Cotton Pest Management Guide 2013–14

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So give us a call or visit your local CGS Branch to get your "Rain grown cotton pack". It contains most of the information you will need to get started, or come back to, the cotton industry!

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to get your essential
information pack.
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Monsanto takes stewardship of biotechnology seriously. Our focus on the best stewardship practices provides you with the tools to get the most from biotechnology traits, the most from every hectare, today and for seasons to come.

But we can't work alone. Taking short cuts on stewardship can increase the likelihood of resistance development and puts the profitability and success of our industry at risk.

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Contents…

From the editor

When it comes to protecting your crop, you are not alone. And it just as well – the pests (insects, weeds and diseases) don't respect farm boundaries. Teamwork between growers, consultants, neighbours and regions builds a secure future. R&D works to support the industry to provide world's best information resources. The 2013–14 Cotton Pest Management Guide builds on the wealth of knowledge from research that the cotton industry has accumulated since the publication began in the 80's and is the industry's premium resource for insect and mite, weed, disease, biosecurity and spray application.

Summary of changes

The **IPM chapter** has received a full re-write that will help you to review your IPM Strategy and identify what you can do to suppress pests on farm and to manage pests in crop. Want the summary? The seasonal IPM planner has also been updated. Also stay informed on pesticide and Bollgard II **resistance trends** and best practice.

BEE Alert –The cotton growing environment is high risk for bees. The CottonInfo team Calendar includes a BEE Alert tab to help improve communication with apiarists (p152). Also products with specific label instructions for bees are indicated in key pest tables.

Changes to the **weed management chapters** speak volumes about the rapid change the industry is experiencing. The time to prepare for potential resistance has passed, the focal point is the reality of Herbicide resistance in Australian Cotton Farming Systems. How are you going to implement the 2+2+0 formula? The tactics toolbox can help. Glyphosate resistance is a big concern for the industry, read up on the issues, and get involved in the discussion.

Reniform nematodes have been added to the common diseases of cotton, and the 2012–13 **disease survey** included. Also find out about **your biosecurity responsibilities**.

The spray application section has been condensed, with expanded resources now in *my*BMP.

Stay informed on **APVMA reviews** and changes to use of common cotton products.

This publication is one of a series of products proudly brought to you by the Australian Cotton Industry CottonInfo Team. Thanks to the researchers, and industry team of authors, reviewers and contributors for helping with this publication.

Susan Maas, Editor

This resource is supported by additional information on best practice at www.myBMP.com.au

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Key insects and mite pests of Australian cotton

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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 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 59–67). Insecticides can be a costly part of cotton production. Ensure that industry thresholds (pages 39–40) 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 pages 142–158. Carefully follow all label directions.

ABBREVIATIONS USED IN TABLES 1–18	
AC = Aqueous concentrate	ME = Microencapsulated
CS = Capsule suspension	OL = Oil miscible liquid
EC = Emulsifiable concentrate	SC = Suspension concentrate
EC/ULV = Dual formulation	SL = Soluble liquid
G = Granule	ULV = Ultra low volume
L = Liquid	WDG = Water dispersible granule
LC = Liquid concentrate	WP = Wettable powder

INSECT PEST	MANAGEMENT AND REGISTERED CHEMICALS
Helicoverpa spp.	Page 10
Aphids	Page 14
Mirids	Page 19
Spider mites	Page 21
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Thrips	Page 30
Locusts	Page 31
Green vegetable bugs	Page 32
Pale cotton stainers	Page 35
Mealybug	Page 36
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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	Set and communicate IPM Goals Develop and Communicate CHAMP	Good record keeping support CHAMP, regulatory requirements and allows end of season assessment of IPM strategy.		
Know your enemy	Do you have your IPM resources? (ID guides, CPMG, CPM).	Participate in IPM training, field days, or workshops; Contact RDO to join mailing list.		
Take a year around approach	Review the success of last year's approach. Plan ahead to ensure necessary resources and insecticides are available. Monitor winter crops for pests and beneficials – manage carefully to avoid disrupting beneficial populations that may later move to cotton.	Build Beneficials. Check other crops for pests and beneficials. Maintain native vegetation in good condition. Consider planting Lucerne strips. Consider the summer cropping plan and risks of pests moving between crops. Check fallow areas for weeds and pests.	Sample pest and beneficial populations in all crops on the farm. Maintain native vegetation. Begin planning for rotation crops. Check fallow areas for weeds and pests.	Reduce pests / resistance risks for next season by considering which rotation crops will be planted and where. Ensure that native vegetation is maintained. Check fallow areas for weeds and pests.
Think of the farm and surrounding vegetation as a whole system.	Enhance vegetation by: Managing for groundcover and diversity; Prioritise connectivity; Enhance habitat with water ways; and, Weed out pest hosts, especially volunteer cotton. Consider rotation crops (type, location, and potential to host pests and disease). Apply IPM to all crops.	Participate in Area wide Management (AWM). Establish and maintain communication with any apiarist in the region. Use best practice spray application to avoid spray drift. Apply IPM to all crops.	Participate in Area wide Management (AWM). Maintain communication with any apiarist in the region. Use best practice spray application to avoid spray drift. Apply IPM to all crops	Participate in Area wide Management (AWM). Maintain communication with any apiarist in the region. Carefully consider Winter rotation crops (type, location, and potential to host pests and disease). Apply IPM to all crops.
Have good on-farm hygiene.	Zero tolerance to volunteer cotton in rotation crops, fallows and non-field areas. Keep farm weed free over winter. Ensure host free period for pests and diseases. Where practical remove weeds from native vegetation areas.	Keep farm weed free. Zero tolerance to volunteer cotton. 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 monitor and manage volunteer cotton including adjacent to fields, as well as non-field areas such as fencelines, channels, perennial vegetation and pastures. Consider chipping where necessary.	Conduct effective crop removal to prevent ratoons.
Consider options to escape, avoid or reduce pests.	When planning cotton, consider proximity to sensitive areas, and other host crops relative to prevailing winds, as well as how beneficials move through the landscape. Select a variety that suits the region's season length. Consider okra leaf shape. Plant spring chickpea trap crop. Consider growing a diverse habitat and manage areas of vegetation to encourage beneficials. Plant lucerne (strips or block) in autumn. If planning to release Trichogramma, plan to sow other crops (eg sorghum) that will host Helicoverpa for the wasps to sting and hence maintain populations	Monitor stubble load and assess risk of soil and other pest activity prior to planting, and decide on control options. Good seed bed preparation, optimum soil temps and variety with seedling vigour promote rapid and healthy seedlings that can outgrow damage. Avoid planting to reduce SLW influx risk. Consider summer trap crop. Cultivate chickpea trap crops by 30 September. Build beneficials through use of pest and damage threshold and careful insecticide choice. Consider food sprays or release of beneficial insects.	Optimise crop inputs to avoid particularly rank or stressed crops. Sample for beneficials and parasitism rates. Build beneficials through use of pest and damage threshold relevant to sampling technique, and careful insecticide choice. Food sprays or release of beneficial insects may be considered.	Slash and pupae bust last generation summer trap crop 2-4 weeks after last defoliation. Pupae busting is required following harvest of Bollgard II cotton and is recommended by the industry's IRMS for all cotton. Come Clean Go Clean to prevent spread of pests on, off and around farm.
Sample crops effectively and regularly.	Ensure you can identify key pests, beneficials and types of plant damage.	Sample for pests, beneficials and parasitism rates in cotton. Monitor early season damage. Track pest trends. Use pest thresholds and the predator to pest ratio.	Sample for pests, beneficials and parasitism rates. Track pest trends and incorporate parasitism into spray decisions. Monitor fruit load. Use pest thresholds and the predator to pest ratio.	Sample for pests, beneficials and parasitism rates in cotton as well as last generation trap crop. Monitor fruit load. Use pest thresholds and the predator to pest ratio.

Key Insects and Mite Pests – *sponsored by* CGS

TABLE 1: Seasonal activity plan for IPM (continued)

	Overwinter/Planning	Planting – first flower	Flower – first open boll	Open cotton – Harvest
Grow a healthy crop	Consider the best rotation crop for your situation. Test soil nutrient status to determine fertiliser requirements for cotton crop. Consider potential disease risks.	Good seed bed preparation, optimum soil temps and variety with seedling vigour promote rapid and healthy seedlings that can outgrow damage. Monitor for leaf loss or discoloration; tip damage; development of first squaring position.	Monitor first position retention, fruit retention, nodes above white flower and vegetative growth.	Monitor for leaf damage/ discolouration, fruit retention, nodes above whiteflower, vegetative growth and for honeydew. Manage nutrition and irragtion to avoid or reduce regrowth that may harbor pests.
Evaluate pest abundance against established thresholds	Monitor weeds. Use thresholds and careful spray selection for all crops.	Use pest and damage threshold, relevant to region, timing and sampling method, and consider parasitism and beneficial activity	Use pest and damage threshold, relevant to region, timing and sampling method, and consider parasitism and beneficial activity	Use pest and damage threshold, relevant to region, timing and sampling method, and consider parasitism and beneficial activity. Monitor for honeydew.
Choose insecticides wisely to conserve beneficials	Monitor weeds 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.	Consider insecticide selectivity and impact on beneficials and bees.	Defoliation may be a late season alternative to an insecticide.
Apply good resistance management principles.	Complete pupae busting. Zero tolerance of ratoon and volunteer cotton including in rotation crops, fallows and non-field areas.	For Bollgard II, adhere to refuge requirements and planting window. For all cotton crops follow IRMS for every spray. Consider choice of at-planting / seed dressings and implications for later sprays. If a phorate is used at planting instead of a neonicotinoid seed dressing then do not use pirimicarb or dimethoate/ omethoate.	Use thresholds and follow IRMS for every spray. Manage Bollgard refuge for attractiveness.	Pupae busting is required following harvest of Bollgard II cotton and is recommended by the industry's IRMS for all cotton. In CQ slash and pupae bust summer trap crop 2–4 weeks after last defoliation.

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]			
										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	Mite	Aphid	Helicoverpa	Toxicity to bees[14]
Bt[11]		√						very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	—	—	—	VL
NP Virus		√						very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	—	—	—	VL
Pirimicarb	250				√			short	very low	VL	VL	VL	VL	L	L	M	VL	VL	VL	VL	VL	M	M	VL	L	—	—	—	VL
PSO (Canopy)[16]	2%	√			√			short	very low	VL	L	L	VL	VL	VL	VL	VL	VL	VL	L	VL	—	VL	H	VL	—	—	—	VL
Methoxyfenozide	400	√						medium-long	very low	L	VL	VL	L	L	L	L	VL	VL	VL	VL	VL	—	VL	VL	VL	—	—	—	VL
Pyriproxyfen	50						√	long	very low	M	—	M	M	VL	—	—	—	—	L	VL	VL	L	VL	VL	VL	—	—	—	L
Etoxazole	38.5		√					short	low	VL	VL	—	L	VL	VL	VL	VL	VL	VL	M	L	—	VL	VL	L	—	—	—	VL
Indoxacarb (low)	60			√				medium	low	L	L	H	M	VL	L	—	L	H	M	VL	VL	—	VL	H	VL	—	+ve	—	—
Indoxacarb (low+salt)	60			√				medium	low	L	L	H	M	VL	L	—	L	H	M	VL	L	—	VL	H	VL	—	—	—	—
Indoxacarb (low+Canopy)	60			√				medium	low	L	L	H	M	VL	L	—	L	H	M	VL	L	—	VL	H	VL	—	+ve	—	—
Rynaxypyr	52.5	√						long	low	L	M	M	L	VL	VL	VL	L	VL	VH	VL	L	—	L	L	VL	—	+ve	—	—
Dicofol[3]	960		√					long	low	L	—	—	—	L	—	—	—	L	—	L	—	M	—	—	VL	—	—	—	VL
Amorphous silica[17]	2500	√						short	low	L	L	—	M	M	—	VL		L	L	L	L	—	—	M	VL	—	—	—	—
Spinosad	96	√						medium	low	VL	M	L	VL	M	L	H	VL	L	VL	VL	M	H	H	H	H	+ve	—	—	H[15]
Diafenthiuron	350		√		√		√	medium	low	M	H	VL	M	L	M	VL	L	H	VL	L	L	H	VL	H	L	—	—	+ve	M
Pymetrozine	150				√			short	low	M	M	M	M	L	L	L	VL	H	M	L	L	L	L	M	VL	—	—	—	VL
Fipronil (v. low)	8			√				medium	low	L	L	L	VL	L	M	—	L	M	L	M	L	—	—	VH	L	+ve	—	—	VH
Fipronil (v. low + salt)	8			√				medium	low	L	L	L	VL	L	M	—	L	M	L	M	L	—	—	VH	L	+ve	+ve	+ve	VH
Indoxacarb[13]	127.5	√		√				medium	low	H[14]	L	VH	VH	L	M	L	L	VH	M	VL	L	—	VL	VH	VL	—	+ve	—	H[15]
Spirotetramat	96				√		√	medium	moderate	M	L	H	H	VL	VL	VL	VL	M	VH	M	M	—	M	M	M	—	—	—	—
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

Key Insects and Mite Pests – *sponsored by* CGS

Acetamiprid	22.5				√			medium	moderate	M	M	VH	H	M	M	H	M	VH	L	VL	L	VH	H	VH	VH	—	—	—	M[15]
Clothianidin (low)	25			√				medium	moderate	M	VL	—	H	L	M	VL	VL	H	H	M	M	H	M	VH	VL	—	—	+ve	—
Amitraz	400	√	√[9]		√[9]			medium	moderate	H	M	VH	H	L	—	—	—	H	VL	M	M	H	L	H	M	—	—	—	L
Fipronil (low)	12.5			√		√		medium	moderate	L	L	H	L	L	H	L	L	VH	L	M	M	—	M	VH	VH	+ve	+ve	+ve	VH
Chlorfenapyr (low)	200	√	√					medium	moderate	M	L	VH	VL	M	VL	H	H	VH	L	L	M	—	VH	H	M	—	—	—	H
Thiamethoxam	100				√			medium	moderate	H	H	H	H	M	M	M	H	H	M	VL	M	—	H	VH	H	+ve	—	+ve	H
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,beta-cyfluthrin, cyfluthrin, bifenthrin, fenvalerate, esfenvalerate, deltamethrin, lambda-cyhalothrin,
5. Organophosphates; omethoate, monocrotophos, profenofos, chlorpyrifos, chlorpyrifos-methyl, azinophos ethyl, methidathion, parathion-methyl, thiometon
6. *Helicoverpa punctigera* only.
7. Bifenthrin is registered for mite and silverleaf whitefly control; alpha-cypermethrin, beta-cyfluthrin, bifenthrin, deltamethrin and lambda-cyhalothrin are registered for control of mirids
8. Persistence of pest control; short, less than 3 days; medium, 3-7 days, long, greater than 10 days.
9. Suppression of mites and aphids only.
10. Impact rating (% reduction in beneficials following application, based on scores for the major beneficial groups); VL (very low), less than 10%; L (low), 10-20%; M (moderate), 20-40%; H (high), 40-60%; VH (very high), > 60%. A '—' indicates no data available for specific local species.
11. *Bacillus thuringiensis*
12. Pest resurgence is +ve if repeated applications of a particular product are likely to increase the risk of pest outbreaks or resurgence. Similarly sequential applications of products with a high pest resurgence rating will increase the risk of outbreaks or resurgence of the particular pest species.
13. Very high impact on minute two-spotted ladybeetle and other ladybeetles for wet spray, moderate impact for dried spray.
14. Data Source: British Crop Protection Council. 2003. The Pesticide Manual: A World Compendium (Thirteenth Edition),. Where LD50 data is not available impacts are based on comments and descriptions. Where LD50 data is available impacts are based on the following scale: very low = LD50 (48h) > 100 ug/bee, low = LD50 (48h) < 100 ug/bee, moderate = LD50 (48h) < 10 ug/bee, high = LD50 (48h) < 1 ug/bee, very high = LD50 (48h) < 0.1 ug/bee. Refer to the Protecting Bees section in this booklet.
15. Wet residue of these products is toxic to bees, however, applying the products in the early evening when bees are not foraging will allow spray to dry, reducing risk to bees the following day.
16. May reduce survival of ladybeetle larvae – rating of moderate for this group.
17. May be detrimental to eggs and early stages of many insects, generally low toxicity to adults and later stages.
18. Will not control organophosphate resistant pests (e.g. mites, some cotton aphid (*Aphis gossypii*) populations
19. Rankings for *Eretmocerus* based on data for *E. mundus* (P. De Barro, CSIRO, unpublished) and for *E. eremicus* (Koppert B.V., The Netherlands (http://side-effects.koppert.nl/#))

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% of Bollgard II area may carry *Helicoverpa* larvae at or above the recommended threshold levels for a short period during peak to late flower. In Bollgard II 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 predator to pest ratio to be applied. Collect eggs to check for parasitism by *Trichogramma*.

