead to an increase in the proportion of resistant individuals to the point that the insecticide fails to provide satisfactory control. This simple scenario is more complex in a field situation as products applied against a target pest not only select for resistance in that pest but in other pests also present at the same time. The IRMS aims to assist users to:

- Lower the risk of inadvertent selection of resistance in pests that are not the primary target of the insecticide application.
- Delay the evolution of pest resistance to key chemical groups, by minimising the survival of individuals with resistance.
- Manage entrenched resistance problems, such as the now widespread resistance in cotton aphids to neonicotinoids.

The IRMS includes all actives commercially available for use in cotton at the time of publication. The IRMS should be consulted for EVERY insecticide/miticide decision.

Principles underlying the IRMS

1. Monitor pest and beneficial populations.
2. Monitor fruit retention.
3. Use recommended thresholds for all pests.
4. For all pest species, aim to use the most selective insecticide options first, delaying the use of broad spectrum insecticides for as long as possible.
5. Comply with all directions for use on product labels.
6. Avoid repeated applications of products from the same insecticide group, even when targeting different pests. Rotate between groups.
7. Do not respray an apparent failure with the same product or another product from the same insecticide group. Rotate to a different group.
8. Control weeds and cotton volunteers in fields and around the farm all year to minimise pest hosts.
9. Pupae bust cotton as soon as possible after harvest.

In-season Troubleshooting

Ratification of the IRMS prior to the start of each season is the responsibility of Cotton Australia's TIMS Committee. A Troubleshooting sub-committee is empowered to act on TIMS' behalf during the cotton season to respond to emergency requests to vary the IRMS. The Troubleshooting sub-committee has a clear process for handling requests (detailed on p59). For further information contact Cotton Australia (02 9669 5222).

How to use the 2015–16 IRMS

Region. There are now two IRMS regions. Central and Southern Regions have been combined. The Northern Region covers Central Queensland and stage dates accounts for the early planting and quicker crop development.

Stage. The dates shown on the strategy charts are for the start of each stage (eg. 15 December 2015 start of Stage 2 for Central & Southern region IRMS). For those individual insecticides and miticides that start or end outside window boundaries, the start and/or end dates are listed.

Selectivity. The products listed in the IRMS are listed in order of decreasing selectivity. For all pest species, aim to use the most selective option in the window first, delaying the use of broad spectrum insecticides for as long as possible.

Use Restrictions. Colours in the table now represent the maximum number of applications per crop per season for any given product.

COMMENTS AND NOTES DESCRIBE ALL USE RESTRICTIONS

NO MORE THAN **ONE** APPLICATION PER SEASON

NO MORE THAN **TWO** APPLICATIONS PER SEASON

NO MORE THAN **THREE** APPLICATIONS PER SEASON

NO MORE THAN **FOUR** APPLICATIONS PER SEASON

Additional restrictions to product use can be found on the right hand column of the table, with links to specific footnotes. Avoid repeated applications of products from the same insecticide group, even when targeting different pests. Rotate between groups.

Key Changes for the 2015–16 cotton season

1. Inclusion of Flonicamid (Mainman) insecticide

Flonicamid is a new insecticide with a novel mode of action (9C). Do not use more than 2 applications. Do not apply consecutive applications.

2. Change to date recommendation for pupae busting for Central & Southern Region from March 9 to March 31

The date change is based on analysis showing 31st March is the first average date where the likelihood of diapuase occurring is 50 per cent. This change is also consistent with the pupae busting date for southern regions in the proposed BG3 RMP.

The date recommendation for northern regions remains the same (March 9) as although diapause is highly variable in northern regions, some diapause does still occur. Pupae busting in conventional cotton is still considered good practice and the earlier date reflects climatic differences and earlier maturing crops.

Insecticide Groups

Active ingredient (proprietary trade names)	Insecticide Group	Chemical Group
Helicoverpa viruses (Gemstar, Vivus)	Not a member of a group	Nuclear polyhedrosis virus
Paraffinic Oil (Canopy, Biopest)	Not a member of a group	Petroleum spray oil
Dicofol	Not a member of a group	UN - Unknown mode of action
Amorphous silica (Abrade)	Not a member of a group	Not a member of a group
Methomyl	GROUP 1A INSECTICIDE	Carbamate
Pirimicarb		
Thiodicarb		
Chlorpyrifos	GROUP 1B INSECTICIDE	Organophosphates
Dimethoate / Omethoate		
Methidathion		
Phorate		
Fipronil	GROUP 2B INSECTICIDE	Phenylpyrazoles (Fiproles)
Alpha-cypermethrin	GROUP 3A INSECTICIDE	Synthetic Pyrethroids
Beta-cyfluthrin		
Bifenthrin		
Cypermethrin		
Deltamethrin		
Gamma-cyhalothrin		
Lambda-cyhalothrin		
Zeta-cypermethrin		
Acetamiprid (Intruder)	GROUP 4A INSECTICIDE	Neonicotinoids
Clothianidin (Shield)		
Imidacloprid (multiple, includes seed treatments)		
Thiamethoxam (multiple, includes seed treatments Voliam Flexi#)		
Sulfoxaflor (Transform)	GROUP 4C INSECTICIDE	Sulfoximine
Abamectin	GROUP 6 INSECTICIDE	Avermectins
Emamectin (Affirm)		
Pyriproxyfen (Admiral, Avante, Muligan)	GROUP 7C INSECTICIDE	Pyriproxyfen
Pymetrozine (Fulfill)	GROUP 9B INSECTICIDE	Pymetrozine
Flonicamid (MainMan)	GROUP 9C INSECTICIDE	Flonicamid
Etoxazole	GROUP 10B INSECTICIDE	Etoxazole
Foliar Bacillus thuringiensis (Dipel)	GROUP 11 INSECTICIDE	Bt microbials
Diafenthiuron	GROUP 12A INSECTICIDE	Diafenthiuron
Propargite	GROUP 12C INSECTICIDE	Propargite
Amitraz	GROUP 19 INSECTICIDE	Amitraz
Indoxacarb	GROUP 22A INSECTICIDE	Indoxacarb
Spirotetramat	GROUP 23 INSECTICIDE	Spirotetramat
Chlorantraniliprole (Altacor) (Voliam Flexi#)	GROUP 28 INSECTICIDE	Diamides
Cyantraniliprole (Exirel)		

#Voliam Flexi has actives from both a Group 28 and Group 4A.
Source: CropLife Australia Insecticide Resistance Management Review Group, 2013 http://www.croplifeaustralia.org.au/

Preamble to the Resistance Management Plan (RMP) for Bollgard II 2015–16

Sharon Downes and Lewis Wilson, CSIRO
Kristen Knight, Monsanto Australia Limited
Greg Kauter, formerly Cotton Australia
Tracey Leven, CRDC

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. When Bollgard II replaced INGARD, the constraint on the area of transgenic cotton was 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 continued efficacy of Bollgard II cotton is therefore even more dependent on the effective implementation of the RMP.

Bollgard II acreage will represent over 90 per cent of the total area of cotton planted in the 2015–16 season. Given the selection pressure exerted by Bollgard II cotton, as well as the high 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, Bollgard 3, 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 Bollgard 3 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

H. armigera. **(Melina Miles, QLD DAF)**

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. Work has also commenced on monitoring field populations of moths for resistance to the new vip3A gene contained in Bollgard 3 technology. Monsanto Australia operates a separate but complimentary monitoring program. The data provides an early warning to the industry of the onset of resistance to Bt cotton. The results 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 have been 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. This method was incorporated into the monitoring program by CSIRO in 2002 and Monsanto in 2003 and detects all previously isolated and potentially new types of resistances but is very labour intensive.

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. F1 screens involve testing the offspring of single-pair matings between moths from resistant strains maintained in the laboratory and moths raised from eggs collected from field populations. They take around 5 weeks to conduct. 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 each of the isolates of Cry2Ab detected until then was the same type of resistance, and subsequently adopted F1 tests.

From 2002 to 2012 CSIRO continued to perform tests which showed that all newly isolated resistances to Cry2Ab were the same type that was initially identified. Similarly, work on Vip3A from 2009 to 2012 showed that all newly isolated resistances were the same type that was initially identified. In 2013 CSIRO shifted to performing only F1 screens to focus on the frequencies of the known resistances. In addition to screening F1 families against the toxin of interest (eg., Cry2Ab), they introduced screens against all classes of Bt toxins (eg., Cry1Ac and Vip3A) in an effort to detect any novel forms of resistance that carry dominance. Every 4 or 5 years CSIRO will incorporate F2 screens into the program to check for any new recessive forms of resistance. In 2013 Monsanto continued to perform both F2 screens and F1 screens.

This chapter uses the 2014 data from the CSIRO and Monsanto programs for the F1 screens.

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 5 in 10,000 (<0.0005 or 0.05 per cent). This gene does not confer cross-resistance to Cry2Ab and in certain environments is largely recessive. It also has a high fitness cost (ie. 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 (NSW DPI) 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

H. punctigera. **(Melina Miles, QLD DAF)**

gut of the insect. Results with *H. armigera* show that the estimate of Cry2Ab resistance frequency for F1 screens at the end of the 2014–15 season is approximately 2 in 100 (0.02, 2 per cent) or less for both programs, which is higher than for F2 screens. The frequencies obtained from the F1 screens are likely to most accurately reflect the situation in the field.

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, since 2008–09 at least 7 individuals which carry a gene that confers resistance to Cry1Ac have been isolated from field populations of *H. punctigera*. F2 tests indicate that the frequency of this gene is still quite rare at less than 1 in 1000 (0.001, 0.1 per cent). It is not cross-resistant to Cry2Ab. In 2013–14, CSIRO used F1 tests against *H. punctigera* for Cry1Ac resistance and detected a frequency of 4 in 1000 (0.004, 0.4 per cent). In 2014–15, CSIRO used F1 tests against *H. punctigera* for Cry1Ac resistance and detected a frequency of 2 in 1000 (0.002, 0.2 per cent). Monsanto also commenced F1 tests this year and did not isolate any resistance alleles.

A gene that confers high level resistance to Cry2Ab is present in field populations of *H. punctigera*. This gene does not confer cross-resistanceto 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. In 2007–08 and 2009–10 CSIRO and Monsanto respectively 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 2014–15 season, the frequency of Cry2Ab genes in *H. punctigera* was approximately 1 in 100 (0.01, 1.0 per cent) for both programs .

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

The high frequency of individuals carrying the Cry2Ab resistance 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 if 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 per cent) compared to a sample from cropping populations collected at the same time (5 in 100, 0.05, 5 per cent). We do not have an F1 resistance frequency for Cry2Ab in *H. punctigera* prior to the widespread adoption of Bollgard II.

Is the frequency of Cry2Ab genes increasing in field populations of *H. armigera*?

CSIRO F2 data for *H. armigera* from 2002 to 2012 suggest a gradual increase in frequency of Cry2Ab resistance genes in recent years. The frequency obtained for 2010–11 was significantly greater than for previous

years, but since then has not continued to increase. Monsanto began collecting F2 screen data for *H. armigera* in 2003–04 and since then there has been no significant change in frequency of Cry2Ab resistance genes over time with an average of 1 in 250 (0.004 or 0.4 per cent).

Since 2004–05 Monsanto has used the F1 protocol developed by CSIRO to screen for resistance to Cry2Ab. CSIRO also has F1 screen data for *H. armigera* since 2007–08. Both data sets analysed independently show that there is no significant difference in the frequencies of Cry2Ab resistance alleles over the longer term; although the frequencies in 2010–11 were higher than in previous years they have since declined. 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*?

At the end of 2008–09 the F2 and F1 data sets from CSIRO demonstrated 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 and afterwards there was a gradual increase in resistance frequencies over time which became statistically significant in 2007–08 and remained highly significant in 2008–09. After declining in 2009–10, resistance frequency increased again in 2011–12 to the highest recorded level (2 in 100, 0.02 or 2 per cent) before declining to 1 in 100 (0.01, 1 per cent) in 2012–13. The complete data set demonstrates a gradual increase in frequency over time.

Monsanto began F2 screens with *H. punctigera* in 2007–08 and in 2010–11 detected a Cry2Ab resistance frequency that was significantly higher than in previous years. However, this may have been an overestimate in frequency as all positives were from one larval collection. In 2013–14 the Cry2Ab resistance frequency is at a similar level to that recorded in 2008– 09 (1 in 185, 0.005 or 0.5 per cent). If the probable overestimation in frequency in 2010–11 is taken into account there has been no significant change in the Cry2Ab resistance frequency over time.

The 2008–09 CSIRO F1 data set for *H. punctigera* demonstrated a 5 fold increase in frequency compared to 2007–08 (from 1 in 100 to 5 in 100 or 0.01 to 0.05). The frequencies obtained from 2009–10 until 2014–15 are lower than those detected in 2008–09 and most recently have declined to the levels first detected in 2007–08. Monsanto began F1 screens for *H. punctigera* in 2009–10 and have recorded no change in frequency of Cry2Ab resistance genes over time with an average of 1 in 100 (0.01 or 0.1 per cent).

Why has *H. punctigera* shown signs of 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. The decline in Cry2Ab resistance frequencies in *H. punctigera* in 2009–10 may reflect some dilution due to immigration of inland individuals but this hypothesis is difficult to test.

What is known about resistance to Vip3A protein in *H. armigera* and *H. punctigera*?

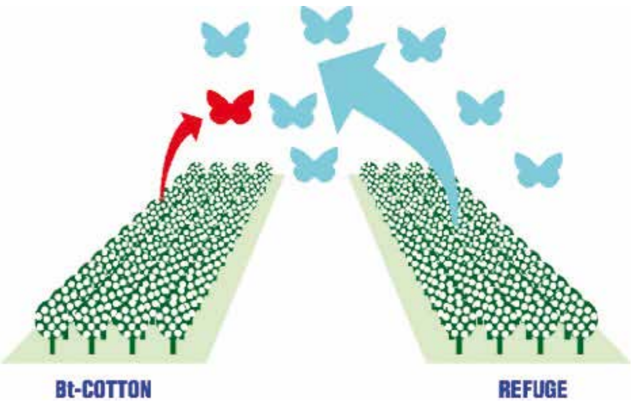
Monitoring for resistance to the Vip3A protein has revealed that genes allowing survival against this toxin already exist in *H. punctigera* and *H. armigera*. Data obtained by CSIRO suggest that the frequency of vip3A resistance genes in *H. punctigera* is around 1 in 100 (0.01, 1 per cent). This estimate is based on F2 screens (2009–2012). The frequencies of Vip3A resistance alleles in *H. armigera* obtained from F2 screens are higher than those fo*r H. punctigera*, at 3 in 100 (0.03, 3 per cent). Therefore, as with Cry2Ab, the early data indicate that there is an unexpectedly high frequency of individuals in field populations that carry a gene conferring resistance to Vip3A protein.

In 2010–11 Monsanto began screens for Vip3A resistance genes in both *Helicoverpa spp.* and estimate from a small sample a frequency for *H. armigera* based on F1 screens of 3 in 100 (0.03 or 3 per cent). The estimate of Vip3A resistance frequency for *H. punctiger*a based on F1 screens is also 1 in 200 (0.005 or 0.5 per cent).

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 finding of a higher baseline frequency of Cry2Ab genes using F1 tests than previously detected using F2 screens is a major concern. It is imperative that all users of Bollgard II steward the technology responsibly. In particular, it is critical that closer attention is paid to managing Bollgard II cotton associated refuges and that effective pupae busting occurs in a timely fashion.

In addition, Monsanto and the TIMS Bt Technical Panel will continue to work together to assess annually new information on resistance frequencies in *Helicoverpa spp.* and knowledge of tactics for Bt resistance management to provide background information and recommendations for the Cotton Australia convened TIMS Committee. Additional measures could be taken in response to significant 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.



Moths produced from refuges dilute resistance genes in the population.

RMP tactics

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. 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. 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 researchers within 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 per cent 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 per cent refuge, half that of an unsprayed cotton refuge, is required for this crop. Initially, sorghum and corn were included as refuge options in the RMP because they were effective at producing *H. armiger*a moths. However, since they are not a preferred host for *H. punctigera*, from 2010–11 sorghum and corn were removed from the RMP as refuge options.

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 raingrown Bollgard II and irrigated Bollgard II?

For raingrown Bollgard II crops the only available raingrown refuge options are sprayed or unsprayed cotton. The reason for this is that the other refuge option available in irrigated Bollgard II (pigeon pea) tends to be planted after the cotton and it's a requirement that raingrown refuges must be planted within the 2 week period prior to the first day of planting Bollgard II cotton. However CSIRO and Monsanto have conducted work on the suitability of pigeon pea as a raingrown conventional cotton treated and not treated by slashing as a potential refuge option. There are also irrigated refuge options for raingrown 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. 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, 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 and all refuges?

The same logic applies as in the previous question. The presence of Bollgard II volunteer plants in a conventional crop or refuge 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 is 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 which is especially important in warmer growing regions. 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?

A permit (PER14804) was issued to vary Bollgard II planting windows by the APVMA on 25 August 2014 that still applies for the 2015-16 season. Refer to summary on page 71.

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 biologial 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.

Am I required to pupae bust in my refuges?

Refuges do not need to be pupae busted. 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, the corresponding refuge should not be cultivated (eg. for weed control, row formation etc).

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. It is critical to time the destruction so that it corresponds with the period of most effective kill of the range of life stages of Helicoverpa. See the 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. Recent work suggests that larvae exhibit strong behavioural responses to the Bt proteins in Bollgard II plants. Detection and avoidance of the Bt toxins results in frequent movement of larvae, potentially within and between plants, resulting in an apparent feeding preference for flowers. These behaviours, coupled with the sometimes temporal and spatial variability of Bt toxin expression in Bollgard II cotton, can result in a proportion of larvae becoming established.

For resistance management reasons, it is recommended that if larvae reach thresholds in Bollgard II fields they should be controlled by spraying. However work conducted by Monsanto suggests that it is unlikely that there will be a yield penalty associated with larvae survival in Bollgard II fields. This is supported by a recent study that used the distribution of larval damage in fields that carried larvae at the current thresholds as the basis for an artificial damage experiment. The work showed that Bollgard II plants could tolerate up to 100 per cent square loss at early flowering, up to 100 per cent square removal alone or in combination with 30 per cent boll damage at peak flowering, and 30 per cent boll damage at late flowering, without impacting yield or quality. Therefore Bollgard II cotton seems to compensate well for damage caused by larvae and the current threshold can be used in most situations without causing significant yield reduction.

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. Part of the end of season general survey of Crop Consultants Association (CCA) members includes questions about control of Helicoverpa in Bollgard II fields.

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

- **Sharon Downes: 02 6799 1576–0427 480 967; or,**
- **Kristen Knight 07 4634 8400–0429 666 086.**

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 61–64). The beneficial/pest ratio (described on page 53) 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 pages 8–9). 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 10.

SUMMARY OF BOLLGARD II PLANTING WINDOW PERMIT

A permit (PER14804) was issued to vary Bollgard II planting windows by the Australian Pesticides and Veterinary Medicines Authority (APVMA) on 25 August 2014. Specifically, this permit is designed to study the effect of an extended planting window on end of season crop management.

Overview of Planting Window Permit

Region	Overview of Permit Window	Mitigation Strategies
NSW and Southern QLD (incl. Darling Downs)	All Bollgard II must be planted by November 30 (an additional 15 days after the RMP window close)	Bollgard II planted within the permit period (November 15–30) must be destroyed within 30 days of completion of harvest
Central QLD	An additional 2 weeks to be allocated adjacent to the current RMP window, at the discretion of the CGA (can be prior or following the current window or 1 week prior and 1 week after current window)	• Bollgard II planted within the permit period must be destroyed within 30 days of completion of harvest • Bollgard II planted later than the current RMP window will require an additional 1 per cent refuge area

In order to take advantage of this permit, the RMP prescribed planting window cannot be varied. In the event that a variation notice is submitted and approved, this permit will no longer apply to the valley in question. The approval of this permit means that the previous planting window extension permit in Emerald is no longer valid and cannot be used.

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2015–16

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

The resistance management plan is based on three basic principles: (1) minimising the exposure of *Helicoverpa spp.* to the *Bacillus thuringiensis* (Bt) proteins Cry1Ac and Cry2Ab; (2) providing a population of susceptible individuals that can mate with any resistant individuals, hence diluting any potential resistance; and (3) removing resistant individuals at the end of the cotton season. The three principles are supported through the implementation of 5 elements that are the key components of the Resistance Management Plan. These elements are:

1. Refuge crops;
2. Planting window;
3. Pupae busting/Trap crops;
4. Control of volunteers and ratoon cotton; and,
5. Spray limitations.

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 New South Wales and Queensland that grow cotton while sections 2 and 3 detail specific requirements for New South Wales and Southern Queensland, and Central Queensland respectively.

Section 1: New South Wales, Southern Queensland & 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 Cry1Ac and Cry2Ab. These unselected moths are expected to dominate matings with any survivors from Bollgard II crops and thus help to maintain resistance to Bt proteins Cry1Ac and Cry2Ab at low levels.

All refuge options are based on the requirement of a 10 per cent 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 A and B, for irrigated and raingrown production scenarios respectively. Irrespective of the irrigation regime for the Bollgard II cotton, all pigeon pea refuges must be fully irrigated so that they are attractive to *Helicoverpa spp.* during the growing period of the Bollgard II cotton.

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

TABLE A: Irrigated Bollgard II cotton refuge options

Crop	Conditions	% of Bollgard II
Cotton	Irrigated, sprayed conventional cotton	100
	Irrigated, unsprayed conventional cotton	10
Pigeon pea	Fully irrigated, unsprayed	5

TABLE B: Raingrown Bollgard II cotton refuge options

Crop	Conditions	% of Bollgard II
Cotton	Raingrown or irrigated, sprayed conventional cotton	100
	Raingrown or irrigated, unsprayed conventional cotton	10
Pigeon pea	Fully irrigated, unsprayed	5

No other refuge options are approved for raingrown Bollgard II.

Note: Unsprayed means not sprayed with any insecticide that targets any life stage of *Helicoverpa spp.*
Bt products must not be applied to any refuge (including sprayed cotton).
If the viability of an unsprayed refuge is at risk due to early or late season pressure by *Helicoverpa spp.*, or any other caterpillar species, contact Monsanto immediately. With prior approval from the Monsanto Compliance and Stewardship Manager, a non-Bt heliocide can be applied.
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.* larvae.

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2015–16

General conditions for all refuges:

(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.

Irrigated: 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.

Raingrown: A raingrown refuge must be planted within the 2 week period prior to the first day of planting Bollgard II cotton.

(b) Pigeon pea refuges should not be planted until the soil temperature reaches 17°C, which is a requirement for germination, and should also be planted into moisture to ensure successful 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 Bollgard II cotton begins to flower the corresponding refuge must not be cultivated.

(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 associated 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 2 km from the Bollgard II cotton.

(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 unless a sufficient buffer is in place to prevent insecticide drift.

(h) In all regions, destruction of refuges should only be carried out after Bollgard II cotton lint removal has been completed.

(i) Refuges for raingrown Bollgard II cotton 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 raingrown Bollgard II crop, then that refuge may be planted in a solid configuration. Raingrown 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 Cry1Ac and Cry2Ab proteins produced by Bollgard II cotton.

Growers must ensure that volunteer and ratoon plants are removed as soon as possible from all fields, including fallow areas, Bollgard II crops, conventional cotton crops and all refuges. **The presence of Bollgard II volunteers/ratoon cotton in any refuge will diminish the value of the refuge and must be removed as soon as possible.**

Note: The refuge should preferably be planted into fallow or rotation fields that have not been planted to cotton in the previous season.

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.*

Section 2: New South Wales & 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 in order to ensure that pupae busting has occurred.

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2015–16

In Refuge crops:

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. 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 Monsanto Regional Business Manager.

Section 3: Central Queensland only

1. Planting Windows

Central Highlands: 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/Clermont: All Bollgard II crops are to be planted into moisture or watered-up in the period between November 4 and December 15, unless advised otherwise by a Bollgard II Planting Window Variation Notice.

Mackenzie: All Bollgard II crops are to be planted into moisture or watered-up in the period between November 4 and December 15, unless advised otherwise by a Bollgard II Planting Window Variation Notice.

2. Refuges

Pigeon Pea refuge should preferably be planted into a fallow or rotation field that has not been planted to cotton in the previous season to avoid volunteer and ratoon cotton.

In Central Queensland soil disturbance of refuge crops can only occur 2 weeks after final defoliation of the Bollgard II cotton.

3. Late summer pigeon pea 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. Raingrown Bollgard II growers who do not have any irrigated cotton on their farm should contact their Monsanto Regional Business Manager for alternative options.

Refuge and late summer trap crops have different purposes and, if pigeon pea is selected for both, two separate plantings may be required. However, where a pigeon pea refuge is utilised as a trap crop the full 5 per cent pigeon pea refuge area must be managed to become the late summer trap crop and must adhere to the requirements in Table 3 below.

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

Criterion	Trap crop*
Minimum area & dimension (Requirement)	A minimum trap crop of 1 per cent of planted Bollgard II cotton 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 should preferably be planted between November 1 and November 30. Note: if growers choose to plant their trap crop to coincide with the planting of pigeon pea refuges they must manage the trap crop in such a way that it remains attractive to *Helicoverpa spp.* 2–4 weeks after final defoliation.
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, except where a pigeon pea refuge is converted to a trap crop. In this case the full 5 per cent pigeon pea refuge area managed to become the late summer trap crop can only be sprayed with virus after the first defoliation of Bollgard II cotton.
Irrigation	The trap crop must be planted into an area where it can receive the additional irrigation required to keep the trap crop attractive to *Helicoverpa spp.* until after the cotton is defoliated.
Weed control	The trap crop should be kept free of weeds and particularly volunteer Bollgard II cotton. When using the full 5 per cent pigeon pea trap crop option, weed control must not be carried out by cultivation once flowering of the associated Bollgard II cotton crop has commenced.
Crop destruction	The trap crop must be destroyed 2-4 weeks (but not before 2 weeks) after final defoliation of the Bollgard II cotton crop, (slash and pupae bust – full soil disturbance to a depth of 10 cm across the entire trap crop area). All Bollgard II and associated trap crops must be destroyed by July 31.

* A pigeon pea trap crop is to be planted so 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 (eg. before November) or too late (eg. mid December) is not adequate for cotton crops planted during September through to October.

** The planting rate is a recommendation based on a minimum of 85 per cent seed germination.

NB: If any grower encounters problems in complying with the RMP, please contact your Monsanto Regional Business Manager. For further background information on the various components of this plan see the Preamble to the Resistance Management Plan for Bollgard II (see pages 70–76).

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2015–16

Ord River Irrigation & Burdekin Bowen Basin & Richmond areas

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

The resistance management plan is based on three basic principles: (1) minimising the exposure of *Helicoverpa spp.* to the Bacillus thuringiensis (Bt) proteins Cry1Ac and Cry2Ab; (2) providing a population of susceptible individuals that can mate with any resistant individuals, hence diluting any potential resistance; and (3) removing resistant individuals at the end of the cotton season. The three principles are supported through the implementation of 5 elements that are the key components of the Resistance Management Plan. These elements are:

1. Refuge crops;
2. Planting window;
3. Pupae busting/Trap crops;
4. Control of volunteers and ratoon cotton; and,
5. Spray limitations.

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).

This RMP is for the following areas:

- Ord River Irrigation Area, Western Australia
- Burdekin Bowen Basin Area, Queensland
- Richmond Area, 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 Cry1Ac and Cry2Ab. These unselected moths are expected to dominate matings with any survivors from Bollgard II crops and thus help to maintain resistance to Bt proteins Cry1Ac and Cry2Ab at low levels.

All refuge options are based on the requirement of a 10 per cent 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 below.

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

Irrigated Bollgard II cotton refuge options

Crop	Conditions	% of Bollgard II	Regions permitted
Conventional Cotton	Irrigated, unsprayed conventional cotton	10	All regions
Pigeon pea	Fully irrigated, unsprayed	5	All regions

Note: Unsprayed means not sprayed with insecticides that target any life stage of *Helicoverpa spp.*
Bt products must not be applied to any refuge.
If the viability of an unsprayed refuge is at risk due to early or late season pressure by *Helicoverpa* spp., or any other caterpillar species, contact Monsanto immediately. With prior approval from the Monsanto Compliance and Stewardship Manager, a non-Bt heliocide can be applied.
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 unless a sufficient buffer is in place to prevent insecticide drift.
Sprayed crops and unsprayed refuges that are planted in adjacent fields must also 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.* larvae.

General conditions for all refuges:

(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.
Ord River Irrigation Area: 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.
Burdekin Bowen and Richmond Areas: Refuges must be sown within the 2 weeks prior to planting any Bollgard II. This timing attempts to mitigate wet season planting risks.

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2015–16

(b) Group J legume innoculant should be used to treat pigeon pea planting seed just prior to sowing to ensure effective root zone colonisation by nitrogen fixing rhizobium bacteria.

(c) Once the Bollgard II cotton begins to flower the corresponding refuge must not be cultivated.

(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 2 km from the Bollgard II cotton.

(g) To account for possible insecticide drift, 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.

(h) Slashing of plants within the refuge should only be carried out after Bollgard II cotton lint removal has been completed. Soil disturbance of refuge crops can only occur 2 weeks after Bollgard II cotton plants have been harvested.

(i) Refuges for Bollgard II crops must be planted in the same row configuration as the Bollgard II crop.

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 proteins Cry1Ac and Cry2Ab 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. **The presence of Bollgard II volunteers/ratoon cotton in any refuge will diminish the value of the refuge and must be removed as soon as possible.**

Note: The refuge should preferably be planted into fallow or rotation fields that have not been planted to cotton in the previous season.