Frequency

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

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

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

Methods

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

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

Thresholds

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

Conventional cotton

Helicoverpa spp.

SEEDLING TO FLOWERING	FLOWERING TO CUT-OUT
2 larvae /m or 1 larvae > 8 mm /m	2 larvae /m or 1 larvae > 8 mm /m or 5 brown eggs /m
CUT-OUT TO 15% OPEN BOLLS	**15% TO 40% OPEN BOLLS**
3 larvae /m or 1 larvae > 8 mm /m or 5 brown eggs /m	5 larvae /m or 2 larvae > 8 mm /m or 5 brown eggs /m

Bollgard II cotton

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

Helicoverpa spp.

SEEDLING TO 40% OPEN BOLLS
2 larvae > 3 mm /m in 2 consecutive checks or 1 larvae > 8 mm /m

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

Using the predator/pest ratio

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

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

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

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

The predator to pest ratio calculated above does not incorporate parasitoids, particularly Trichogramma, in the calculation. To use both predators and parasitoids, the level of egg parasitism should be deducted from the number of Helicoverpa eggs before the predator to pest ratio is calculated. Levels of egg parasitism can vary greatly from farm to farm, region to region and from season to season. Generally levels decline as the season progresses. Notes on how to monitor egg parasitism levels and how to use the predator/pest ratio refer to page 51.

Key beneficial insects

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

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

Predators of pupae – common brown earwig

Predators of moths – orb-weaver spiders and bats

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

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

Parasitoids of pupae – banded caterpillar parasite

Selecting an insecticide

The insecticide products registered for the control of *Helicoverpa* spp. in cotton are presented in Table 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 64–65).

***The total number of predators must only include the key beneficial insects marked by a similar.**

Resistance profile

Conventional cotton

Widespread use of Bollgard II cotton has reduced reliance on chemical insecticides. However large plantings of Bollgard II does not change the overall frequencies of resistance genes in the Helicoverpa population and will not 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%. This means that field failures are now likely for this product. Resistance to general pyrethroids has increased to 90%. Therefore the use of conventional chemistries for control of H. armigera in conventional and Bollgard II crops should be used according to the relevant thresholds and the principles of the IRMS applied to all spray decisions (pages 59–67).

Pupae busting is another key tactic for mitigating resistance risk to all insecticides targeting H. armigera, including Bollgard II. 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 Bollgard II crops, follow the pupae busting directions 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.	

Bollgard II cotton

A gene is present in field populations of *H. armigera* that has the potential to confer high-level resistance to Cry1Ac. CSIRO and Monsanto data suggests that this gene occurs at a low frequency which is probably less than 5 in 10,000. It is not cross-resistant to Cry2Ab and in certain environments is largely recessive.

A gene that confers high level resistance to Cry2Ab is also present in field populations of *H. armigera*. This gene does not confer cross-resistance to Cry1Ac. In 2012–13 around 1–2% of the *H. armigera* population carried the Cry2Ab resistance gene. The continued efficacy of Bollgard II has become even more dependent on how the industry manages its refuges and implements the other elements of the resistance management plan (RMP). For further details, including information about recent changes in the frequency of Cry2Ab resistance genes in *H. armigera*, refer to the Preamble to the RMP for Bollgard II on page 68.

Over-wintering habit

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

Alternative hosts

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

Further Information:

CSIRO Narrabri
Sharon Downes: (02) 6799 1576 or 0427 480 967.
Colin Tann: (02) 6799 1557 or 0429 991 501.

Qld DAFF, Toowoomba
Melina Miles: (07) 4688 1369.

NSW DPI, Narrabri
Lisa Bird: (02) 6799 2428.

Native budworm

Helicoverpa punctigera

Helicoverpa armigera & *punctigera* moths. (Hugh Brier DAFF Qld)

Damage symptoms

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

Sampling

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

Thresholds

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

Key beneficial insects

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

Selecting an insecticide

The insecticide products registered for the control of native budworm in cotton in Australia are presented in Table 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 native budworm to occur in mixed populations with the cotton bollworm often limits insecticide control options to those that are also efficacious on the cotton bollworm.

Bollgard II cotton

A gene 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 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 2012–13 around 1–1.5% of the *H. punctigera* population carried a Cry2Ab resistance gene.

The continued efficacy of Bollgard II has become even more dependent on how the industry manages its refuges and implements the other elements of the resistance management plan (RMP). For further details, including information about recent changes in the frequency of Cry2Ab resistance genes in *H. punctigera* refer to the Preamble to the RMP for Bollgard II on page 68.

Over-wintering habit

The native budworm 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% of overwintering pupae collected from numerous crops and fields in cotton regions during 2007 and 2008 were *H. punctigera* suggesting that this strategy may now be more common. If conditions are favourable during winter, sparse but large populations survive and breed on native host plants in inland (central) Australia. As these winter annuals hay-off in spring, large migrations of moths may fly to cotton growing areas in eastern Australia.

Alternative hosts

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

Further Information:

CSIRO Entomology, Narrabri
Sharon Downes: (02) 6799 1576 or 0427 480 967
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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	0.3 or 0.6 L/ha	No	For the control of *Helicoverpa punctigera* only. Use the higher rate alone or the lower rate with a suitable mixing partner. Do not use more than twice in one season – 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 74
Beta-cyfluthrin	25 g/L EC	0.46–0.8 L/ha	Yes	Can be mixed with mineral spraying oil for ULV applications or with water for EC applications.
Bifenthrin	100 g/L EC 250g/L EC	0.6–0.8 L/ha 0.24–0.32L/ha	Yes	Time spray to coincide with egg hatch. DO NOT apply to larvae >5 cm.#
Cyfluthrin	50 g/L EC	0.6 L./ha or 0.8 L/ha	Yes	Application should be timed to coincide with egg hatch.
Cypermethrin	200 g/L EC 250 g/L EC 260 g/L EC	.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	5.5 g/L ULV 27.5 g/L EC	2.5–3.5 L/ha 0.5–0.7 L/ha	Yes	Use low rate as ovicide and high rates for small to medium larvae.#
Emamectin benzoate	17 g/L EC	0.55–0.7 L/ha	No	Apply at or just prior to hatching. 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* >10mm and/or *H.armigera* <5mm.#
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 details. Target application to coincide with egg hatching.
Magnet		0.5L/100 m row (10–50 cm bands) in 72 m or 36 m		Use including insecticides as per label instructions
Methomyl	225 g/L SL	0.5–1.0 L/ha 1.8–2.4 L/ha	Yes	Ovicidal rate. Larvicidal rate. Higher rate of larvicidal rate may cause reddening of foliage, if excessive use an alternative. Do not apply during periods of plant stress.#
Paraffinic oil	792 g/L	2% or 2L/100L of water		Use a minimum of 80L/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.
Chlorantraniliprole	350 g/kg WDG	0.090 or 0.150 g/ha + non ionic surfactant @ 125 gai/100 L	No	Target brown eggs or hatchling to 2nd instar larvae before they become entrenched in squares, flowers and bolls. Use high rate where the potential is for >3.5 larvae/m and to achieve longer residual control.
Thiodicarb	375 g/L SC 800 g/L WG	0.5–1.0L/ha + Larvacide 2.0-2.5L/ha 0.235–0.470 kg/ha + Larvacide 0.940–1.2kg/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 occasionally a pest of young cotton but both species decline as temperatures increase (generally early December).

Damage symptoms

Nymphs and wingless adults of cotton aphid cause early to late season damage to terminals, leaves, buds and stems which can result in yield loss. Cotton aphids have also been shown to transmit the disease Cotton Bunchy Top (CBT). CBT is described on page 124. Once bolls begin to open, the sugary 'honeydew' excreted by aphids can contaminate the lint. Green peach aphid can cause more severe damage to plant growth than cotton aphid at lower densities.

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.

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 the presence of tubercles (on the head between the antenna), and the long siphunculi (tubes between the back legs). Cotton aphid and cowpea aphid don't have tubercles (the head is smooth between the antenna) and the siphunculi are very short. Adults of cowpea aphid are shiny black and nymphs are always dusky 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, CSIRO Plant Industry at Narrabri, to arrange for a sample to be sent for identification. Contact details are provided at the end of this section.

Population: Sample for non-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.

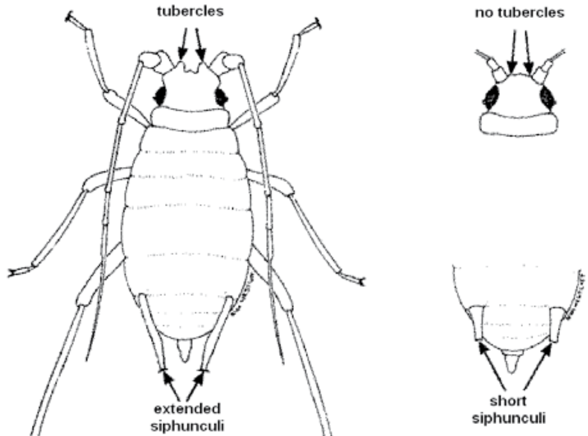
Frequency

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. The presence/absence sampling method is no longer recommended during this part of the season as recent research has found that this technique has poor precision in the range from 80–100% plants infested.

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



Green peach aphid *Myzus persicae*   Cotton aphid *Aphis gossypii*

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 change 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. After first open boll the thresholds aim to protect the quality of the lint by avoiding contamination from 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 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, control 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 125 for hosts of CBT.

Cotton aphid

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 and can occasionally be found late season. As it is more damaging than cotton aphid the threshold for control is lower. 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 usually declines as temperatures increase. Control would only be needed if plants were showing signs of damage and stunting.

Key beneficial insects

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

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

Selecting an insecticide

The insecticide products registered for the control of cotton aphid and green peach aphid in cotton in Australia are presented in Table 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 HIGH 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 or dimethoate and pirimicarb. Strong cross-resistance between phorate and pirimicarb. Strong cross-resistance between all the chloronicotinyls. *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

Aphids and mummies. (Lewis Wilson, CSIRO)

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 compound 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 stipulated 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 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.

Aphids on cotton. (Lewis Wilson, CSIRO)

Alternative hosts

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

Winter weeds that support green peach aphids include; turnip weed and marshmallow. Spring germinations of peach vine and thornapples also host green peach aphid. Canola is an attractive host crop through late winter and early spring.

Further Information:

CSIRO Plant Industries, Narrabri
Lewis Wilson: (02) 6799 1550 or 0427 991 550.

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	225 g/L SL	0.05–0.1 L/ha	Yes	Ensure good coverage. Use high rate under sustained heavy pressure.
Amitraz	200 g/L EC	2.0 L/ha		Suppression when used for controlling Helicoverpa.
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	200g/L SC	0.125–0.25L/ha + Maxx Organsilicone Surfactant 0.02 L/L of water	Yes	Apply when aphid numbers are low and beginning to build.
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	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.#
Imidacloprid	200 g/L SC	0.25 L/ha	Yes	Add Pulse penetrant at 0.2% v/v (2 mL/L water).#
Omethoate	800 g/L SL	0.25 L/ha	Yes	Apply by ground or air.#
Paraffinic oil	792 g/L 815 g/L	2% or 2L/100 L of water, 2.5 L/ha		Apply by ground rig using a minimum of 80L/ha of water. If populations exceed 20% per terminal use in a mixture with another aphicide.
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	240g/L SC	0.3–0.4L/ha	No	Add Hasten Spray Adjuvant 1.0L/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	240g/L SC	0.2–0.3L/ha	No	Use higher rate for heavy infestations or when water volume is reduced, such as with aeerial 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.#

#See label for instructions to minimise impact on bees.

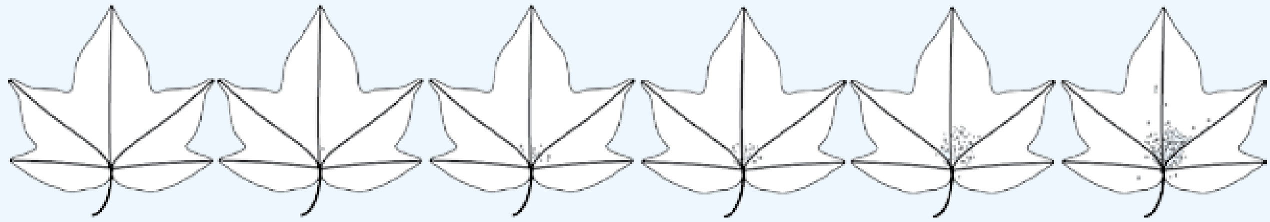
SAMPLING PROTOCOLS FOR COTTON APHID FOR USE UNTIL FIRST OPEN BOLL

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.



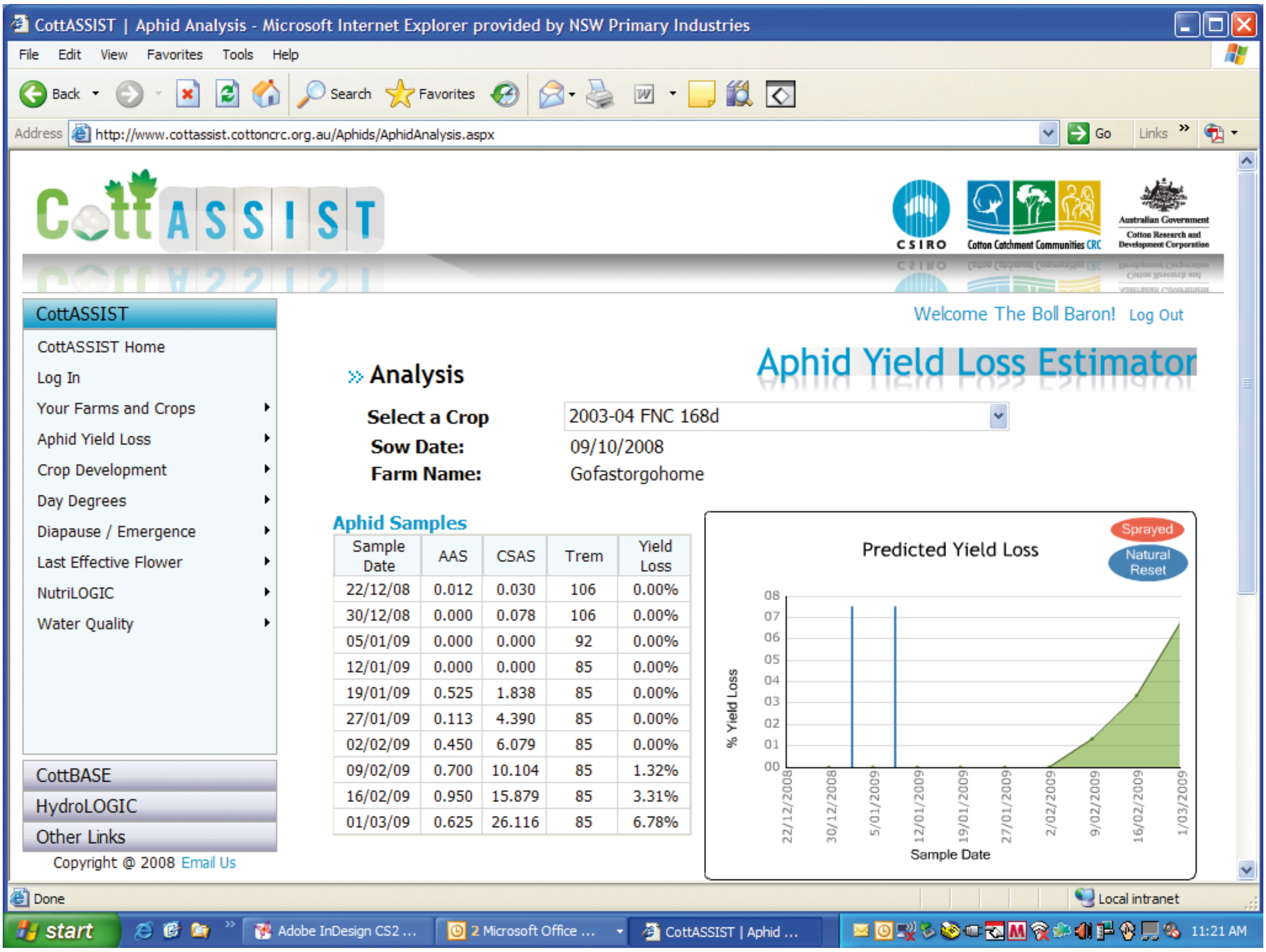
Score = **0**	Score =**1**	Score = **2**	Score = **3**	Score = **4**	Score = **5**
No aphids	1–10 aphids	11–20 aphids	21–50 aphids	51–100 aphids	> 100 aphids

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 on the 'Industry' home page in the Cotton CRC website.

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

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



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

STEP 4. MANUAL CALCULATION OF THE 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% open bolls. If for example aphids are first found 9 weeks after planting, the Time remaining would be ~100 days. As the Season Aphid Score accumulates with each consecutive check, continue to read down the '100' days remaining column to estimate yield loss. When aphids are sprayed, or, if aphids disappear from the crop then reappear at a later time, reassess the time remaining based on the number of days left in the season at the time of their reappearance.

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

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

Key Insects and Mite Pests – *sponsored by* CGS

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 buds and mid season damage to squares and small bolls. Types of damage include blackening and death of terminals of young plants, rapid square loss without the presence of *Helicoverpa* spp. larvae and blackening of pinhead squares.

Square loss depends upon where the mirids are feeding and size of the squares. Feeding on ovules and anthers causes squares to drop but feeding on leaves or stems does not cause square loss. Small and medium sized squares usually drop from mirid feeding. Large squares do not drop but can develop parrot beaked boll if >70% anthers are damaged. This is why mirid numbers and square loss does not always match, and why retention as well as mirid numbers should be considered when making a spray decision. The rate of mirid feeding varies with temperature, with highest rates of feeding between at 27°C and 32°C, which also suggest 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, while bolls damaged later than this will be retained but not continue normal development and will incur yield loss. Black, shiny spots indicate feeding sites on the outside of bolls. When sliced open warty growths and discolouration of the immature lint can be seen within the boll.

Sampling

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

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

Frequency

Sample at least 2 times/week.

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

Methods

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

When beat sheeting, each sample consists of the row of plants being vigorously pushed 10 times with a 1 m stick towards the sheet. Preliminary research has shown that the number of samples required for a good estimation of mirid numbers is between 8–10.

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

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

Thresholds

Yield loss due to mirid feeding varies with crop stage. Different thresholds apply at different times of the season, depending on the crop's capacity to compensate for the damage incurred. When applying the thresholds, always use the crop damage component together with the mirid numbers.

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

		Planting to 1 flower/m	Flowering to 1 open boll/m	1 open boll/m to harvest
Adults or nymphs/m				
Visual Sampling	cool region	0.7	0.5	–
	warm region	1.3	1.0	–
Beatsheet Sampling	cool region	2	1.5	–
	warm region	4	3	–
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.

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

Key beneficial insects

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

Selecting an insecticide

The insecticide products registered for the control of green mirid in cotton in Australia are presented in Table 6 on page 20. The use of more selective insecticide options will help to conserve beneficial insects (see Table 3 on pages 8–9). For the last few years research by Qld DAFF entomologists has showed that salt mixed with low rate of chemical increase efficacy against mirid and stinkbug but reduce impact on beneficials. However, to date, only one chemical (Steward) has a registration to mix with salt. Early season use of dimethoate for the control of green mirids may inadvertently select for carbamate resistance in aphids, and also increase the risk of silverleaf whitefly outbreaks.

Resistance profile

Mirids aren't known to have developed resistance to insecticides in Australian cotton. Currently there is no resistance monitoring program for mirids. However 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.

Overwintering habit

Mirids are known to survive on weeds and native plant hosts surrounding cotton fields. They are also known to breed on native hosts in inland (central) Australia in winter and can migrate to cotton growing areas in spring in a similar way to the native budworm (see section on Native Budworm, page 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 the movement into cotton. Other crop hosts include soybeans, mungbeans, pigeon pea, safflower and sunflowers. It is assumed that mirids migrate between these crops. Weeds hosts include turnip weed, noogoora burr, variegated thistle and volunteer sunflowers.

Further Information:
Qld DAFF, 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	225 g/L SC	0.1 L/ha	Apply with 0.2% Incide penetrant. Target nymphs and/or adults. On above threshold or increasing populations, suppression only may be observed.
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.#
Beta-cyfluthrin	25 g/L EC	0.6 L/ha When	Helicoverpa spp. are present follow Helicoverpa spp. instructions. Otherwise apply at threshold levels as determined by field checks.#
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.#
Clothianidin	200 g/L SC	0.125–0.25L/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	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.#
Gamma-cyhalothrin	150 g/L CS	0.05 L/ha	Apply at recommended threshold levels as indicated by field check.#
Imidacloprid.	200 g/L SC	0.25 L/ha	Add Pulse penetrant at 0.2% v/v (2 mL/L water). See withholding period.#
Indoxacarb	150 g/L EC.	0.65 L/ha or 0.85 L/ha	Under high populations suppression only may be observed.#
Indoxacarb + Salt	150 g/L EC	0.3 or 0.4L/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.	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.

Key Insects and Mite Pests – *sponsored by* CGS

Spider mites

Two-spotted spider mite – *Tetranychus urticae*
Bean spider mite – *T. ludeni*
Strawberry spider mite – *T. lambi*

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

Bean spider mite (this species is 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 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.

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

Sampling

'Sampling protocols for mites in cotton' are presented in full on page 23.

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

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

Frequency

Sample at least weekly. Begin at seedling emergence.

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

Methods

Presence/absence sampling allows many plants to be sampled quickly, thus increasing the likelihood of finding mites if they are present. It is helpful to plot the development of mite populations on a graph. This allows changes in mite population to be seen at a glance. The detailed sampling protocol for monitoring mite populations is on page 23.

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% 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 24 to determine whether the rate of increase warrants control.

Squaring to first open boll

Control if mite populations increase at greater than 1% of plants infested per day in two consecutive checks, or if more than 30% of plants are infested. Use Table 7 on page 24 for details.

First open bolls to 20% open bolls

Control is only warranted if mites are well established (greater than 60% plants infested) and are increasing rapidly (faster than 3% of plants infested per day). Use Table 7 on page 24 for details.

Crop exceeds 20% 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 25.

Mite population %. 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. Compared with the rate of change that you would expect if the yield loss from the mite population was 4%. This value (4%) 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 %. 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 24 for areas with different season lengths:

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

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

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

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

To use the charts

- 1. Select the chart appropriate for your region.
- 2. Go to the section that is closest to the current infestation level of the field i.e. 10%, 30% or 60%.
- 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 (that is, mites are generally favoured by hot dry conditions). Differences between the more mite resistant 'okra' leaf varieties and the normal leaf varieties are built into the charts. The effect of beneficials is also built is as high predation 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, 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 25.

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, and organophosphates. 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)	
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 recent history of developing resistance to miticides. While current resistance levels are low for all products excluding OPs 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 nodes, thrips cease to be a pest and become veracious 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 that has developed in mites in recent years has occurred 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 to establish if bean spider mite causes 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 occuring.

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.

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 Plant Industries, 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% 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 % of the plants total leaf area that is damaged by mites).

Continue to monitor mite numbers, damage levels and infestation levels at least weekly, or more frequently if infestation levels are high (> 30% of plants infested).

If the level of infestation, damage level or mite number per plant declines then control is unnecessary, but monitoring should continue.

If mite numbers per plant do not decline after about 6 weeks, if the damage levels exceed an average of 20% of plant leaf area, or if infestation levels increase, then predators are not abundant enough to control mites and a miticide should be applied.

After about 6–8 true leaves, specific mite counts and damage scoring can cease, but continue to use the presence/absence sampling method (points 1–6) until 20% open bolls.

Miticide Resistance Monitoring

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

Farm Name ....

Field ....

Region (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.

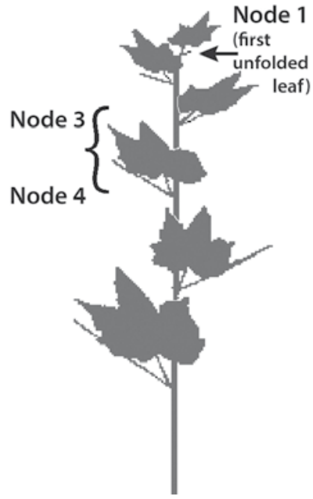


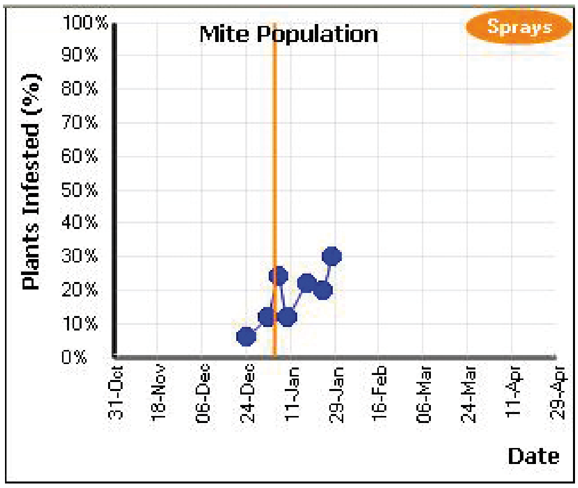
TABLE 7: Yield reduction caused by mites

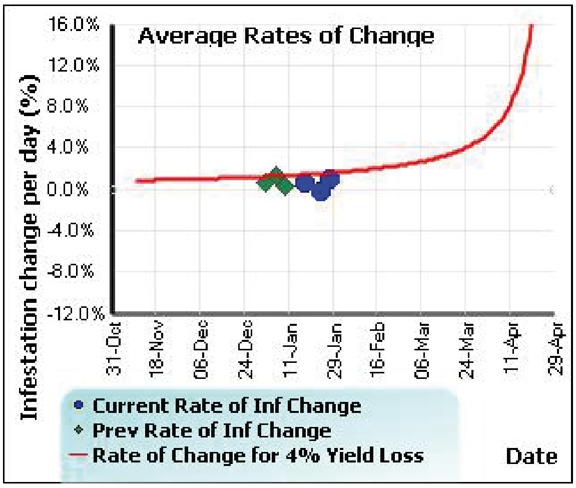
The charts below can be used to estimate the percentage of yield reduction caused by mites, for different cotton growing regions.

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. Boggabri, Breeza, Cecil Plains, Pittsworth, Trangie																					
10	1.7	6.3	13.6	23.7	52.2	100.0	100.0	2.6	7.7	15.7	26.5	56.3	100.0	100.0	4.1	10.2	19.2	30.9	62.8	100.0	100.0
20	1.6	5.6	12.1	21.0	46.4	100.0	100.0	2.3	7.0	14.1	23.7	50.3	100.0	100.0	3.8	9.4	17.4	27.9	56.3	100.0	100.0
30	1.4	4.9	10.7	18.6	40.9	100.0	100.0	2.1	6.3	12.6	21.0	44.5	100.0	100.0	3.5	8.5	15.7	25.0	50.3	100.0	100.0
40	1.2	4.3	9.4	16.2	35.7	97.4	100.0	1.9	5.6	11.1	18.6	39.1	100.0	100.0	3.3	7.7	14.1	22.3	44.5	100.0	100.0
50	1.1	3.8	8.1	14.1	30.9	84.2	100.0	1.7	4.9	9.8	16.2	34.1	89.3	100.0	3.0	7.0	12.6	19.8	39.1	97.4	100.0
60	0.9	3.3	7.0	12.1	26.5	71.9	100.0	1.6	4.3	8.5	14.1	29.4	76.7	100.0	2.8	6.3	11.1	17.4	34.1	84.2	100.0
70	0.8	2.8	5.9	10.2	22.3	60.6	100.0	1.4	3.8	7.3	12.1	25.0	65.0	100.0	2.6	5.6	9.8	15.1	29.4	71.9	100.0
80	0.7	2.3	4.9	8.5	18.6	50.3	97.4	1.2	3.3	6.3	10.2	21.0	54.3	100.0	2.3	4.9	8.5	13.1	25.0	60.6	100.0
90	0.6	1.9	4.1	7.0	15.1	40.9	79.1	1.1	2.8	5.3	8.5	17.4	44.5	84.2	2.1	4.3	7.3	11.1	21.0	50.3	92.0
100	0.5	1.6	3.3	5.6	12.1	32.5	62.8	0.9	2.3	4.3	7.0	14.1	35.7	67.3	1.9	3.8	6.3	9.4	17.4	40.9	74.3
110	0.4	1.2	2.6	4.3	9.4	25.0	48.3	0.8	1.9	3.5	5.6	11.1	27.9	52.2	1.7	3.3	5.3	7.7	14.1	32.5	58.4
120	0.3	0.9	1.9	3.3	7.0	18.6	35.7	0.7	1.6	2.8	4.3	8.5	21.0	39.1	1.5	2.8	4.3	6.3	11.1	25.0	44.5
130	0.2	0.7	1.4	2.3	4.9	13.1	25.0	0.6	1.2	2.1	3.3	6.3	15.1	27.9	1.4	2.3	3.5	4.9	8.5	18.6	32.5
140	0.2	0.5	0.9	1.6	3.3	8.5	16.2	0.5	0.9	1.6	2.3	4.3	10.2	18.6	1.2	1.9	2.8	3.8	6.3	13.1	22.3
150	0.1	0.3	0.6	0.9	1.9	4.9	9.4	0.4	0.7	1.1	1.6	2.8	6.3	11.1	1.1	1.6	2.1	2.8	4.3	8.5	14.1
160	0.1	0.2	0.3	0.5	0.9	2.3	4.3	0.3	0.5	0.7	0.9	1.6	3.3	5.6	0.9	1.2	1.6	1.9	2.8	4.9	7.7
170	0.0	0.1	0.1	0.2	0.3	0.7	1.2	0.2	0.3	0.4	0.5	0.7	1.2	1.9	0.8	0.9	1.1	1.2	1.6	2.3	3.3

Key Insects and Mite Pests – *sponsored by* CGS

MITE YIELD LOSS ESTIMATOR CHARTS





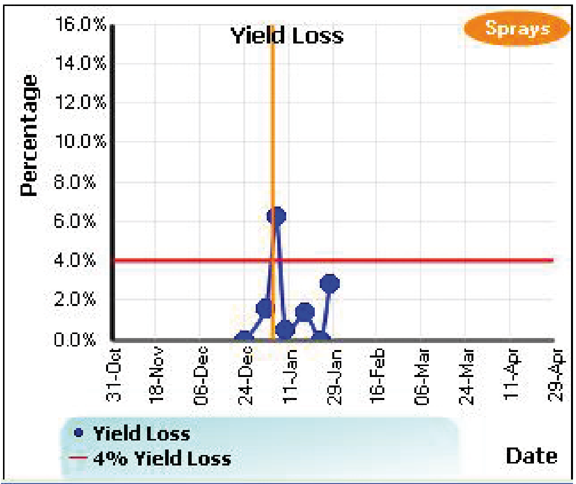


TABLE 8: Control of mites

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 250g/L EC	0.6–0.8 L/ha 0.24–0.32L/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	400 g/L EC	0.5 L/ha.	Will not control organophosphate-resistantmites. 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	Apply by ground rig only .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.