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 must be left uncultivated for two weeks after harvest to allow emergence of any pupating *Helicoverpa spp.*

4. Planting windows

All Bollgard II crops and cotton refuges are to be planted into moisture or watered-up in a five week window.

In each region, the start date of the planting window will be determined by TIMS in consultation with local growers and reflected in a regionally amended Bollgard II Planting Window Variation Notice.

The planting window will occur within the following periods:

- **Ord River Irrigation Area:** March 1 and May 1.
- **Burdekin Bowen Basin Area:** December 1 and April 1.
- **Richmond Area:** December 1 and April 1.

5. Refuge

Unsprayed Pigeon Pea refuge should preferably be planted into a fallow or rotation field that has not been planted to cotton in the previous season.

6. End of season chick pea trap crop

An end of season chick pea trap crop must be planted. The planting configuration of the trap crop should be the same as that of the Bollgard II crop. The table below shows the requirements for the chick pea trap crop.

End of season chick pea trap crop requirements

Criterion	End of season chick pea trap crop
Minimum area & dimensions	A trap crop of 1 per cent of planted Bollgard II crop area is required. This planting must be at least 24 m x 24m wide.
Planting time	In April for Burdekin Bowen Area. In July/August for Ord area. The trap crop is to be planted such that it is attractive to *Helicoverpa spp.* from 2 weeks before defoliation of the Bollgard II cotton. It must remain attractive to *Helicoverpa spp.* until at least 2 weeks after defoliation of the Bollgard II cotton.
Insect control	The trap crop should be monitored and sprayed with insecticide if the larval pressure threatens the viability of the crop.
Irrigation	The trap crop is to remain attractive to *Helicoverpa spp.* until after defoliation of cotton. In some cases this may require one additional irrigation after the cotton is defoliated. The trap crop must be planted into an area where it can receive the additional irrigation required to ensure the trap crop remains attractive to *Helicoverpa spp.*
Weed control	The trap crop should be kept free of weeds and particularly volunteer Bollgard II cotton.
Crop destruction	The trap crop must be destroyed 2-4 weeks after defoliation of the Bollgard II cotton crop, but not before 3 weeks (slash and pupae bust – full soil disturbance to a depth of 10 cm across the entire trap crop area). All Bollgard II cotton and associated trap crops must be destroyed by: Burdekin Bowen Basin/Richmond Area – August 31; Ord River Irrigation Area – December 10

NB: If any grower encounters problems in complying with the resistance management plan, please contact your Monsanto Regional Business Manager.

Unsprayed pigeon pea refuge agronomy

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Establishing and growing an attractive refuge is a mandatory component in the Resistance Management Plan (RMP) for Bt Cotton. The purpose of a refuge is to generate significant numbers of *Helicoverpa spp.* moths which have not been exposed to selection pressure from either of the Bt proteins. Attractive, fully irrigated, unsprayed pigeon pea will, on average, produce twice as many moths as the same area of unsprayed cotton. As well as producing high numbers of moths, it is also crucial that the timing of production of moths from refuges matches that of Bollgard II cotton crops. A well-watered refuge with adequate nitrogen is most likely to sustain larvae through to pupation and consequently produce the most moths. This is key to delaying Bt resistance. .

The following information is intended to assist growers establish and maintain effective pigeon pea refuges. Growers should refer to the RMP for guidance on mandatory refuge requirements.

Planting

Field selection

Pigeon pea can be grown on many soil types but are susceptible to waterlogging, therefore select fields that have good post-irrigation/rainfall drainage. Avoid fields that were sown to cotton during the previous season as this will reduce the likelihood of volunteer and ratoon cotton occurring in refuges. The presence of Bt cotton in refuge areas diminishes the resistance mitigation potential of a refuge. Similarly selecting fields with a low weed seed bank also enables easier management of weeds that can compete with pigeon peas and reduce refuge effectiveness.

Larvae in pigeon pea refuge. (Photo: Johnelle Rogan)

Ideally, refuges should be sown in a field area adjacent to the Bt cotton crop. Be mindful to ensure sufficient separation to avoid the drift of herbicides or insecticides applied to the cotton or other crops onto the refuge area.

As with many other legumes, pigeon pea can have allelopathic effects on subsequent crops which should be taken into account when making field selections.

Crop establishment

Timing

Similar to mung and soybeans a minimum soil temperature of 17°C and rising is optimal for pigeon pea establishment. In most cotton production regions these conditions occur during October-November. Under the RMP, pigeon pea should be sown within the two week period prior to planting Bollgard II, or if not possible, completed within 3 weeks of the first day of sowing Bollgard II for irrigated crops.

Sowing and inoculation

Nitrogen fixation by legumes such as pigeon pea is optimal in soils with very low residual soil N. The use of peat based group J inoculation formulations on seed just prior to planting will help to ensure effective rootzone colonisation by effective strains of Rhizobium bacteria. To ensure efficacy of inoculant, follow all label requirements and directions regarding storage, handling and application.

Seed germination percentages can vary greatly (<30 per cent to >80 per cent). Growers are advised to have a current germination test for either purchased or farm-saved seed. Seed size can also be quite variable and therefore the sowing rate needs to account for seed size and germination statistics with the overall aim being to establish a stand of no less than 4 plants per metre of crop row. Sowing rates typically fall within the range of 25–40 kg/ha. Higher plant populations will produce plants with thinner stalks, which makes later crop destruction much easier.

Pigeon peas row spacing should match that of the corresponding Bt cotton crop.

Seed bed preparation and planting

Ensure that the seedbed has good tilth to maximise seedling emergence and establishment. Seed should not be sown deeper than 5 cm. Levelling of any seed trenches created during planting is important, particularly when residual herbicides have been used and/or the field is to be watered up. The use of press wheels with light pressure has been shown to improve emergence.

Pre-irrigation

Pre-irrigation and planting into moisture is generally recommended over watering up. Some growers choose to water up the refuge with the rest of the field, then replant into this moisture if a replant is required.

Crop nutrition

Pigeon pea requires inoculation with Group J inoculant. Nodulation will be limited in high nitrogen soils. A well-grown crop of pigeon pea can add up to 38 kg/ha of nitrogen. Pigeon pea is much more sensitive to phosphorus deficiency than cotton. In soils with long cropping histories where soil P may be depleted, pigeon pea is likely to respond to addition of phosphorus and zinc. Like cotton, pigeon pea is highly VAM dependent and in long fallow situations, it may even be more responsive to P and Zn.

Weed management

Pigeon pea are poor competitors with weeds during establishment particularly when planted under cool conditions.

While there are a number of herbicides available for use under permit, as seen in Table 22, inter-row cultivation can be a useful tactic. However cultivation can inadvertently kill (the Bt-susceptible) Helicoverpa pupae present in the soil at the time. For this reason it is a requirement that once Bollgard II cotton begins to flower the corresponding refuge should not be cultivated. The presence of Bollgard II volunteers/ratoon cotton in any refuge will diminish the value of the refuge and must be removed as soon as possible.

Irrigation

Pigeon pea can be very sensitive to waterlogging on heavier soil types. Avoiding irrigation prior to heavy rainfall predictions and only watering every second row can be useful tactics for reducing the risk of water logging, as well as selecting a site with good drainage. In principal, growers should use the same best management tactics on the pigeon peas as those being used for their cotton crops eg. getting water on and off the field in a timely and effective manner.

Being a drought tolerant plant pigeon pea generally has a lower water requirement compared to cotton. However, it is important to ensure crops do not become moisture stressed as this reduces attractiveness and can delay or truncate the flowering period. If soil moisture is well managed pigeon pea will respond very quickly with attractive regrowth after insect attack.

Destruction and harvest of pigeon pea refuge crops

Harvest or destruction of a pigeon pea refuge should only be carried out after the corresponding Bt cotton crop has been fully picked. In NSW and Southern Qld, soil disturbance should only occur after Bollgard II cotton fields have been pupae busted, (to ensure maximum emergence of pupae from refuges), and preferably be left uncultivated until the following October to enable the emergence of overwintering pupae. In Central Queensland soil disturbance of refuge crops can only occur 2 weeks after final defoliation of the Bollgard II cotton. Growers in Central Queensland using pigeon pea for trap crop purposes should refer to the late summer pigeon pea trap crop requirements of the RMP for full details.

Note – No crop product or crop residue is to be fed to livestock.

TABLE 22: Herbicides available for use in pigeon pea (registered or permit number Per13758)

Active Ingredient	Mode of Action	Concentration and formulation	Application rate of product	Comment
Prometryn*	C	500 g/L	Apply up to 4.5 L/ha	Apply up to the maximum rate pre planting and incorporate, or as a post-emergent directed spray towards the base of established plants (Per13758)
		900 g/kg	Apply up to 2.5 kg/ha	
Trifluralin	D	480 g/L*	Apply up to 2.3 L/ha	Apply up to the maximum rate pre planting and incorporate. Rate dependent on soil type, refer to label or Per13758
		500 g/L	Apply up to 1.6 L/ha	
		530 g/L	Apply up to 1.5 L/ha	
		600 g/L	Apply up to 1.35 L/ha	
Butroxydim *	A	250 g/L	Apply 180 g/ha	Apply the specified rate as a post-emergence spray over the top of the pigeon pea crops. (Per13758)
Fluazifop-p*	A	212 g/L	Apply 1 L/ha	
		128 g/L	Apply 1.6 L/ha	
Haloxyfop*	A	130 g/L	Apply 0.6 L/ha	
Haloxyfop*	A	520 g/L	Apply 0.150 L/ha	
Sethoxydim*		186 g/L	Apply 1 L/ha	Apply specified rate as a post-emergence spray over the top of the pigeon pea crops. (Per13758)
Clethodim*	A	240 g/L	0.250–0.375 L/ha (2–3 leaf stage)	Always apply with D-C-trate at 2 L/100 L or Hasten or Kwickin at 1 L/100 L Uptake at 500 mL/100 L spray volume. The lower doses will provide effective control if applied under ideal conditions to weed that are smaller, actively growing and free from temperature or water stress. (Per13758)
Quizalofop*	A	99.5 g/L	0.25–1 L/ha (dependent on growth stage and species of weed)	Refer to permit for growth stages of species and critical comments. (Per13758)
Diquat	L	200 g/L	2–3 L/ha	Harvest aid
Diquat/paraquat	L	135 g/L + 115 g/L	0.8–2.4 L/ha	Apply pre-sowing, in minimum 50–100 L water
Pendimethalin	D	330 g/L	2.5–3 L/ha	Incorporate into the soil within 24 hours of application. Use higher rate on heavy textured soils or those high in organic matter. May be applied by aerial or ground spraying. In Macquarie Valley area, only apply by air when ground is too wet for ground application.
		435 g/L	1.9–2.3 L/ha	
		440 g/L	1.9–2.25 L/ha	
		455 g/L	1.8–2.2 L/ha	
		475 g/L	1.74–2.11 L/ha	
Metribuzin	C	480 g/L	750 m L/ha	Furrow irrigated: apply after furrowing out, within 2 weeks before sowing and incorporate. For post-emergence: apply to actively growing seedling stage weeds provided crop plants have at least 2 trifoliate leaves. Do not spray if rain is likely to fall within several hours. Overhead irrigated: apply pre-emergence then irrigate.
		700 g/kg	470 g/ha	
		750 g/kg	470 gha	

*Use of these products is under permit (Per13758).

NOTE: Only apply to pigeon pea crops that are to be destroyed at the end of the season or to be harvested for seed for refuge replanting only. No crop product or crop residue is to be fed to livestock. Refer to all labels and permit conditions. Please go to www.apvma.gov.au to check allowable usages.

Herbicide resistance in Australian cotton farming systems

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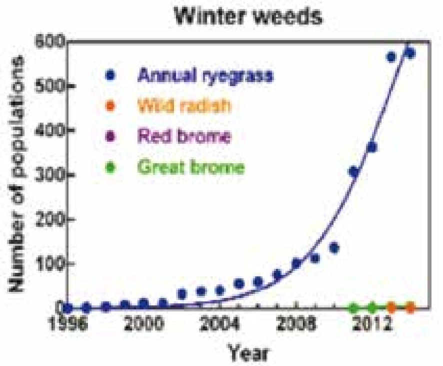
Introduction

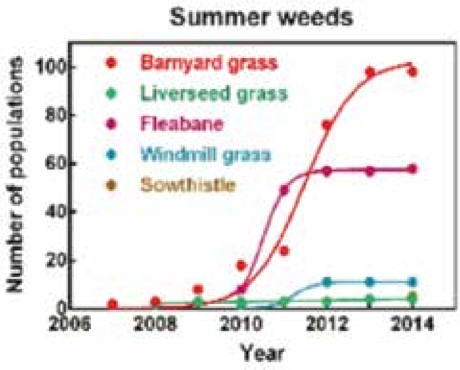
Weed populations are naturally genetically diverse. Due to this diversity it is likely that a small number of individuals may exist that are able to survive exposure to a particular herbicide mode of action (MOA). When a herbicide from this MOA is used upon the population, individuals that have this gene present may survive and set seed, whereas the majority of plants without the gene (susceptible plants) are killed. While it might only be one or two individuals surviving at first, continued use of the same MOA herbicide will result in an ever-increasing proportion of the population being able to survive those herbicide applications. In Australia, herbicides have been grouped according to their mode of action (the way they work) which is represented by a letter code on the label and are ranked according to their resistance risk. Research has shown that weeds can develop resistance to any single control tactic used alone, not only herbicidal ones. For example, annual ryegrass has developed a more prostrate growth habit which allows it to set seed below the level that weed seed harvesters can reach.

FIGURE 1: Number of confirmed cases of winter and summer weeds has increased.

The increase in confirmed cases of glyphosate-resistance in winter weeds beween 1996 and 2014 is:



The increase in confirmed cases of glyphosate-resistance in summer weeds beween 2007 and 2014 is:



Source: Preston, C. The Australian Glyphosate Sustainability Working Group. Online. Internet. Wednesday 10 Sep 2014 Available http://www.glyphosateresistance.org.au/

Throughout the world, there are currently 246 herbicide resistant weed species (143 dicots and 103 monocots) and resistance has been documented in 22 of the 25 known herbicidal modes of action. Costs of weed control in cotton in the US have increased from $150 to $400 per acre due to the evolution of resistance to glyphosate. While historically the Australian cotton industry has had a strong integrated weed management system, the extensive use of herbicide tolerant (HT) cotton varieties since 2006 has meant that glyphosate now accounts for more than 80 per cent of all herbicide used within cotton. Herbicide resistance is a reality in the Australian cotton industry with 10 weed species now confirmed as glyphosate resistant, 7 of which occur widely in cotton farming systems.

Why the need for an industry wide strategy

Experience with conventional insecticide resistance has encouraged a proactive culture to resistance issues in the Australian cotton industry. The increased use of glyphosate and escalating incidence of resistance (Figure 1) has brought about the need for an industry wide Herbicide Resistance Management Strategy (HRMS). While there are significant resources available for control of specific weeds and a plethora of information is available on integrated weed management, a need to develop an industry wide strategy in conjunction with industry stakeholders was identified. This strategy would draw the available information together enabling growers to understand and manage the risks of herbicide resistance in Australian cotton farming systems.

How was the HRMS strategy developed?

The Herbicide Resistance Management Strategy was developed by the TIMS herbicide technical panel to help the Australian cotton industry manage the risk of herbicide resistance, and in particular to manage the risks associated with glyphosate. The strategy indicates how different combinations of weed control tactics affect the timeframe to resistance development as well as their impact on the weed seed bank. The draft strategy was circulated widely to industry and modified based on industry feedback, prior to its ratification by the TIMS committee.

The modeling used as the foundation of the HRMS is based on barnyard grass control in glyphosate tolerant cotton where three over the top (OTT) glyphosate applications are made in any one season. The time to resistance development and effect on the weed seed bank was predicted using combinations of weed control tactics used in crop and in the summer fallow phase for both irrigated and raingrown cropping systems. The models indicate that in irrigated cotton, crop competition provides higher weed control than in raingrown systems. The model demonstrates that the weed control tactics used in the summer fallow phase have the greatest impact on the time to glyphosate resistance development.

Will the HRMS change in the future?

It is expected that the HRMS will go through a similar process of annual reviews for continuous improvement like the Insecticide Resistance Management Strategy (IRMS). The IRMS started from a basic position and has matured overtime with the benefit of stakeholder feedback. It is anticipated that HRMS will be expanded to include more scenarios, tactics, and combinations of tactics as well as mature to be relevant in a multi-herbicide-trait cotton system.

Why does the HRMS only focus on glyphosate?

Glyphosate resistance has been confirmed in 10 weed species in Australia (Table A); 7 grass species and 3 broadleaf species; 4 winter-growing and 6 summer-growing weed species. The latter have been selected mainly in chemical fallows. The strong reliance on glyphosate in the current farming system and the increasing number of cases of glyphosate resistance (Figure 1) has meant that for the first HRMS, glyphosate is the key focus.

It is important to note that the principles behind the strategy, particularly the use of a diverse range of tactics and the control of survivors are applicable to other groups as well as group M (glyphosate). There is concern that glyphosate resistance may result in reliance on other herbicidal groups, leading to multiple resistance, for example, reliance on the repeated use of Group A grass selective herbicides can quickly lead to development of Group A resistance. The intent is to expand the HRMS to incorporate other modes of action and multi-trait HR cotton varieties.

TABLE A: Confirmed glyphosate weeds

Weed species	Year first documented	Number of confirmed populations May 2014
Annual ryegrass (*Lolium rigidum*)	1996	574
Barnyard grass (*Echinochloa colona*)	2007	98
Liverseed grass (*Urochloa panicoides*)	2008	4
Fleabane (*Conyza bonariensis*)	2010	58
Windmill grass (*Chloris truncata*)	2010	11
Great brome (*Bromus diandrus*)	2011	5
Wild radish (*Raphanus raphanistrum*)	2013	2
Sowthistle (*Sonchus oleraceus*)	2014	4
Red brome (*Bromus rubens*)	2014	1
Sweet Summer grass (*Brachiaria eruciformis*)	2014	1

Preston, C. The Australian Glyphosate Sustainability Working Group. Online. Internet. Wednesday 10 Sep 2014 Available http://www.glyphosateresistance.org.au/

How to use the HRMS

Given that glyphosate resistance takes around 18 years to develop when used alone in an irrigated cotton cropping system and 14 years in raingrown, it is important to identify the likelihood of resistance development in your own operation. The HRMS table (page 86–87) enables you to determine which other weed control tactics can be incorporated into your management system by providing guidance as to how much extra time they will give you until resistance develops, and demonstrating the effect they will have on the weed seed bank, which is critical to effectively managing resistance.

How do non-cropping areas relate to the HRMS?

Areas adjacent to cotton fields such as irrigation channels, head ditches, tail drains, roadways, fence lines and areas next to stock routes can be a significant entry source for resistant weed seeds. Where possible, use a range of tactics to manage weeds in these non-crop areas, and do NOT rely on glyphosate to manage weeds in these non-crop areas. Prevent survivors of herbicide application from setting seed.

Why does the strategy include weed seed bank as well as herbicide resistance risk?

The key to good weed management is having low weed seed bank levels. Not only does this reduce impact on the crop, but it also reduces herbicide resistance risk. The more weed seeds present, the more likely that an individual containing herbicide resistance genes will be present and hence likely to become a problem.

Do I have to adhere to the HRMS?

The HRMS is not intended to be prescriptive, and is aimed to be an industry mechanism for communicating the herbicide resistance risks from different tactics. It has been designed to present the risk related to a range of tactic combinations, to allow growers and consultants to make their own informed decisions.

Assessing your own risk

For a more detailed assessment of the resistance risks for individual paddocks, use QLD DAF's Online Glyphosate Resistance Toolkit, available via www.cottoninfo.net.au. This tool allows you to check what your current level of risk is for developing glyphosate-resistant weed populations on your farm. You can use it more than once, to rate different paddocks on your farm or to try out different scenarios. The tool allows you to enter information on your current practices (including crop rotation, crop density, and weed control tactics) and to identify which weed species you usually have to control. The tool will then calculate a glyphosate resistance risk score for the paddock, and a level of risk for each weed identified. The risk assessment tool can show you the areas of greatest risk in your crop

A patch of glyphosate resistant awnless barnyard grass, likely to have started near a road. Consider whole of farm use of herbicides. (Photo: T.Cook NSW DPI)

Glyphosate resistant barnyard grass was confirmed in 2007. This infestation had a 'blow-out' as the previous summer period was extremely wet and prevented access to the paddock and hence no effective treatment at an early growth stage. (Photo: T.Cook NSW DPI)

Surviving glyphosate resistant awnless barnyard grass plants amongst dead susceptible plants and dead plants of other species.

rotation and herbicide use, and whether there are any weed species you need to treat carefully. Use these suggestions to get the best results from any changes you make.

The online Glyphosate Resistance Toolkit is available online through the CottonInfo or QLD DAF websites. The toolkit also contains a herbicide resistance quiz which explains the important drivers in herbicide resistance development.

What does herbicide resistance look like?

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 isolated patches. These are often surrounded by dead 'susceptible' plants of the same species, or other species usually controlled by the herbicide applied. This is the critical time to identify the problem. 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. Resistant weed seeds can also be transported in to a management unit through irrigation channels, vehicle tyres or blow in on the wind in the case of species such as fleabane.

How can I confirm if my weeds are resistant?

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 seedling/small plants as large numbers need to be collected and posted. Upon arrival they are potted up 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 received before January. When plants are sent for Quick tests, results are usually available within 4–8 weeks.

Welcome to the
Online Glyphosate Resistance Toolkit

Collecting seed samples:

- Collect 2000–3000 seeds from plants you suspect are resistant. Barnyard grass = 1 cup 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.
- Shake seed heads into a bucket to ensure only ripe seed is 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 contact details, field and weed management history and testing required 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@plantscienceconsulting.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

How do I manage glyphosate resistant weeds?

The strategy to **manage** glyphosate resistant weeds is similar to the strategy to **prevent** glyphosate resistance – integrate a range of different tactics throughout the weed lifecycle to rapidly deplete the soil weed seed bank, and prevent further seed set/recruitment. This means that the HRMS is just as relevant to managing resistance weeds as it is preventing them. If detected early, managing known patches of herbicide resistant weeds by applying an intensive program of different tactics and ensuring weeds do not set seed, may be effective in preventing the problem spreading.

Refer to Weed Management page 88.

For more information on herbicide resistance visit www.weedsmart.org.au

Contact David Thornby on 0421 957629 or david@innokasintellectual.com.au

Herbicide Resistance Management Strategy

Explanatory notes: 2015-16

The Herbicide Resistance Management Strategy (HRMS) is designed as a tool for weed management in irrigated and raingrown farming systems incorporating herbicide tolerant (HT) cotton, to delay glyphosate resistance.

This strategy predicts the increased number of years of sustainable glyphosate use that can be achieved using glyphosate plus other tactics both in crop and in summer fallow compared to a glyphosate alone system. It also predicts the effects these tactics will have on the weed seed bank.

The strategy has been developed in response to the escalating problem of group M herbicide resistance. This first version of the HRMS focuses on a glyphosate tolerant cotton system; however the current availability of other HT and future availability of multi-trait herbicide tolerant varieties have also been considered in the design of the strategy, and may require a more sophisticated strategy to follow into the future.

The formula to manage/delay glyphosate resistance:
Extensive modelling of potential glyphosate resistance development has found that irrespective of whether a farm is irrigated or raingrown, or the weed species present, or the amount of glyphosate used, the most effective way to delay resistance is to use:

2 non-glyphosate tactics targeting both grasses and broadleaf weeds during the cotton crop
+
2 non-glyphosate tactics in summer fallow targeting both grasses and broadleaf weeds
+
0 survivors, control survivors of glyphosate applications and do not allow them to set seed.

If a tactic is selected that only targets grass weeds, then an additional tactic that targets broadleaf weeds will need to be included.

How to use the industry HRMS:
This strategy has been designed to help the Australian cotton industry manage the risk of herbicide resistance by indicating how different combinations of weed control tactics affect the timeframe to resistance development as well as their impact on the weed seed bank.
Seed bank control is modelled on barnyard grass; however tactics are applicable to all weeds. The same practices apply to managing situations where resistant populations are already present.

Given the diversity of the Australian cotton farming system, the HRMS is not intended to be prescriptive, and is aimed to be an industry mechanism for communicating the herbicide resistance risks from different tactics.

Increased time to resistance:
Modelling has been used to predict the increased time to resistance as compared to a glyphosate only system, as the key determinant of risk. Identify where your cotton system already sits on the timeline to glyphosate resistance.

Research indicates glyphosate resistance develops in grass weeds in 13 years (raingrown) and 19 years (irrigated) in a glyphosate only system. Resistance in broadleaf weeds is slower to develop and takes around 18 years in both irrigated and raingrown systems with a summer fallow. Glyphosate resistance is delayed by 4-6 years if residual + double knock is already used in summer fallow.

Cropping System:
The HRMS models two systems:

- Continuous back to back irrigated glyphosate tolerant cotton with no summer fallow, and
- Raingrown glyphosate tolerant cotton grown every second year, alternating with long summer fallows.

Determine the system that is most similar to your own. If you grow irrigated cotton but at a reduced frequency whether it is broken up by summer fallows or rotation cropping, it is more appropriate to use the raingrown scenario. This will be somewhat conservative, as irrigated cotton is able to provide more crop competition.

In a raingrown scenario, rotation cropping should be considered similar to a fallow, and using 2 non-glyphosate tactics should be applied. Raingrown or irrigated rotation crops provide an important opportunity to incorporate other tactics, rotate herbicide groups, vary the time of year crop competition suppresses weeds and produce stubble loads that reduce subsequent weed germinations.

In-Crop Tactics:

- Each model assumes that three over the top (OTT) glyphosate applications are made. Reducing the number of glyphosate applications in-crop does not impact the time to resistance substantially. The control of survivors and use of non-glyphosate tactics is much more significant.
- The model assumes that the first weed flush of the season is the largest emergence. Start early in the season for weed seed bank control.

- A key principle of herbicide usage in an IWM system is to rotate herbicide groups.
- Residual herbicides need back up, such as tillage, chipping and non-glyphosate knockdowns. When using residuals, consider plant back periods.
- Aim for 100 per cent control of glyphosate survivors after glyphosate application. In terms of survivor control, high efficacy with an alternative tactic is good, but high frequency control is better than reliance on efficacy. Cultivation after glyphosate application is predicted to achieve 80 per cent survivor control, whereas cultivation plus chipping is predicted to achieve 99.9 per cent survivor control. Other tactics for survivor control could be equally effective, such as shielded or spot-spraying with an effective knockdown herbicide.
- The *Monsanto Roundup Ready Flex Cotton Weed Management Guide* can be referenced for in-crop tactic options.

Summer Fallow tactics:

- The raingrown model compares glyphosate-only summer fallows with fallows that include 2 non-glyphosate tactics (residual herbicide followed by double knock).
- Summer fallows may include any two non-glyphosate tactics such as residual or knockdown herbicides or tillage that are effective on the weed species.
- See page 89 for comments on rotation crops.

Seed Bank Control:

A high weed burden contributes to herbicide resistance risk, as the more weeds that are present, the more likely that a resistant individual will be present and hence multiplies. Strategies are best aimed at driving down the seed bank and preventing seed bank replenishment.

Seed bank Control Key:

Very high = <10 seeds/m2
High = 10-100 seeds/m2
Med =100-500 seeds/m2
Low = 500-1500 seeds/m2
Very low =>1500 seeds/m2

Other management recommendations:

- Control weeds in adjacent areas (channels, tail drains, fencelines and roadsides) to minimise the seed bank and eliminate unknown weed seed sources. Do NOT rely on glyphosate to manage weeds in non-crop areas. Manage adjacent areas as fallows and rotate non-glyphosate tactics including residual herbicide and chipping of weeds.
- Be aware of weed seed contamination sources (eg waterways, vehicle/machinery, and farm inputs). Establish and maintain COME CLEAN. GO CLEAN to prevent introduction and transport of resistant seeds. Monitor high risk areas around machinery sheds and where vehicles enter and exit the farm.
- Monitor and follow up to ensure weeds that survive glyphosate applications are controlled using a non-glyphosate tactic before they are able to set seed
- Get suspect weed survivors tested for resistance - see page 82.
- Patch control - control weeds in isolated patches
- Use IWM best practice when employing tactics
- Regular scouting and correct weed identification
- Good record keeping
- Timely implementation of tactics
- Rotate herbicide mode of action groups
- Always follow label recommendations
- Consider other aspects of crop agronomy.

Assessing your own risk:

For a more detailed assessment of the resistance risks for individual paddocks, use QLD DAF's *Online Glyphosate Resistance Toolkit*, available via www.cottoninfo.net.au.

Australia glyphosate sustainability working group findings so far:

All of the glyphosate resistant weed populations (confirmed) have occurred in situations where there has been intense use of glyphosate, often over 15 years or more, few or no other effective herbicides used and few other weed control practices used.

This suggests the following are the main risk factors for the evolution of glyphosate resistance:

- Intensive use of glyphosate - every year or multiple times a year for 15 years or more
- Heavy reliance on glyphosate for weed control
- No other weed control measures

Preston, C. The Australian Glyphosate Sustainability Working Group. www.glyphosateresistance.org.au.

Key findings for delaying resistance development:

Using specific, well-timed, non-glyphosate tactics to control glyphosate survivors after every glyphosate application is the best-performing option & should be the first action.