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*) are present in cotton but 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.

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. While other biotypes of *Bemisia tabaci* such as Q-biotype haven't been detected in widespread monitoring of Australian cotton, it is important to continue to check for their presence. A molecular test is needed. This test and the industry's resistance monitoring program are being conducted by entomology staff at Qld DAFF, Toowoomba.

Collect a minimum of 50 4th instar whitefly from cotton leaves across the whole sampling area (i.e. do not collect nymphs from only 1 or 2 leaves).

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

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

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

Frequency

Sampling should commence at flowering and occur twice weekly from peak flowering (1300 Day Degrees).

1. Define your management unit

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

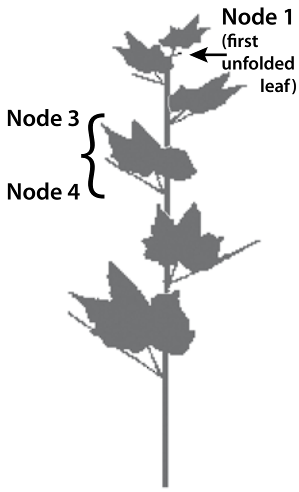
2. Choose a plant to sample

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

3. Choose a leaf

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

Estimate Whitefly Abundance



Adults

Binomial sampling (presence/absence) is highly recommended as it is less prone to bias than averaging the number of whitefly/leaf.

Score leaves with 2 or more whitefly adults as 'infested'. Score leaves with 0 or 1 whitefly adults as 'uninfested'.

Calculate the percentage of infested leaves.

Nymphs

- Nymph abundance is not used in the Threshold Matrix. Use it as supporting information only.
- The presence of large nymphs on leaves at 6, 7 and 8 nodes below the plant terminal validate the assumptions about SLW population dynamics that underpin the spray thresholds. As leaves are assessed for SLW, they can be picked and used to monitor populations of aphids and mites.

Thresholds

For SLW, there are separate thresholds for early season suppression, control and for knockdown late in the season. Thresholds are based on rates of population increase relative to the accumulation of day degrees and crop development. A Threshold Matrix has been developed to assist in the interpretation of population monitoring data. Frequent population monitoring is essential in order to use the Threshold Matrix effectively (see page 29).

The SLW threshold matrix is designed to manage a population that builds gradually in the crop and hence follows a predictable growth trajectory. Large populations of adult silverleaf whitefly migrating into cotton crops will therefore reduce the reliability of the threshold matrix. This can occur if SLW adults leave crops that have been defoliated and seek new hosts. Decisions for management need to consider time of season, time to defoliation and evidence of honeydew. If the crop is maturing early in warmer conditions that the chance that eggs laid by immigrating whitefly will develop into nymph populations that could contaminate lint is high, where as if the crop is maturing later, when it is cooler this is less likely. Similarly, the closer to defoliation that the influx occurs the lower risk that a nymph population will have time to develop. Finally, honeydew on leaves is a good indicator of potential lint contamination. Once there is significant honeydew on lower leaves some remedial action should be taken to prevent contamination of bolls. 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 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.

Parasitised SLW nymph. (Zara Hall, formerly Qld DAFF)

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
			Heavily speckled leaves in lower canopy	Control (Admiral® or Movento®)
	<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	Knockdown &/or defoliate early &/or delay picking if bolls contaminated

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.

Species verification and resistance monitoring

Sending collections to Qld DAFF Toowoomba

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

Richard Lloyd
Qld DAFF
203 Tor Street, Toowoomba QLD 4350
Phone (07) 4688 1315

Ensure samples are clearly labelled and include the following information:

Collector's Name ....

Phone No. ....

Farm Name ....

Fax No. ....

Email address..

Field .... Postcode ....

Region (e.g. Gwydir)..

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

Comments ....

....

....

....

....

....

Selecting an insecticide

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

Resistance profile – SLW

When silverleaf whitefly was first identified in Australia in 1994 it already possessed resistance to many older insecticide groups. Four products all with different modes of action are currently registered for control of SLW in cotton. Refer to the SLW Threshold Matrix, page 29, 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 Admiral and Bifenthrin and no resistance to Pegasus and Movento. Compliance with the IRMS will ensure the limited products available for SLW control will remain efficacious into the future. To delay the development of resistance, ENSURE ONLY A SINGLE APPLICATION OF ADMIRAL 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 Biloela north, the winter generation time is 80 days, while in the Macintyre, Gwydir and Namoi valleys, generation time increases to 120 days.

Alternative hosts

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

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

In cotton growing areas the important 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, 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:

Qld DAFF, Toowoomba
Jamie Hopkinson: 07 4688 1152.
Richard Lloyd: (07) 4688 1315.
Paul Grundy: (07) 4688 1533 or 0427 929 172

Qld DAFF, Emerald
Richard Sequeria: (07) 4983 7410 or 0407 059 066.

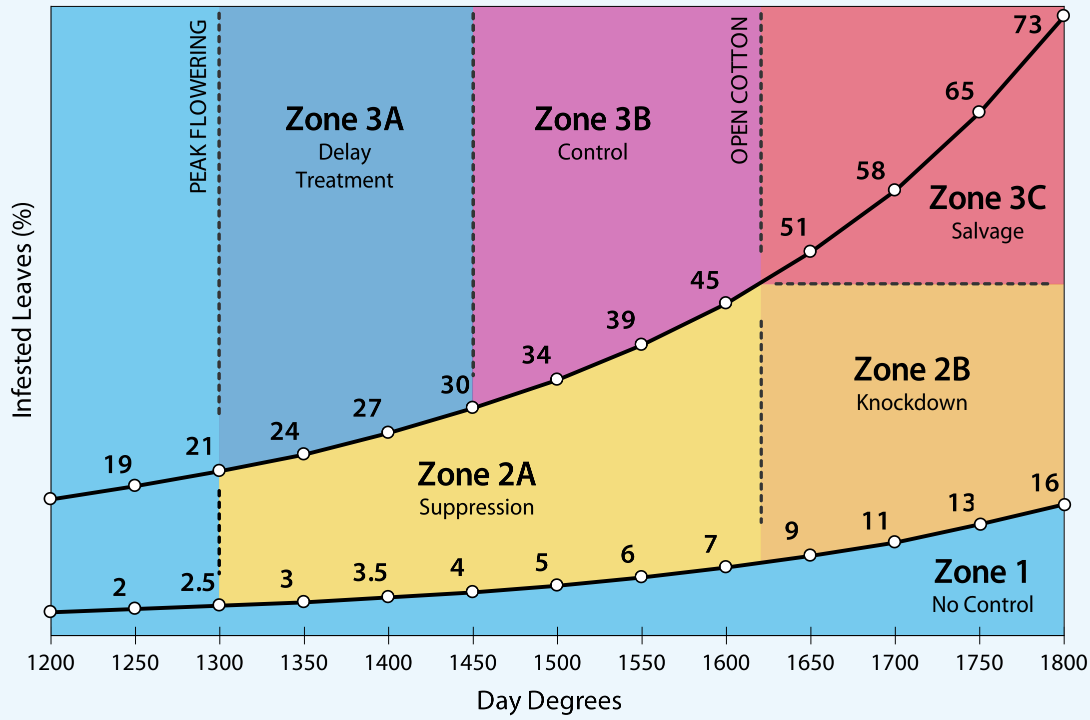
Silverleaf Whitefly Threshold tool on www.cottassist.com.au

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. Do not apply more than 2 applications per crop.#
Diafenthiuron	500 g/L SC	0.6 or 0.8 L/ha	Apply when population densities are 10–20% leaves infested. Suppression may not be satisfactory once population densities exceed 25% infestation, or when high numbers of adults are invading from nearby fields.#
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 twice in one season.
Spirotetramat	240g/L SC	0.3–0.4L/ha + Hasten Spray Adjuvant 1.0L/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.
Zone 2A **Suppression**	This Zone represents a wide window of opportunity for the most economic and low-risk control of SLW. Conventional (non-IGR) insecticides, such as diafenthiuron (Pegasus), can control or provide useful suppression of low-medium density populations. Movento can control a wide range of nymphal population densities.
Zone 2B **Knockdown**	Lint contamination can result from uncontrolled medium density populations in-crops with open bolls. Early action in Zone 2A can prevent the need for higher-risk remedial action in Zone 2B. Pegasus may be effective for remedial control (knockdown) of population densities up to 45% infested leaves in Zone 2B. (NOTE: The Pegasus label indicates that the product may not give satisfactory control of populations >25% infested leaves. This is based on an overseas sampling model. For Australian conditions this equates to ~45% infested leaves). Efficacy will depend upon coverage and environmental conditions. For higher densities approaching the Zone's upper boundary, an application of Zone 3B products may ultimately be required.
Zone 3A **Delay Treatment**	Controlling high density populations before 1450 DD is not recommended due to the likely resurgence of the population and need for additional control to protect lint from 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 be come 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 pryiproxifen, trade name Admiral, and non-IGR products such as Spirotetramat (trade name Movento), are effective in this zone. ENSURE ONLY A SINGLE APPLICATION OF ADMIRAL OCCURS WITHIN A SEASON. Delaying IGR use beyond 50% infested leaves or 1650 DD can result in yield loss, lower efficacy of the IGR and significant lint contamination. Do not apply more than 2 applications of Movento within a season. 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.
Zone 3C **Salvage**	Once the populations exceeds 50% leaves infested, the use of an IGR by itself is unlikely to prevent lint contamination due to the inherent time delay in population decline following application. Rapid knockdown of the population using a conventional insecticide is required before applying the IGR (or similar). The lack of insecticides offering robust knockdown of SLW at high densities make this a 'high risk' zone.

Check the APVMA website for other control options that may become available in cotton under permit – www.apvma.gov.au

Thrips

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

Damage symptoms

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

Sampling

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

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

Frequency

Sample at least weekly.

Begin sampling at seedling emergence and continue sampling until thrips abundance declines and plants begin to recover.

Methods

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

When assessing leaf damage, a rough guide is, if the average size of a thrips damaged leaf is less than 1 cm^2, then leaf area reduction is often greater than 80%.

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

Thresholds

As thrips occur in cotton in most years the most effective management option is to use a seed treatment or at planting insecticide applied with the seed. This protects plants during the establishment phase and has the advantage of being less likely of negatively affecting 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 even yield loss if very severe. In warm/hot climates, plants have an ability to outgrow and compensate for thrips damage and yield loss due to thrips damage is only likely 1 year in 10. In regions with cooler climates early season, where season length is limited, there is less ability to compensate and yield loss may be incurred 1 year in 2. In both instances the seed treatment or at planting insecticide applied with the seed should provide sufficient control for plants to establish. Thrips populations will decline naturally in early December. Thrips are also often blamed for tipping out, but are rarely the cause.

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.

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

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 some damage to the undersides of leaves. Research has shown that high levels of damage would be required to affect yield, and control should not be considered unless >50% of leaf area is damaged and the crop is pre-cutout. These larvae are also predatory and will eat spider mite eggs, often presenting mites outbreaks from developing.

Key beneficial insects

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

Selecting an insecticide

The insecticide products registered for the control of thrips in cotton in Australia are presented in Table 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.

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)

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

Overwintering habit

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

Alternative hosts

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

Further Information:

CSIRO Plant Industries, Narrabri
Lewis Wilson: (02) 6799 1550 or 0427 991 550.

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

Key Insects and Mite Pests – *sponsored by* CGS

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	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.

Australian plague locust
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 Livestock Health and Pest Authorities (LPHA). In Queensland, landholders are asked to report the prescence 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

Threshold based on plant damage. Locust can cause significant damage in a short period of time especially if cotton 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. At times of high risk permit applications may be made. Contact Cotton Australia for more information. Seedling cotton may require quicker action.

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)

In some states free insecticide may be available for locust control in certain circumstances. In NSW, the LPHA coordinate 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 LPHA rate payers once locust nymphs have banded. BQ coordinates locust control in Qld, and undertake strategic aerial control of locusts where there is any threat of migration to/within the area where Local Governments make contribution to the Contingency Fund. BQ does not directly protect crops.

Further Information
In NSW – contact your local Livestock Health and Pest Authority. www.lhpa.org.au
In QLD – contact your local Biosecurity Officer 132523
Australian Plague Locust Commission (APLC) www.daff.gov.au/animal-plant-health/locusts

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 case, it is hard to peel the carpel off the damaged lint which may result tight lock and yield loss. Damage symptoms cannot be distinguished from those caused by mirids. GVB damage varies with boll age, small bolls will suffer more damage than old bolls. Bolls aged up to 7 days old could drop. Eight to 24 days old bolls will not drop but still can suffer significant damage. Bolls aged 25 days and above will not suffer any damage.

Sampling

Sample for adults and nymphal instars of the pest. GVB instars four and five inflict the same amount of damage as adults. Third instar GVBs cause half the damage of adults, and a cluster (more than 10) of first and second instars cause as much damage as one adult.

It is important to correctly identify which instars are present to determine whether or not the population has reached the threshold.

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

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

Frequency

Sample at least weekly.

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

TABLE 11: Control of green vegetable bug

Active ingredient	Concentration and formulation	Application rate of product	Comments
Green vegetable bug *Nezara viridula*			
Dimethoate	400 g/L EC	0.34–0.5 L/ha	Apply when pests appear. 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	0.125–0.25L/ha + Maxx Organsilicone Surfactant 0.02L/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.

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Best Practice


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

Methods

GVBs are most visible early to mid morning making checking easier at this time. Visual sampling and beat sheets are equally effective checking methods while the crop is squaring. From flowering onwards when the crop is most susceptible to damage, beat sheeting is twice as efficient for detecting 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.

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

Thresholds

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

Convert nymph numbers to adult equivalents and include in the counts. Fourth or fifth instars are each equivalent to 1.0 adult, each third instar counts as 0.5 adult and clusters of 10+ first/second instars count as 1.0 adult.