- Actions taken to control glyphosate survivors should be made to every weed flush in a given year, where possible. Modelling shows that inter-row cultivation is a useful tactic for survivor control, and is further enhanced when followed up with chipping.
- Irrigated systems present greater opportunity to delay glyphosate resistance through more timely herbicide applications to even weed flushes and through enhanced crop competition compared to raingrown systems.
- Summer fallows where glyphosate only is used pose the greatest risk of glyphosate resistance development; taking two non-glyphosate actions in every summer fallow is predicted to be of substantial benefit for seed bank control and in many cases to extend the lifespan of glyphosate (especially on barnyard grass) if even a single non-glyphosate action is also taken in crop.
- Using two non-glyphosate actions in every summer fallow is predicted in many cases to extend the lifespan of glyphosate (especially on barnyard grass) in conjunction with a single non-glyphosate action in crop.
- In almost all cases, strategies that work best to slow or prevent resistance are the same as the best strategies for controlling resistant seed banks in the long term.
- Resistance can be imported through machinery or other methods regardless of glyphosate use history.

Cotton HRMS:

Irrigated back to back cotton

Decreasing - Non-glyphosate tactics and survivor control - increasing

Increased time to 100% resistance	In crop tactics 3 x OTT glyphosate applications PLUS	Seed bank control	Comments
>20 years	Very high survivor control after **each** OTT glyphosate	Very high	Aim to avoid controlling last in-crop flush with glyphosate alone
	Moderate survivor control after **each** OTT glyphosate	Very high	Control survivors of OTT applications
	2 x strategic in crop cultivations	Very high	Time the second cultivation to control last weed flush and escapes prior to row closure
10-20 years	Pre-plant residual plus residual layby	Very high	Consider plantback period restrictions
5-10 years	Very high survivor control after **first** OTT glyphosate	Very high	Control survivors from first flush which has highest weed germination
	Cultivation + grass selective herbicide (note: repeated use of Group A grass selective herbicide can lead to development of Group A resistance)	Effects on seed bank not yet modelled	
<5 years	Moderate survivor control after **first** OTT	Low	Control survivors from the first flush which has the highest weed germination
nil	Glyphosate only	Very low	Test survivors for glyphosate resistance

Simulation data provided by D. Thornby

Model Assumptions:

- Glyphosate tolerant cotton grown every summer with a short winter fallow. 3 in-crop glyphosate applications are made + 1 in fallow.
- Cultivation occurs in winter for crop destruction, pupae busting, stubble management and seedbed preparation but not specifically for weed control.
- The first weed flush of the season is the largest emergence.
- Pre-plant residual + layby assumes a maximum of 90 per cent efficacy and an average of 70 per cent to 85 per cent efficacy over 30 years.
- Seed bank control is modelled on barnyard grass
- Survivor control:
  Very high survivor control = 99.9 per cent. This can be achieved through cultivation then chipping or spot spraying with an alternative mode of action.
  Moderate survivor control = 80 per cent. This can be achieved through cultivation.

Notes:

- Do NOT rely on glyphosate to manage weeds in non-crop areas (channels, tail drains, head ditches). Manage adjacent areas as fallows and rotate with non-glyphosate tactics to control weeds and cotton volunteers.
- COME CLEAN. GO CLEAN to prevent introduction and transport of resistant seeds. Monitor high risk entry areas and patch manage introduced weed seeds.
- Monitor and follow up to ensure survivors are controlled by another tactic before they are able to set seed. Have suspect weed survivors tested for resistance
- Conduct regular scouting and correct weed identification.
- Keep good records.
- Ensure timely implementation of tactics
- Rotate herbicide mode of action groups.
- Always follow label recommendations.
- See page 88 for additional tips on IWM and use of tactics.

Cotton HRMS:

Raingrown cotton every second summer

Decreasing - Non-glyphosate tactics and survivor control - increasing

Increased time to 100% resistance	Summer fallow tactics	In crop tactics 3 x OTT glyphosate applications PLUS	Seed bank control	Comments
>20 years	2 non-glyphosate tactics	Very high survivor control after **each** OTT glyphosate	Very high	The most effective scenario for delaying glyphosate resistance
10-20 years	Glyphosate only fallow	Very high survivor control after **each** OTT glyphosate	Very high	Very high frequency & efficacy of survivor control is required if in-crop only tactics are used.
	2 non-glyphosate tactics	Moderate survivor control after **each** OTT glyphosate	High	Lower intensity in-crop tactics can give excellent results if backed up in summer fallows. Specific, frequent, well-timed control of glyphosate survivors provides long-term resistance delay/ management
5-10 years	Glyphosate only fallow	Two strategic cultivations	Low	Time last cultivation to control late flushes and escapes
<5 years	Glyphosate only fallow	Pre-plant residual + layby	Very Low	These tactics give limited increased time to resistance and poor seed bank control
	Glyphosate only fallow	Moderate survivor control after **each** OTT	Very Low	
	2 non-glyphosate tactics	Glyphosate only	Very Low	
nil	Glyphosate only fallow	Glyphosate only	Very Low	

Simulation data provided by D. Thornby

Model Assumptions:

- Glyphosate tolerant cotton grown every second summer, alternating with long summer fallows.
- 2 non- glyphosate tactics in summer fallow – model uses residual herbicide followed by double knock.
- Model assumes pre-plant residual + layby has a maximum of 90 per cent efficacy, averages 70 per cent to 85 per cent efficacy.
- Seed bank control modelled on barnyard grass
- Survivor control:
  Very high survivor control = 99.9 per cent. This can be achieved through cultivation then chipping or spot spraying with an alternative mode of action.
  Moderate survivor control = 80 per cent. This can be achieved through cultivation.

Notes:

- Do NOT rely on glyphosate to manage weeds in adjacent non-crop areas (roadways, fencelines). Manage adjacent areas as fallows and rotate with non-glyphosate tactics to control weeds and cotton volunteers.
- COME CLEAN. GO CLEAN to prevent introduction and transport of resistant seeds. Monitor high risk entry areas control weeds in isolated patches
- Monitor and follow up to ensure that survivors of glyphosate applications are controlled using another tactic before they set seed. Have suspect weed survivors tested for resistance
- Conduct regular scouting and correct weed identification.
- Keep good records.
- Ensure timely implementation of tactics
- Rotate herbicide mode of action groups
- Always follow label recommendations
- See page 88 for additional tips on IWM and use of tactics.

Weed management tactics for Australian cotton

Susan Maas, Ian Taylor, CRDC
Jeff Werth, David Thornby, QLD DAF
Graham Charles, Jon Baird, NSW DPI

Develop a strategy

It is important to strategically plan how different tactics will be utilised to give the best overall results for the existing weed spectrum. A short term approach to weed management may reduce costs for the immediate crop or fallow, but is unlikely to 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.

Having good records on crop rotations, herbicides and other tactics used as well as weed species present will help to develop a plan that identifies where there are particular risks in the system and also where there might be opportunities to incorporate additional tactics. Deployment of tactics recognises the full range of farming system's inputs that impact on weeds and the interactions of these inputs, as shown diagrammatically in Figure A. The herbicide resistance management strategy (HRMS) can help to inform the effectiveness of combinations of tactics on reducing the weed seed bank as well as the risk of herbicide resistance.

Know your enemy

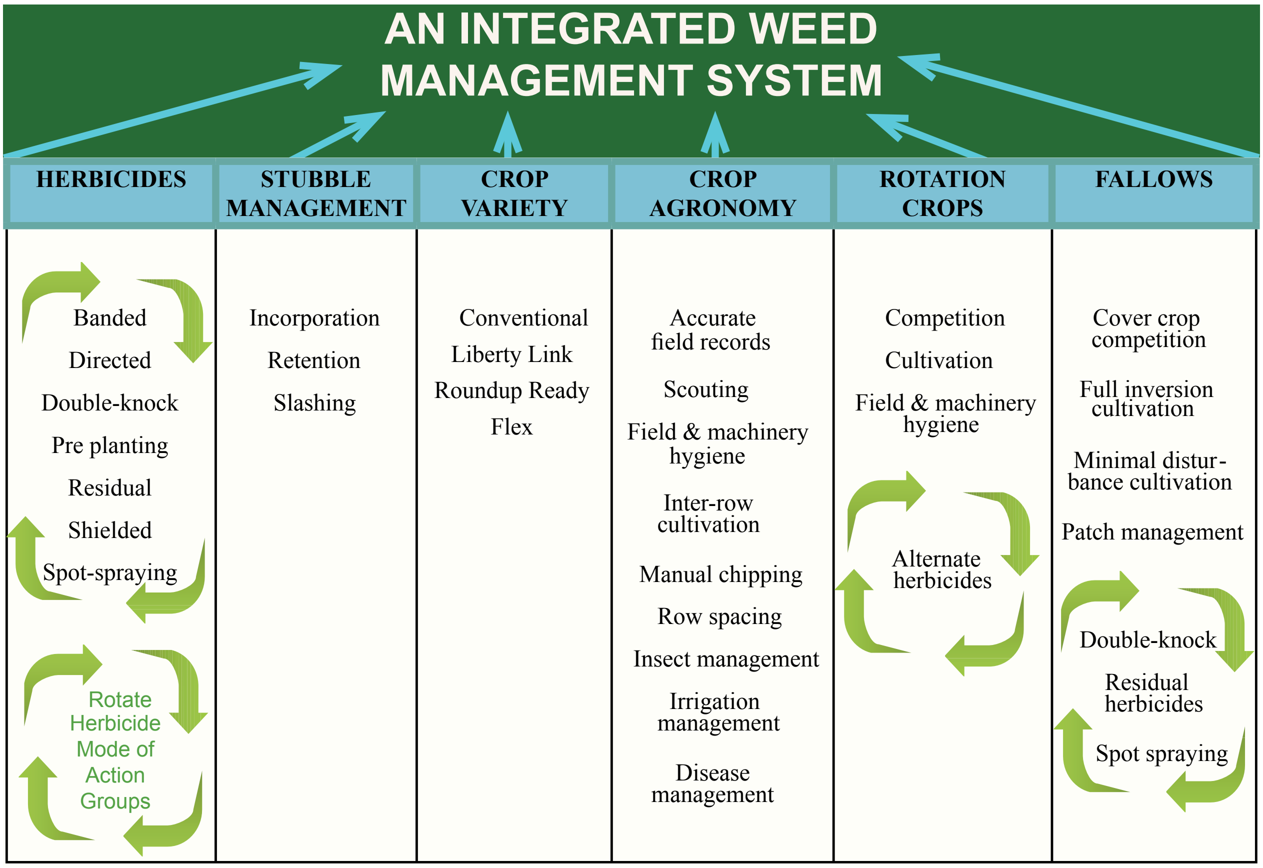
In developing a strategy it is important to consider what weed species are present. Ensure that weeds are correctly identified, and consider which tactics, or combination of tactics, are going to be most effective for your weed spectrum. Similar species may respond differently to control measures. For 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. The Weed ID guide and WEEDpak are key resources that can assist.

It is important to identify particular problem areas. Managing these patches more intensively may help to prevent a problem weed or resistance spreading.

Time your 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.

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



AN INTEGRATED WEED MANAGEMENT SYSTEM

HERBICIDES	STUBBLE MANAGEMENT	CROP VARIETY	CROP AGRONOMY	ROTATION CROPS	FALLOWS
Banded Directed Double-knock Pre planting Residual Shielded Spot-spraying Rotate Herbicide Mode of Action Groups	Incorporation Retention Slashing	Conventional Liberty Link Roundup Ready Flex	Accurate field records Scouting Field & machinery hygiene Inter-row cultivation Manual chipping Row spacing Insect management Irrigation management Disease management	Competition Cultivation Field & machinery hygiene Alternate herbicides	Cover crop competition Full inversion cultivation Minimal disturbance cultivation Patch management Double-knock Residual herbicides Spot spraying

Think about the whole farming system

In developing a strategy it is important to consider weed management in the context of other in-crop agronomic issues, other crops and across the whole farm.

Crop competition

Most agronomic decisions have some impact on weed management. An evenly established, vigorously growing cotton crop can compete strongly with weeds, especially later in the season. 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. Delaying planting on weedy fields until last, gives more opportunity to control weeds that emerge prior to planting and better conditions for cotton emergence and early vigorous growth. Research has shown that in irrigated crops, weed-free periods of 8-9 weeks from planting cotton provides enough time for the crop to out-compete later emerging weeds and significantly reduced seed production. Refer to the Weed Threshold in the Australian Cotton Production Manual for more.

Plan weed management to fit with other operations

Look for opportunities in the cropping system to time operations to combine weed control tillage. There are a number of opportunities, particularly in irrigated cotton, where tillage can be used. These include pupae busting, incorporation of fertilisers, seed bed preparation and maintaining irrigation furrows.

Consider impact of weeds on the whole farming system

Weed management is also an important consideration for pest and disease management. Many cotton pests rely on weed hosts and cotton volunteers prior to migrating into cotton fields. Pests that gain the greatest advantage from weeds are those that are unable to hibernate/over winter when conditions are unfavourable, such as spider mites, cotton aphids, mirids and silver leaf whitefly. Some weeds and cotton volunteers/ratoons can act as a reservoir for plant viruses such as cotton bunchy top disease which can cause significant loss of yield. Certain weeds that host diseases can also allow inoculum to build up in the soil increasing the risk for subsequent crops.

Rotation crops

Rotation crops provide an opportunity to introduce a range of different tactics into the system particularly herbicide groups that are not available in cotton. Having a mix in rotations may also vary 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. Where cotton is grown in rotation with crops, such as winter cereals or maize, retaining the stubble cover from these rotation crops for as long as possible reduces weed establishment and encourages more rapid breakdown of weed seed on the soil surface. In terms of the HRMS, rotation crops should be considered similar to a fallow, and with the aim to use at least 2 non-glyphosate tactics.

SUGGESTED INTERVALS FOR SOME COMMON DOUBLE KNOCK HERBICIDE COMBINATIONS IN THE NORTHERN GRAINS REGION

Weed	First application	Second application	Recommended timing*	Comments
BROADLEAF WEEDS				
Most broadleaf weeds	glyphosate	Group L (eg. paraquat)	7 to 21 days. Optimal timing is generally 10 to 14 days	
Difficult to control broadleaf weeds such as fleabane (*Conyza bonariensis*)	Group I (e.g Amicide® Advance, Tordon®) with or without glyphosate	Group L (eg. paraquat)	7 to 21 days. Optimal timing is generally 7 to 10 days	If interval is greater than 14 days, use maximum label rates of Group L herbicide
	glyphosate plus saflufenacil	Group L (eg. paraquat)	7 to 21 days. Optimal timing is generally 10 to 14 days	Only target rosettes less than 6 leaf
Difficult to control broadleaf weeds such as sowthistle/ milkthistle (*Sonchus oleraceus*)	glyphosate	2,4-D	2 to 4 days	Recommended to split applications due to incompatibility within the plant. As both products are systemic, the interval needs to be short.
	glyphosate	Group L (eg. paraquat)	7 to 10 days.	Only target small rosettes
	glyphosate plus saflufenacil	Group L (eg. paraquat)	7 to 21 days. Optimal timing is generally 10 to 14 days	Only target small rosettes
GRASS WEEDS				
Most grass weeds including: Annual ryegrass (*Lolium rigidum*) Barnyard grass (*Echin ochloa colona* & *E. crus-gali*)	glyphosate	Group L (eg. paraquat)	4 to 14 days. Optimal timing is generally 5 to 7 days	
Feathertop Rhodes grass (*Chloris virgata*)	haloxyfop	Group L (eg. paraquat)	7 to 14 days. Optimal timing is generally 7 to 10 days	Refer to APVMA permit 12941 (QLD ONLY)
Windmill grass (*Chloris truncata*)	quizalofop	Group L (eg. paraquat)	5 to 14 days. Optimal timing is generally 7 to 10 days	Refer to APVMA permit 13460 (NSW ONLY)

SOURCE: Independent Consultants Australia Network

Non-crop areas

Non-crop areas on the farm such as channels, tail drains, fence lines and roadsides can be a source of development and introduction of herbicide resistance into the farming system. Manage these areas as a fallow, using a range of tactics including residual herbicides and chipping of weeds. Do NOT rely on glyphosate to manage weeds in non-crop areas.

Come Clean Go Clean

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.

Control survivors before they set seed

To be effective in preventing resistance, weeds that survive a herbicide application must be controlled by another tactic before they are able to set seed. Spray applications should be monitored soon after a control is implemented, to assess efficacy. Weed audits are a requirement of growing Liberty Link and Roundup Ready Flex cottons. See pages 94–97 for details. Weeds may need to be closely examined, as some are capable of setting seed while very small and many weeds respond to varying day-length, so a winter weed emerging in late winter or spring may rapidly enter the reproductive phase of growth in response to lengthening daylight hours.

For a range of reasons, situations will occur when some weeds escape control by herbicides. Missed strips due to blocked nozzles, inadequate tank mixing, 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 an IWM strategy that survivors not be allowed to set seed.

EFFICACY OF KNOCKDOWNS IN FOUR WINTER FALLOW FIELD EXPERIMENTS, MEASURED AT 6 WEEKS AFTER TREATMENT, WHEN APPLIED TO 1- AND 3-MONTH-OLD WEEDS (THE RANGE OF EFFICACY ACROSS THE EXPERIMENTS IS IN BRACKETS)

Herbicide	Weed control (%)			
	1-month-old weeds		3-month-old weeds	
Glyphosate + 2,4-D	84	(62–100)	76	(63–96)
Glyphosate + Tordon 75-D®	93	(86–99)	84	(62–98)
Glyphosate + 2,4-D fb Spray.Seed®	96	(93–100)	93	(87–97)
Glyphosate + Tordon 75-D® fb Spray.Seed®	99	(97–100)	97	(92–100)
Glyphosate + 2,4-D fb Alliance®	96	(92–99)	90	(78–100)
2,4-D fb Spray.Seed®	97	(97–98)	83	(68–97)
2,4-D#	88	(81–95)	53	(48–57)
Amitrole®#	90	(84–95)	96	(95–97)
Spray.Seed®#	84	(78–89)	22	(13–30)

fb = followed by a 7-day interval
# = applied in only two of the four field experiments
Source: Steve Walker (QAAFI, University of Queensland), Michael Widderick, Andrew McLean and Jeff Werth (Toowoomba, QLD DAF).

In terms of survivor control, research indicates that high efficacy with an alternative tactic is good, but high frequency control is better than reliance on efficacy. Cultivation after glyphosate application, is predicted to achieve 80 per cent survivor control, whereas cultivation plus chipping is predicted to achieve 99.9 per cent survivor control. Other tactics for survivor control could be equally effective, such as shielded or spot-spraying with an effective knockdown herbicide. See In-crop Tactics below.

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. Historically chipping has been an important part of the cotton farming system, however this has dramatically reduced in recent years. As a tool to prevent survivors setting seed, chipping has been shown to be a cost effective means of preventing survivor seed set.

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 label rate of a herbicide from a different herbicide group to the herbicides most recently used to ensure that all weeds are controlled. This intensive tactic can be particularly useful for new weed infestations where weed numbers are low, or where weeds are outside of the field and difficult to get to, such as roadside culvets.

New weed detection technologies provide an opportunity to use spot spraying across large areas of fallow. This can provide opportunity to reduce herbicide costs, while still ensuring robust label rates are applied to problem weeds. Refer to the herbicide label for plant-back limitations relevant to the rate applied. Applicators should follow manufacturer recommendations for speed and nozzle type, as well as allowable products to ensure that application is effective.

In-crop tactics

Pre-plant/at planting

Prior to planting there is an excellent opportunity to incorporate a non-glyphosate herbicide or combination of herbicides, or to integrate cultivation with a pre-planting operation such as seed bed preparation. In irrigation systems consider utilising pre-irrigating to cause a flush of weeds to emerge and be controlled before cotton emergence.

Knockdown herbicides from Group C (Bromoxynil), Group I (2,4-D, Dicamba, Fluroxypyr), Group L (paraquat, paraquat/diquat), Group M (glyphosate) and Group N (glufonsinate) can be used to target weeds that have emerged in the field. This can be made more effective when used as a double knock (refer to Suggested intervals for some common knockdown herbicide combinations page 89). Refer to Table 24: Plant-backs to cotton for herbicides used in seedbed preparation.

Residual herbicides remain active in the soil for an extended period of time (months) and can act on successive weed germinations. This can be particularly effective in managing the earliest flushes of in-crop weed, when the crop is too small to complete. Broadleaf and grass weeds can be targeted with residual herbicides from Group C (fluometuron/prometryn, fluometuron, prometryn) and grass weeds only targeted with Group D (pendimethalin, trifluralin) or group K (S-metolachlor).

Most residual herbicides need to be incorporated into the soil for optimum activity. Adequate incorporation of some residual herbicides is achieved through rainfall or irrigation, but others require incorporation through cultivation. Soil surfaces that are cloddy or covered in stubble may need some pre-treatment such as light cultivation or burning to prevent 'shading' during application. Ash from burnt stubble may inactivate the herbicide, and therefore must be dissipated with a light cultivation or rainfall prior to herbicide application.

Crop safety is an important consideration for use of residuals. Always follow label direction and if you are inexperienced in the use of residuals in cotton it is encouraged that you discuss your circumstances with your consultant, chemical supplier or the manufacturer.

The persistence of residual herbicides needs to be considered in order to avoid impacts on rotation crops. Persistence is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall/irrigation, temperature and the herbicide's characteristics. It can be quite complex. For example, moisture can be a big factor, however it is not the volume of rain, but the length of time the soil is moist that is the critical factor. A couple of storms, where the soil dries out quickly won't contribute as much to the breakdown of residuals, compared with soil staying moist for a few days. Tables 23 to 26 provide information on some plant-back limitations. Refer to product label for more information. If growers are concerned that the residual is still active in the lead up to planting, look for the presence of susceptible weeds in the treated paddock or pot up soil from the treated and untreated area, sow the susceptible crop and compare emergence. Where there is a concern, plant the paddock last and pre-irrigate if it is to be irrigated. It is important to ensure that best practice is followed in terms of capture and management of runoff water.

Post-emergence

Once cotton has emerged there are still many opportunities to incorporate different tactics. Check label for restrictions on node development.

Herbicide tolerant cotton traits, mean that weeds need only be controlled if and when germinations occur, meaning herbicide application can be timed to have maximum impact on weed populations. When targeting the over the top application of glyphosate (Round up Ready Flex), or glufosinate (Liberty Link) aim to treat actively growing weeds, and avoid allowing weeds to become too large. Avoid using the same herbicide to control successive generations of weeds, and ensure survivors are not able to set seed. Do not apply more than the allowable number of OTT applications. Refer to pages 94 and 98–101 for more information.

Grass selective herbicides (Group A) can be applied over the top of cotton. This group has a high risk of resistance and repeated use will lead to the development of Group A resistance. It is important that in managing glyphosate resistance, that resistance to other herbicides doesn't develop.

The Metolachlor label now includes over the top use in-crop from 4 node up to 18 node crop growth and can be used with glyphosate. This provides additional residual control of grass weeds.

To avoid leaf spotting use a directed or shielded spray. Other lay-by/ shielded spray options include prometryn, diuron, flumioxazin, and pendimethalin.

In-crop cultivation, and if required chipping, provides important non-herbicide options for control of herbicide survivors. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the damage to soil caused by tractor compaction and soil smearing from tillage implements. Care should be taken in set-up to minimise the plant damage. Inter row cultivation can increase Fusarium Wilt.

Post-harvest

Some weeds are likely to be present in the crop later in the season – even in the cleanest crop. These weeds will produce few seeds in a competitive cotton crop, but can take advantage of the open canopy created by defoliation and picking. Removing the crop residues and weeds as soon after picking as practical greatly reduces the opportunity for these weeds to set seed. Refer to management of volunteers and ratoons (page 109).

Fallow management

Weed management in the fallow is an important component of a weed management plan. Summer fallows following a Roundup Ready Flex cotton crop where only glyphosate herbicide is used for weed control, poses the greatest risk to glyphosate resistance development. The continued use of Glyphosate for controlling summer weeds means that summer weeds are only exposed to the one mode of action herbicide. The Herbicide Resistance Management Strategy recommends at least two non-glyphosate tactics in summer fallows. Residual herbicides and double knock tactics provide good alternatives to a glyphosate only fallow herbicide. Refer to Table 23 Herbicide plant-backs from rotation crops to cotton. It is recommended that for larger weeds that may be tolerant to herbicides, a strategic cultivation be used for weed control. Field activities such as fertiliser placement and bed cultivators should be set up to have adequate soil disturbance to eradicate weeds during these mechanical tasks, this will lessen the pressure to control weeds with further actions.

For more information: The Australian Cotton Production Manual includes information on weed control tactics.

TABLE 23: 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, barley, oats, triticale fallows	9 months	Plant-back interval on black cracking clay soils. When rainfall is less than 100 mm for a period of 4 months or greater 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	Following treatments of up to 1.4 kg/ha.
			18 months	Following treatments of 1.4 kg/ha to 3.3 kg/ha.
Primextra Gold	atrazine + s-metolachlor	Cereal Crops: sorghum, maize. Other Field Crops: sugarcane	6 months	When rates up to 3.2 L/ha are used.
			18 months	When rates up to 3.2 L/ha are used. On alkaline soils, a bioassay or analytical test should be undertaken.
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.
Lontrel750SG	clopyralid	Cereal Crops: wheat, barley, oats, triticale. Other Field Crops: canola. Pastures and Fallows	3 months	When rates up to 30 g/ha are used.
			6 months	When rates of 30–120 g/ha are used.
			24 months	When rates above 120 g/ha are used. For all rates at least 100 mm rain required during plant-back period.
diuron	diuron	Cereal Crops: wheat, barley, oats, triticale, cereal rye. Legumes: lupins. Pastures: perennial grass seed crops, lucerne	DO NOT replant treated areas within 2 years of application of diuron except when otherwise stated on label.	
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	2 years	For NNSW and Qld a minimum of 50 mm and preferably 100 mm rain or more must have fallen over the warm months of the year.
Balance	isoxaflutole	Legume Crops: chickpeas. Other Field Crops: sugarcane, fallow	7 months	350 mm rainfall (do not include flood/furrow irrigation) between application and planting the subsequent crop.
Sakura	Pyroxasulfone	wheat (not Durum), triticale	5 months + 150 mm of rainfall	Less total rainfall between application and planting of the following crop than 150 mm may require extended plant-back period.
Spinnaker	imazethapyr	Legume Crops: chickpeas, faba beans, field peas, mungbeans, soybeans. Other Field Crops: peanuts. Pastures: lucerne, serradella, sub clovers	22 months	Raingrown cotton.
			18 months	Irrigated only. (Providing rainfall and irrigation exceeds 2000 mm).
Tordon 75D	picloram + 2,4-D	Cereal Crops: wheat, barley, oats, triticale, sorghum, maize. Other Field Crops: sugarcane. Pastures: Pastures	12 months (Nth NSW & Qld)	Do not use on land to be cultivated for growing susceptible crops within 12 months of application. Based on normal rainfall.
Tordon 242	picloram + MCPA		12 months (Nth NSW & Qld) 20 months (Sth NSW)	Based on normal rainfall.
simazine	simazine	Legume Crops: chickpeas, faba beans, lupins. Fruit & vegetable crops, Forestry & Ornamental. Other Field Crops: TT canola. Pastures: lucerne, sub clover, perennial grasses	9 months	When up to 2.5 kg/ha are used.
Logran	triasulfuron	Cereal Crops: wheat, barley, oats	15 months Soil pH Less than 7.5	700 mm rainfall between application and sowing the plant-back crop.
			18 months Soil pH 7.6–8.5	
Grazon Extra	triclopyr + picloram + aminopyralid	Fallow	4 months (0.2 L/ha) 6 months (0.4 L/ha)	During drought conditions (<100 mm rainfall in a 4 month period) the plant-back is significantly longer

TABLE 23: Herbicide plant-backs from rotation crops to cotton (continued)

Trade name	Herbicide active ingredient	Registered for use in	Plant-back to cotton	Notes
Raptor	imazamox	Legume Field Crops: field peas, soybeans. Other Field Crops: peanuts. Pastures: lucerne, legume-based pastures.	10 months	Must have 800 mm of rainfall or applied irrigation.
Hussar	mefenpyr-diethyl + iodosulfuron-methyl sodium	Cereal Crops: wheat.	12 months	Rainfall of less than 500 mm following Hussar use may result in extended re-cropping intervals for summer crops sown in the following season.
Sencor 700 Sencor 480	metribuzin	Cereal Crops: wheat, barley, oats. Legume Crops: chickpeas, faba beans, lentils, vetch, lupins, field peas, soybeans (irrigated). Other Field Crops: potatoes.	12 months 6 months for rates <1.5 L/ha; 12 months for rates > 1.5 L/ha	This could be longer if there have been long dry periods between crops.
Atlantis	metsulfuron methyl + mefenpyr-diethyl	Cereal Crops: wheat.	12 months	Rainfall of less than 500 mm following Atlantis use may result in extended re-cropping intervals for summer crops sown in the following year.