Comparing damage between stinkbugs using GVB adult equivalents

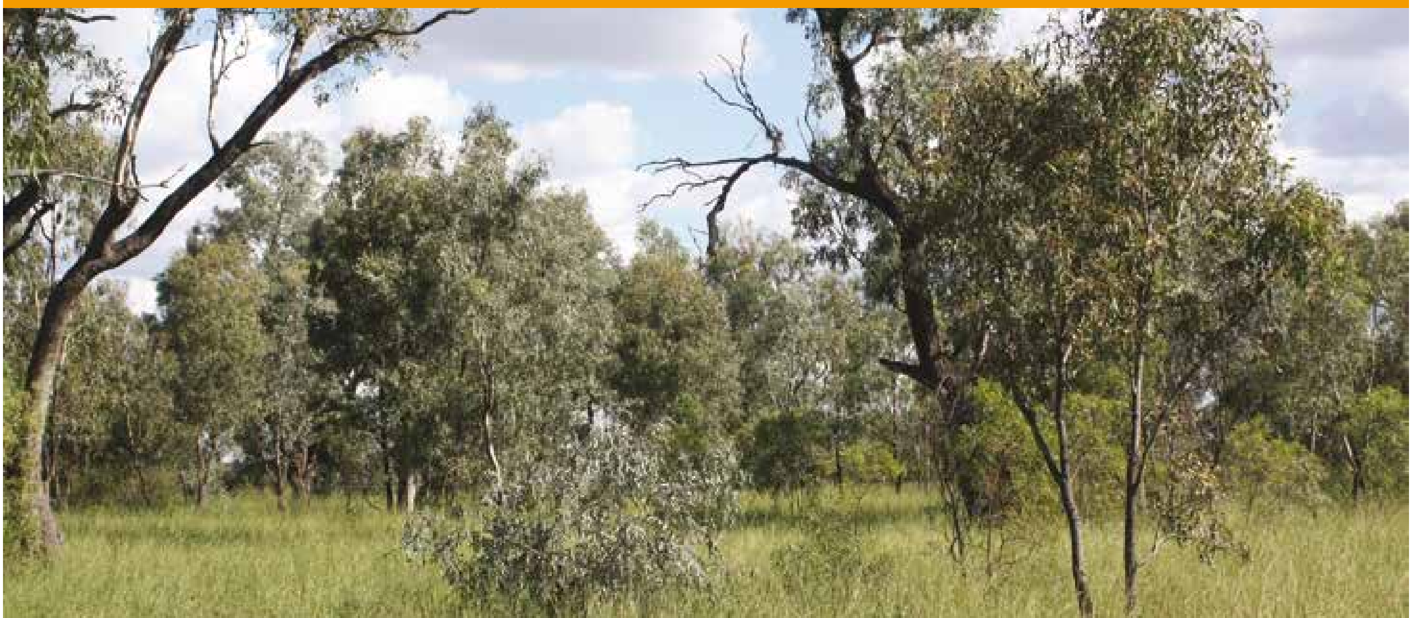
There are 5 more stinkbugs occasionally occur in cotton causing similar type of damage as GVB.

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 an egg parasite, they parasitise GVB eggs by inserting their eggs inside GVB eggs. After hatching they will remain inside GVB eggs to continue to feed and mature. *Trichopoda* is an adult parasite. They lay eggs on GVB adults and hatched out larvae bore into GVB and kill them.

Beneficial insects every season…



Support beneficial insects, not pests.
Graze native veg carefully to prevent broadleaf weeds.
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Best Practice

GVB with 4 Trichopoda parasite eggs. (Hugh Brier DAFF Qld)

Selecting an insecticide

The insecticide products registered for the control of GVBs in cotton in Australia are presented in Table11. Mid-season use of dimethoate for GVB control could have implications for managing insecticide resistance in aphids.

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

Further Information:

Qld DAFF, Toowoomba
Moazzem Khan: (07) 4688 1310 or 0428 600 705.

Key Insects and Mite Pests – *sponsored by*

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;
- Inability to survive high temperatures (> 40°C); and,
- Need for free water to be present.

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

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

Pale cotton stainers are able to damage bolls at any age. They will feed on young bolls, up to two weeks old, leading to boll shedding. 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. At this stage 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.

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

Sampling

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

Frequency

Sample at least weekly once bolls are present.

Usually cotton becomes infested by adults that fly into fields around the time of first open boll, though sometimes, perhaps due to seasonal conditions populations can be found earlier, during boll maturation. Flights of up to 15 km have been recorded. Adults will mate soon after arrival. The expanding population of developing nymphs 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 some growth stages favour the lower canopy, visual searching is also a good complementary technique.

Bolls of varying ages should be cut open to confirm and monitor for signs of damage. Studies have shown pale cotton stainer bug cause almost no marking to the boll surface. Warty growths may be found on the inside of the boll wall if young bolls are damaged, but older bolls will not have these. To confirm damage bolls need to be opened and seeds cut and examined for browned, dried damage areas. After a week, the lint may begin to have a more yellow appearance and locks will be stuck to the boll wall – a good indication of pale cotton stainer feeding.

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

Thresholds

Action threshold during boll development:

When adults and nymphs are observed in the crop and damage to developing bolls is detected, an action threshold of 3 pale cotton stainers/m is recommended. This threshold is based on the relationship between cotton stainer damage and the damage caused by 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% of bolls affected should be used to prevent a colour downgrade.

Key beneficial insects

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

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

Selecting an insecticide

As an occasional pest, there are few products registered for their control. The synthetic pyrethroids lambdacyhalothrin (Karate Zeon, Matador) and gamma-cyhalothrin (Trojan) are registered; check the labels of these products for more information. However their status as an occasional pest is influenced by their susceptibility to insecticides used for the control of Helicoverpa and other pests. Cotton stainers may be incidentally controlled when carbamates such as carbaryl or organophosphates such as dimethoate are used. Any decision to use broad spectrum insecticides such as SPs should take into account their impact on beneficial insects and the subsequent risk of flaring whitefly and other secondary pests should also be considered.

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 between cotton seasons assist greatly in limiting population development (see below).

Alternative hosts

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

Further Information
Qld DAFF, 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% reduction in harvestable bolls. Honeydew excreted by the insects onto the leaves and lint can promote the development of black sooty mould.

Sampling

At low densities, mealybugs can be present anywhere on the plant. 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 assessment of mealybug on these plant parts may give reliable estimations in the field.

Volunteer cotton in a field can be a source of mealybug within the crop. Volunteer cotton grows earlier than cultivated cotton and therefore attracts overwintering mealybug populations in the field (on the root zone of weed hosts or under the soil) and later disperses these 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 e.g. 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) 46881369 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

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 DAFF)

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. There is some anecdotal evidence that mealy bug may also be flared by foliar fertilisers.

- 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.

Key beneficial insects

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

Aenaisus bamabwalei, a parasiotid of solenopsis mealybug parasitoids 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 in 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 DAFF research found that the crawler stage can live for up to 6 days, and the 3rd instar stage for up to 50 days without food or water.

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 nest 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, sow thistle, bladder ketmia, native rosella, vines (cow, bell and potato), crownbeard, stagger weed, marshmallow, verbena, raspweed, and volunteer cotton.

Further information:

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

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 *Apryprius 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.
Azadiractin A&B	5 g/L	0.8 L/ha	Apply product in the planting furrow to enable seed/soil contact. Apply in a minimum of 150 L of water per ha.

#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*			
Beta-cyfluthrin	25g/L EC	0.06L/ha	Apply at recommended thresholds as indicated by field checks.#
Clothianidin	200 g/L SC	0.125–0.25L/ha + Maxx Organsilicone Surfactant 0.02 L/L of water	Apply when numbers reach threshold levels requiring treatment.
Dimethoate	400 g/L EC	0.35–0.375 L/ha (QLD&WA) 0.35 L/ha (NSW)	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	250g/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, 0.4 or 0.5 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.#
Beta-cyfluthrin	25 g/L EC	0.6 or 0.8 L/ha	Application should be timed to coincide with egg hatching.#
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.#
Methoxyfenozide	240 g/L SC	1.7 L/ha or 2.5 L/ha	Apply with recommended adjuvant. Use high rate on rapidly growing crops.
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	1.75L/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 0.5–0.7 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: Up to 15% open	1 open boll/m to harvest: After 15% open	Comments
***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. The Helicoverpa development model in CottonLOGIC can be used to estimate the development of a given egg and larval population over the next three days, taking into account estimated natural mortality levels for the time of season.
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) (light)	20% 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. Some cotton aphid strains are resistant to organophosphates and carbamates. Aphids can carry and transmit cotton bunchy top virus. Monitor plants in aphid hotspots for symptoms of this disease, such as mottling of leaf margins.
Green peach aphid					
% of plants infested	25%				May be a problem early season, populations normally decline in hot weather. Some populations are resistant to organophosphates and carbamates.
Mites					
% of leaves infested	30% Normally suppressed by predators. Use the table on page 21.	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 24 to base thresholds on potential yield loss. 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 less than 1 cm long). Control is also justified if there is a reduction in leaf area of more than 50% once the plant has reached the six true leaf stage. Thereafter, thrips are unlikely to affect the yield or maturity date of cotton crops. If conditions were cool or the plant had another set-back then the thresholds could be reduced.
Damage (reduction in leaf area)	80%	–	–		
Green vegetable bug					
Visual	–	0.5	0.5		Green vegetable bug cause significantly more damage to bolls less than 21 days old and prefer bolls 10 days old or less. Older bolls are generally not preferred. Instars 4, 5 and adults do the same amount of damage. Instar 3 does half the damage of instar 4 and 5 and adults. A cluster (more than 10) of first and second instars does as much damage as one adult. Thresholds are in adult equivalents.
Beat sheet, OR	–	1	1		
Damage to small bolls (14 day old)	–	20%	20%		
Pale cotton stainers					
Visual	–	1.5	1.5		Threshold is based on relationship between cotton stainer damage and damage caused by other plant bugs. Both 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	–	–	–	
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		

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TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2013*					
Active Ingredient	Chemical Group	Insecticide Group	Concentration & formulation	Trade Name	Marketed by
Abamectin	avermectin	6	18 g/L EC	ABA 18	Genfarm Landmark
				ABA 18	Genfarm Landmark
				Abachem 18	Imtrade
				Abacin 18	Farmalinx
				Abaken 18	Kenso Agcare
				Abamect	Nufarm
				Abamectin 18	4Farmers, Apparent; Country; Chemtura; eChem; Mission Bell; Pacific; Rainbow; Titan AG
				Abamix 18	Hextar Chemicals
				Ac Whistler	Avichem
				Acarmik	Rotam Limited
				Agrimec	Syngenta
				AW Announce	AgriWest
				Biomectin	Jurox
				Catcher 18	Sinon
				Gremlin	Sipcam
				Kill-a-mite	Sevroc
				Mite Terminator	Rosmin
				Stealth	PCT Holdings
				Vantal 18 EC	Ospray
				Wizard 18	Farmoz
Acetamiprid	neonicitinoids	4A	225g/L SL	Acetemprid 225	eChem
				Crown 225 SL	Everris
				Intruder	Agnova
				Primal	Farmoz
				Supreme 225g/L	Nippon Soda
Alpha-cypermethrin	pyrethroid	3A	100 g/L EC	ACP Alphacyp 100	Australis Crop protection
				Alf 100 EC	AW
				Alpha 100	Biotis
				Alpha C 100 EC	Ozcrop
				Alpha Duo 100	Genfarm Landmark; Opal; Conquest
				Alpha Duop 100	Grow Choice
				Alphacyp 100	Australis Crop Protection
				Alpha-Cyp 100 DUO	eChem
				Alphacyper 100 EC	Farmalinx; Rygel; WSD
				Alpha-Cypermethrin 100 EC	WSD
				Alpha-cypermethrin	4Farmers; Chemforce; Country; Grass Valley; Halley; Masmart; Mission Bell; Ospray; Sabakem; Rainbow
				Alpha-Cypermethrin 100 Duo	Apparent
				Alpha-Duo 100	Titan AG
				Alpha-Scud Elite	Farmoz
				Alphasip Duo	Sipcam
				Antares 100	Campbell
				Astound Duo	Nufarm
				Centaur 100	Genfarm Landmark
				Buzzard	PCT International
				Dictate Duo 100	Imtrade
				Dominex Duo	FMC
				Fastac Duo	BASF
				Fastac Xcel	BASF
				Ken-Tac 100	Kenso AgCare
				Mascot Duo	Crop Care
				Unialphacyper 100	Ravensdown
				Unichoice 100 EC	United Phosphorus
Alpha-cypermethrin	pyrethroid	3A	250 g/L SC	Alpha forte 250 SC	Conquest
				Alpha forte 250 SC	Rygel Aust
				Alpha-cypermethrin 250SC	Genfarm Landmark
				Googly Alpha Duo 250SC	Sherwood

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TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2013* (continued)

Active Ingredient	Chemical Group	Insecticide Group	Concentration & formulation	Trade Name	Marketed by
Amitraz	triazapentadiene	19	200 g/L EC	Amitraz 200 EC/ULV	ChemAg
				Amitraz 200 EC/ULV	Jurox
				Amitraz Duo	Genfarm Landmark Crop Protection
				Amitraz EC/ULV	eChem
				Amitraz Elite EC/ULV	Farmoz
				Hitraz 200 EC/ULV	Rotam
				Mitra 200 EC/ULV	United Phosphorus
				Opal Duo	Nufarm
				Ovasyn Options	Arysta Lifescience
Amorphous silica	not a member of any chemical group		450 g/L SC	Abrade Abrasive Barrier	Grow Choice
Azadiractin	UN	UN	5 g/L	Green Gold Neem	Friendly Ag products
Bacillus thuringiensis	Bt microbials	11	Btk* HD1** SC	Dipel SC	Valent BioSciences,Sumitomo Chemical Australia Chemical Australia
				Costar	Syngenta
				Agree	Certis
				BioCrystal kurkatis	Grevillia Ag
*Bacillus thuringiensis subspecies KURSTAKI. ** Strain type.					
Betacyfluthrin	pyrethroid	3A	25 g/L EC	Bulldock Duo	Bayer CropScience
Bifenthrin	pyrethroid	3A	100 g/L EC	AC Beast	Axichem
				Agfen 100 EC	AW
				Akostar	AAko
				Arrow 100 EC	Conquest
				Astrol 100 EC	Crop Care
				Bi-Thrin 100 EC	KD Plant Care
				BiFendoff 100	Grow Choice
				Bifenthrin 100 EC	4 Farmers; Country; David Grays; Genfarm Landmark; Imtrade; Ravensdown; Sabakem; Titan AG; Ospray; Farmalinx
				Bisect Duo 100 EC	United Phosphorus
				Compel	Ecofertiliser
				Disect 100 EC	UPL
				Fenithrin	Sipcam Pacific
				Fernstar 100 EC	Biotis Life Science
				Out of Bounds	Barmac
				Sarritor	Nuchem
				Tal-Ken 100	Kenso Agcare
				Talstar 100 EC	FMC
				Venom 100 EC	Farmoz
			250 g/L EC	Astrol	Crop Care
				Bifenthrin 250EC	Enviromax; Ospray
				Stockade	Apparent
				Talstar 250 EC	FMC
			300 g/L EC	Bifenthrin Ultra 300 EC	Imtrade
Chlorantraniliprole	diamides	28	350 g/kg	Altacor	Dupont
Chlorpyrifos	organophosphate	1B	500 g/L EC	AW Chop 500	AgriWest
				Chemicide 500	Hextar
				Chlorban 500 EC	United Phosphorus
				Chlorpos	Farmalinx
				Chlorpyrifos 500	4Farmers; Agro Alliance; Agspray; Chemforce; Conquest; Crop Smart; David Grays; Ezycrop; FMC; Genfarm Landmark; Halley; Imtrade; Novaguard; Shondong Rainbow; Spalding; Ravensdown; Agrimart industries; Apparent; Mission Bell; Nufarm; Ozcrop; Sabakem; Sabero; WSD