TABLE 24: Plant-backs to cotton for herbicides used in seedbed preparation

Herbicide active ingredient	2,4-D amine 700 g/L (2,4-D amine 300 g/L)			dicamba 700 g/kg (dicamba 500 g/L)			fluroxypyr 200 g/L (fluroxypyr 333 g/L)			triclopyr 600 g/L
Rate L or g/ha	0.5 (1.1)	0.5–.98 (1.1–2.3)	0.98–1.5 (2.3–3.4)	140 (200)	200 (280)	400 (560)	0.375 (0.225)	0.75 (0.45)	1.5 0.9)	0.16
Plant-back[1] (days)	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 25: Herbicides with unknown plant-back periods to cotton

Trade name	Active ingredient	Registered for use in
Intervix	imazamox + imazapyr	Clearfield crops (all other – 34 months).
Ally	metsulfuron methyl	Cereal Crops: wheat, barley, triticale Legume Crops: chickpeas (desiccant).
Harmony M	metsulfuron methyl + thifensulfuron	Cereal Crops: wheat, barley, triticale.
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 26: Cotton herbicide plant-backs to rotation crops

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	Adzuki bean	Chickpea	Cowpea	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	24	24	24	24	24	24	24	24	24	24	24	24	24	24	12	24	24	24	24	24	24	24
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]	24	21	NI	24	21	24	24	NI	3	NI	24	NI	NI	NI	NI	21	NI	3	NI	18	18	27
pendimethalin	6	0[3]	12	12	12	NI	NI	NI	NI	NI	NI	NI	NI	NI	6	NI	NI	NI	6	NI	NI	NI
prometryn	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
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 NSW DPI

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

Herbicide tolerant technology

Liberty Link Technology

Developed by **Bayer CropScience** in association with the Herbicide Tolerance Technical Panel of the Transgenic and Insect Management Strategies Committee of Cotton Australia

Liberty 200 Herbicide mode of action

In plants, the glutamine synthetase enzyme combines ammonium with glutamate to form glutamine which is then used by plants in photosynthetic processes. The active ingredient of Liberty 200 Herbicide, glufosinate-ammonium, inhibits the actions of the glutamine synthetase enzyme, stopping plants 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 that weeds should be targeted at the 2–6 leaf growth stage. 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. 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 derived from the common soil bacterium, *Streptomyces hygroscopicus* which allows it to express 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.

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.

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

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 usage. 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 Flex 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 or page 109.

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 Program 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 shown on page 94. 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 remedial action taken to control any surviving weeds prior to seed set. Return completed forms to Bayer CropScience by December 31. Audit data will be collated and reported to the TIMS Weeds Subcommittee.

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. (eg. temperatures below 33°C and relative humidity above 50 per cent.)

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 compatibilities.

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

Roundup Ready Flex technology

Monsanto Australia Limited,
Graham Charles, NSW DPI **and Tracey Leven,** CRDC

How does Roundup Ready Flex cotton work?

The primary effect of glyphosate on plants is the inhibition of the production of EPSPS. EPSPS is an enzyme responsible for the production of amino acids essential for protein construction and plant growth.

Monsanto identified a soil bacterium that produces a modified form of the EPSPS enzyme, the CP4 strain. The CP4 strain of EPSPS is not inhibited by glyphosate. Roundup Ready Flex cotton plants produce the modified form of EPSPS, so are able to continue producing amino acids and proteins after glyphosate has been applied. Roundup Ready Flex cotton contains two copies of the CP4 EPSPS gene and a 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. Only glyphosate products registered for usage in Roundup Ready Flex can be used OTT of Roundup Ready Flex cotton. Usage must be in accordance with the label and the Crop Management Plan (CMP). Registered glyphosate products 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 per cent bolls open and harvest. However, the total amount of herbicide applied to any one crop must not exceed 6 kg/ha in a total of 4 applications as illustrated in Figure A (over page). Crops that are intended for seed production must not have an application of glyphosate past the 60 per cent 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 with no effect on fruit retention, fibre quality parameters or yield.

Weed management in Roundup Ready Flex

Roundup Ready Flex cotton offers growers an increased margin of crop safety, a more flexible window for OTT applications of glyphosate, 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. Refer to weed section pages 88–93 for detailed information on integrated weed management recommendations.

Know your field history

A combination of the relative effectiveness of previous herbicide programs and other agronomic practices employed on a farm is likely to 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 appropriate herbicide and herbicide rate are chosen for the target weed species. By knowing field history, growers can determine which weed control tools they should use and when they should be employed to achieve the best results.

Pre-plant knockdown

Starting with a 'clean' field provides seedling cotton with the best possible conditions to emerge and to develop, unhindered by the competitive effects of weeds. Pre-plant weed control can be achieved using tillage and/or the appropriate registered herbicides. The use of glyphosate tank mixes or herbicides with other modes of action is encouraged prior to planting to strengthen the IWM program. It is important that any cotton volunteers are controlled at this stage.

The role of residual herbicides

Residual herbicides should be used where appropriate in the Roundup Ready Flex 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 field's 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 a registered glyphosate product 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.

Subsequent OTT applications

After the first OTT application, the use of subsequent OTT applications (up to a 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(s) chosen.Select the timing and application rate of the registered glyphosate product based upon the most difficult to control weed species in each field. Refer to label for more information.

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.

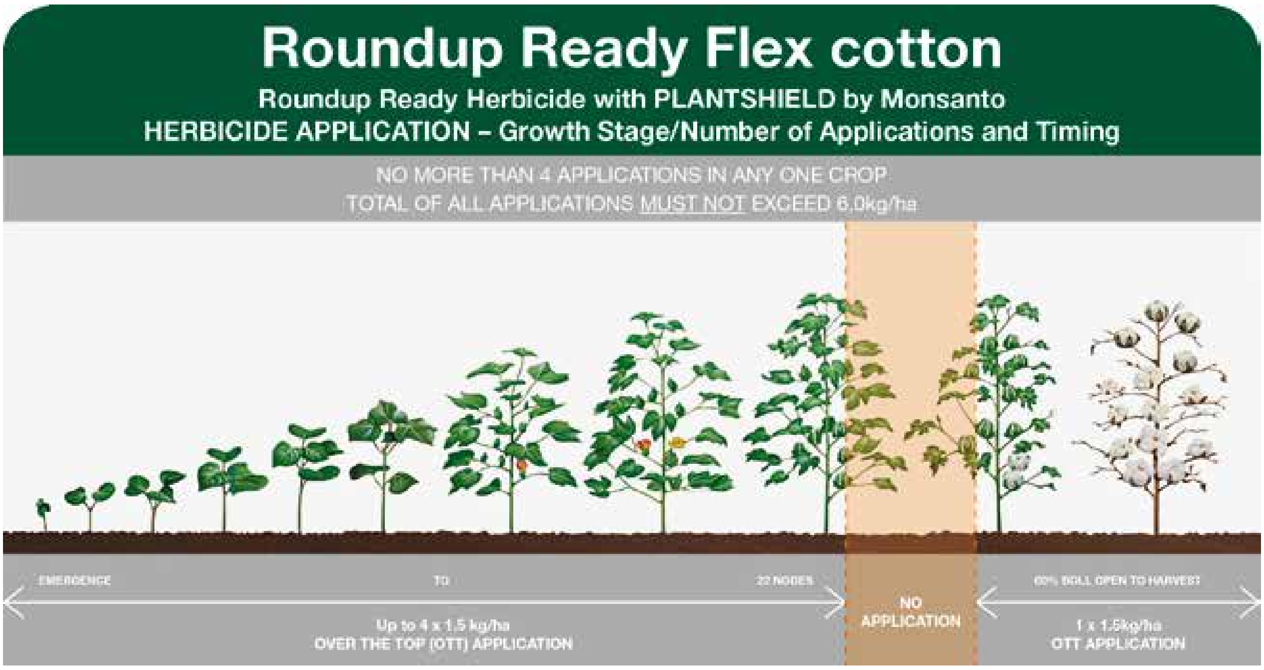
Pre-harvest application

One application of a registered glyphosate product may be made OTT between 60 per cent 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

It is a requirement of the Technology User Agreement (TUA) that growers sign annually that all persons growing and managing Roundup Ready Flex cotton crops comply with a Crop Management Plan (CMP). Within each CMP, there are the requirements for a Planting Audit and a Weed Management Post Spray Survey.

FIGURE A: Roundup Ready Flex cotton allows you to spray a registered glyphosate product over the top (OTT) of your cotton from emergence through to 22 nodes.



Planting audit

The Technology Service Provider (TSP) is responsible for completion of the planting audit by no later than 5 December, as set out in the Technology User Agreement (TUA). The information required includes:

- Number of hectares sown;
- Location of Roundup Ready Flex cotton on the farm unit;
- Date/s of sowing; and,
- A record of compliance with the Bollgard II Resistance Management Plan (RMP) and the Crop Management Plan (CMP).

Weed management Post Spray Survey

Only accredited TSPs will be able to conduct the Weed Management Post Spray Survey.

TSPs will undertake the Post Spray Survey on a percentage of fields growing Roundup Ready Flex cotton in accordance with Table A. TSPs will assess all weeds remaining ten to fourteen days after an OTT (application of a registered glyphosate product at a minimum of 6 nodes crop growth, and not exceeding 16 nodes.)

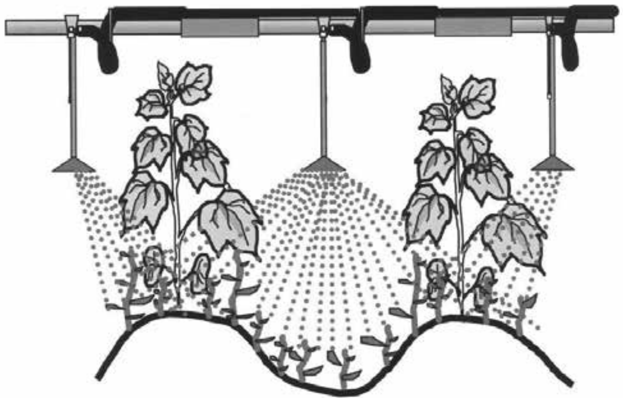
TABLE A: Post Spray Survey requirements in field

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

Table A outlines how to assess the field for the presence of surviving weeds. The minimum distance between each assessment (ie each 100 metres linear row) must be 100 rows. In addition to the assessment of surviving weeds, the TSP is required to record:

- Reasons as to why survival of weeds has occurred. For example, this may be due to shading, environmental conditions, subsequent germinations, off label weeds or suspected resistance
- 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. Details on this strategy must be provided
- Adverse event reporting. Growers and TSPs are required to report any adverse event, such as suspected weed resistance, to the herbicide registrant as soon as it is identified. The herbicide registrant must report any cases of confirmed resistance to the APVMA.

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



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

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. Refer to pages 109–110 for more information.

Application guidelines

Timing options

The glyphosate label for OTT usage in Roundup Ready Flex 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 per cent open. 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 per hectare of glyphosate may be applied through all growth stages of Roundup Ready Flex cotton in any one growing season.

Tank-mixtures with other herbicides or insecticides are not recommended for over-the-top applications of glyphosate due to the potential for reduced weed control or crop injury. (Refer to Label for Directions for use – Roundup Ready Flex cotton).

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, a spray volume of 50–80 litres per sprayed hectare is recommended for optimum performance. Nozzles and pressure settings must be selected to deliver a minimum of a COARSE spray quality (American Society of Agricultural Engineers (ASAE) S572) at the target. For aerial application, nozzles and pressure settings must be selected to deliver a minimum of a COARSE spray quality (ASAE SS572) at the target. A minimum total application volume of 40L per hectare needs to be used. Do not apply by aircraft at temperatures above 30°C or if relative humidity falls below 35 per cent.

Other Sources of Information can be found on Monsanto Australia's Cotton Stewardship Page www.monsanto.com/global/au/products/pages/cotton-stewardship.aspx

Roundup Ready Flex Cotton Weed Management Guide

Roundup Ready Flex Cotton Weed Resistance Management Plan

www.weedsmart.org.au/

Cotton Weed Control Guide

Tracey Leven, CRDC
Jon Baird, NSW DPI

Registration of a herbicide is not a recommendation 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 herbicide 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:

- **QLD DAF, cost $7.50 plus postage and handling. Contact QLD DAF in Toowoomba – 07 4688 1200 or;**
  in Dalby – 07 4669 0800 to place an order.
- **NSW DPI, cost $12.00 plus postage and handling. Contact NSW DPI, Yanco – 1800 138 351.**

ABBREVIATIONS USED IN TABLES 27–34

AC = Aqueous concentrate
CS = Capsule suspension
DF = Dry flowable granule
GR = Granule
EC = Emulsifiable concentrate
LQ = Liquid
SC = Suspension concentrate
SL = Soluble concentrate
SP = Soluble powder
WDG (WG) = Water dispersible granule
WP = Wettable powder

TABLE 27: 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	0.28–4.5/100 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.
Glyphosate	M	Various	Various	Rates vary with formulations and species present. For dry channel – choose product with a specific irrigation channel registration. Do not allow water to return to channels for 4 days. For aquatic areas – select product with a specific aquatic weed control registration. See label for details for application around aquatic areas.
Imazapyr + glyphosate	B + M	150 g/L + 150 g/L LQ SC	5.0 L/ha	Drain channel prior to treatment. Only apply to irrigation delivery and recirculation channel which are lockable or which may be flushed to a recirculation dam or settling pond. For best results apply in early autumn with minimal weed growth. Allow six weeks before channel is re-used. Refer to label for directions on flushing.
Pendimethalin	D	330 g/L EC 440 g/L AC	4.5–9.0 L/ha 3.4–6.75 L/ha	Drain channel prior to treatment. If 25–50 mm rain has not fallen within 14 days flush and stand for 1 day, and use to pre-irrigate for cotton. Do not use water in channel to irrigate or pre-irrigate susceptible crops.

TABLE 28: Control of weeds around aquatic areas

Active ingredient	Mode of Action group	Concentration and formulation	Application rate of product	Comments
Glyphosate	M	Various	Various	Rates vary with formulation and species present. Choose a glyphosate product that has a specific aquatic weed control registration. See label for details for application around aquatic areas.

TABLE 29: 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	II	225 g/L AC 300 g/L AC	0.8–3.6 L/ha 0.66–2.7 L/ha	Refer to label for restrictions to prevent drift, adjuvant recommendation and plant-back to cotton. Plant-back period starts after 15 mm is applied in dry conditions.
Amitrole + paraquat	L + Q	250 g/L + 125 g/L	2–4 L/ha	Can be part of double knockdown. Sowing can occur immediately after application .
Carfentrazone-ethyl	G	240 g/L EC	0.025–0.0.75 L/ha Up to 0.1 L/ha for control of volunteers.	Apply as a tankmix with glyphosate or products containing paraquat. Do not sow for 1 hr.
Carfentrazone-ethyl + Glyphosate	G + M	7.2 g/L + 432 g/L	Up to 2.5 L/ha Varies with target and tillage	NSW only. Refer to label.
Dicamba	I	500 g/L AC 700 g/kg WG	0.16–0.56 L/ha 0.115–0.4 kg/ha	NSW – up to 14 days plant-back period; QLD – higher rates have 21 days plant-back.
Diuron	C	900 g/kg WG	1 – 2 kg/ha	Do not use on light sandy soils. Do not make a second pre-emergent application to the same field during the same crop as injury to the crop may occur.
Fluometuron	C	500 g/kg WG, AC, SC 900 g/kg GR, WG	2.8 – 5.6 L/ha 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, WG	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 WG	30 g/ha + tank mix parner 45 g/ha	Addition to knockdown herbicides will increase the speed of activity and may improve final control. For control of volunteer cotton (incl. RR varieties). Always apply with a recommended adjuvant.
Fluroxypyr	I	200 g/L EC 400 g/L EC	0.75–1.5 L/ha 0.375- 0.75 L/ha	Certain broadleaf weeds. See label for details of mixtures with glyphosate and plant-back restrictions.
Glyphosate	M	Various	Various	Controls most annual grasses and broadleaf weeds. Refer to label for rates on specified weeds and recommendations.
Glyphosate Glufosinate-ammonium	M N	690 g/kg WG	0.265–1.5 kg/ha	In fallows and prior to sowing Roundup Ready Flexcotton only.
Glyphosate Glufosinate-ammonium Metolachlor	M N K	200 g/L SL in 100L water	3.75 L/ha	Maintenance of summer fallow prior to planting. Do not sow crops until 14 days or more have elapsed after the final application.
		720 g/L EC 960 g/L EC	2.0 L/ha 1.5 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 GR	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 SL	1.2–2.4 L/ha	Refer label for rate for annual grass and broadleaf seedlings stage.
Paraquat + diquat	L	135 g/L + 115 g/L SL	0.8–2.4 L/ha	Refer label for rate for annual grass and broadleaf seedlings stage.
Pendimethalin	D	330 g/L EC 435 g/L EC 440 g/L EC 455 g/L AC 475 g/L EC	3.0 L/ha 2.28 L/ha 2.25 L/ha 2.2 L/ha 3.11 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, WG	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 600 g/L EC	1.2–2.3 L/ha 1.1–2.25 L/ha 0.96-1.35 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 30: Weed control at or after planting and before crop emergence

Active ingredient	Mode of action group	Concentration and formulation	Application rate of product	Comments
Chlorthal dimethyl	D	750 g/kg WG 900 g/kg WG	6.0–15.0 kg/ha 5.0-12.0 kg/ha	Apply at time of planting. Use higher rate for areas under irrigation.
Diuron	C	500 g/L SL 900 g/kg GR, WG	1.8–3.5 L/ha 1.0–2.0 kg/ha	DO NOT apply more than 1.8 kg of active ha per year. See page 156 for further restrictions. Avoid light soils. Spray immediately after planting.
Fluometuron	C	500 g/L AC, SL 900 g/kg DF, WG	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, SL 440 g/kg + 440 g/kg DF, WG	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 960 g/L EC	2.0 L/ha 1.5 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 SL	0.8–2.4 L/ha	Refer label for rate for annual grass and broadleaf seedlings stage
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, SL 900 g/kg DF, WG	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 31: Weed control pre-harvest

Active ingredient	Mode of Action group	Concentration and formulation	Application rate of product	Comments
Glyphosate	M	Various	Various	Controls Bathurst burr, Noogoora burr, winter annual weeds. Use higher rates for Nutgrass control. May be applied alone orwith harvest aid. Apply when 60 per cent bolls are open.
		690 g/kg WG	0.710–1.5 kg/ha	Registered for use in Roundup Ready Flex cotton. Apply when 60 per cent bolls are open. Check label for details.

TABLE 32: 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 WG	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	750 g/kg WG 900 g/kg WG	(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 SL 900 g/kg DF, WG	2.0–3.5 L/ha 1.0–2.0 kg/ha	DO NOT apply more than 1.8 kg of active ha per year. See page 156 for further restrictions. Cotton should be at least 30 cm high. Use 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, SL 900 g/kg DF, WG	2.8-5.6 L/ha 1.5–3.0 kg/ha	Controls many broadleaf weeds and annual grasses. 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, SL 440 g/kg + 440 g/kg DF, WG	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 WG	60 or 90 g/ha	Apply as a shielded spray. Do not contact cotton foliage.
Glufosinate-ammonium	N	200 g/L SL	3.75 L/ha in 100 L water	Only apply to Liberty Link cotton varieties. Maximum 2.25kg a.i./ha/season (3 applications). As a contact herbicide coverage is critical to effectiveness.

TABLE 32: Weed control after crop emergence (includes layby) (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Application rate of product	Comments
Glyphosate	M	Various	Various	Apply with shielded sprayer. Do not apply in cotton less than 20 cm high. Rates vary with formulations and species present.
		690 g/kg WG	0.52–1.5 kg/ha	Only apply over-the-top to Roundup Ready Flex cotton varieties up to 22 node stage of growth. No more than 4 applications in total are permitted. DO NOT TANK MIX FOR OVER-THE-TOP APPLICATION
Halosulfuron–methyl	B	750 g/kg GR 750 g/kg WG	65–130 g/ha	Shielded sprayer 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. Apply from 2 leaf to before onset of flowering.
MSMA	Z	720 g/L LQ, SL 800 g/L LQ, SL	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, SL	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, SL 900 g/kg GR, WG	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.
Trifloxysulfuron sodium	B	750 g/kg WG	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 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
2,4-D present as the isopropylamine salt	I	300 g/L	2,4-D 300 IPA	Sabakem, Agro-Alliance, Ezycrop, Agspray Chemical Co, Crop Smart, New Australia Agricultural Development Company, Farmalinx, Ospray, Agrimart, Agcare,, Ravensdown, Accensi, Novaguard, Spalding, Easyfarm, Ozcrop, Rainbow International Co, Profeng, Pacific AgriScience, FMC, Forward
			Amine 300	Titan, Ruralchem, Hextar, Conquest, Genfarm, Sinochem
			Aminex 300	ACP
			Applause 300	Agri West
			Basilica 300	Chemtura
			Cobber	Crop Care
			Ken-Star	Kenso
			Smash 300	Imtrade
			Surpass 300	Nufarm
			Weeds Out 300	Biotis Life Science
			Zulu 300	ADAMA
		400 g/L	Abound	Dow AgroSciences
			2,4-D 400 IPA	FMC
		450 g/L	2,4-D 450 IPA	Apparent, Farmalinx, Rainbow, Ozcrop
			Kenstar 450	Kenso
			Pass 450	Crop Smart
2,4-D present as dimethylamine and monomethylamine salts	I	700 g/L	Amicide Advance 700	Nufarm
2,4-D present as dimethylamine and diethanolamine salts	I	475 g/L	Accensi 2,4-D 475 Dual Selective Herbicide	Accensi
			Amine 475	Titan
			Amine Plus 475	Conquest
			Aminex 475	ACP
			Cobber 475	Crop Care
			Exceed	Apparent
			Surpass 475	Nufarm
Amitrole + ammonium thiocyanate	Q	250 g/L	Amitrole	Imtade, Farmalinx
		250 g/L + 220 g/L SL	Amitrole T	Nufarm
Amitrole + paraquat	Q + L	250 g/L + 125 g/L	Alliance	Crop Care
Butroxydim	A	250 g/kg WG	Factor WG	Crop Care
			Vulcan	FMC

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Carfentrazone-ethyl	G	240 g/L EC	Carfentrazone 240 EC	4Farmers, Titan, Landmark Operations, Agrochemical
			Hammer	FMC
			Nail	Crop Care
			Punch	Osspray
			Spike	Conquest
			Task	FMC
		400 g/L EC	Artillery	ADAMA
			Elevate	ADAMA
			Hammer 400	Crop Care
			Nail	Crop Care
Carfentrazone-ethyl + Glyphosate	G + M	7.2 g/L + 432 g/L	Broadway	FMC
Chlorthal dimethyl	D	750 g/kg WG	AC Discord 750 WG	Axichem
			Clorthal dimethyl 750WG	Macphersons, Novaguard, FMC, Ezycrop
			Dynamo 750 WG	Farmalinx
			Prethal 750 WG	KD Plant Care
		900 g/kg WG	Dacthal 900 WG	Crop Care
			Chlor-Dime	Mission
		900 g/kg WG	Pterodactyl	Imtrade
Clethodim	A	120 g/L EC	Select 120	Arvesta
		240 g/L EC	Agro-Essence	Agro-Alliance
			Akodim	Aako
			Arysta Select	Arysta
			Blade 240EC	Ravensdown
			Carbine 240	Axichem
			Cleodim 240	Grow Choice
			Clethim 240 EC	Farmalinx
			Cletho 240 EC	Kenso
			Clethodim 240 EC	4Farmers, Agcare, Agrismart Agvantage, Apparent, Australian Progressive Supplies, ACP, Biotis Life Science, Chemforce, Crop Pro, Easyfarm, Echem, Ezycrop, FMC, Forward, Generex, Imtrade, Landmark Operations, Mission Bell, Nisso, BASF Agro Co, Novaguard, Ospray, Ozcrop, Pacifi AgriScience, Sabakem, Sanonda, Rainbow, Shanghai Agrochina, Spalding, Titan, Wellfarm
			Cluster 240 EC	Hextar
			Coerce 240EC	Agri West
			Eco Cletho 240 EC	Sanplus
			Genie	Chemtura
			Grasidim	Sipcam
			Havoc	Crop Care
			Macro Protect	Louis Dreyfus Commodities
			Nissodim 240 EC	BASF
			Nitro 240	Conquest
			Platinum	ADAMA
			Rygel	Profeng
			Scalpel 240 EC	Sinochem Agro
			Select	Sumitomo Chemical
			Sequence	Nufarm Australia
			Smart	Crop Smart
			Status	Sumitomo Chemical
			Sumistatus 240 EC	Sumitomo Chemical
			Uproot 240 EC	UPL.
			Whitestar	Agricultural Product Services
		360 g/L EC	Arysta Select Xtra 360	Ospray
			Clethodim 360	Apparent
			Cletho 360	Kenso Agriculture
			Rainbow	Rainbow

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Dicamba	C	500 g/L AC	Camquesta 500 AC	Conquest
			Cutlass 500	ADAMA
			Dicam 500	Farmalinx
			Dicamba 500 AC	Accensi, ACP, Cheminova, Chemtura, FMC, Grow Choice, Kenso, Ozcrop, Rainbow, Titan, Agrochina, Landmark
			Dicer 500	Hextar
			Kamba 500	Nufarm
		500 g/L SC	Dicam 500	Faramlinx
			Dicamba 500 SC	4Farmers, Apparent, Imtrade, Sabakem, Ravensdown
			Diffuse	Axichem
			Ditch	Agri West
		700 g/kg WDG	Cadence	Syngenta
			Camquesta 700	Conquest
			Dicamba 700	Ospray, Rallis, Titan, Rainbow, Kenso
			Dicam 700	Farmalinx
			Dicamba 700 WDG	Apparent, FMC, Rallis
			Kamba Dry	Nufarm
			Volley	Sipcam
Diuron	C	500 g/L SL	Various for multiple products	Various for multiple products
		900 g/kg WG DF	Various for multiple products	Various for multiple products
Fluazifop-p	A	128 g/L EC	Fusilade Forte	Syngenta
		212 g/L EC	AC Flare	Axichem
			Flazz	Agriwest
			Fluazifop-p 212	4Farmers, Apparent, Ezycrop, Novaguard,
			Fulisade	Sygenta
			Fuziler	Chemnova Australia
			Genfarm Fluazifop	Landmark Operations
			Resilience	ADAMA
			Rootout 212	Sinon
Fluometuron	C	500 g/kg WG, AC, SC	Cotoran Wg, Sc	ADAMA
			Reliance Liquid	Crop Care
			Fluocam 500	Sipcam
			Fluometuron 500 Sc	Ozcrop
		900 g/kg DF	Nu-Tron 900df	Nufarm
		900 g/kg WG	Fluometuron 900 Wg	ADAMA, 4Farmers, Ozcrop, Rainbow, Sabakem, Titan
Fluometuron + prometryn	C	250 g/L + 250 g/L AV	Bandit Liquid	Crop Care
		250 g/L + 250 g/L SL	Flupromix 500	Sipcam
		250 g/L + 250 g/L SL	Cotogard SC	ADAMA
		440 g/L + 440 g/L DF	Convoy DF	Nufarm
		440 g/L + 440 G/L WG	Cotogard WG	ADAMA
			Fluproguard	Sabaken
		450 g/L + 450 g/L WG	Flupromix	Sipcam
Flumioxazin	G	500 g/kg WG	Pledge	Sumitomo Chemical
			Terrain	Sumitomo Chemical
			Valor	Sumitomo Chemical

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Fluroxypyr	I	140 g/L EC	Hotshot	Dow AgroSciences
		200 g/L EC	Acclaim	Sipcam
			Comet 200	Nufarm
			Dozer	Axichem
			Flagship 200	ADAMA
			Flotilla	Ospray
			Floxor 200 EC	Farmalinx
			Fluroken 200	Kenso
			Fluroxypyr 200EC	4Farmers, Accensi, Apparent, ACP, Chemtura, Crop Smart, Ezycrop, FMC, Landmark Operations, Novaguard, Ospray, Ozcrop, Pacific AgriScience, Sabakem, Rainbow, Titan
			Hebroxy 200	Hextar
			Neon 200	Conquest
			Prostar	Proterra
			Restrain 200	Grow Choice
			Rockstar 200	Imtrade
			Rox.Star 200	KD Plant Care
			Starane 200	Dow AgroSciences
			Staroxy 200	Echem
			Trample 200	Agri West
			Uni-Rane	UPL
		333 g/L EC	Fluroken 333	Kenso
			Starane Advanced	Dow AgroSciences
		400 g/L EC	Comet 400	Nufarm
			Decoy 400	Crop Care
			Floxor 400	Farmalinx
			Fluroxypyr 400	Accensi, ACP, Titan
			Neon 400	Conquest
			Stroid 400	FMC
			Dozer 400	Axichem
Glufosinate–ammonium	N	150 g/L SC	Liberty 150	Bayer CropScience
		200 g/L CS	Liberty 200	Bayer CropScience
			Basta 200	Bayer CropScience
		280 g/L Sc	Liberty 280	Bayer CropScience
Glyphosate	M	360 g/L AC, EC, LQ, SL,450 g/L AC, L, 470 g/L AV, SL, 480 g/L AV, 490 g/L AV, 500 g/L AV, EC, SL, 510 g/L AV, 540 g/kg AV, 570 g/ka AV, SL, 680 g/L WG, 690 g/kg WG, 700 g/L WG, 875 g/L WG, 840 g/L WG, 900 g/L WG	Various for multiple products	Various for multiple products
Halosulfuron–methyl	B	750 g/kg DF	Sedgehammer	Amgrow
			Sempra	Nufarm
		750 g/kg WDG	Halo	Imtrade
			Halosulfuron 750	Enviromax Technologies, Ozcrop, Apparent, Rainbow, Wellfarm
			Kenpra	Kenso
			Nut-Buster	Ospray
			Nutless	Axichem
			Yowler	Agriwest
			Nutgrass Killer	Imtrade
Haloxyfop-p	A	130 g/L	Judgement 130	Imtrade
		520 g/L EC	Halfback 520	Axichem
			Haloxyfop 520EC	Apparent, Crop Smart, Easyfarm, Grow Choice, Imtrade, Landmark, Mission Bell, Opal, Ruralchem, Sabakem, Sanonda, Shanghai Agrochina
			Harpoon 520	Agri West
			Hermes 520	Titan
			Inquest	Sipcam
			Whitestar	Agricultural Product Services

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Haloxyfop-r	A	130 g/L	Asset	Nufarm
			Convict	Cheminova
			Decree 520 EC	Sinochem
			Exert 520	Crop Care
			Firepower	ADAMA
			Gallant West	Dow AgroSciences
			Halomac 520	Macspred
			Halox 520	Echem
			Haloxyfop 520 EC	4Farmers, Accensi, Agro-Alliance, ACP, Chemforce, Chemtura, Ezycrop, Farmalinx, Kenso, Novaguard, Ozcrop, Profeng, Rainbow, Wellfarm, FMC
			Jasper	UPL
			Recon 520	Conquest
			Trekker 520 EC	Spalding
			Verdict 520	Dow AgroSciences
			Weloxy 520 EC	Hextar
Imazapyr + glyphosate	B + M	150 g/L + 150 g/L AV	Arsenal Xpress	BASF, Nufarm
Metolachlor	K	720 g/L EC	Bouncer	Australia Limited
			Clincher	ADAMA
			Metal 720	Imtrade
			Metoken 720	Kenso
			Metolachlor 720 Ec	4Farmers, Accensi, Agro-Alliance, Chemforce, Chemtura, Conquest, Crop Smart, Ezycrop, FMC, Grow Choice, Halley, Landmark Operations, Novaguard, Ozcrop, Profeng, Ravensdown, Sabakem, Rainbow, Spalding
			Scrimmage 720	Agri West
			Strada	Sipcam
			Chaser	Ospray
Metolachlor	K	960 g/L EC	Clincher Plus	ADAMA
			Metal Plus 960	Imtrade
			Metolachlor 960	4Farmers, Accensi, Apparent, ACP, FMC, Landmark Operations, Mission Bell, Proterra, Rainbow, Titan
			Metolamax 960	Conquest
			Metor 960	Farmalinx
			Smasha 960	Agritrading
			Strada Xtreme	Sipcam
MSMA		500 g/L SC	Arena	Agricorp
			MSMA 720	Agspray
			Monopoly	Barmac
			Vesta	Campbell
		720 g/L SC	MSMA 720	Ancom
		720 g/L SL	Armada 720 SL	Hextar
			Daconate 720	Cropcare
		800 g/L LQ	Megalith	Agriwest
Norflurazon	F	800 g/kg DF	Zoliar 800	Agnova Technologies, Sygenta
Oxyfluorfen	G	240 g/L EC	Cavalier	ADAMA
			Conversion 240	Australias Crop Protection
			Convert 240 Ec	Ospray
			Crossbar	UPL
			Encore	Conquest
			Goal	Dow AgroSciences
			Gowel 240 EC	Sinon
			Offend 240	Grow Choice
			Olright 240 EC	Agri West
			Ox 240	Kenso, Spalding
			Oxen	Imtrade
			Oxxel 240 Ec	Axichem
			Oxydox 240 Ec	Hextar
			Oxyfan 240 Ec	Farmalinx
			Oxyfluorfen 240 Ec	4Farmers, Accensi, Agrismart, Agro-Alliance, Apparent, Landmark Operations, Opal Australasia, Ozcrop, Profeng, Ravensdown, Ruralchem, Titan, Wellfarm, Sabakem, Ezycrop, Novaguard, Rainbow
			Point	Kendon
			Crossbar	UPL
			Puncher	UPL
			Striker	Nufarm
			Smart Ox	Crop Smart
		480 g/L EC	Goaltender	Dow AgroSciences

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Paraquat	L	250 g/L SL	Alliance	Crop Care
			Agroquat 250	Agrogill
			Explode 250	Conquest
			Gramoxone 250	Sygenta
			Inferno	Sipcam
			Nuquat 250	Nufarm
			Para-Ken 250	Kenso
			Paraquat 250 SL	Multiple
			Piston 250	Axichem
			Putout 250	Agri West
			Quash 250	Hextar
			Shirquat 250	Crop Care
			Sinmosa 250	Sinon
			Sprayquat 250	Kendon
			Spraytop 250 Sl	ADAMA
			Uniquat 250	UPL
		334 g/L SL	Para-ken 334	Kenso
		360 g/L SL	Gramoxone 360	Syngenta
Paraquat + diquat	L	135 g/L + 115 g/L AV	Alarm	Sipcam
			Blowout	Ozcrop
			Brown Out	4Farmers
			Burner	Agrogill
			Combik 250	Sinon
			Dibromquat 250	Hextar
			Di-Par 250	Landmark Operations
			Dismantle	Agri West
			Kwicknock 250	Grow Choice
			Paradat	Farmalinx
			Paradym 250	Ronic International
			Paraquat & Diquat 250 Sl	Accensi, Agcare, Agro-Alliance, Apparent, Easyfarm, Ezycrop, FMC, Forward, Fosterra, Mission Bell, Naadco, Novaguard, Pacific AgriScience, Sanonda, Rainbow
			Premier 250	Halley
			Revolver	Nufarm
			Scorcher 250	Conquest
			Smart Combination 250	Crop Smart
			Spalding Exocet 250	Spalding.
			Speedy 250	Kenso
			Spray & Sow	ADAMA
			Spray.Seed 250	Syngenta Australia
			Spraykill 250	Imtrade
			Spray-Out 250	Ospray
			Spray-Plant 250	Sipcam Pacific Australia
			Titan Eos	Titan
			Uni-Spray 250	UPL
			Wildfire 250	Ravensdown
Pendimethalin	D	330 g/L EC	Charger 330 EC	Conquest
			Cyclone 330 EC	Imtrade
			Fist 330	UPL
			Ipimethalin 330	Finchimica
			Pendant	Amgrow
			Pendi 330	Kenso
			Pendimethalin 330EC	4Farmers, Halley, Rallis, Sabakem, Rainbow, Titan, EChem
			Rifle 330	Nufarm
			Stomp 330e	BASF
		435 g/L EC	Panda 435	Farmalinx
			Panida Grande	Sipcam
			Pendimethalin 440 EC	FMC
			Pendimethex	ADAMA
		440 g/L EC	Argo 440EC	Colin Campbell
			Cyclone 440EC	Imtrade
			Cronos 440 EC	Colin Campbell
			Rifle 440	Nufarm
			Romper 440EC	Crop Care
			Stomp 440	BASF
		455 g/L AV	Stomp Aqua	BASF
			Stomp*Xtra	BASF
		475 g/L	Panida Max	Rallis

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Prometryn	C	500 g/L SC	Gesagard 500 SC	Syngenta
			Promesip 500	Sipcam
			Prometrex 500	ADAMA
			Prometryn 500	Accensi, Sabakem, Ozcrop
			Proton	Crop Care
		900 g/kg DF	Prometryn 900 DF	Nufarm
		900 g/kg WG	Gesagard 900 WG	Syngenta
			Prometrex 900 WG	ADAMA
			Prometryn 900	Ozcrop
Propaquizafop	A	100 g/L EC	Shogun	ADAMA
Saflufenacil	G	700 g/kg WG	Sharpen	Nufarm
s-Metolachlor	K	960 g/L EC	Bouncer	Nufarm
			Clincher Gold	ADAMA
			Dual Gold	Sygenta
			Heist 960	UPL
			Metoken Gold	Kenso
			Metor-S 960	Farmalinx
			s-Metolachlor	Landmark Operations
			S-Maestro	Rainbow
			Metal Gold	Imtrade
Triclopyr	I	600 g/L EC	Axeman 600	Apparent
			Biosorb 600	Biotis Life Science
			Garlon 600	Dow AgroSciences
			Grando 600	Crop Care
			Hurricane 600	Imtrade
			Invader 600	Nufarm
			Maca 600	Conquest
			Ranger 600	Hextar
			Redeem 600	Sipcam
			Safari 600	ADAMA
			Sindicate	Sinon
			Tricky 600	Axichem
			Triclon 600	Grow Choice
			Triclops	Crop Culture
			Triclopyr 600 EC	4Farmers, Accensi, Agrimart, Agriwest, Agro-Alliance, Aimco, Apparent, Ausagri, Australian Progressive Supplies, ACP, Chemforce, Crop Smart, David Gray & Co, Echem, Ezycrop, FMC, Halley, Kenso, Landmark Operations, Macspred, Mission Bell, Novaguard, Opal, Ospray, Ozcrop, Oztec, Pacifi AgriScience, Profeng, Ravensdown, Rainbow, Superway, Sabakem, Sabero, Spalding, Titan, Western Stock Distributors
			Tripyr	Farmalinx
			Uni-Lon 600	UPL
			Weedpro Tryclops	Pct
		750 g/L EC	Hurricane Ultimate 750	Imtrade
		755 g/L EC	Garlon Fallow master	Dow AgroSciences

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2015 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed By
Trclopyr + picloram	I	400 g/kg EC	ACP Regrowth	ACP
			Apparent Woody Herbicide	Apparent
			Brush ‘N’ Wood	Apparent
			Conqueror	Nufarm
			Fightback	ADAMA
			Gnarly	Agri-West
			Grass-Up	Grow Choice
			Grazon Extra	Dow AgroSciences
			Hatchet	Conquest
			Ken-Zon	Kenso Agcare
			Pickout	Cheminova
			Picker	Imtrade
			Prazon	Sabakem
			Scrubba	Axichem
			Token	Sipcam
			Triclopyr + Picloram 400 EC	Accensi, FMC, Landmark Operations, Halley, Mission Bell, Ozcrop, Rainbow, Titan
			Tripclo	Hextar
			Tri-Pic	Superway
			Tripicloram 400	Farmalinx, Macspred
			Tuffwood	Freezone
			Woodpecker	Goobang
Trifloxysulfuron sodium	B	750 g/kg WG	Envoke	Syngenta
Trifluralin	D	480 g/L EC	Agriralin 480	Agri Environmental
			Clearoff	Axichem
			Contender 480	Hextar
			Mr T 480	Agritrading
			Snare	Corporate Cropping
			Tango 480	Landmark Operations
			Treflan	Dow AgroSciences
			Tricon Flexi	Conquest
			Trampoline 480	Sinon
			Triflur X 480	Nufarm
			Triflur Boost	Extol
			Trifluralin 480 EC	Multiple
			Trifluralinx 480	Farmalinx
			Triflurasip	Sipcam Pacific Australia
			Triflurex	ADAMA, Nufarm
			Trigen 480	Landmark Operations
			Trilogy	ADAMA
			Unity	UPL
		500 g/L EC	Trilogy Xtra	ADAMA
		530 g/L EC	Trifluralin 530 Ec	Accensi
		600 g/L EC	Tricon Maxi 600	Conquest
			Trifluralin 600 Ec	4Farmers, Landmark Operations
			Trilogy 600	ADAMA

Volunteer and ratoon cotton

Ngaire Roughley, QLD DAF and CottonInfo
Susan Maas, CRDC
Frank Taylor, Nufarm

The control of unwanted cotton is an essential part of good integrated pest and disease management and general farm hygiene. Unwanted cotton is generally described as either:

- **Volunteer cotton –** plants that have germinated, emerged and established unintentionally and can be in-field or external to the field (roadsides, fence lines etc).
- **'Ratoon' cotton –** also known as 'stub' cotton, ratoon is cotton that has regrown from left over root stock from a previous season.

Control of volunteers

Cultivation and herbicides are the two most common methods of volunteer cotton control. Both require the cotton plants to have germinated and emerged before control can occur. Planning to control volunteers is a key part of an integrated weed management strategy and should consider issues such as rotational crops, and other weeds present in the field. Reducing the amount of viable seed left in fields (through clean pick, stubble management) and around farm (through clean up after module removal and spillages) will reduce the amount of volunteers that germinate. It is also important to remember that volunteers and ratoons that are left to set seed will also contribute to volunteers.

Cultural

- Broadacre cultivation will control seedling volunteers as well as large volunteers in a fallow situation. Effective cultivation will only occur if the cultivation implement cultivates both the furrow and hill avoiding strips being left uncultivated. Cultivation will also manage other weeds besides seedling volunteer cotton which makes it an excellent non-chemical control to include within an integrated weed management program. The disadvantage of cultivation is that it only controls established seedlings, is slow and can cause moisture loss or soil damage if conducted at the wrong time.
- Seedling volunteers can be controlled reasonably well with less invasive physical removal such as kelly chains. These break the seedling cotton stems and can be particularly useful close to planting.
- Where isolated plants remain during a fallow and in non-field areas, spot spraying and physical removal by chipping can be effective.
- In-crop cultivation with sweeps that lift or till out volunteers and other weeds are effective tools for control when volunteers are small.
- Aim to plant refuge crops into fallow areas, rotation fields that have not been planted to cotton in the previous season.

Best practice…

- **Plan to control volunteers as part of an integrated weed management strategy.**
- **Target plants when small, using the appropriate herbicide option applied in a sufficient spray volume to achieve good coverage. Read all labels before use to confirm timing and rates. ALWAYS FOLLOW LABEL DIRECTIONS. Undertake crop destruction operations as soon as practical after picking to minimise the number of residual stalks that can regrow into ratoon cotton.**
- **Ensure cultivation implements are set up to cultivate both hill and furrow, to avoid leaving uncultivated strips.**
- **Manual removal of plants (ie. chipping) may be necessary where isolated plants remain in non-field areas.**
- **Where possible, aim to rotate crops to avoid growing back to back cotton.**
- **Always Come Clean Go Clean!**

Chemical

- Pre-watering is a method used to establish volunteers prior to planting, providing a window for appropriate herbicide control.
- While glyphosate is effective at controlling seedling (up to 2nd leaf stage) non-glyphosate tolerant volunteers, the widespread adoption of Roundup Ready Flex® cotton eliminates the use of glyphosate. Likewise Liberty Link® volunteer seedlings cannot be readily controlled with glufosinate.
- With all contact herbicides, excellent spray coverage is essential for adequate control. This often means high (eg. 100 L/ha) water volumes per hectare. Coverage can often be compromised due to shading, stubble and lint. Ensure appropriate spray quality which may vary depending on the product selected, but generally a medium-coarse spray quality would be adequate at 100 L/ha.
- Rotation cropping enables residuals to be included in the mix and is a good cultural control. Where rotations are planned, ensure that good control is achieved as cotton plants hidden within subsequent crops can continue to harbour pests and disease and won't be as obvious as bare fallows.
- Most herbicide options work best on seedling volunteers. Where plants become well established control is much more difficult, as there are no herbicides registered for controlling plants larger than 9 nodes in size.
- Table 34 (over the page) provides a list of herbicides that have registration for control of volunteer cotton. Not all brands of these actives have volunteer cotton on the label. Refer to label for specific use information.
- Ensure label directions are followed, especially where volunteers are located near water ways.
- For more detailed information on chemical options for controlling volunteer cotton, see WEEDpak, section F4.

Ratoon cotton

Ratoon cotton is normally a product of minimum tillage where either conventional cotton is double cropped back to a winter cereal, or cotton is grown consecutively, from one season to the next. In theory ratoon cotton should not occur due to the requirement of harvested cotton to be controlled with adequate cultivation and soil disturbance as soon as practical after picking. This usually involves some sort of mulching and/or root cutting followed by cultivation to destroy the cotton root system.

In conducting this cultivation an additional aim is to destroy over-wintering *Helicoverpa spp.* pupae. This pupae control is a frontline strategy in managing insecticide resistance for the cotton industry and is mandatory if growing Bollgard II cotton. Thorough crop destruction can be particularly challenging in a zero till situation, where the only soil disturbance is pupae busting. This operation should be conducted carefully to minimise the number of residual stalks that can regrow the following spring.

Ratoon cotton plants are inherently difficult to control chemically due to the large root mass they have accumulated in the previous crop and the comparatively small leaf area for herbicide absorption.

ALWAYS FOLLOW LABEL DIRECTIONS

For more:

Australian Cotton Production Manual: Chapter 15, Integrated Disease Management and Chapter 17, Managing cotton stubble/residues.
www.cottoninfo.com.au/publications

WEEDpak: www.cottoninfo.com.au/publications

Come Clean Go Clean:
www.cottoninfo.com.au/publications

Managing ratoons and volunteers:
www.cottoninfo.com.au/publications

Come Clean Go Clean:
Rogue cotton plants in the farming community:
Checking your farm for volunteer plants:
www.youtube.com/cottoninfoaust

TABLE 34: Herbicides that have registration for control of volunteer cotton

Active ingredient	Mode of Action group	Concentration & forumulation	Application rate of product	Stage	Comments
Amitrole + Ammonium Thiocyanate	Q	250 g/L + 220 g/L SL	4.3–5.6 L/ha	Cotyledon – 8 leaf	See label for rain fastness. Apply in 50–100 L/ha water. Addition of 0.25% LI700 may improve results. Tank mix with glyphosate. Sowing can occur immediately after application. Bleaching of isolated crop leaves may be seen after emergence
Amitrole + Paraquat	Q + L	250 g/L + 125 g/L SC	3–4 L/ha	Up to 8 leaf	Can be applied after an initial spray of a glyphosate herbicide (Double Knockdown). Refer to label for spot spray rates.
Bromoxynil	C	200 g/L EC	1.5 L/ha or 1–1.5 L/ha with glyphosate	Cotyledon – 6 leaves	Apply in minimum of 80 L/ha water for Roundup Ready cotton. See label for rain fastness. Refer to label for restrictions on spray quality & condition.
Carfentrazone-Ethyl	G	400 g/L EC	Roundup Ready: 0.045–0.060 L/ha plus adjuvant Conventional 0.030 – 0.045 L/ha	2–6 leaf and post harvest control	Apply minimum spray volume of 80 L/ha. Tank mix with glyphosate, or products containing paraquat. Refer to label for adjuvant recommendation.
	G	240 g/L EC	Roundup Ready: 0.075–0.1 L/ha plus adjuvant Conventional 0.050–0.075 L/ha		
Paraquat + Diquat	L	135 g/L + 115 g/L SL	1.6–2.4 L/ha SL 2.4–3.2 L/ha	1–4 leaf 5–9 leaf	Apply in 50–100L water/ha. For best results, spray during humid conditions in the late evening.
Flumetsulam	B	800 g/kg WG	50 g/ha	Pre-emergent	Do not apply post-emergent treatments if rain is likely within 4 hours. Do not irrigate (any method) treated crop of pasture for 48 hours after application. May be banded (>40%) over the row or broadcast. Minimum spray volume 150 L/ha for optimum results.
Flumioxazin	G	500 g/kg WG	45 g/ha plus adjuvant	Up to 4 leaf	Do not apply post-sowing pre-emergent. Apply no later than 1 hour prior to sowing or post sowing up to 2 days before first crop emergence. Can be tank mixed with glyphosate to control other weeds that may be present. Refer to label for adjuvant details.
Glufosinate-Ammonium	N	200 g/L SL	3.75 L/ha in 100L water	2–6 leaf; summer fallow	Liberty® 200 is registered for non-residual control of conventional cotton volunteers in Liberty Link crops. Basta® is only registered for summer fallow situations. Do not apply more than 3 applications per season. DO NOT APPLY TO COTTON VARIETIES OTHER THAN LIBERTY LINK COTTON.
Metribuzin	C	750 g/kg WG	470 g/ha	Pre-emergent	Registered for control of volunteer cotton in pigeon pea. Refer to label for critical comments.
		480 g/L SC	0.750 L/ha	Pre-emergent	Registered for control of volunteer cotton in pigeon pea. Refer to label for critical comments.
Fluroxypyr	I	333 g/L	0.45 L/ha 0.6 L/ha	2–6 leaf 5–7 leaf	Summer fallow.
Saflufenacil	G	700 g/kg	17–26 g/ha plus 1% Hasten or high quality MSO	17g/ha for cotyledon to 4 leaf; 26g/ha from cotyledon to 6 leaf in fallow or post harvestt	Use a spray volume of 80-250 L/ha. Increase water volume if weed infestation is dense and/or tall. See label for mandatory no spray zone.

Integrated Disease Management

Ngaire Roughley, QLD DAF and CottonInfo

Acknowledgements: Susan Maas (CRDC), Stephen Allen (CSD), Karen Kirkby, Peter Lonergan (NSW DPI); Linda Smith, Linda Scheikowski, Cherie Gambley, Murray Sharman (QLD DAF)

Developing an Integrated Disease Management (IDM) strategy for your farm

A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. Integrated Disease Management involves the selection and application of a harmonious range of control strategies that are integrated with management of the whole farm.

Disease control strategies should be implemented regardless of whether or not a disease problem is evident, as the absence of symptoms does not necessarily indicate an absence of disease.

IDM at planting

Preparing optimal seed bed conditions

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.

Sowing date/temperature

Sowing in cool and/or wet conditions favours disease. Where possible, delay planting until soil temperatures are at least 16°C and rising. Refer to the Australian Cotton Production Manual for more information on crop establishment.

Cotton symptoms guide app now available.

Plant resistant varieties

For back to back fields, disease risks can be higher, increasing the importance of planting resistant varieties and using other IDM strategies.

Australian cottons are completely resistant to Bacterial blight, however some old Pima varieties are still susceptible. New blight resistant varieties of Pima are available.

There are a number of varieties that have good resistance to Verticillium wilt or Fusarium wilt, with levels of resistance indicated by higher V rank and F rank respectively. In addition to resistance, consider the seedling vigour of a variety particularly when watering up or planting early. Refer to CSD variety notes for more information.

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.

Replanting

Replanting decisions should be made on the basis of stand losses, not on the size of the seedlings. Refer to the Australian Cotton Production Manual for more information on crop establishment.

IDM in crop

Fungicides

All cotton seed sold in Australia for planting is treated with a standard fungicide treatment for broad spectrum disease control. Other examples of fungicides include seed treatments for seedling disease control and foliar sprays for the control of Alternartia leaf spot on Pima cotton.

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 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. Tail water should also be managed to minimise the risk of disease spread.

Agronomic management

High planting rates can compensate for seedling mortality, but a dense canopy favours development of bacterial blight, Alternaria leaf spot and boll rots. Optimise crop nutrition and irrigations to avoid rank growth and a dense canopy. Use growth regulators where required.

If Black root rot is present, either manage for earliness to get the crop in on time (in short season areas) or manage for delayed harvest to allow catch up (in longer season areas).

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 wilt, Fusarium wilt and Alternaria leaf spot. Excess nitrogen greatly increases the risk of boll rot particularly in fully irrigated situations. Refer to NUTRIpak or the Australian Cotton Production Manual for more information on cotton nutrition.

Conduct your own in-field disease survey

It is important to be aware of what diseases are present and where they occur. Conduct early and late season disease surveys and record findings to allow comparison over time (see below for in season troubleshooting). Train farm staff to look for and report unusual symptoms and if a suspect cotton plant is located, contact your state department cotton pathologist.

QLD DAF pathologist, Linda Smith – (07) 3255 4356 or 0457 547 617

NSW DPI pathologist, Karen Kirkby – (02) 6799 2454 or 0428 944 500

Exotic Plant Pest Hotline 1800 084 881

Refer to the Cotton Symptoms Guide or the Australian Cotton Pest Management Guide for instructions on how to send a sample.

In season disease trouble shooting

Early season

- Compare number of plants established per metre with number of seeds planted per metre. Refer to the Australian Cotton Production Manual for more information on crop establishment and replanting considerations.
- Walk the field and look for plants that show signs of poor vigour or unusual symptoms.
- Examine roots by digging up the seedling – never pull the seedling from the ground.

During and late season

- Walk field and look for plants that are dead, show signs of poor vigour or have unusual symptoms.
- Cut stems of plants showing symptoms of disease and examine for discoloration.

IDM post harvest

Control alternative hosts and volunteers

Having a host free period prevents build-up of disease inoculum and carryover of disease from one season to the next. The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, Tobacco Streak Virus and Alternaria leaf spot can also infect common weeds found in cotton growing areas. Refer to WEEDpak F5 Table 1 for weeds known to be hosts of cotton pathogens.

Having a host free period is particularly important for diseases such as Cotton Bunchy Top, which can only survive in living plants. Controlling alternative hosts, especially cotton volunteers and ratoons will help reduce the risk of quality downgrades and yield loss from cotton bunchy top.

Crop residue management

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 cotton and some rotation crop residues. Crop residues should therefore be managed carefully to minimise carryover of pathogens into subsequent crops.

If Fusarium wilt is known to be present in a field, residues should be slashed and retained on the surface for at least one month prior to mulching, in order to disinfect the stalks through UV light exposure.

In all other circumstances (including the presence of Verticillium wilt and other diseases), crop residues should be incorporated as soon as possible after harvest to afford a host free disease period.

Crop rotations are utilised to assist in disease management

Successive crops of cotton can contribute to a rapid increase in disease incidence, particularly if susceptible varieties are used. A sound crop rotation strategy should be employed using crops that are not hosts for the pathogens present.

Aerial photo of fusarium damage.

The pathogen that causes Verticillium wilt has a large host range and most legume crops are hosts of the Black root rot pathogen. Legumes such as mungbeans and soy beans are known hosts of the Fusarium wilt pathogen. Some alternative crops such as vetch, canola and mustards can provide a biofumigation effect against black root rot under specific management regimes.

Cotton is highly dependent on mycorrhiza, specialised fungi which form beneficial associations with plant roots and can act as agents in nutrient exchange. Bare fallow for more than 3 to 4 seasons or removal of top-soil (especially more than 40 cm) may result in a severe lack of mycorrhiza. A cereal or green-manure crop may restore sufficient mycorrhizal fungi for cotton.

The Cotton Rotation Finder (found on the IPM module of *my*BMP) can assist with developing a rotation strategy.

IDM all year round

Control of insect vectors

Diseases caused by a virus or phytoplasma are often 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. Control of insect vectors should consider IPM principles and resistance risks (See IPM chapter).

Viruses can only survive in living plants. Control of cotton ratoons and volunteers throughout winter will reduce pathogen levels and also lower vector insect populations, drastically reducing disease risk.

Come Clean Go Clean

Minimise the risk of moving diseases on or off your farm, from field to field or farm to farm by considering machinery movements within the farm and having a strategy for ensuring clean movement of machinery onto and around the farm.

Minimise spillage and loss when transporting modules, hulls, cotton seed or gin trash.

Ensure all staff and visitors are aware of the requirements to 'Come Clean-Go Clean' (see the fact sheet at www.cottoninfo.com.au/publications).

For more information, resources and tools see:

***my*BMP www.mybmp.com.au**

CottonInfo www.cottoninfo.net.au

Common diseases of cotton

Ngaire Roughley, QLD DAF and CottonInfo

Acknowledgements: Susan Maas (CRDC), Stephen Allen (CSD), Karen Kirkby, Peter Lonergan (NSW DPI); Linda Smith, Linda Scheikowski, Cherie Gambley, Murray Sharman (QLD DAF)

Seedling diseases

Seedling diseases may be caused by numerous pathogens acting alone or in combination that commonly cause 'damping off' (death of seedlings) and reduced plant stands. The main pathogens attacking cotton seedlings are *Rhizoctonia solani, Pythium ultimum* and *Fusarium* spp. (not the Fusarium wilt pathogen).

Symptoms

- Pre-emergent seed rots.
- Post-emergent damping off (wilting, collapse and death of seedlings).
- Slow early season growth, small cotyledons and reddened hypocotyls.
- Lesions on roots.

Affected plants may be scattered across the field or concentrated in poorly drained areas. In some situations seedling disease may be particularly evident in rows where other factors such as fertiliser placement, herbicide application, planting depth etc have had an effect.

Favoured by

Anything that slows down germination and seedling growth favours infection by pathogens causing seedling disease. This includes cool and/or wet weather, poorly formed beds, compaction, waterlogging, incorrect planting depth, poor placement of fertiliser (under the plant line), excessive rates of herbicide at planting, movement of herbicide into the root zone (ie. by rain) and infection by other pathogens.

Host range

Seedling disease pathogens have a wide host range and can survive on the residues of many crops and weeds. There is some evidence that seedling diseases may be more severe after incorporation of legume residues.

IDM tactics

- Use a variety with good seedling vigour
- Use effective seed treatment fungicides
- Plant into well prepared, high, firm beds
- Carefully position fertiliser in the bed – not under the plant line
- Plant into moisture rather than planting dry and watering-up
- Delay planting until temperature and moisture conditions are optimum
- Be careful with the use of herbicides at planting
- Incorporate rotation crop residues as soon as possible after harvest (especially legume crop residues)

Black root rot

Pathogen: *Thielaviopsis basicola*

Symptoms

Affected crops may 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 the fungus 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.

Favoured by

- Cool wet conditions – soil temperatures below 20°C are most favourable, but infection will still progress at temperatures up to 25°C.
- Medium to heavy clay soils.
- Cotton following susceptible crops, including most legumes and cotton.

Host range

All varieties of cotton are susceptible. Most legumes are susceptible, including faba bean, soybean, cowpea, field pea, chickpea, mung bean, lablab and lucerne. Datura weeds (thornapple, castor oil) are also hosts. Non-hosts include cereals, sunflower, brassicas such as canola and broccoli, onions and woolly pod vetch.

IDM tactics

- Choose more indeterminate varieties that have the capacity to 'catch up' later in the season.
- Use Bion® Plant Activator seed treatment.
- Plant into well prepared, high, firm beds.
- Pre-irrigate/plant into moisture in preference to 'watering up'.