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2013* (continued)

Active Ingredient	Chemical Group	Insecticide Group	Concentration & formulation	Trade Name	Marketed by
Chlorpyrifos	organophosphate	1B	500 g/L EC	Cutter Chlorpyrifos	Ivory Chem Aust
				Cyren 500	Ospray
				Fortune 500	PCT International
				Generifos	Grow Choice
				Kensban 500	Kenso Corporation
				Lorsban 500	Dow AgroSciences
				Strike-out 500 EC	Farmoz
Clothianidin	neo-nicotinoids	4A	200 g/L SC	Shield	Sumitomo Chemical Australia
Cypermethrin	pyrethroid	3A	200 g/L	ULV Boom 200	Genfarm Landmark
			200 g/L EC	Cypermethrin 200	Halley
				ULV Boom 200	Genfarm Landmark
				Cypermethrin 200 EC	Halley; Titan AG; United Farmers Co-op; WSD
				Cypershield 200	Imtrade
				Cyrux 200EC	United Phosphorus
				Ken-Cyper 200	Kenso AgCare
				Scud Elite	Farmoz
			250 g/L EC	Arrivo 250EC	FMC
				Arrivo 250EC	FMC
				Cyper 250 Plus	Genfarm Landmark
				Cypermethrin 250 EC	Country
				Cyrux 250 EC	United Phosphorus
			260 g/L EC	Cypermthrin 260 EC	AW; 4Farmers
Deltamethrin	pyrethroid	3A	27.5 g/L EC	Deltaguard ULV	PCT International
				Akodelthrin	Aako
				Ballistic Elite	Farmoz
				Decis Options	Bayer CropScience
				Delta Duo	Imtrade
				Deltamethrin Duo	Apparent; Echem; Halley
				Deltashield 27.5	ChemAg
				Dicast	Sinon
				D-Sect	Cropro
				Surefire Deltashield	PCT International
Diafenthiuron	organotonin miticides	12B	500 g/L SC	Difen 500 SC	eChem
				Pegasus	Syngenta
				Receptor	Farmoz
Dicofol	organochlorine	UN	240 g/L EC	Miti-Fol EC	Farmoz
			480 g/L EC	Kelthane MF	Cropcare
Dimethoate (See permit 13155)	organophosphate	1B	400 g/L EC	Danadim	Ospray
				Danadim	Ospray
				Dimethoate	Imtrade
				Dimethoate 400	Nufarm; 4Farmers; Accensi; Aust. Crop Protection; Conquest; Farmoz; Halley; Superway; Titan AG
				Dimetholinx	Farmalinx
				Rogor	Ospray
				Rover	Sipcam
Dimethoate (See permit 13155)	organophosphate	1B	400 g/L EC	Saboteur	Crop Care
			400 g/L EC	Stalk	PCT Holdings
			400 g/L EC	Unidime 400	United Farmers Co-op
			400 g/L EC	Saboteur	Crop Care
			400 g/L EC	Stalk	PCT Holdings
			400 g/L EC	Unidime 400	United Farmers Co-op
Emamectin benzoate	avermectin	6	17 g/L EC	Affirm	Syngenta
Esfenvalerate	pyrethroid	3A	50 g/L EC	Sumi-Alpha Flex	Sumitomo Chemical Australia
Etoxazole	Etoxazole	10B	110 g/L SC	ParaMite	Sumitomo Chemical Australia
				Swoop	Nufarm
Fipronil	phenyl pyrazole	2B	200 g/L SC	Albatross 200 SC	Farmoz
				Ancestor	Crop Culture
				Fipronil 200 SC	Enviromax; Sherwood
				Flak	AgriWest
				Kaiser	Campbell
				Legion	Crop Care

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TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2013* (continued)

Active Ingredient	Chemical Group	Insecticide Group	Concentration & formulation	Trade Name	Marketed by
Fipronil	phenyl pyrazole	2B	200 g/L SC	Onslaught	Apparent
				Regent 200 SC	BASF
				Rhyme	Ospray
				Surefire Vista	PCT
			800 g/L WG	Fipronil 800 WG	Gharda; Mission Bell; 4Farmers
				Regal 800 WG	Imtrade
				Regent 800 WG	BASF
Gamma -cyhalothrin	pyrethroid	3A	150 g/L CS	Trojan	Dow AgroSciences, Ospray
Helicoverpa NPV	nuclear polyhedrosis virus		5 x 10^9 PIB/mL **LC	Vivus Max + Optimal	Ag Biotech
			2000 MObs/mL	Gemstar	Sipcam
			2x10*5 MLObs	Heliocide	Agrichem
Imidacloprid	neonicitinoids	4A	200 g/L SC	Annihilate	Imtrade
				Annihilate 200 SC	Imtrade
				Confederate 200SC	Hextar
				Confidor 200 SC	Bayer CropScience
				Couraze 200 SC	Ospray
				IMI 200 SC	Farmalinx
				Imidacloprid 200 SC	Agrimart; Agro-Alliance; Apparent ; EnviroMax; Genfarm Landmark; Mission Bell; 4Farmers; Pacific; Superway
				Imi-flow 200	Masmart
				Kohinor 200	Farmoz
				Komondor 200 SC	Crop Culture
				Nuprid 200SC	Nufarm
				Provado	Bayer
				Rygel Imidacloprid 200 SC	Profeng
				Savage 200	Kenso
				Sindor 200 SC	Sinon
				Surefire Spectrum 200SC	PCT Holdings
				Umiforce Utility	Sherwood Chemicals
				Utility	Chaindrite
			350 g/L SC	Nuprid 350 SC	Nufarm
				Couraze Classic	Ospray
			700 g/L WG	Senator 700 WG	Crop Care
Indoxacarb	oxadiazine	22A	150 g/L EC	Steward	Dupont
Lambda -cyhalothrin	pyrethroid	3A	250 g/L CS	Agro lambda 250SC	Novaguard
				Cyhella	Zelam
				Flipper 250 CS	Sherwood
				Lambda 250 CS	Ezycrop; Novaguard
				Lambda –cyhalothrin 250	4Farmers; Chemtura; Mission Bell; Shondong Rainbow
Lambda -cyhalothrin	pyrethroid	3A	250 g/L CS	Limit 250 CS	Sinochem
			250 g/L ME	Karate Zeon	Syngenta
				Kung Fu 250	Imtrade
				Matador Zeon	Crop Care
Magnet	UN	UN		Magnet	Ag Biotech
Methidathion	organophosphate	1B	400 g/L EC	Ridacide	Aako
			400 g/L EC	Suprathion 400 EC	Farmoz
Methomyl	carbamate	1A	225 g/L AC	Marlin	DuPont
				Methomyl 225	Ospray; Hextar Chemicals
				Sinmas 225	Sinon Australia
			225 g/L EC	Electra 225	Farmoz
			225 g/L LC	Lannate L	Cropcare
				Methomyl 225	FMC; Imtrade; Mission Bell
				Nudrin 225	Crop Care
			225 g/L SC	ACP Methomyl 225	Australis Crop protection
				KDpc Metho	KD Plant Care
				Methomyl 225	EzyCrop; Novaguard; Shandong Rainbow; Titan Ag
				Seneca	Ronic International

TABLE 18: Insecticide trade names and marketers – Registered chemicals as at June 30, 2013* (continued)

Active Ingredient	Chemical Group	Insecticide Group	Concentration & formulation	Trade Name	Marketed by
Omethoate	organophosphate	1B	800 g/L SL	Folimat 800	Ayrsta Lifescience
				Sentinel 800	ChemAg
Paraffinic oil	petroleum spray oil (PSO)		792 g/L EC	Canopy	Caltex
			814 g/L EC	Summer Insecticidal Spray Oil	Sacoa
			838 g/L EC	Cropshield	Sacoa
			846 g/L EC	Broadcoat	Caltex
			861 g/L EC	Empower	Victorian Chemical Co
			827 g/L LC	D-C-Tron	Caltex
			859 g/L LC	CottOil	Sacoa
Phorate	organophosphate	1B	100 g/kg G	Thimet 100	Barmac
				Umet 100G	UPL
			200 g/kg G	Thiamet 200G	Barmac
				Umet 200G	UPL
				Zeemet 200G	UPL
Piperonyl butoxide	synergist	synergist	800 g/L EC	Enervate	Nufarm
				PBO 800 EC	Farmoz
				Piperonyl Butoxide –	Agspray
				Puppet	Imtrade
				Summit PBO Synergist –	Sipcam
				Synergy	Crop Care
Pirimicarb	carbamate 1A 500 g/kg WDG	1A	500 g/kg WDG	Aphidex WG	Farmoz
				Atlas 500 WG	Titan AG
				Diri-ken 500 WG	Agcare
				Piri-ken 500 WG	Kenso Agcare
				Piricarb WG	Farmalinx; Shondong
				Piricarb 500 WG	Rainbow
				Pirimicarb 500 WG	Ospray; Genfarm Landmark; Apparent; Imtrade; OzCrop; 4Farmers
				Pirimidex WG	Conquest
				Pirimor WG	Syngenta
			500 g/kg WP	Aphidex 500 WP	Farmoz
				Pirimicarb 500 WP	4Farmers
Propargite	propargite	12C	600 g/L EC	Bullet	Crop Care
				Comite	Chemtura Australia
				Dyna-Mite 600	Farmoz
				Mitigate	United Phosphorous
				Propamite	Sipcam Pacific
				Treble	Nufarm
Pymetrozine	pymetrozine	9B	500 g/kg WDG	Fulfill	Syngenta
Pyriproxyfen	pyriproxyfen	7C	100 g/L EC	Admiral	Sumitomo Chemical Australia
Spirotetramat	spirotetramat	23	240 g/L SC	Movento	Bayer Cropscience
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	Farmoz
			800 g/kg WDG	Confront 800 WG	Imtrade
			800 g/kg WDG	Thiodicarb 800 WG	Mission Bell
Sulfoxaflor	Sulfoximines	4C	240 g/L SC	Transform	Dow Agrosciences

(*Some products that are registered but no longer commercially available have been omitted)

TABLE 19: Insecticide seed treatment trade names and marketers – Registered chemicals as at June 30, 2013

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.

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Integrated Pest Management (IPM) in cotton

Susan Maas, CRDC; **Sandra Williams,** CSIRO;
Lewis Wilson, CSIRO; **Robert Mensah,** NSW DPI; and,
Tracey Leven, CRDC.

Introduction

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

The key challenge to long term effective management is conserving and utilising beneficial insects for pest control and preventing 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 repeatedly that reliance on a single tactic (sample, chemical spray) 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 around 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 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 IPM resources on your farm and tactics you may use up front to conserve beneficials and suppress pest populations across the farm. Consider 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 entire farming team.

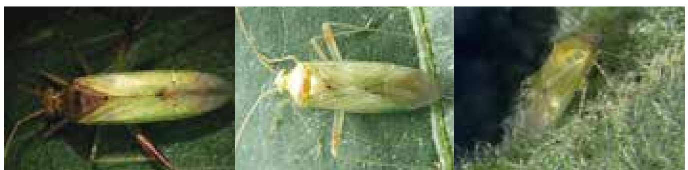
As insecticides still play an important role in an IPM system, develop and implement a chemical handling application management plan (CHAMP), formerly PAMP, to minimise the risks associated with pesticide application specific to your farm. A CHAMP will help to establish good communication with everyone 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 consult the myBMP website.

What can I do to 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, 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. Consider how your IPM strategy can target different mechanisms of pest survival. For information about key pests and mites of Australian cotton go to p 5. Refer to the Cotton Production Manual and the 'Guide to Pests and Beneficials in Australian Cotton Landscapes' for more information.



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 DAFF; 3 C. Mares, CSIRO)

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

2. Take a year around approach

Seasonal conditions and farming practices during the winter months can have a big influence on summer pest population.

Divide the year up into logical phases and consider what actions could be taken in each phase to reduce overall risk in that as well as later phases, refer to the IPM calendar pages 6–7. Take into account factors such as (i) crop history (eg 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), (ii) crop sequences that encourage build up and movement of the same pest between crops (eg late soybeans will inherit silverleaf whitefly populations from nearby maturing cotton), (iii) management of weeds in fallows and crops (iv) planning ahead for likely insecticide needs so selective options are available when needed, (v) having a plan for sampling crops and ensuring information is on hand for pest identification and thresholds. 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 the insecticide has decayed will survive better and potentially cause more economic damage. If beneficials are killed by sprays 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 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, 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:

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

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

The cotton pest and beneficial guide and 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 118 for more information.

Control the pests and leave the rest

Knock out whitefly, mites, aphids and everything else and you could end up with a domino effect. PEGASUS™ has excellent translaminar, contact and vapour activity. It knocks down feeding pests hard, yet because of its unique chemistry, is soft on beneficial species.

Talk to your consultant or local distributor about Syngenta's solutions.

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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. The Bollgard II trait maybe most appropriate for fields adjacent to sensitive areas. Conventional cotton may benefit from being embedded amongst Bollgard II cotton and rotation crops. In this situation pest loads are diluted across all the crop area. The conventional crops may gain some protection by Bollgard II crops intercepting some of the Helicoverpa population and surrounding 'low spray' Bollgard II crops can act as sources for rapid re-entry of beneficials if sprays are required on the conventional crops. Bollgard II 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 to cause damage to the adjacent Bollgard II crops. Conventional crops (particularly unsprayed refuge) and Bollgard II crops should be separated by at least 20m 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.

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 insect predators through the landscape.

Varietal selection

Select a variety that suits the growing region in terms of season length. Choosing a variety and growing conditions that favour vigorous establishment can help reduce the need to rely on seed or at planting treatments and protect the crop from pests to which no effective insecticidal options are available.

The okra leaf shape reduces the rate at which silverleaf whitefly and two-spotted mite populations are able to increase in cotton.

The Bollgard II trait is ideally suited to IPM as the level of control of Helicoverpa spp. provided by the plant reduces the need to spray for those pests, which in turn lowers the need to spray for other pests.

Seed treatment

Seed treatments provide prophylactic protection against early season/establishment pests. In general they are less disruptive to beneficial populations that spraying the crops with a foliar insecticides because most options available are not very selective. Prior to using a seed treatment be aware of andplan how the resistance risks will be managed.

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.

Create a diversion

Summer trap cropping aims to concentrate a pest population into a smaller less valuable area by providing the pest with a host crop that is more highly 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 Helicoverpa. armierga 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 72) and is recommended by the industry's IRMS for all cotton (page 64).

Build bigger populations of beneficials

Careful farm management and planning can enhance beneficials 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 enables beneficials insects (particularly predators) to be attracted, retained and conserved in the crop. 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 (see Table 1).

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. Planning is required to ensure that introduction can be timely. Lacewings and lady beetles are predators of a range of insect pests, and are highly effective against mealybug where there are no effective insecticidal options. Trichogramma spp. can be purchased and released into crops. Two or more releases one week apart are suggested. If possible the best method is to release the Trichogramma spp. into a nearby flowering sorghum or maize crop rather than into cotton. This will provide the Trichogramma spp. with enough Helicoverpa spp. eggs to carry over the population, given 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.