Rhizoctonia seedling disease. (Alison Seyb, formerly DPI NSW)

Black root rot. (Stephen Allen, CSD)

- Time sowing to avoid cool temperatures if possible, but sow early if conditions are warm enough (minimum soil temperature of 16°C and rising). Temperature measurements should be taken in the fields where black root rot occurs.
- Replanting decisions should be made on the basis of stand losses, not the size of the seedlings. Watch for early onset of water stress and irrigate accordingly, but avoid waterlogging.
- Anticipate delayed growth and later maturity and manage the crop accordingly (black root rot 'steals' time from your crop).
- Minimise tailwater.
- Practice good farm hygiene – COME CLEAN, GO CLEAN. FarmCleanse (used at 10 per cent) is effective against *T. basicola* and is a useful aid to decontaminate vehicles after mud is removed. An alternative is Bio-Cleanse.
- Rotate with non-host crops (eg. cereals, canola) for more than one season if possible.
- Rotate with biofumigation crops such as vetch or mustard between consecutive cotton crops or after a wheat fallow. The success of biofumigation depends upon the growth of the biofumigation crop and good incorporation (at least four weeks before planting cotton).
- Avoid legumes and control weeds.
- Control volunteer and ratoon cotton.
- Flooding of fields for 30 days during summer reduces the population of *T. basicola* dramatically. This option will be limited by the topography of fields and the availability of water.

Verticillium wilt

Verticillium dahliae

CRDC-funded research has found that there is more than one strain of *Verticillium dahliae* in Australian cotton. To understand the diversity of the strains of *V. dahliae* we have in Australian cotton and where they are located, diseased stems from fields need to be collected and the pathogen analysed by a pathologist.

Symptoms

Symptoms of Verticillium wilt and Fusarium wilt are similar. Verticillium wilt has dark brown to black streaks through the centre of the stem when cut diagonally. When cut lengthways, stems show brown flecking of the inner tissues, rather than continuous browning which is associated with Fusarium wilt infected plants. Severe cases need to be diagnosed by a pathologist to determine whether the pathogen is Fusarium *oxysporum f.* sp. *vasinfectum* or *Verticillium dahliae.* In some instances there are fields with both Verticillium and Fusarium Wilt present. Multiple stems should be sent if this is suspected.

Verticillium wilt. (Stephen Allen, CSD)

V. dahliae can also cause a characteristic yellow mottle between the veins and around the leaf margins. Lower leaves are usually affected first. Dead tissue develops at the leaf edges and may replace the mottled areas.

Favoured by

Verticillium wilt is favoured by cooler temperatures. Varieties that are resistant at 25-27°C are susceptible at 20-22°C.Verticillium wilt is most severe during extended wet weather and or waterlogging and in late maturing crops. Extending the period of crop growth late in the season increases this risk.

The disease is also favoured by excessive use of nitrogen which results in late season growth and also by potassium deficiency.

Host range

V. dahliae causes vascular wilt on more than 250 plant species. There is some host specificity between strains. Volunteer and ratoon cotton, soybeans, 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.

IDM tactics

- Select varieties with a high V rank.
- Manage for earliness, including optimising nutrition and water inputs.
- Avoid over-watering, waterlogging and late season irrigations that extend maturity.
- Minimise tailwater to reduce risk of spread.
- Avoid inter-row cultivation with knives if possible. This causes root damage and provides an entry point for the pathogen.
- Aim to ensure that crops destruction occurs soon after picking to reduce the build-up of inoculum.
- Rotate with non-host crops (ie. sorghum and cereal crops).
- Avoid/control alternative hosts, including volunteer and ratoon cotton.
- Send any suspicious plant samples to your state pathologist for correct identification of pathogen. See page 123 for a form and checklist on sending plant samples for diagnosis.
- Come Clean Go Clean.

Fusarium wilt

Pathogen: *Fusarium oxysporum* f. sp. *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

Fusarium wilt. (Linda Smith, QLD DAF)

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 individual plants or as a small patch, often but not always, near 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 – eg. waterlogging, root damage through cultivation, cool and wet growing conditions.
- Poor farm hygiene on and between farms and between districts.

Host range

The *FOV* pathogen is specific to cotton but can also live in the residues of most non-host crops. Bladder ketmia, sesbania pea, dwarf amaranth, bellvine and wild melon are alternative weed hosts that show no external symptoms. These weeds may act as an on-farm reservoir for the disease and need to be managed in-crop and during fallow periods.

IDM tactics

- If your farm is free from this disease, try to keep it this way! Ensure all farm staff and contractors practice good farm hygiene and Come Clean Go Clean.
- Select varieties with a high F rank and use BION® Plant Activator, a seed treatment that helps protect seeds and emerging plants from Fusarium wilt and Black root rot.
- If possible, delay planting until soil temperatures are 16°C and rising.
- Manage the crop to avoid stresses such as waterlogging, over-fertilisation and root damage.
- Avoid mechanical inter-row cultivations if possible, as this causes root damage and provides an entry point for the pathogen.
- Conduct regular field inspections for early detection and containment of isolated outbreaks. Send any suspected samples to Dr Linda Smith (QLD DAF) (see page 123 for a form and checklist on sending plant samples for diagnosis).
- Isolate affected areas from irrigation flows and traffic to avoid spreading the pathogen.
- Minimise tail water from affected fields.
- After harvest, root pull and retain crop residues on the surface for at least month prior to incorporation. Raking and burning the whole field is NOT an option as raking is likely to spread the pathogen (if present).
- Fusarium can survive on non-host crop residues, so residues should be buried or baled as soon as possible after harvest. Avoid green manure crops.
- Rotate with non-hosts for up to 3 years. Hosts such as legumes can potentially increase disease. A summer sorghum/maize-fallow-cotton rotation can increase cotton plant survival, reduce disease incidence and increase yield in the third year compared to continuous cotton.

Alternaria leaf spot

Alternaria macrospora
Alternaria alternata

Symptoms

A. macrospora: brown, grey or tan lesions (spots) 3 to 10 mm in diameter on lower leaves, sometimes with dark or purple margins. Circular dry lesions on bolls. When a susceptible crop is exposed to a favourable environment then defoliation occurs rapidly (especially in Pima varieties). Affected leaves develop an abscission layer, senesce and then drop to the group.

A. alternata: purple specks or small lesions with purple margins on bolls and leaves.

Favoured by

Spores can only germinate when there is an adequate dew period – a period of several hours of free moisture on the leaf surface. Epidemic development is therefore favoured by either repeated heavy dews or extended periods of wet weather.

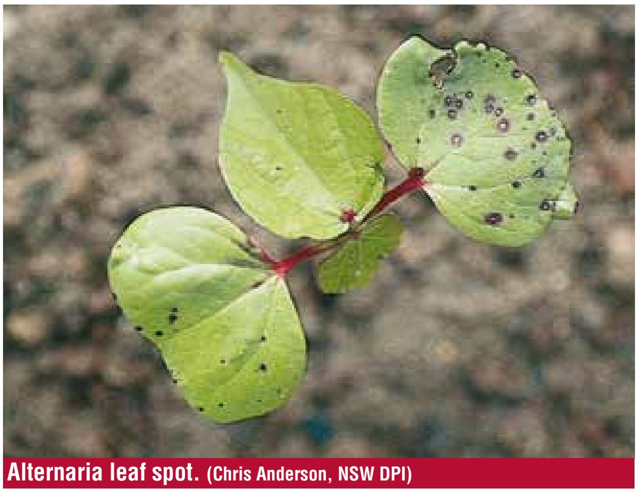
- Symptom development is suppressed by periods of very hot weather.
- Plants are most susceptible at the seedling stage and late in the season when the crop begins to cut-out. Symptom development is favoured by any physiological or nutritional stress eg. heavy fruit load or premature senescence.
- Pima varieties are most susceptible.

Host range

The host range of *a.macrospora* includes cultivated cotton and some malvaceous weeds such as bladder ketmia, sida and anoda weed.

IDM tactics

- Don't plant susceptible varieties in fields with infected residues from a previous crop retained on the surface.
- Provide balanced crop nutrition (especially potassium).
- Manage crop to avoid extremely rank growth.
- Use foliar fungicide applications for Pima varieties – NOT before flowering.
- Incorporate crop residues as soon as possible after harvest.
- Control alternative weed hosts and volunteer cotton plants.



Alternaria leaf spot. **(Chris Anderson, NSW DPI)**

Boll rot, seed rot and tight lock

Boll rots are caused by a number of pathogens, including fungi and bacteria. Tight lock refers to a type of boll rot, where the lock remains hard and fails to fluff out. The term seed rot is used to describe a boll rot which begins in the seed.

Phytophthora boll rot

Infected bolls quickly turn brown and become blackened (sometimes with areas of white mould on the surface before opening prematurely). The locks, which remain compact and do not fluff out, can be easily dislodged and fall to the ground. Symptoms are most prevalent on the lower bolls. Phytophthora boll rot usually occurs when soil is splashed up onto low bolls that are beginning to crack open or when low bolls are subject to inundation by tail water backing up into rows.

Sclerotinia boll rot

Sclerotinia boll rot characteristically has black fungal structures (2 to 10 mm diameter) within and/or on the surface of the rotted bolls. A white cottony fungal growth may be present and the branch adjacent to the boll may also be affected. The sclerotinia germinate to produce apothecia (small cream coloured 'golf tees') which release clouds of microscopic spores that can only infect the plant thorough dead or dying tissue (eg. flower petals). The fungus then grows into healthy plant tissue such as the developing boll and down the fruiting branch towards the main stem.

Fusarium boll rot

Not to be confused with Fusarium wilt, Fusarium boll rot causes similar boll rots to Phytophthora, with mould sometimes having a pink discolouration.

Diplodia boll rot

Diplodia boll rot starts as dark brown lesions which rapidly expand to cover the whole boll as the rot progresses. In the later stages of development, bolls become covered with a black smut-like fungal growth which can easily be rubbed off the boll surface.

Several other fungi can cause secondary boll rots in cotton, taking advantage of injury or wounds in the boll wall, often cause by insect pests.

Anthracnose boll rot

Characterised by large spreading lesions on bolls, often with a pink spore mass in the centre. The pathogen is able to infect all parts of the cotton plant and at any stage of growth. Seedling stems may be girdled at or near the base of the stem. Anthracnose boll rot is uncommon in Australia, but has is occasionally seen in Queensland cotton crops.

Seed rots

Seed rot refers to boll rot that begins in the seed. Pathogens gain entry to the unopened boll when sucking insects (such as green vegetable bug, mirids and pale cotton stainers) feed on the developing seeds through the boll wall. Small black spots 1-2 mm diameter on the surface of the boll indicates the feeding of sucking insects on developing seed within the boll. Seeds within the maturing green bolls are swollen and discoloured yellow or brown. When the affected bolls open, the locks with infected seed fail to fluff out and remain compact and discoloured. Seed rots do not necessarily affect the whole boll and may be limited to one or two locks.

Favoured by

- Boll rots are favoured by wet and humid conditions, especially from a thick rank canopy and high moisture from rains and dews.
- Rainfall on exposed soil that splashes soil up onto low bolls enables infection for some boll rots. Low mature bolls and lodged plants are at high risk of infection.
- Boll rots and tight locks can also develop when bolls that are opening are exposed to wet weather.
- High numbers of sucking pests soon after flowering can increase the likelihood of seed rots.

Host range

There are a broad range of fungi and bacteria involved in boll rots and host range varies between species. For example, Phytophthora hosts include safflower, pineapple, tomato and citrus as well as a large number of ornamental plants derived from the Australian native flora. Sclerotinia hosts include sunflower, safflower, soybeans and most pasture legumes.

IDM tactics

- Field drainage should not allow water to back-up into the field and inundate low bolls on plants near the tail drain.
- Avoid very low plant populations which result in exposed soil that can be splashed up onto low bolls at the end of the season.
- Avoid rank growth and a dense crop canopy if possible.
- Assess incidence prior to or after defoliation by counting all of the bolls on ten plants from each of ten randomly selected sites across the field. Counts should not be confined to areas near the tail drain as this may give a misleading result.
- Thoroughly incorporate crop residues as soon as possible.
- Practice good farm hygiene and Come Clean Go Clean.

Cotton bunchy top (CBT)

Cotton bunchy top (CBT) is a viral disease spread by the cotton aphid.

Symptoms

Leaves usually have pale green angular patterns around the margins and darker green centres, and can be leathery and brittle compared to the leaves on healthy plants.

After the plant is infected, subsequent growth is characterised by small leaves, short internodes and small bolls. This is usually limited to growth that occurred after the plant was infected; growth before infection usually appears normal.

When plants are affected at a very early stage (eg. as seedlings) the

CBT has a distinctive leaf mottling. (Stephen Allen, CSD) growth of the whole plant is affected and has a compact, severely stunted appearance. Roots appear hairy and dark brown in comparison to the light yellow-brown colour of healthy roots and form small knots on the secondary root branches.

Symptoms are difficult to distinguish in perennial volunteer cotton & late crops (post cut-out) where there has been insufficient new growth to show symptoms. There is usually a period of 3-8 weeks from infection until symptoms become obvious.

Patches of infected plants may occur around ratoon plants that were affected by CBT and survived from the previous season. These infected ratoon plants often also harbour aphids which can then move to adjacent plants, spreading the disease.

Favoured by

Cotton bunchy top (CBT) virus can only survive in living plants. Fields at highest risk of CBT are those with high aphid populations, in close proximity to ratoon cotton. Ratoons act as both a preferred host for the aphids and a reservoir for the disease, creating a source of infection in the new season. Disease spread is favoured by climatic conditions suitable for aphid reproduction, feeding and spread. The risk from CBT appears to be higher after wet winters and lower after dry winters. Mild winters enable more volunteer and ratoon cotton and aphids to survive between season and cropping cycles. Cotton aphid has a broad host range, including many weeds. The presence of weed hosts allow cotton aphid populations to persist overwinter, increasing the likelihood of aphids moving into cotton early in the season.

Host range

CBT virus can infect many different host plants. However, the most critical alternative host plant is ratoon or volunteer cotton. They survive between seasons, retaining leaves through winter and supporting infected aphid populations from one season to the next. The importance of the other host plants is not well understood but in some situations Marshmallow weed (*Malva parviflora*) may be an important over-wintering host for virus and aphids.

Thirteen natural field hosts of CBT have been identified including: cotton, *Abutilon theophrasti* (Velvetleaf), *Anoda cristata* (Spurred anoda), *Chamaesyce hirta* (Asthma plant), *Gossypium sturtianum* (Sturt's desert rose), *Hibiscus sabdariffa* (Rosella), *Hibiscus trionum* (bladder ketmia), *Lamium amplexicaule* (deadnettle), *Malva parviflora* (Marshmallow weed), *Malvastrum coromandelianum, Medicago polymorpha* (burr medic), *Sida rhombifolia* (Paddy's lucerne), and *Trianthema portulacastrum* (black pigweed). *Gossypium australe* and *Cicer arietinum* (chickpea) were also found to be experimental hosts.

These are currently the only known hosts of CBT. However the virus may have a wider host range than originally thought and include further non-Malvaceae species.

IDM tactics

1. **Avoid the problem –** elimination of hosts, particularly over winter, is the most effective means of minimising the risk of CBT. Break the green bridge and step 2 will not be required.

- CBT virus can only survive in living plants. If there is a break in the presence of host between cotton seasons, this will reduce the risk of CBT surviving on-farm through winter. Cotton volunteers, regrowth and ratoons are an important host of CBT. Good crop destruction and control of ratoons and volunteers is critical for controlling CBT. This also removes an important over winter host for cotton aphid.

- Growers should also control volunteer cotton plants on their farms, especially near sheds, head ditches, water ways, riparian areas and roads.
- Good on-farm management of broad leaf weeds is important as they can also host aphids and some may be hosts for CBT.
- Controlling volunteers or ratoons may force winged aphids to move to nearby cotton crops and spread CBT. To reduce this risk, control volunteers/ratoons before cotton emerges.

2. Manage the risk – aphid control should not be the primary means of preventing infection.

- Don't over-react to aphids. Excessive use of aphicides will select resistance and restrict control options.
- Sample young cotton regularly for aphids and assess aphid spread within the field.
- If aphid populations are unhealthy (many beneficials present, high mortality and little spread) then keep monitoring. If healthy then consider selective control so that beneficials can provide ongoing mortality.
- If a high influx of aphids is experienced consider a quick selective control to reduce the risk of CBT infection.
- Maintain the beneficial complex to help control aphids.

Reniform nematode

The pathogen

Reniform nematode (*Rotylenchulus reniformis*) is a plant parasitic nematode that feeds on the plant root using retractable, hollow, spear-like mouthparts causing plant stunting. It has a worldwide distribution within tropical and subtropical regions and was confirmed as a new pest to Australian cotton in late 2012, first identified in Central Queensland. Reniform nematodes are one of the most damaging nematode pests capable of attacking a wide range of crop plants as well as many weed species.

Symptoms

Feeding causes damage to the plant resulting in stunting and generally poor plant growth. The reniform nematode does not typically cause complete plant death, however they reduce the productivity of the crop. Populations can be quite uniform in their distribution across a field, making detection of early plant symptoms difficult.

Favoured by

The reniform nematode is largely distributed in tropical and subtropical regions although it can be found in warm temperate regions as well.

Damage potential differs widely according to soil type. Sandy soils tend to promote the greatest level of damage, while nematode survival and reproductive success is favoured by soils with higher (20-40 per cent) silt or clay.

Host range

The reniform nematode has a very wide host range including chickpeas, mungbeans, pigeon pea, sunflower and vetch. Certain crops are considered to be non-hosts, including corn, canola, faba beans, safflower, sorghum, soybean, wheat, barley, triticale and oats.

IDM tactics

- Come Clean Go Clean – good farm hygiene is the key to minimising the spread of the Reniform nematode.
- Rotating with non-host crops such as wheat or sorghum to reduce base populations. Long fallows can help to also break the life cycle; however it is important to control any weeds and cotton volunteers which may grow in the bare fields.
- Cotton stubble management – cotton stalks should be cut and soil tilled through the stubble zone as soon as possible after harvest to destroy breeding sites. Ensure root cutting is successful and there is no re-growth.
- Plant into good conditions including optimum soil temperature, no water stress and well-formed beds.
- Monitor crops for patches of stunted plants and submit root samples for testing if you are suspicious. Send any suspected samples to Dr Linda Smith (QLD DAF).

Assessment

Growers and consultants across the industry are asked to monitor for patches of unexplained unthrifty or stunted plants and send a sample of soil if concerned. Nematodes cannot be seen with the naked eye in the soil or in plants. Affected roots may have small nodules/knots.

- Mark patches with GPS or on a map so that they can be monitored next season.
- Scrape off the dry top soil and sample 10-15 cm deep using a small trowel or soil corer.
- If there is more than one patch in a field, collect multiple samples from these areas in a bucket, and mix through.
- Place approximately 400 g in a clearly labelled plastic bag.
- Postage and handling – the extraction process relies on live nematodes so please keep cool in an esky without an ice brick, but DO NOT STORE SAMPLES IN THE FRIDGE.

Include information about the sample sheet (see page 123 for a form and checklist on sending plant samples for diagnosis). ▮▮▮

Cotton pathology

Karen Kirkby, Peter Lonergan, Beth Cooper,
Sharlene Roser, NSW DPI
Linda Smith, Linda Scheikowski, John Lehane, QLD DAF
Stephen Allen, CSD

Commercial cotton crops across NSW and Queensland were inspected between October-December 2014 and February-April 2015. 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 100 fields that were surveyed in NSW and 45 fields in Queensland. This represents the 32nd consecutive season of quantitative disease surveys of cotton in NSW and the 13th consecutive season of cotton disease surveys in Queensland.

Patchy storms led to variable rainfall in most regions. Generally the dry conditions following winter aided in field preparation. Growers used a combination of pre-watering, rain moisture and watering up. Many tended to delay pre-water and planting and waited for rain. This pushed the crop back and reduced exposure to usual heat of January.

A relatively warm finish to summer and some cooler night time temperatures coupled with rain events saw Verticillium wilt symptoms being observed in December through to February. The Australian Cottongrower (April-May 2015) reported "Verticillium wilt has really increased across the valley – as the crop matured the symptoms have become more prevalent. The level of incidence is causing some concern to growers and consultants".

The incidence and severity of plant diseases is determined by environmental conditions. The cooler night temperatures early season favoured the appearance of Verticillium symptoms beginning in December in some crops in NSW. The cooler and wetter autumn weather led to late development of patches of severe Verticillium wilt, especially in the Namoi region. In Qld an unusually high incidence of Verticillium wilt was detected on the Darling Downs, compared to previous seasons. A property that had not previously been visited as part of disease surveys had 40 – 80 per cent of plants expressing disease in some fields.

Southern NSW had a favourable growing season. Planting started well with seedlings emerging after 10 days in some of the crops planted in September. Most growers chose to pre-irrigate resulting in warmer planting temperatures. The southern valleys had above average heat units and less cold shock days.

Volunteer cotton – (Carry-over from the previous season)

Information on the occurrence of volunteer cotton was collected during the annual disease surveys and is based on visits to 52 farms in NSW during October and December of 2014 (Table 1). The number of farms with (1) mature cotton plants surviving along roadsides, fence lines, along channels and in tail water return systems or drains, (2) volunteer cotton in fallow or rotation fields and (3) mature cotton plants surviving from the previous season or regrowth from stubs (Ratoon cotton) in current cotton crops, were recorded.

Volunteer cotton plants were observed on 32 of the 52 farms visited during the disease surveys (61.5 per cent). The presence of volunteer and ratoon cotton plants (Figure 1) surviving from the previous season enables pests and pathogens such as aphids, mealy bugs and cotton bunchy top (Figure 1) to overwinter and initiate new outbreaks in the spring.

FIGURE 1: Volunteer and ratoon cotton provide a season to season green bridge.

Cotton Industry Biosecurity Plan – Crop Surveillance for Priority Pests

During these surveys particular attention was given to surveying fields for the presence/absence of exotic diseases including Cotton Leaf Curl Virus, Blue disease, Phymatotrichopsis (Texas) 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.

The defoliating strain of *Verticillium dahliae* VCG 1A was detected in both NSW and Queensland this season.

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 from both *Rhizoctonia* (Figure 2) and *Pythium* spp. 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.

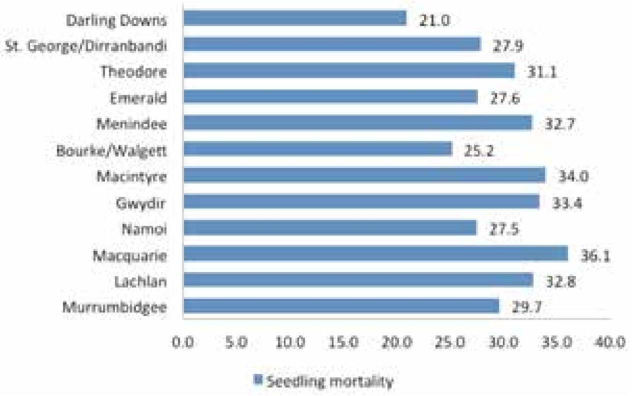
FIGURE 2: Seedling with symptoms caused by *Rhizoctonia* spp.

TABLE 1: The occurrence of volunteer cotton plants surviving from the previous season on farms in NSW in the spring of 2014

	1. Along channels, roads, fences	2. In fallows and rotation crops	3. In the current crop (regrowth from stubs)	Total
In NSW	15/52 (28.8%)	5/52 (9.6%)	21/52 (40.4%)	32/52 (61.5%)

Mean seedling mortality (Figure 3) for the crops inspected was 31.2 per cent in NSW and 29.9 per cent in Queensland in the 2014–15 season, (33.5 per cent and 29.6 per cent in 2013–14 and 32.1 per cent and 29.6 per cent in 2012–13). The highest seedling mortality was in Macquarie Valley with 36.1 per cent and the lowest in the Darling Downs with 21.0 per cent. Problems with crop establishment included: false and true wireworm, the necessity to flush irrigate while seedlings were still emerging, uneven moisture in the seed bed resulting from rain prior to planting as well as the activity of the seedling disease pathogens.

FIGURE 3: Mean seedling mortality in the 2014–15 season. Seedling mortality is derived from the difference between the number of seed planted and the number of plants established.



Fusarium wilt

Fusarium wilt (*Fusarium oxysporum* Schlecht f.sp. vasinfectum Atk. Sny. & Hans.) is most severe when October/November rainfall is above normal and when temperatures are below normal. The disease is least severe when it is hot and dry in spring. The widespread adoption of the new, more resistant, varieties reduced the potential impact of the disease. Fusarium wilt was obvious during early season surveys in QLD. Later in the season common symptoms included gaps in the stand, stunted growth and a dark brown discoloration of the vascular tissue in the stem. Wilting, dead and dying plants were not always present as was observed in previous years with more susceptible varieties.

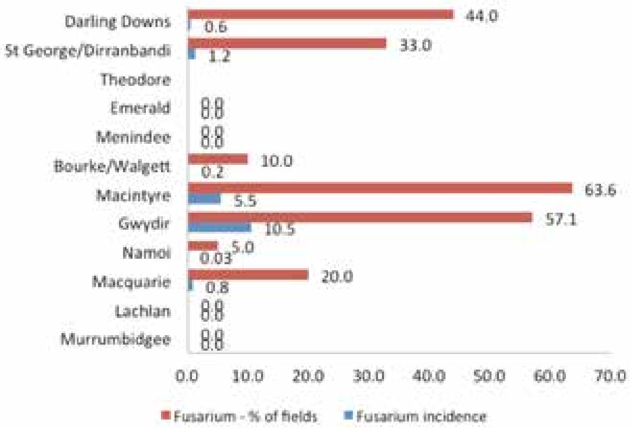
There are six suspected reports of Fusarium wilt on farms in the Murrumbidgee, Namoi (west of Narrabri) and Macquarie Valleys awaiting VCG confirmation by Dr Linda Smith (DAF) who provides a free, confidential diagnostic service for Fusarium wilt of cotton funded by the Australian cotton industry. There was one confirmed diagnosis of Fusarium on a survey farm in the Murrumbidgee but not collected from fields surveyed this season.

Fusarium wilt was observed in 20 per cent of the fields surveyed in NSW with a state average of 2.2 per cent. The average percentage of fields infected and the incidence (percentage of plants infected) respectively for the different valleys of NSW were: 63.6 per cent and 5.5 per cent in the Macintyre Valley, 57.1 per cent and 10.5 per cent in Gwydir Valley, 20 per cent and 0.8 per cent in the Macquarie and 5 per cent and 0.03 per cent in the Namoi Valley (Figure 4).

It is interesting to note that black root rot was also present in 17 of the 20 fields in NSW where Fusarium wilt was recorded.

Fusarium wilt was observed in six out of 45 fields surveyed in Queensland, including four out of nine irrigated crops on the Darling Downs and two out of six fields in St George/Dirranbandi. No rain grown crops were included in the 2014–15 survey as there was insufficient rain during winter for cotton to be planted. The incidence of Fusarium wilt averaged 0.6 per cent, 1.2 per cent and 0 per cent respectively for the Darling Downs, St. George/Dirranbandi and Emerald/Theodore areas compared to 1 per cent, 0.9 per cent and 0.1 per cent in the previous season.

FIGURE 4: The mean incidence of Fusarium wilt of cotton in 2014–15.



Transects have been established in fields near Emerald, Theodore, Moura, St George, Boggabilla, Moree, Boomi, Narrabri and Gunnedah. The incidence of Fusarium wilt is assessed along these transects in seasons when cotton is grown in these fields. In NSW, no transect fields were planted.

Assessments of one transect in the Emerald region during the 2013–14 season and again in the 2014–15 season showed increasing disease incidence from 0.7 to 1.7 per cent. The disease incidence at a second transect has decreased from 1.2 per cent in 2012–13 season to 0 per cent in 2014–15.The decrease in disease incidence can be attributed to the use of varieties with high F. rank and cultural practices such as crop rotation to reduce Fov inoculum levels. Transects in Moura and Theodore could not be assessed due to cyclonic conditions.

Black root rot

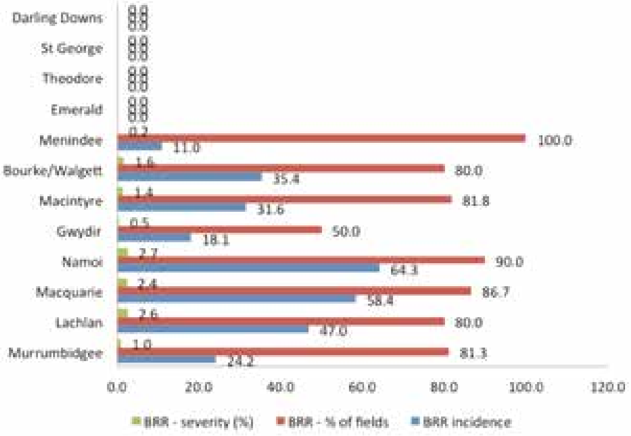
Black root rot of cotton (*Thielaviopsis basicola* [Berk.] & Br.) is favoured by cool weather conditions early in the season. The pathogen colonises the root surface, suppresses the development of secondary roots and stunts seedling growth. When temperatures rise, the tap root expands and the blackened root surface is sloughed off and disappears. Black root rot of cotton was apparent early in the 2014–15 season but the severity of symptoms declined with the above average spring temperatures – except where the warm temperatures caused seed beds to dry back too quickly and an extra irrigation was required to establish the crop.

The average incidence of black root rot within fields was 36.2 per cent for NSW. The disease was found in all of the fields visited in the Menindee area, 50 per cent of fields surveyed in the Gwydir Valley; 80 per cent of fields in the Bourke/Walgett area, 82 per cent of fields in the Macintyre Valley, 87 per cent in the Macquarie Valley and 80 per cent in the Lachlan Valley and 81 per cent of fields in the Murrumbidgee Valley. High incidence (greater than 30 per cent) of black root rot was recorded in 45 of the 100 fields surveyed. Twenty percent of the fields with a high incidence of black root rot also recorded Verticillium wilt.

Assessment of disease severity is based on the proportion of each tap root that is blackened where '0' indicates healthy and '10' indicates 100 per cent of the tap root blackened. The mean severity of black root rot for fields in the Murrumbidgee, Lachlan, Macquarie, Namoi, Gwydir and Macintyre Valleys was .1.0, 2.6, 2.4, 2.7, 0.5 and 1.4 respectively.

Black root rot has previously been recorded in all Queensland cotton production areas except the Burdekin. The disease was not observed this season in Queensland.

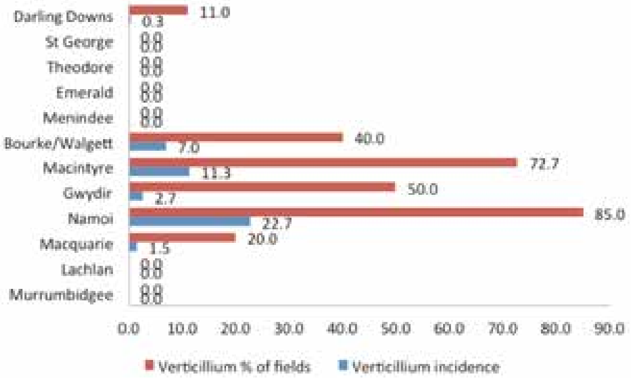
FIGURE 5: The incidence (per cent plants) and percentage of fields infected and severity of black root rot of cotton in cotton production areas in 2014–15.



Verticillium wilt

Verticillium wilt (*Verticillium dahliae Klebahn*) is also favoured by cooler weather. The disease was observed in 34.4 per cent of fields surveyed in NSW during the 2014–15 season. However, the average incidence was only 5.7 per cent of plants infected (Figure 6). This can be compared with average incidences of 6.8 per cent, 3.7 per cent, 3.8 per cent and 4.1 per cent in the 2011–12, 2010–11, 2009–10, and 2008/09 seasons (respectively).

FIGURE 6: The distribution and incidence of Verticillium wilt of cotton in 2014–15.



Verticillium wilt was observed in 72.7 per cent of the fields surveyed in the Macintyre Valley during the 2014–15 season and the average incidence was 11.3 per cent of plants affected (Figure 6). The disease was observed in 85 per cent of fields surveyed in the Namoi Valley, 50 per cent of fields in the Gwydir Valley and 40.0 per cent of fields in the Bourke/Walgett area where the average incidence of the disease was 22.7 per cent, 2.7 per cent and 7.0 per cent (respectively). A total of 5 fields in the Namoi Valley had over 30 per cent incidence, those being 45.5 per cent, 50 per cent, 52.5 per cent, 56.5 per cent and 95 per cent.

Verticillium wilt is rarely observed in Queensland production areas. In the 2014–15 season, Verticillium wilt was observed in 11 per cent of fields surveyed on the Darling Downs with an incidence of 0.3 per cent. Outside of the survey, the incidence of Verticillium wilt on a property on the Darling

Downs was 40-80 per cent. Verticillium wilt was also detected in a field at St George not included in the survey. No Verticillium was detected in Emerald.

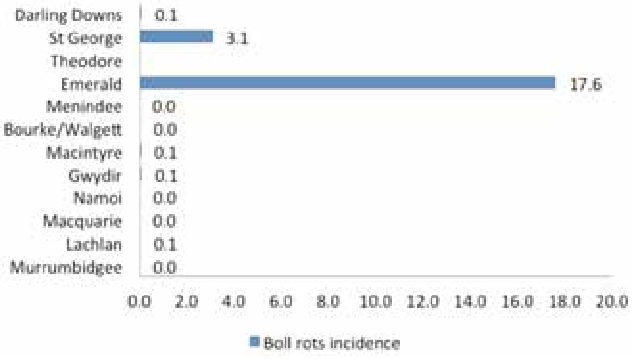
Boll rots

The average incidence of boll rots in the 2014–15 season was 7 per cent in Queensland and 0.04 per cent in NSW (Figure 7). It should be remembered that the disease surveys are completed in February and the final incidence of boll rots at harvest may have been significantly higher.

The most common boll rot in NSW production areas is Phytophthora boll rot, which develops when soil is splashed up onto low opening bolls. Historically, boll rots are most severe in Emerald and Theodore when opening bolls are subjected to extended periods of wet and cloudy weather and harvest is delayed.

There was a significant increase in the mean incidence of boll rots from 1.5 per cent in 2013–14 to of 7 per cent in 2014–15. The incidence of boll rots was highest in Emerald at 17.6 per cent. Contributing factors to increased boll rot were extended periods of wet and cloudy weather when bolls were opening.

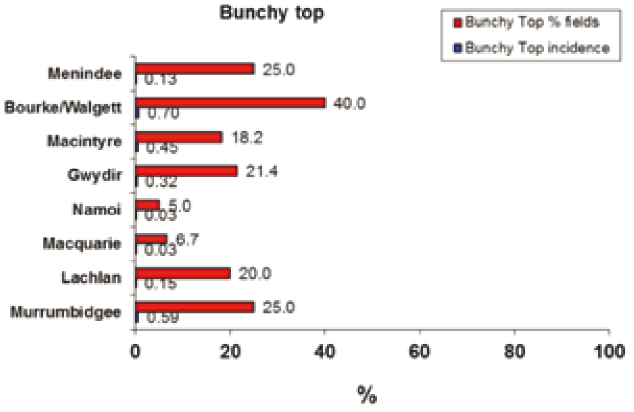
FIGURE 7: The average incidence of boll rots in each of the cotton production areas for the 2014–15 season.



Other diseases and disorders

Cotton Bunchy Top was observed in 20.2 per cent of the fields surveyed in NSW with an average incidence of 0.3 per cent for NSW (Figure 8). Bunchy top was not observed this season in Queensland production areas.

FIGURE 8: Cotton Bunchy Top in the 2014–15 season.



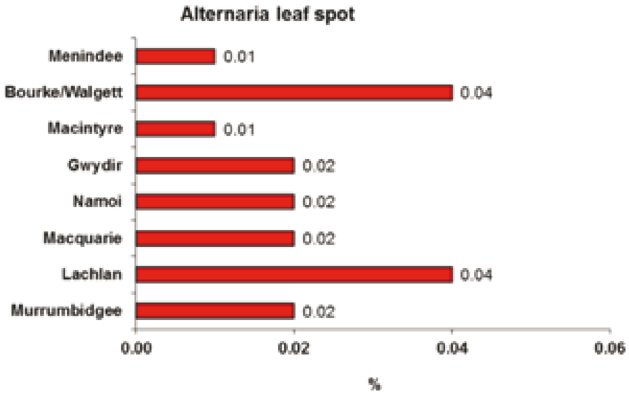
Seed rot was observed in 16 of the 45 (35.6 per cent) crops inspected in Queensland. The average incidence was only 1.1 per cent. .

Tobacco Streak Virus was not observed. Premature senescence was noted in 6.7 per cent of the crops surveyed in Queensland. However, the average incidence was less than 0.1 per cent.

Sclerotinia boll and stem rot was not observed during disease surveys in the 2014–15 season in NSW or Queensland.

Alternaria leaf spot was present at low levels in all regions of NSW (Figure 9) and was generally of minor significance averaging 0.02 per cent for NSW.

FIGURE 9: Incidence of Alternaria leaf spot in the 2014–15 season.



Acknowledgments: These surveys were made possible with the financial support of the CRDC, CSD, NSW DPI and QLD DAF. The cooperation of cotton growers is greatly appreciated.

SENDING A SAMPLE FOR DIAGNOSIS BY A PATHOLOGIST – ATTACH A COMPLETED FORM TO EACH SAMPLE

Collected/Submitted by: (eg. 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	☐ Raingrown
☐ 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 local CottonInfo RDO to determine the appropriate pathologist and address for submitting sample

IF FUSARIUM WILT IS SUSPECTED, SAMPLES MUST BE SENT TO:
QLD DAF Ecoscience Precinct – contact Linda Smith, Ph 07 32554356, Email: linda.smith@daf.qld.gov.au

When sending samples:

- Send multiple samples (eg. 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.

Cotton Disease Control Guide

Ngaire Roughley, QLD DAF and CottonInfo
Tracey Leven, CRDC

Registration of a pesticide is not a recommendation 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

Spray Log Books

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

- **QLD DAF at Toowoomba (07 4688 1200) or Dalby (07 4669 0800).**
- **NSW DPI at Yanco (1800 138 351).**

Best practice…

- **Plan your crop layout to avoid sensitive areas including homes, school bus stops, waterways, grazing land and non-target crops.**
- **Establish communication processes to manage safety and reduce risk – consult with neighbours to minimise risks from spraying near property boundaries, and keep neighbours informed of your spraying decisions. Ensure that all spray contractors have details of any sensitive areas near spray targets.**
- **Give careful consideration to the selection and application of pesticides.**
- **Carefully follow all label directions – use the correct application equipment and techniques.**
- **Ensure chemicals are transported handled and stored appropriately.**
- **Ensure unwanted chemicals and chemical containers are disposed of appropriately.**
- **Keep comprehensive records.**

ABBREVIATIONS USED IN TABLES 35–36

EC = Emulsifiable concentrate
FC = Flowable concentrate
SC = Suspension concentrate
WD = Water dispersible granule
DF = Dry flowable
SL = Soluable concentrate

TABLE 35: Control of cotton diseases

Active ingredient	Fungicide chemical group	Concentration and formulation	Application rate of product	Comments
Rhizoctonia solani (Damping off)				
tolclofos-methyl	X	500 g/L SC	0.12 L/ha or 0.12 L/10 km row	QLD and NSW only. Apply as an in-furrow spray or by water injection at time of planting.
		100 g/L	40 g/kg of seed	Put with seed immediately before planting
Pythium spp. and *Phytophthora* spp. (Damping off)				
metalaxyl-m	D	350 g/L EC	85g/100 kg seed	Commercial application recommended. Apply as a dust or slurry before sowing.
Rhizoctonia solani and *Pythium* spp.				
azoxystrobin + metalaxyl-m + fludioxonil	K D L	75 g/L FC 37.5 g/L FC 12.5 g/L FC	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 and Black Root Rot				
acibenzolar-s-methyl		500 g/L FC	1.2 mL/100 kg seed	Seed treatment for suppression of Fusarium wilt and Black root rot.
Fusarium Wilt				
metalaxyl-m	D	350 g/L	0.043 L/100 kg seed	For Fusarium wilt disinfection. Commercial application recommended.

TABLE 36: 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 + metalaxyl-m + fludioxonil	12.5 g/L FC + 37.5 g/L FC + 75 g/L FC (seed treatment)	Dynasty	Syngenta
tolclofos-methyl	100 g/kg	Rizolex	Sumitomo Chemical
	500 g/L SL	Rizolex liquid	Sumitomo Chemical
	500 g/L SL	Tolex	Genfarm Landmark

Cotton growth regulators and defoliants

Tracey Leven, CRDC

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. Mepiquat chloride can help to manage crop growth. There are many factors that should be considered when making the decision to apply Mepiquat chloride. For more information refer to 2015 Australian Cotton Production Manual. CottASSIST provides support in calculating vegetative growth rates.

Note: Some defoliant products containing Ethephon are labelled as a 'Growth Regulator'. Ethephon is used for preparing the crop for harvest and may cause significant fruit loss if used at inappropriate times.

Defoliation

The safe timing of defoliation is when the youngest boll expected to reach harvest is physiologically mature. This usually occurs when 60–65 per cent of bolls are open. In addition to timing of harvest aids, it is important to consider product, rate and application issues. For more information on defoliation refer to 2015 Australian Cotton Production Manual.

Registration of a chemical is not a recommendation 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 TABLES 37–40

AC = Aqueous concentrate
DF = Dry flowable
EC = Emulsifiable concentrate
LQ = Liquid
LC = Liquid concentrate
SC = Suspension concentrate
WG = Water dispersible granule

TABLE 37: 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. 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 or to induce cut-out.

TABLE 38: Plant growth regulators trade names and marketers

Active ingredient	Concentration and formulation	Trade name	Marketed by
Mepiquat	38 G/L AC	Adjust 38	Rotam
		Chemquat	Imtrade
		Concorde	Nufarm
		Cot-Trol 38	Hextar
		Fix 38	Chemtura
		Fortune	Syngenta
		Mepi-C	Miller
		Mepidef	Farmalinx
		Mepipower 38	Axichem
		Mepiquat 38 Plant Growth Regulator	Accensi, Agri West, Cheminova, Conquest, Echem, Kenso, Landmark, Macro Protect, Ozcrop, Oztec Rural, Pacific Agriscience, Rainbow, Sabakem, Titan Ag
		Piqme 38	UPL
		Pix	BASF
		Reign	Bayer Cropscience
		Reward	ADAMA

TABLE 39: Cotton defoliation products

Active ingredient	Concentration and formulation	Application rate of product	Comments
Carfentrazone-ethyl	240 g/L EC	0.08 – 0.1 L/ha	Desiccate regrowth following defoliation. Do not harvest for 1 day and do not graze or feed cotton trash to livestock.
Cotton seed oil	860 g/L LQ	2 L/ha	Apply in combination with thidiazuron as specified on the label.
Diquat	200 g/L AC	2.0–3.0 L/ha	Short staple varieties only. May damage green bolls.
Ethephon	720 g/L AC (900 g/L SC)	0.5-1.0 L/ha (0.4-0.8 L/ha) 1.3 L/ha (1.04 L/ha) 2.0-3.0 L/ha (1.6-2.4 L/ha)	Acceleration of boll opening Pre-conditioning Defoliation – Accelerated boll opening in combination with a defoliant
Ethephon + AMADS	275 g/L + 873 g/L AC	0.5–1.0 L/ha 3-4 L/ha 4 L/ha	Defoliation and accelerated boll opening. Boll opening and supplementary defoliation. Boll opening.
Ethephon + Cyclanilide	720 g/L + 90 g/L LC	1.3=2.5 L/ha 1.3 L/ha 0.33-0.67 L/ha	Acceleration of boll opening and enhancement of defoliation. Pre conditioning. Enhancement of defoliation
Parraffinic oil/Non-ionic surfactant Adjuvants	582 g/L LQ 598 g/L EC 653 g/L EC 792 g/L EC 815 g/L EC 830 g/L EC	0.5-1.0 L/100 L water 0.5 L/ha 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 in combination with defoliants such as Drop and Prep Apply with Dropp Ultra or DroppWP 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 raingrown and moisture stressed cotton. Can damage immature green bolls.
Petroleum oil	827 g/L LQ 844 g/L EC 846 g/L EC 859 g/L LQ 861 g/L	2 L/ha 2 L/ha 2 L/ha 2 L/ha 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 specified 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	0.04-0.08 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	11.0-22.0 L/ha	Apply 2–3 weeks before anticipated picking dates. Apply when temperatures are high and soil moisture moderate.
Thidiazuron	490 g/kg WG 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 the label rate of 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 the label rate of cotton spray oil
	240 g/L + 120 g/L SC	0.075-0.1 L/ha 0.1-0.125 L/ha 1.25-1.5 L/ha 1.5-2 L/ha	Ideal Good Average Cold Conditions. Plus the label rate of cotton spray oil

TABLE 40: Defoliation products trade names and marketers

Defoliant	Concentration and formulation	Trade name	Marketed by
Diquat	200 g/L AC	Desi-Tex 200	Macphersons
		Dia-Kill 200	Sinon
		Diquat 200	Accensi, Farmalinx, Imtrade, Kd Plant Care, Kenso, Landmark Operations,, Ozcrop, Rainbow, Titan Ag, Cheminova
		Hydrogel D	Better Safe
		Reglone	Syngenta Australia
		Sanction 200	Conquest Crop Protection

TABLE 40: Defoliation products trade names and marketers (continued)

Defoliant	Concentration and formulation	Trade name	Marketed by
Ethephon	720 g/L AC, SC, EC	Boll Cracker 720	Australis Crop Protection (ACP)
		AC Euchre	Axichem
		Ethephon 720	4Farmers, Accensi, Agri West, Agro-Essence, Apparent, Cheminova, Conquest, Echem, Ezycrop, Imtrade, Kenso, Landmark, Novaguard, Ozcrop, Pacific, PGR, Proterra, Rainbow, Sabakem, Titan Ag, Oztec, Eurochem
		Esculate Ultramax	ADAMA
		Ethic 720	Amgrow
		Ethon 720	Farmalinx
		Galleon	Nufarm Australia
		Goku Growth Regulator	Proplan
		Prep 720	Bayer Cropscience
		Promote 720	ADAMA
		Sentral 720	Hextar Chemicals
	900 g/L	Promote Plus 900	ADAMA
Ethephon + AMADS	275 g/L + 873 g/L AC	CottonQuik	Nufarm
Ethephon + Cyclanilide	720 g/L + 90 g/L LC	Finish 720	Bayer CropScience
Parraffinic oil/Non-ionic surfactant Adjuvants	432 g/L LQ	Turbo Charge	4Farmers
Adjuvants	582 g/L LQ	Paraffinic Oil	Apparent
		AC Para Spray Oil	AxiChem
		Infuse	Rygel
		Penatrol	BD Chemicals
		Pro Stickup	APS
		Smartup	Crop Smart
		Uptake Spraying	Dow AgroSciences
	598 g/L EC	Enhance Spray Adjuvant	Sacoa
		PowerSurge Spray Adjuvant	Conquest
		Sticka Sprayoil	ACP
	725 g/L EC	Banjo	Nufarm
	792 g/L SC	Canopy Insecticide	Caltex
	815 g/L EC	Biopest Paraffin Oil	Sacoa
	815 g/L EC	Bioclear	Caltex
	826 g/L EC	Cotton Spray oil	SBC
	830 g/L EC	Trump	Victorian Chemicals
Paraquat + diquat	135 g/L + 115 g/L AV	Refer to Table 33	Refer to Table 33
Petroleum oil	827 g/L L	D-C-Tron	Caltex
	838 g/L EC	Cropshield	Socoa
	844 g/L EC	Summer	Sacoa
	846 g/L EC	Broadcoat	Caltex
	859 g/L L	Cottoil	Sacoa
	861 g/L	Empower	Victorian Chemicals
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	ETee	Sipcam Pacific
Sodium chlorate	300 g/L L	Leafex	Total Ag
Thidiazuron	490 g/kg WP	Lanceadrop	Lances Link
	500 g/L SC	Dropp Liquid	Bayer Cropscience
		Escalate 500 SC	ADAMA
		Mace 500 SC	Conquest Crop Protection
		Reveal Liquid	Nufarm Australia
		Tentacle SC	Agri West
		Thidiazuron 500DC	Accensi, Apparent, Cheminova, Echem, Kenso, Landmark, Oztec, Proterra, Sabakem, Titan Ag
		Thiron	Farmalinx
		Timezone 500	ACP
Thidiazuron + diuron	120 g/L + 60 g/L SC	Do Away	Ospray
		Escalate Ultra	ADAMA
		Thidiazuron + diuron	Titan Ag
		Thi-Ultra	eChem
	240 g/L + 120 g/L SC	Dropp ultramax	Bayer CropScience
		Esculate Ultramax	ADAMA

Biosecurity – we all have a responsibility

Brad Siebert, Plant Health Australia
Susan Maas, CRDC
Nicola Cottee, Cotton Australia

While Australia's national quarantine system helps to prevent the introduction of harmful exotic pests, the threat they pose is still very real. In addition to the possibility of pests entering via natural routes, rapid increases in overseas tourism, imports and exports make it all the more likely that incursions of exotic plant pests will occur. Biosecurity is the protection of your property and the entire industry from the entry, establishment and impact of exotic pests. As an exotic can affect everyone, farmers, agronomists and the community, it is important that everyone plays a part in biosecurity, preparing for and managing threats.

Biosecurity – a legal responsibility

New biosecurity laws proposed for QLD and NSW are likely to include the introduction of a general biosecurity obligation. This means that everyone will have to take an active role in managing the biosecurity risks under their control.

Anyone going on to farms has a biosecurity responsibility

- **Come Clean Go Clean –** Vehicles, farm equipment and people can carry pests, especially attached to soil or plant debris. People can even carry aphids from farm to farm. Clean down between farms, including vehicles and footwear. Suggest using an on-farm vehicle where possible.
- **Spotted anything unusual? –** Investigate unusual symptoms and pests and get them identified. Vigilance is vital for an early detection of exotic plant pest threat.

Growers have a biosecurity responsibility

- **Check your crop frequently** looking out for unusual crop symptoms and if you find anything suspicious, report it immediately. Make sure that you and your farm workers are familiar with the most important cotton pests. Don't move the infected material.
- **Call the Exotic Plant Pest Hotline 1800 084 881,** a dedicated reporting line that will be answered by an officer from your state department of primary industries. Early reporting improves the chance of effective control and eradication.
- **Come Clean Go Clean –** should be practiced on all farms regardless of whether pests or diseases are known to be present. Communicate your requirements using clear signage to ensure only essential vehicles and equipment gain access to any growing area. Provide contractors and visitors with a dedicated wash down area with FarmCleanse, Bio-Cleanse or equivalent and a decent water supply to clean their equipment and tools prior to entry and exit.
- **Visits to farms overseas should be declared on re-entry to Australia.** All clothes and footwear should be thoroughly washed before returning, or left behind. Fungal spores can even be carried in hair, so a shampoo is worthwhile.
- **Ensure all seed is pest free.** This includes cotton and other refuge and commercial crops. Keep records of all farm inputs just in case.
- **Maintain zero tolerance of cotton volunteer plants and other weeds** at all times throughout the year to prevent pests harbouring there.

Industry has a biosecurity responsibility

Plant biosecurity in Australia operates as a partnership between governments and industries, with all parties sharing responsibility for maintaining the integrity and performance of the plant biosecurity system. Plant Health Australia (PHA) is the national coordinator of the government-industry partnership for plant biosecurity in Australia, funded equally by the Australian Government, State/Territory Governments and plant industry members. Cotton Australia is a member and CRDC is an associate member of PHA.

Industries that join PHA are permitted to sign the Emergency Plant Pest Response Deed (the EPPRD) which is the formal legally binding agreement that sets out how eradication responses to emergency plant pest incidents are to be managed and funded. It also outlines a framework for reimbursing growers whose crops or property are directly damaged or destroyed in the course of a response plan.

Cotton industry biosecurity

The Industry Biosecurity Plan for the Cotton Industry was developed in consultation with the Industry Biosecurity Group, coordinated by PHA and included representatives from Cotton Australia, the Australian Government, relevant state/territory agriculture agencies, researchers and PHA. PHA, with funding from CRDC, has led the third review of the Cotton Industry Biosecurity Plan. The Industry Biosecurity Plan for the Cotton Industry is a framework to coordinate biosecurity activities and investment for Australia's cotton industry. It provides a mechanism for industry, governments and stakeholders to better prepare for and respond to, incursions of pests that could have significant impacts on the cotton industry.

A risk assessment carried out during the development of the Industry Biosecurity Plan identified 15 high priority pests that currently do not exist in Australia, that could establish in our farms and threaten production. The defoliating strain of Verticillium wilt was identified within this list, however has since been confirmed in Australia and the detection is currently managed by Government and industry. The other high priority pests include:

- **Boll weevil**
- **Brown marmorated stink bugs**
- **Cotton aphid (exotic strains)**
- **Cotton bollworm (Helicoverpa armigera) (carrying Bt resistance alleles)**
- **Cotton stainer; red bugs**
- **False codling moth**
- **Silverleaf whitefly (exotic biotypes)**
- **Tarnished plant bug**
- **Western plant bug**
- **Bacterial blight (exotic/hypervirulent races)**
- **Cotton blue disease**
- **Cotton leaf curl virus**
- **Fusarium wilt (exotic races)**
- **Texas root rot**

Further information on cotton industry biosecurity contact Cotton Australia on (02) 9669 5222 or go to www.cottonaustralia.com.au/research/biosecurity/

To learn more about on-farm biosecurity for cotton growers, download a copy of the Cotton Industry Farm Biosecurity Manual from the biosecurity section of PHA's website: www.phau.com.au

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, the cotton boll weevil eradication program has been largely successful, but at a cost of hundreds of millions of dollars.

Boll weevil. (Source: Alton N. Sparks, Jr., University of Georgia, Bugwood.org)

Brown marmorated stink bug

Halyomorpha halys

Brown marmorated stink bug (BMSB) is a typical stink bug with a shield shaped body. Stink bugs emit a pungent odour when disturbed. There are a number of Australian native stink bugs which are similar to BMSB. However, the distinct features of adult BMSB are the white bands on the antennae, sides of the abdomen and on the legs. BMSB can damage very large bolls.

Brown marmorated stink bug. (Source: Steven Valley, Oregon Department of Agriculture, Bugwood.org)

Cotton stainer; red bugs

Dysdercus spp

These often colourful bugs tend to form groups, which help them find mates. These bugs look like and cause damage similar to the already endemic pale cotton stainers (*Dysdercus sidae*). Many Dysdercus species transfer microorganisms that increase staining of the cotton bolls that they prefer to feed on.

Adults and nymphs of the cotton stainer, *Dysdercus suturellus* (Herrich-Schaeffer). (Photograph by Lyle J. Buss, University of Florida. http://entnemdept.ufl.edu/creatures/field/bugs/cotton_stainer.htm)

Bt resistant Cotton bollworm

Helicoverpa armigera (carrying Bt resistance alleles)

The introduction of Bt cotton, has dramatically reduced the need to control the major insect pests, *Helicoverpa* spp. There are also exotic, Bt tolerant, strains of endemic pests such as *H. armigera* which carry resistance alleles (eg dominant resistance to Cry1Ac in China) that would have a significant effect on Australia's cotton industry if they were to become established in Australia. With the movement of *H. armigera* into South America, there is also some concern that *Helicoverpa Zea* (American cotton boll worm) may hybridise with *H. armigera.*

False Codling moth

Thaumatotibia leucotreta

False codling moth is a pest of economic importance to many crops in its native habitat including avocado, citrus, corn, cotton, macadamia, peach and plum. Adult false codling moths are small, brownish-gray moths up to 20 mm, with a triangular mark on the outer part of the wing with a crescent shaped mark above it.

False Codling moth. (Source: Marja van der Straten, NVWA Plant Protection Service, Bugwood.org)

Tarnished plant bug and Western plant bug

Lygus lineolaris and Lygus Hesperus

The 'Lygus' plant bugs have a wide host range. In cotton, feeding causes seed abortion, stem or leaf wilting and poor seed germination. It is likely control of these plant bugs would be very disruptful to the current Australian IPM system. Both of these plant bugs are known to occur predominantly in North America.

Tarnished plant bug. **(Source: Scott Bauer, USDA Agricultural Research Service, Bugwood.org)**

Whitefly

Bemisia tabaci (Biotypes other than B and AN)

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, eg. 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)**

Cotton 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.

If a new aphid strain enters the country it may have a different insecticide resistance profile making control more difficult, or may carry an exotic plant disease. **(Photo: L. Wilson)**

Cotton leaf curl disease (CLCuD)

CLCuD, sometimes referred to as Gemini virus, can cause yield losses of up to 35 per cent 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, QLD DAF)**

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 cotton 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, NSW DPI)

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 per cent 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 rot. (Chris Anderson, NSW DPI)

Blue disease

Cotton Leafroll Dwarf Virus

Blue disease is a virus specific to cotton that can reduce yield potential by up to 20 per cent. 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.

Blue disease. (Murray Sharman QLD DAF)

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 having 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.

Bacterial blight.

Best practices for aerial and ground spray applications to cotton

Bill Gordon, Bill Gordon Consulting Pty Ltd.
Adapted from earlier versions by
Andrew Hewitt, Centre for Pesticide Application and Safety, University of Queensland
Peter Hughes, formerly QLD DAF
Tracey Leven, CRDC

When using pesticides, best practice means not only doing the best job you possibly can, but also being able to demonstrate what you have done and how it has impacted others.

A lot of time, effort and money are spent on spray application. To achieve the best value from that effort requires that the application technique is matched to the target, the product and the weather conditions. Movement of spray away from the target area, wastes product and increases the risk of damage or residues onto non-target crops or sensitive areas.

This chapter provides a summary of factors to be considered in optimising spray application, with an expanded version available in the Australian Cotton Production Manual. New technologies and information are continually becoming available, and readers should consult additional information where available. Recommended additional resources are highlighted and can be found in the *my*BMP resources section www.myBMP.com.au

Planning

The development of a comprehensive Chemical Handling and Application Management Plan (CHAMP) is an important part of the Best Management Practice (BMP) program in cotton. The CHAMP 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; and,
- Accident and emergency procedures.

Having a CHAMP in place helps to ensure that everyone involved in pesticide application has a clear understanding of their responsibilities.

Legal requirements

Always read and follow the label when handling and applying chemicals.

Label conditions may specify spray quality, spray conditions including mandatory wind speed range, and no-spray zones/buffers. Be aware of federal and state regulations for chemical application. Staff responsible for handling and applying pesticides must be qualified according to relevant state and federal requirements.

There may also be workplace health and safety requirements related to storage and use of hazardous chemicals, which require a hazard analysis to be completed, in addition to maintaining an inventory of the hazardous chemicals you use and store and current copies of the Safety Data Sheets for each of those chemicals.

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.

Label Instructions

Many product labels now include a range of mandatory statements, Such as the DO NOT statements on the label. Some examples include:

Mandatory spray qualities

Labels typically require the use of a coarse spray quality or larger, or a medium spray quality or larger according to the ASABE1 or BCPC2 classification systems. Ensure nozzles are selected from charts that refer to either of these standards and equipment is setup and used appropriately to achieve the required spray quality.

Be aware that a new ASABE standard (S572.1) is being introduced, which requires nozzles to be tested with an adjuvant added (compared to the old standards that only required water). The new standard makes the spray qualities appear smaller than those previously published. Before purchasing a new set of nozzles, make sure you consult a current nozzle chart to check the spray quality classification of the nozzle.