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 and types of plant damage. The Cotton pest and beneficials guide is available 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 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.

Count pests and beneficials, and measure crop health. These three pieces of information form the backbone for making pest control decisions.

How to sample for pests and beneficials

There are a range of sampling techniques available. Make sure you familiarise yourself with these techniques and use those that are appropriate for the economic threshold, and the crops, pests and beneficials. Refer to the relevant key pest section for more information about recommended technique and monitoring frequency.

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

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

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 mirids, and each sample consists of 20 sweeps along a single row of cotton using a standard (380 mm) sweep net.

It is generally not possible to make a decision about whether control is needed based on just one check. The decision making system needs to be flexible to allow for the action of beneficials and natural mortality. Insect numbers should be recorded either as numbers per metre or as a percentage of plants infested to easily compare numbers with the appropriate industry threshold and to allow a predator to prey or pest ratio to be determined.

How much to check

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.

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

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

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

Note: Increasing the number of samples will increase the level of accuracy. For some pest species there are specific recommendations, see pages 5–37.

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 predator to prey or pest ratio to be determined.

Guidelines for the predator to pest ratio

Predator 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 predator to prey ratio calculated for Helicoverpa spp. may also be enough to manage other secondary pests. Monitor fruit retention and damage in addition to the use of the ratio.

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

The predator to pest ratio is calculated as –

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

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 life stages.

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

TABLE 21: Friends in the field

	Heliothis	Aphid	Mealybug	Spider Mites	Slw	Green Mirid	Jassids	Thrips	Notes
Red and blue beetle	X	X							Also predator of slow moving insects; The larvae feed on small worms and other soil organisms
Lady beetles	X	X	X	X	X		X		Scale insects
Apple dimpling bug (yellow mirid)	X			X	X				While can cause damage, threshold is 5 times greater. 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								and other caterpillars
Predatory shield bug	X								and other caterpillars
Minute pirate bugs				X	X			X	
Assassin bug	X					X			And other caterpillars
Lacewings	X	X	X	X				X	Larvae is the predator, but you need adult to lay on your crop to get the predatory larvae
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

Incorporating parasitoids into spray decisions

Parasitoids are important beneficials in Australian cotton farming systems. These useful insects are easily overlooked because they are often small or secretive. There are a range of parasitic wasps and flies that attack *Helicoverpa* spp., green vegetable bugs, aphids and whiteflies. Recently parasitism of solenoposis mealybug by *Aenasius bambawalei* (Hayat) has been confirmed in Australia. Parasitised mealybugs are easily identified by a dark brown pupal case within the white mealybug.

Trichogramma spp. wasps are egg parasitoids capable of causing high mortality of *Helicoverpa* spp. in-crops. The wasp lays an egg(s) inside a *Helicoverpa* spp. egg and the hatch wasp larva(e) feeds on the egg, preventing hatching. 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).

The predator to prey ratio calculation does not incorporate parasitoids particularly *Trichogramma* spp. (egg parasitoid).

Beneficial insect to pest ratio:

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

The same decision making protocol above is used.

DECISION MAKING PROTOCOL IN CONVENTIONAL AND BOLLGARD II CROPS

Conventional crops

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

Bollgard II crops

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

7. Aim to grow 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 both its yield potential, fibre quality and capacity to compensate for pest damage. While yield (and quality) potential will largely be determined by variety of crop, soil moisture content and irrigation, its agronomic management, and the weather, 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

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present. Acceptable damage levels will vary depending on yield expectations and climatic conditions.

Damage monitoring for pests should be conducted regularly and includes: Leaf area loss or discoloration:

- Tip damage;
- Fruit retention or fruiting factor; and,
- Boll damage.

Refer to key pests 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. It is well documented that excessive early fruit loss can delay final maturity. However, it is also known that holding too much fruit can reduce crop growth, as the plants use their resources to fill the bolls they have set rather than continuing to grow and set more fruit. This is referred to as premature cut-out which results in reduced yield potential.

Cotton development can be predicted using daily temperature data (day degrees). Monitoring crop vegetative and reproductive 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 squaring nodes, vegetative growth rate, fruit development and nodes above white flower can each be tracked to assist with crop management decisions. The user enters real crop data as the season progresses, 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 https://cottassist.com.au/ or through www.myBMP.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% loss of leaf area were affected.

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 squaring nodes above the flower, or 8 NAWF. The bolls produced on these fruiting branches will contribute a large proportion of final yield. Once boll set commences and the crop is 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:

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

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 Cotton Production manual for more information.

Good communication before and during the season is key to successful IPM. (Photo: Amanda Thomas)

First position fruit retention

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

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

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

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

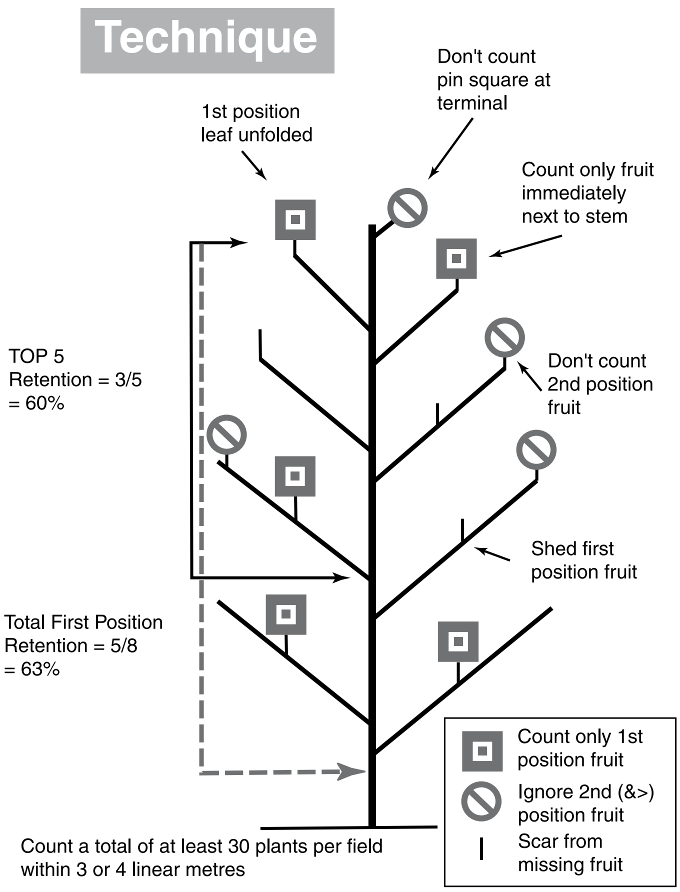
Final retention at maturity

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

Fruiting factor

Fruiting factors allow total fruit load to be monitored throughout the season. Fruiting factors should be used when first position retention falls below recommended levels (i.e. 50–60%), to ensure excessive fruit loss has not occurred or in situations where a crop is heavily tipped out and retention is difficult to determine.

FIGURE 1: A technique for checking fruit retention



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

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

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

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

The ideal fruiting factor 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 control the pests to below threshold levels, thereby avoiding a 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 uses 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 lifestages. 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 64–67)

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, the impact on beneficials table 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, if foraging bees carry residual insecticide back to the hive after the application and 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 151 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.

The use of biopesticides such as NPV, 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% 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

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silverleaf whitefly, as well as assessing spray efficacy.

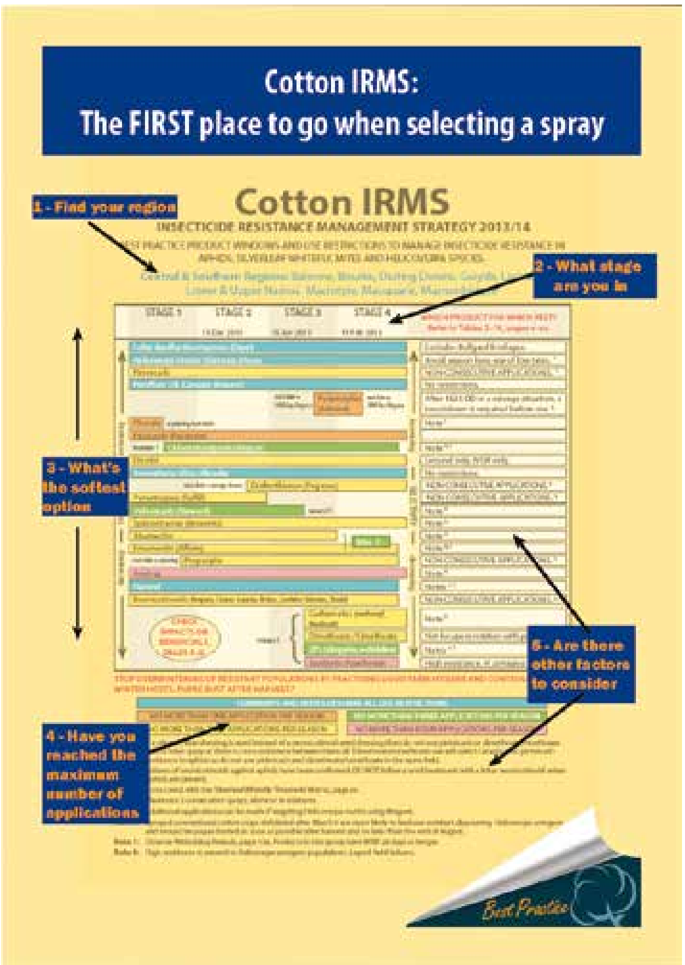
Pests such as aphids and mites often infest the edges of a field, not the entire field area. Consider whether it is possible to manage this type of infestation by only spraying the field borders. This may enable beneficial populations to keep pace with the remainder of the pest population in the field.

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 need to control pests remain effective.

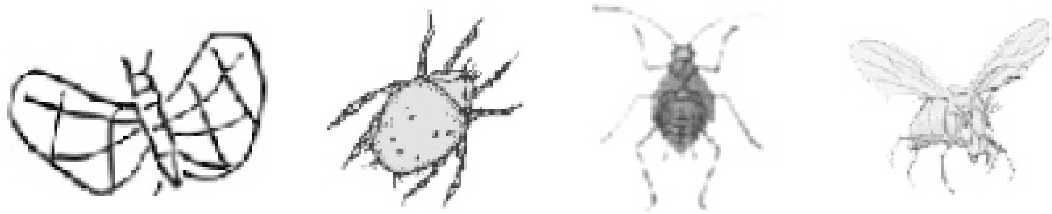
In cotton, where insecticide resistance has been a major problem there are well defined industry sanctioned Insecticide Resistance Management Strategies (IRMS) (pages 64–67). Responsible stewardship of Bollgard II is also important. Refer to the Resistance Management Plan (pages 68–79).

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



Insecticide & Bt Resistance Testing

In-season testing of field populations of



Helicoverpa – Mites – Aphids – Whitefly

Sharon Downes/Lisa Bird
02 6799 1500

Grant Herron
02 4640 6471

Richard Lloyd
07 4688 1315

to monitor changes in resistance across the industry

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Insecticide Resistance Management Strategy (IRMS) for 2013–14

Lisa Bird and David Larsen, NSW DPI
Sharon Downes and Lewis Wilson, CSIRO
Melina Miles, Qld DAFF
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 Bollgard II cotton. Additional resistance management requirements are also in place for managing the risk of *Helicoverpa* spp. developing resistance to Bollgard II (refer to pages 75–79). 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 (refer to page 29).

Checklist

- Use recommended thresholds for all pests to minimise insecticide use and reduce resistance selection. Refer to Table 17 pages 39–40.
- Monitor first position fruit retention at flowering and aim to retain at around 60% or alternatively maintain a fruiting factor of between 1.1 and 1.3. Refer to IPM section page 52.
- 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 64–67).
- 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% 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. In Bollgard II 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 2013–14 IRMS decided?

The development of the Insecticide Resistance Management Strategy is driven by the Transgenic and Insect Management Strategies (TIMS) Committee. 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. They remain rare until they are selected for with a toxin, either from an applied pesticide or from within Bollgard II. Once a selection pressure is applied, resistance genes can increase in frequency as the insects carrying them are more likely to survive and produce offspring. If selection continues, the proportion of resistant insects relative to susceptible insects may continue to increase until reduced effectiveness of the toxin is observed in the field.

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 addition restrictions at side and footnoted. Insecticide groups are listed on page 67. 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.

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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.

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 29, 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 Bollgard II, 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 Bollgard II. 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 Bollgard II cotton.

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

H. armigera is closely linked with cropping regions and the widespread use of Bollgard II may be affecting the size of natural populations of this pest. In most seasons, the majority of moths are locally generated, so Bollgard II 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 Bollgard II, 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, Bollgard II will have little effect on the size of these populations, especially early in the season following the annual spring migration events of this species. However the size of these populations will be strongly influence by the availability of hosts 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 Bollgard II?

Whenever insecticides are used there is selection pressure for resistance. In Bollgard II 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 charts 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 Bollgard II will not change the frequencies of resistance genes being carried by *H. armigera* moths. The same proportion of resistant and susceptible moths will continue to lay eggs in cotton – be it conventional or Bollgard II. Hence the likelihood of resistance development to foliar and soil applied insecticides remains the same, even if the overall size of the H. armigera population is reduced. Continuing to follow the IRMS will ensure that the industry retains the ability to control *H. armigera* effectively with insecticides on conventional cotton both now and in the future The IRMS should always be consulted when making a spray decision, even in Bollgard II cotton.

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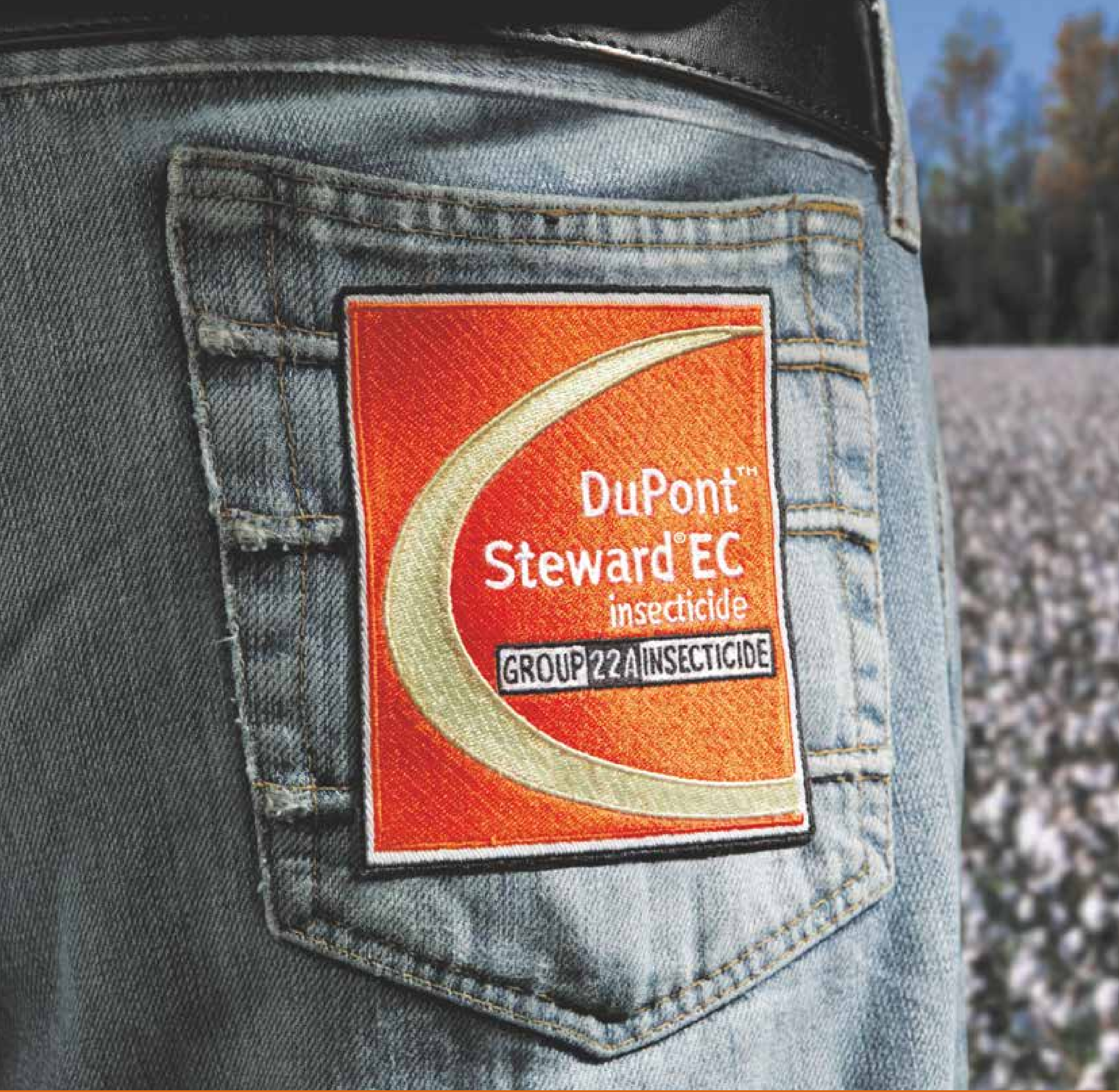

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When do stage windows start and stop?