Mandatory wind speed range

Labels state that the wind speed must be above 3 km/h and less than either 15 km/h or 20 km/h (depending on the product) as measured at the site of application. Minimum wind speeds at night should be above 11 km/h to ensure turbulence (mixing of the air) and to minimise the likelihood of a surface temperature inversion being present.

No spray zones

A NO SPRAY ZONE is the downwind distance between the sprayed area and a sensitive area. The NO SPRAY ZONE cannot be sprayed when the wind is towards the sensitive area (which may be a residence, public area, water body, pasture, terrestrial vegetation or another susceptible crop), ie. a label may include several NO SPRAY ZONE tables. The distance required for the NO SPRAY ZONE may differ for the various types of sensitive areas.

Always check the label to see if a no spray zone is required, and how wide the no spray zone has to be for the product you wish to apply. NO SPRAY ZONES for aerial applications are much larger than those required for ground application.

Record keeping

Record keeping requirements are now included on the label or permit of many products. It is a legal requirement to maintain those records, in addition to any state based requirement for record keeping.

Communication and neighbour notification

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 and staff of your spray intentions, regardless of label requirements. By doing this, sensitive crops or areas that you may not have been aware of can be accounted for.

Open communications with neighbours is critical when using Roundup

Ready Flex or Liberty Link cotton. Herbicide drift onto fields of cotton without the appropriate tolerance traits can result in serious yield losses.

Cotton is extremely sensitive to phenoxy via off-target application. To assist with reducing drift it is essential that you identify your cotton fields on the CottonMap website (www.cottonmap.com.au). This map will be used by spray contractors, resellers, agronomist and neighbours to identify crops.

Monitoring and recording weather conditions

Weather conditions need to be checked regularly during spray applications (this means continual visual observations and actual measurement at least every load) and recorded as per label requirements.

Labels contain a legal requirement to measure weather parameters at the site of application. This can be done with handheld equipment (eg. Kestrel 3000, 3500, 4000 or equivalent) or portable weather stations. Alternatively on-board weather stations that provide live weather information while the sprayer is operating (such as the Watchdog systems) are available.

***my*BMP resources: Fact sheet on weather monitoring equipment.**

Spray Log Books

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

- **QLD DAF at Toowoomba (07 4688 1200) or Dalby (07 4669 0800).**
- **NSW DPI at Yanco (1800 138 351).**

Growers can also subscribe to websites that provide forecasts of conditions for spraying up to 10 days in advance. These sites evaluate a range of 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.

Temperature and humidity

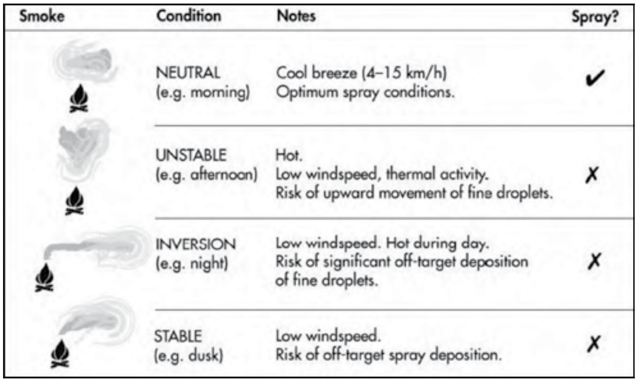
Higher ambient air temperatures and lower relative humidity conditions increase evaporation rates. Since droplet size of water-based sprays decreases rapidly with higher evaporation rates, drift tends to increase.

Water-based sprays should not be applied under conditions of high temperature and low relative humidity (RH). Spraying is best conducted when the delta T (the difference between the wet bulb and dry bulb) is more than 2 and less than 10°C. This may be extended to 12°C where targets are not stressed and a coarse spray quality or larger is used. Refer to Fact Sheet on Tips to Reduce Spray Drift for a Delta T Chart in *my*BMP resources.

When using coarse sprays at high water volume rates, evaporation may be less significant, which may allow some applications to continue into marginal delta T conditions (where soil moisture exists, and the targets are not in a stressed condition). Never start a spraying operation when the Delta T is below 2 or above 10–12.

***my*BMP resources: Tips for reducing drift fact sheet**

EFFECT OF ATMOSPHERIC STABILITY



Smoke	Condition	Notes	Spray?
	NEUTRAL (e.g. morning)	Cool breeze (4–15 km/h) Optimum spray conditions.	✓
	UNSTABLE (e.g. afternoon)	Hot. Low windspeed, thermal activity. Risk of upward movement of fine droplets.	✗
	INVERSION (e.g. night)	Low windspeed. Hot during day. Risk of significant off-target deposition of fine droplets.	✗
	STABLE (e.g. dusk)	Low windspeed. Risk of off-target spray deposition.	✗

Surface temperature inversions

Labels state that spraying must not occur during a surface temperature inversion. There is a high risk of surface temperature inversions being present at night.

The APVMA suggest that applicators should anticipate that a surface temperature inversion will be present every night between sunset and shortly after sunrise, unless there is heavy low level cloud, it is raining or the wind speed remains above 11 km/h for the entire evening.

For more information refer to the GRDC factsheets on Surface Temperature Inversions and Tips to reduce spray drift.

***my*BMP resources: GRDC Surface temperature inversions and tips to reduce spray drift**

Vegetative plantings for spray drift barriers

Effective vegetative barriers can reduce drift by as much as 60 to 90 per cent. A good vegetative barrier will be comprised of a mixture of tree and shrub species with foliage all the way to the ground. The planting arrangement and density should allow for air to partly flow through the barrier. Dense vegetative barriers (without airflow) act like impermeable walls, directing wind containing the spray drift up and over the top of the barrier, increasing how far drift may travel. Do not locate vegetative barriers where airflow will be obstructed by adjacent objects such as turkey's nests, water storages or large banks.

The minimum height for a vegetative barrier should be at least 1.5 times the release height of the spray, when the barrier has a porosity of around 50

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, NSW DPI.

* 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 145 for more information.

For more information on best practice for aerial and ground spray application go to www.myBMP.com.au.
(Photo: Cotton Australia – Jack Hawkins)

per cent (visually this means you can see 50 per cent light and 50 per cent dark when you look through the vegetation). As the porosity reduces, the height of the vegetative barrier needs to be increased. For example, at 40 per cent the height should be 2 times the release height for the spray.

Trees and shrubs with long thin or needle like leaves, or hairy leaf surfaces are the most effective at trapping airborne droplets. Many trees and shrubs are effective at trapping droplets from ground applied sprays from early stages in their development, so make sure the species chosen is hardy, and drought tolerant with thick cuticles to help them survive small doses of pesticide.

Most guidelines suggest that the optimum width of the barrier is 20 m with a 10 m maintenance strip on either side. It is important that remnant native vegetation is protected from negative impacts such as spray drift. This vegetation should be identified as sensitive areas along with riparian areas and waterways.

***my*BMP resources: Department of Natural Resources (DNR) planning guidelines**

Summary of factors that influence spray drift and best practice

The aim of spray application is to transfer active ingredients through the atmosphere to the target in an effective manner with minimal off-target losses. Application technique needs to be matched to the target and weather conditions. Achieving the best outcome from spray application requires the careful consideration of many factors.

- Setting appropriate spray release height
- Avoid excessive travel speed for ground rigs
- Pressure at the nozzle
- Suitable water volumes and quality
- Nozzle selection
- Maintenance and hygiene

These factors are expanded in the Australian Cotton Production Manual.

Spray drift

Spray drift can occur as droplets and particles or as vapours.

Droplet and particle drift

Droplet and particle drift is a common cause of off-target damage from pesticides. It is particularly obvious where herbicides drift onto susceptible crops. Water in the spray droplets evaporates resulting in finer droplets and particles of herbicide. Smaller droplets remain airborne longer and hence are susceptible to further evaporation and drift kilometres away from the intended target. Droplet drift is also increased when relative humidity is high (Delta T values is less than 2). 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 for several hours or even days after application. The risk of vapour drift can be avoided by choosing active ingredients with low volatility. The amine and salt forms of herbicides have a lower volatility than the low volatile ester forms. Even products 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 page 136.

Additional considerations for aerial applications

Aircraft setup and operation

Higher airspeeds (above approximately 110–115 knots) can cause air shear, where droplets shatter into smaller sizes. Some faster, larger turbine aircraft have difficulty in producing a Coarse Spray Quality due to their fast airspeed. Reducing air speed (through slower aircraft) and/or reducing nozzle angle or deflection is an effective way to reduce air shear. The lowest air shear occurs when aircraft nozzles are directed straight back on the aircraft (0°) and operated at higher pressure. The boom length on an aircraft should not exceed 65 to 75 per cent of the wingspan, and sprays should only be released when the aircraft is level over the target (never while climbing). All aerial operators (using hydraulic nozzles or rotary atomizers) should be able to provide a written assurance to the grower that they are complying with the product labels' spray quality requirements.

Further information:

2015 Australian Cotton Production Manual

Spray Drift Management Principles, Strategies and Supporting Information, www.publish.csiro.au/Books/download.cfm?ID=3452

SPRAYpak Cotton Growers' Spray Application Handbook, 2nd Edition www.cottoninfo.com.au/publications

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, and at www.cottoninfo.net.au

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.dilgp.qld.gov.au/resources/policy/plng-guide-sep-ag.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

Additional resources can be found at www.myBMP.com.au

[1]American Society of Agricultural and Biological Engineers
[2]British Crop Production Council

Legal responsibilities in use of pesticides

New South Wales

Jenene Kidston, NSW DPI

The Pesticides Act 1999 is the primary legislative instrument controlling the use of pesticides in NSW and is administered by the Environment Protection Authority (EPA). 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, ie. 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 (eg. temperature, rainfall, relative humidity);

An example form that captures all the information required by the Pesticides Regulation 2009 is provided on page 144. Notes on how to fill it in, can be downloaded from the NSW DPI website. A self-carbonating record book is available for purchase through the QLD DAF Dalby and Toowoomba offices and through the NSW DPI 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 and hold a prescribed qualification. Only domestic use, such as home gardens, is excluded, provided the pesticide is a specific domestic/home garden product.

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.

Queensland

Russel Scholl and Darren Fry, QLD DAF

In Queensland the Chemical Usage (Agricultural and Veterinary) Control Act 1988 (Chem Usage Act) imposes requirements on all users of pesticides similar to those under the NSW Pesticides Act 1999. All chemical users are required to use agricultural chemical products for the crop or situations specified on the approved label instructions or under the conditions of a permit granted by the Australian Pesticides and Veterinary Medicines Authority. Persons using chemicals must also apply agricultural chemical products according to all other label instructions, including any use instructions or restraints that may be listed, including droplet size, wind speed and direction, mandatory downwind no-spray zones and other off-target spray drift reduction risk management practices. There are significant penalties imposed on anyone found to have breached the Chemical Usage Act for failing to observe label instructions.

Under the Agricultural Chemicals Distribution Control Act 1966 (ACDC Act) aerial distribution contractors and ground distribution contractors must be licensed. Pilots and ground spray operators working for these contractors must also be licensed. In most instances, agricultural producers applying agricultural chemicals on their own land do not need to hold a licence. However, growers are strongly encouraged to complete chemical application training to improve their skills and knowledge in application technology, handling, storing and transporting chemicals.

Queensland growers are strongly encouraged to keep records of all their chemical applications along the same lines as NSW growers. Growers must keep records of chemical treatment activities where specified on the label instructions or under the conditions of a permit. Workplace health and safety also requires spray records to be maintained. Aerial and ground distribution contractors are required to make records of all their spraying activities and keep these for a minimum of 2 years.

Additional advice on legal responsibilities in applying pesticides in QLD, contact Biosecurity Queensland 13 25 23.

Refer to www.mybmp.com.au for further information on record keeping associated with spray application.


CASE IH
AGRICULTURE

Safe storage, handling, use & disposal of chemicals

By **Phil Tucker,** drumMUSTER/Chemclear

A critical part of responsible use of pesticides is their safe storage, transport and handling, as well as appropriate disposal of product that is no longer wanted or able to be used. Storing, handling and applying pesticides correctly greatly reduces any potential negative impacts to you, your staff, your business, your neighbours and the environment.

Many registered pesticides are classified as hazardous chemicals, and most of those that are not, pose some risk to the health of those who use them or are exposed to them. Workplace health and safety regulations exist in both NSW and Qld to protect workers from the short and long term health effects from exposure to hazardous chemicals. *my*BMP provides guidance and resources to meet your requirements for handling, storage and application of chemicals and petrochemicals. The templates provided also help to document the farm specific procedures in place to minimise as well as respond in the event of an injury, fire, or spill. It is important that these procedures are communicated to all staff.

Recycle chemical containers

Empty chemical containers present a risk to people and the environment. All containers should be triple rinsed or pressure washed during mixing, with contents added to the spray tank, and securely stored. 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.

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

- Triple rinse 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.
- 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. Dispose of rinsate in spray tank appropriately.
- Inspect the container, particularly the thread and screw neck to ensure all chemical residues have been removed.
- 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.
- 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.
- Store cleaned containers preferably in a sheltered place with caps removed, where they will remain clean and dry until they can be delivered to a drumMUSTER collection centre.

If your container is rejected, the inspector will request that your container is taken home, properly cleaned and returned for recycling in your next delivery.

As more resellers turn to using Intermediate Bulk Containers (IBCs), many are still unsure about the right way to return IBCs once they've been used. Agsafe has prepared a quick and easy guide that may assist users on how to send IBCs back for recycling or reuse. **www.drummuster.com.au/containerrecycling/the-abcs-for-your-ibcs/**

For information on the drumMUSTER program phone 1800 008 707 or contact your local representative:		
Northern NSW	**Southern NSW**	**Queensland**
Phil Tucker	**Vernon Keighley**	**Colin Hoey**
0427 925 274	**0406 745 030**	**0428 964 576**

Safely dispose of unwanted chemicals

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 chemical's 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.

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.

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. NB an inventory form can be obtained from the ChemClear website.
2. Register the inventory for the next collection in your area. Book on freecall 1800 008 182; fax 03 9369 4380 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 ensuring that transportation is safe. Never place chemicals in the boot of a car or back of a station wagon. Refer to ChemClear website for information about safe transportation.

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, or within 2 years of expiry or deregistration, and 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.

Pesticides and the environment

By **Stacey Vogel,** CottonInfo

The cotton industry's guidelines for minimising risk to the environment are another component of *my*BMP.

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 risk that a particular product poses to the environment (native terrestrial and aquatic plants and animals) 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 and pyrethroids. 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 IRMS highlights insecticides with label warning about bee safety. The relative toxicities of cotton insecticides to honeybees are listed in Table 3 on pages 8–9.

Table 3 ranks the acute toxicities of products to bees based on LD50 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 41 summarises the currently available information. ALWAYS READ AND FOLLOW LABEL INSTRUCTIONS.

Bee field activity is temperature and food related. Bees become more active at temperatures above 12-13 degrees with maximum flight activity reached at 18 degrees. At temperatures above 35 degrees, water gathering bees are deployed by the hive. The overall flight activity of a hive will be limited if there is no nectar or pollen to collect. With water gatherers the main flight activity occurs when temperatures are above the mid thirties.

Bees forage within a 2 to 4 km radius of their hive. They may travel up to 7 km 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 being foraged by bees eg. coolibah.

Coolibah trees (*Eucalyptus microtheca*) are a primary source 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 northern NSW buds appear in November and the trees begin to flower mid-late December finishing about the end of January, budding and flowering times vary by a few weeks in both the southern and central Qld areas. When heavy budding occurs beekeepers may 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:

- Notifying 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;
- Informing 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 on to non-target crops and native vegetation used by foraging bees; and,
- Avoiding drift and contamination of surface waters where bees may drink (see advice on risk management for aquatic organisms).

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

NSW Apiarist Association
Kate McGilvray (Secretary)
info@nswaa.com.au
Phone: 02 6373 1435, Fax: 02 6373 1436

Qld Beekeepers Association
Colleen Morris (secretary)
qbainc@bigpond.com
Phone: 07 5465 3682

NSW DPI
Doug Somerville, Technical Specialist (Honey Bees)
Ph: 02 4828 6619 Mob: 0427 311 410
doug.somerville@dpi.nsw.gov.au

QLD DAF
Patricia Swift, Apiary officer
Ph: 07 5466 2216
patricia.swift@daff.qld.gov.au

Protect bees when using Fipronil
Refer to label statement:

'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.'

Where possible, use EC or 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.

'Bee Connected'

Communication between growers and bee keepers is critical in reducing the risk of unintended exposure of bees to any products that may have the potential to negatively impact bee health. BeeConnected is a nation-wide, user-driven smart-phone app and website that enables collaboration between beekeepers, farmers and spray contractors to facilitate best-practice pollinator protection. Growers log the location of their properties through a Google Maps-based platform with GPS capability. Beekeepers can use the same functions to log the present or future locations of their beehives. When a beehive is logged nearby to a farmer's property, both users are sent automated notifications and are able to chat further about their activities via a secure internal messaging service. CropLife Australia provide BeeConnected to the community free of charge as part of their Pollinator Protection Initiative. **Please note,** this new service from Croplife replaces the 'Bee Alert' system that CottonInfo was running.

For more information and to participate in this great service go to: www.beeconnected.org.au/

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

Protecting birds

Organophosphate and carbamate insecticides can be particularly toxic to birds, especially in granular formulations. 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 (not registered in cotton, but relevant to crops grown in rotation with cotton) 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; and,
- Prompt collection and burial of rodent carcasses where these occur in open situations.

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.

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 (ie. 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.

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; and,
- Actively discouraging birds from feeding in crops which are to be sprayed.

Pesticides can also indirectly impact on bird populations through the loss of plants and animals on which they feed and through loss of habitat. Reduce potential food and habitat loss through:

- Protecting sensitive areas such as remnant vegetation, riparian areas and waterways from spray drift;
- Where possible use target specific pesticides as opposed to broad-spectrum pesticides which are more likely to impact on non-target organisms and plants in the environment. and adopt an Integrated Pest Management (IPM) approach to controlling pests;
- 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 risk is to follow the protection statements on labels, minimise spray drift, and to dispose of chemical containers and waste in accordance with label directions and codes of practice.

Protecting remnant native vegetation

Remnant native vegetation, ie any native patches of trees, shrubs or grasses that still remain in the landscape, can be damaged by herbicide and defoliant poisoning either via leaching through the soil or absorption through the leaves.

The risk to remnant vegetation can be managed by:

- Preventing drift by implementing best practices for spray application;
- Installing natural or artificial barriers to intercept spray drift;
- Adhering to product label NO SPRAY ZONE instructions;
- Selecting target specific herbicides as opposed to broad-spectrum herbicides;
- Select non-soil active herbicides when remnant vegetation is nearby; and,
- Using an Integrated Weed Management approach when managing environmental weeds.

BeeConnected

For more information and to participate in the bee connected service go to: www.beeconnected.org.au/

The cotton growing environment is a high risk environment for bees. (Photo: Lance Pendergast, QLD DAF)

TABLE 41: Cotton insecticides with known residual toxicities to honey bees

Active Ingredient	Chemical group	Residual toxicity to bees[1]	Comment
clothianidin	neonicotinoids		Residues may remain toxic to bees several days after application.
fipronil	phenyl pyrazole	7 to 28 days	Long residual. See label extract page 141.
clothianidin	neo-nicotinoids		Residue may remain toxic for several days after spraying.
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.
chlorfenapyr	pyrole		Foraging behaviour could be affected for >2 days
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[2].
methidathion	organophosphate	3 days	

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] United States Environment Protection Agency.

PESTICIDE APPLICATION RECORD SHEET

NSW GOVERNMENT
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):		

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:			Number of animals treated:		

Pest density/incidence: ☐ Heavy ☐ Medium ☐ Light

Application Data

Full label product name:			Rate/dose:	Water rate L/ha:	
Permit No:		Expiry date:	Adjuvants:		Total ha:
Total L or kg:		WHP:	ESI:	Date suitable for sale:	
Equipment type:		Release height:	Speed:	Nozzle type*:	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
Start:					
Finish:					

Comments:

* Include brand and capacity, eg. Teejet AI 11002.

Update on APVMA reviews

Role of APVMA

The Commonwealth of Australia and the states and territories work together to regulate agricultural chemicals and veterinary medicines in Australia. Before agricultural or veterinary chemical products can be legally sold, supplied or used in Australia, the products must be evaluated and registered by the Commonwealth Government, through the Australian Pesticides and Veterinary Medicines Authority (APVMA). The APVMA assesses all such products prior to registration using risk analysis and imposes product label restrictions to manage identified environmental or health risks. The individual states and territories are then responsible for user compliance with these label instructions and limitations.

Search for registered products: https://portal.apvma.gov.au/pubcris

Search for existing permits: https://portal.apvma.gov.au/permits

Labels

As part of the product registration process, the APVMA approves certain aspects of a product label called the relevant particulars. These particulars include information that identifies the product and information that explains how the product is to be used, how to store and dispose of the product and the action to take in the case of poisoning. Labels on chemical products are legally binding.

Spray drift

The possibility of off-target spray drift accompanying the application of pesticides is a concern both to the community and the agricultural industry, and is a constant challenge to manage. The APVMA is responsible for ensuring that off-target pesticide spray drift does not harm human health, the environment or Australia's international trade.

Since 2010 the APVMA applied a mandatory consideration for the assessment of all new unique agricultural chemical products that are labelled for use outdoors and can be applied as sprays or dusts. This means some products will require mandatory label instructions that include:

- Minimum droplet size for ground boom or aerial applications
- Wind speed operating range of 3 to 20 kilometres per hour
- Maximum boom height for ground boom application
- Nozzle orientation and shut off requirements for orchard or vineyard equipment
- Not applying the product when there is a surface temperature inversion present
- Observing downwind no-spray zones from certain identified sensitive areas

The APVMA is currently reviewing this process prior to expanding its applicability to other application types and reconsidering existing products.

Chemical reviews and changes to use of common cotton products

The APVMA undertakes chemical reviews, which can reconsider the registration of agricultural and veterinary chemicals in the marketplace if potential risks to safety and performance have been identified. Prior to 1 July 2014 the timeframe of individual reviews was determined by the scope and specific details of the review. From 1 July 2014, chemical reviews will be completed within a prescribed timeframe. Although extensive industry consultation has already been conducted for a number of these chemicals, the cotton industry has identified further consultation periods to respond directly to any relevant proposed regulatory decisions. Chemicals currently under review include 2,4-D (LVE), chlorpyrifos, diazinon, dimethoate, diquat, fipronil, methidathion, omethoate and paraquat.

Under the new review process, chemicals that have previously sat indefinitely on the review list will now require action within a prescribed timeframe. Where it is determined from review that a product registration is to be cancelled, the maximum legislative phase-out period on actives, products or labels that might be cancelled as part of a review is 12-months.

The APVMA has nominated 39 chemicals on a Priority Candidate Review List (PCRL), of which 6 are relevant to cotton production systems:

- Methomyl
- Phorate
- Trifluralin
- Amitrole
- Dicofol
- Propargite

The cotton industry is currently working with the APVMA to scope usage of and reliance on these chemicals in current cotton systems, to inform the prioritisation process. **III**

Re-entry periods after spraying

Ngaire Roughley, QLD DAF and CottonInfo
Mark Scott, formerly NSW DPI

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 use each day.

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

Refer to Table 18, page 43 for the trade names of active ingredients.

INSECTICIDES WITHOUT LABEL RE-ENTRY PERIODS

Active ingredient	Hazard Classification (WHO 2009)
Bt, Chlorantraniliprole, Clothclothianidin	Unlikely to present acute hazard in normal use
Clothianidin	Slight
Alpha-cypermethrin, Pirimicarb	Moderate

TABLE 42: 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.
Alpha-cypermethrin 250	Do not allow entry into treated areas for 12 hours after application.
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.
Chlorantraniliprole/ Thiamethoxam	Do not allow entry into treated areas until spray has dried.
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 until the spray deposits have dried.
Etoxazole	Do not allow entry into treated areas until spray has dried.
Fipronil	Do not allow entry into treated areas until spray has dried.
Gamma-cyhalothrin	Do not allow entry into treated areas until spray has dried
Helicoverpa NPV	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.
Magnet	Do not allow entry into treated rows until at least 24 hours after treatment. Do not allow entry into treated rows up to 72 hours after application when deposits are still moist.
Methomyl	Do not allow entry into treated areas until at least 24 hours after treatment.
Omethoate	Do not allow entry into treated areas until at least 24 hours after treatment.
Profenofos	Do not enter treated areas without protective clothing for 34 days 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.
Spirotetramat	Do not allow entry into treated areas until the 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.

Withholding periods (WHP) after pesticide application

Ngaire Roughley, QLD DAF and CottonInfo
Mark Scott, formerly NSW DPI

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 prohibit 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.

Pesticide 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.

TABLE 43: 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.
Alpha-cypermethrin	14 days	Not stated.
Amitraz	21 days	Not stated.
Amorphous silica	0 days	0 days
Bacillus thuringiensis	0 days	0 days
Bifenthrin	14 days	Do not allow livestock to graze crops, stubble or gin trash.
Beta-cyfluthrin	28 days	Not stated.
Chlorantraniliprole	28 days	Do not allow livestock to graze crops, stubble or gin trash.
Chlorantraniliprole/ Thiamethoxam	28 days	Do not allow livestock to graze crops, stubble or gin trash.
Chlorfenapyr	28 days	Do not graze or cut for fodder.
Chlorpyrifos-methyl	28 days	Not stated.
Clothiandin	5 days	Do not graze or cut for fodder. Do not allow livestock to graze crops, stubble or gin trash.
Cyantraniliprole	14 days	Do not graze or cut for fodder. Do not allow livestock to graze crops, stubble or gin trash.
Cypermethrin	14 days	Not stated.
Deltamethrin	7 days	Not stated.
Dicofol	7 days	Do not graze or cut for stock fodder.
Diafenthiuron	14 days	Do not feed treated cotton fodder or cotton trash to livestock.
Dimethoate	14 days	Do not graze or cut for stock fodder. Do not feed cotton fodder, stubble or trash to livestock.
Emamectin benzoate	28 days	Do not harvest, graze or cut for stock fodder for 4 weeks after application. Do not feed trash to animals including poultry.
Esfenvalerate	7 days	Not stated.
Etoxazole	21 days	Do not graze treated crops or feed cotton trash to livestock.
Fipronil	28 days	Do not graze or cut for stock fodder.
Gamma-cyhaldthrin	21 days	See label for the Export Slaughter Interval (ESI).
Helicoverpa NPV	0 days	0 days.
Imidacloprid	7 days	Do not allow livestock to graze crops, stubble or gin trash.
Indoxacarb	28 days	Do not allow livestock to graze crops, stubble or gin trash.
Lambda-cyhalothrin	21 days	Not stated.
Magnet®	WHP varies with insecticide mix –see label.	WHP varies with insecticide mix – see label.
Methidathion	3 days	Not stated.
Methomyl	0 days	Do not graze or feed crop to animals.
Omethoate	21 days	Not stated.
Paraffinic oil	1 day	Not stated.
Pirimicarb	21 days	21 days
Phorate	70 days	70 days
Profenofos	28 days	Not stated.
Propargite	28 days	Do not feed cotton trash, stubble or failed crops.
Pymetrozine	28 days	Do not graze crop stubble or gin trash.
Pyripoxyfen	28 days	Do not graze or cut for stock fodder. Do not feed treated cotton trash to livestock.
Spirotetramat	21 days	Do not feed cotton fodder, stubble or trash to livestock.
Sulfoxaflor	14 days	Do not feed cotton trash to animals.
Thiamethoxam	28 days	Do not allow livestock to graze crops, cotton stubble or gin trash.
Thiodicarb	21 days	21 days
Growth regulator and defoliant chemicals		
Dimethipin	7 days	7 days
Ethephon	7 days	Do not graze
Mepiquat	28 days	Do not graze
Paraquat + diquat	7 days	1 day (livestock) 7 days (horses).
Pyraflufen-ethyl	7 days	Do not feed cotton trash or stubble
Sodium chlorate	0 days	Do not graze treated areas or feed cotton trash to livestock.
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 Tables 18, 38 and 40 for the trade names of active ingredients.

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Meet our team

Led by CottonInfo Program Manager Warwick Waters (0437 937 074, warwick.waters@crdc.com.au), the CottonInfo team of Regional Development Officers, Technical Specialists & *my*BMP experts are all here to help!

Regional Development Officers

Regional Development Officers provide cotton research outcomes and information directly to growers, agronomists, consultants and agribusinesses in each region. Contact your local Regional Development Officer for the latest research, trials and events in your area.

Geoff Hunter	Amanda Thomas	Sally Dickinson	Kieran O'Keeffe	TBC	Katie Slade	Alice Devlin
Namoi, Central QLD	*Macquarie/Bourke*	*Border Rivers, St George, Dirranbandi*	*Southern NSW*	*Darling Downs*	*Upper Namoi*	*Gwydir*
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Technical Specialists

Technical specialists are experts in their fields and provide in-depth analysis, information and research to the industry, for the benefit of all growers. Contact the technical specialists to learn more about water use efficiency, nutrition, soil health and much, much more.

Sally Ceeney	Janelle Montgomery	Lance Pendergast	Sandra Williams	René van der Sluijs
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TBC	TBC	TBC	TBC	
Disease, Volunteer and Ratoon Management	*Spray Application*	*Integrated Weed Management*	*Nutrition and Soil Health*	
P:	P:	P:	P:	
E:	E:	E:	E:	

*my*BMP team

The *my*BMP team run the industry's best management practice program, *my*BMP. Contact the *my*BMP team to learn more about - or to participate in - *my*BMP.

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CottonInfo is a joint initiative of Australian Government Cotton Research and Development Corporation, CSD, Cotton Australia

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