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

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

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

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

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

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

Yes. Pupae busting is an effective, non-chemical method of preventing resistance carryover from one season to the next. 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 the Cotton CRC website. The model was developed from field research conducted on the Darling Downs by Qld DAFF 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 the 9th March are more likely to harbour insecticide resistant diapausing *Helicoverpa armigera* larvae and should be pupae busted as soon as possible after picking and no later than the end of July.

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

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

The use of mixtures to overcome the effects of resistance requires very careful consideration. 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 (e.g. amitraz and methomyl) in sprays to take the pressure off larvicides. When targeting sprays against eggs and very small larvae do not expect 100% control with any insecticide or mixture of insecticides. If larval numbers are reduced below threshold then the treatment should be regarded as effective. Some mix partners provide more than additive kill (synergism), but this is not always the case. 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. 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

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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 (e.g. if the pests are sick and have ceased feeding).

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

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

If a field failure is suspected to be due to insecticide resistance, collect a sample of the surviving pest from the sprayed field using the industry guidelines and send to the relevant researcher.

- **For Helicoverpa, Lisa Bird (02) 6799 1500.**
- **For mites and aphids, Grant Herron (02) 4640 6333.**
- **For whitefly, Richard Lloyd (07) 4688 1315.**

Sending samples for testing can confirm or rule out resistance as the cause of the spray failure and is an important part of assessing the presence of resistance across the industry.

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

TIMS TROUBLESHOOTING COMMITTEE CONTACTS 2013–14

Name	Telephone	Fax	Email
Lewis Wilson, CSIRO (chair person)	(02) 6799 1550	(02) 6793 1186	lewis.wilson@csiro.au
Tracey Leven, CRDC	(02) 6792 4088	(02) 6792 4400	tracey.leven@crdc.com.au
Greg Kauter, Cotton Australia	(02) 9669 5222	(02) 9669 5511	gregk@cotton.org.au
Lisa Bird, NSW DPI	(02) 6799 2428	(02) 6793 1186	lisa.bird@dpi.nsw.gov.au

Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2013/14

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 2012)	STAGE 3 (15 Jan 2013)	STAGE 4 (15 Feb 2013)	WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2–16, pages 7–38.
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 date = 1450 Day Degrees	Pyriproxyfen (Admiral) end date = 1800 Day Degrees	After 1625 DD in a salvage situation, a knockdown is required before use. [3]
Phorate at planting insecticide				Note [1]
Etoxazole (Paramite)				
December 1 Chlorantraniprole (Altacor)				Note [4,7]
Dicofol				Ground only. NSW only.
Amorphous silica (Abrade)				No restrictions.
start date = canopy closure	Diafenthiuron (Pegasus)			NON CONSECUTIVE APPLICATIONS. [3]
Pymetrozine (Fulfill)				NON CONSECUTIVE APPLICATIONS. [3]
Indoxacarb (Steward)		January 31		Note [4]
Spirotetramat (Movento)				Note [3]
Abamectin			} Max. 3	Note [4]
Emamectin (Affirm)			} Max. 3	Note [4,7]
start date = squaring	Propargite			NON CONSECUTIVE APPLICATIONS. [7]
Amitraz				Note [4]
Fipronil				Notes [4,7]
Neonicotinoids (Amparo, Cruiser, Gaucho, Actara, Confidor, Intruder, Shield)				NON CONSECUTIVE APPLICATIONS. [2,7]
		February 1	Carbamates (methomyl, thiodicarb)	Note [5]
		February 1	Dimethoate / Omethoate	Not for use in rotation with pirimicarb. [1,7]
		February 1	OPs (chlorpyrifos, methidathion)	Notes [4,7]
		February 1	Synthetic Pyrethroids	High resistance, *H. armigera*. [3,4,7,8]

SELECTIVITY: increasing (top) — decreasing (bottom)

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 **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 seed treatment with a foliar neonicotinoid when aphids are present.

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 March 9 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 158. Products in this group have WHP 28 days or longer.

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

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Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2013/14

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 2012) | STAGE 3 (15 Dec 2012) | STAGE 4 (15 Jan 2013)

WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2–16, pages 7–38.

SELECTIVITY: increasing (top) → decreasing (bottom)

Product	Bar colour	Window notes	Restrictions
Foliar *Bacillus thuringiensis* (Dipel)	Blue		Excludes Bollgard II refuges.
Helicoverpa viruses (Gemstar, Vivus)	Blue		Avoid season long use of low rates.
Pirimicarb	Yellow		NON CONSECUTIVE APPLICATIONS. [1]
Paraffinic Oil (Canopy, Biopest)	Blue		No restrictions.
Pyriproxyfen (Admiral)	Orange	start date = 1450 Day Degrees; end date = 1800 Day Degrees	After 1625 DD in a salvage situation, a knockdown is required before use. [3]
Phorate	Orange	at planting insecticide	Note [1]
Etoxazole (Paramite)	Orange		
Chlorantraniprole (Altacor)	Green		Note [4,7]
Amorphous silica (Abrade)	Blue		No restrictions.
Diafenthiuron (Pegasus)	Yellow	start date = canopy closure	NON CONSECUTIVE APPLICATIONS. [3]
Pymetrozine (Fulfill)	Yellow		NON CONSECUTIVE APPLICATIONS. [3]
Indoxacarb (Steward)	Green		Note [4]
Spirotetramat (Movento)	Yellow		NON CONSECUTIVE APPLICATIONS. [3]
Abamectin	Yellow	February 1; Max. 3 (Abamectin + Emamectin)	Note [4]
Emamectin (Affirm)	Yellow	Max. 3 (Abamectin + Emamectin)	Note [4,7]
Propargite	Yellow	start date = squaring	NON CONSECUTIVE. [7]
Amitraz	Pink		Note [4]
Fipronil	Blue		Notes [4,7]
Neonicotinoids (Amparo, Cruiser, Gaucho, Actara, Confidor, Intruder, Shield)	Yellow		NON CONSECUTIVE APPLICATIONS. [2,7]
Carbamates: (methomyl, thiodicarb)	Yellow		Note [5]
Dimethoate / Omethoate	Yellow		Not for use in rotation with pirimicarb. [1,7]
OPs: (chlorpyrifos, methidathion)	Green		Notes [4,7]
Synthetic Pyrethroids	Pink		High resistance, *H. armigera* [3,4,7,8]

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]

- Blue: COMMENTS AND NOTES DESCRIBE ALL USE RESTRICTIONS
- Orange: NO MORE THAN **ONE** APPLICATION PER SEASON
- Yellow: NO MORE THAN **TWO** APPLICATIONS PER SEASON
- Green: NO MORE THAN **THREE** APPLICATIONS PER SEASON
- Pink: 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 seed treatment with a foliar neonicotinoid when aphids are present.

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 March 9 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 158. Products in this group have WHP 28 days or longer.

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

Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2013/14

Explanatory notes for all regions

IRMS Guidelines:

The use of pesticides selects for resistance in pest populations. Many products used in cotton for insect and mite control are efficacious against more than one important pest. In every population of every pest species there will be a small proportion of individuals with the ability to survive an insecticide. 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.

For 2013/14, the IRMS includes all actives commercially available for use in cotton at the time of publication. This means the IRMS should be consulted for EVERY insecticide/miticide decision. This change aims to address the risks of resistance in pests that are not the primary target of the insecticide applicaton and improve the relevance of the IRMS to insecticide use on Bollgard II cotton.

Principles underlying the IRMS

1. Monitor pest and beneficial populations.
2. Use recommended thresholds for all pests.
3. Monitor fruit retention.
4. Comply with all directions for use on product labels.
5. Avoid repeated applications of products from the same insecticide group, even when targeting different pests. Rotate between groups.
6. Do not respray an apparent failure with the same product or another product from the same insecticide group. Rotate to a different group.
7. 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.
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 page 62). For further information contact Greg Kauter, Cotton Australia (02 9669 5222).

How to use the 2013/14 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 2013 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 2013/14 cotton season

In addition to the new layout the following changes to the IRMS include:

- **Restrictions on first foliar spray based on seed treatment.** Neonicotinoid resistance in cotton aphids remains at high levels and there are limited 'soft options' for aphid control. 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.

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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, including seed treatments)		
Thiamethoxam (multiple, including seed treatments)		
Abamectin	GROUP **6** INSECTICIDE	Avermectins
Emamectin (Affirm)		
Pyriproxyfen (Admiral)	GROUP **7C** INSECTICIDE	Pyriproxyfen
Pymetrozine (Fulfill)	GROUP **9B** INSECTICIDE	Pymetrozine
Etoxazole	GROUP **10B** INSECTICIDE	Etoxazole
Foliar Bacillus thuringiensis (Dipel)	GROUP **11** INSECTICIDE	Bt microbials
Diafenthiuron (Pegasus)	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)	GROUP **28** INSECTICIDE	Diamides

Source: CropLife Australia Insecticide Resistance Management Review Group, 2012 http://www.croplifeaustralia.org.au/

Preamble to the Resistance Management Plan (RMP) for Bollgard II 2013–14

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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.

The total area of cotton planted in the 2013–14 season is predicted to remain at the large scale that it increased to in 2010–11 and the Bollgard II acreage will still represent over 90% of the total area planted to cotton in Australia. 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 III, 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 III will directly impact on the requirements for the RMP for that technology. Therefore, it is critical that the industry complies fully and effectively with the RMP for Bollgard II.

The 5 Elements of the Bollgard II RMP

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

Your questions answered

How do we test whether the RMP is effective?

To evaluate the effectiveness of the RMP the CRDC funds a program that monitors field populations of moths for resistance to Cry1Ac and Cry2Ab. Work has also commenced on monitoring field populations of moths for resistance to the new vip3A gene contained in Bollgard III 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 Bollgard II and the potential risk of resistance developing to Bollgard III. 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 are conducted. F2 screens involve testing the grandchildren of pairs of moths raised from eggs collected from field populations, and therefore take about 10 weeks to run. To increase the number of insects that could be processed during the season, CSIRO developed protocols for testing the frequency of the Cry2Ab resistance gene detected with F2 screens using a shorter method called an F1 test. F1 screens involve testing the offspring of single-pair matings between moths from resistant strains maintained in the laboratory and moths raised from eggs collected from field populations. They take around 5 weeks to conduct.

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

A gene is present in field populations of *H. armigera* that has the potential to confer high-level resistance to Cry1Ac. CSIRO and Monsanto data suggests that this gene occurs at a low frequency which is probably less than 5 in 10,000 (<0.0005or 0.05%). This gene does not confer cross-resistance to Cry2Ab and in certain environments is largely recessive. It also has a high fitness cost (i.e. resistant individuals develop slowly and are more likely to die) but this disadvantage is not likely to greatly impact on the development of resistance. In addition, Dr Robin Gunning (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 gut of the insect. F2 tests indicated that the frequency

H. armigera. (Melina Miles, Qld DAFF)

of the gene for resistance to Cry2Ab in 2012–13 was 1 in 100 (0.01, 1%) or less.

In 2004 CSIRO developed protocols for testing the frequency of resistance using a modified and shorter version of the F2 method called an F1 test. This method assumes that the various isolates of Cry2Ab detected so far are of the same kind. These protocols were immediately adopted by Monsanto. During the following two years CSIRO performed experiments which verified that the same mechanism appears to confer resistance in all of the isolates of Cry2Ab detected to date. In 2007–08 CSIRO began F1 tests in *H. armigera* in earnest. Results with *H. armigera* show that the estimate of Cry2Ab resistance frequency for F1 screens.

At the end of the 2012–13 season is approximately 2 in 100 (0.02, 2%). Currently, we believe that the frequencies obtained from the F1 screens are likely to most accurately reflect the situation in the field.

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 a five 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 ats less than 1 in 1000 (0.001, 0.1%). It is not cross-resistant to Cry2Ab.

A gene that confers high level resistance to Cry2Ab is present in field populations of *H. punctigera*. This gene does not confer cross-resistance to Cry1Ac. The most extensively studied colony of resistant insects (called Hp4–13) demonstrates the same broad characteristics as the SP15 strain of Cry2Ab resistant *H. armigera*. The resistance is recessive, occurs at a high level, and is due to an alteration of a binding site in the gut of the insect. F2 tests indicated that the frequency of this gene in 2012–13 was 1 in 100.

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 2012–13 season, the frequency of Cry2Ab genes in *H. punctigera* was approximately 12 in 1000 (0.012, 1.2%).

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%) compared to a sample from cropping populations collected at the same time (5 in 100, 0.05, 5%). 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* 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 9 in 1000 (0.009 or 0.9%).

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%) before declining to 1 in 100 (0.01, 1%) in 2012–13. The complete data set continues to demonstrate a significant 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 2012–13 the Cry2Ab resistance frequency is at a similar level to that recorded in 2008–09 (7 in 1000, 0.007 or 0.7%). If the probable overestimation in frequency last season 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 2012–13 are lower than those detected in 2008–09. From 2009–10 until 2011–12 there was a gradual increase in frequency from 1 in 100 (0.01 or 1%) to 4 in 100 (0.04 or 4%) but in 2012–13 the frequency declined to 15 in 1000 (0.015 or 1.5%). The shifts in F1 screen data from 2007–08 to 2012–13 mirror those of the F2 screen data, however since the data set is restricted to the last four years only, it is not possible to look for longer term shifts over time. 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 1000 (0.012 or 1.2%).

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.

H. punctigera**.** **(Melina Miles, Qld DAFF)**

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%). This estimate is based on both F2 screens and F1 screens; unlike the situation for Cry2Ab, there is no significant difference among the frequencies obtained with both methods and therefore the frequency reported is from the pooled data. The frequencies of Vip3A resistance alleles in *H. armigera* obtained from F2 screens are higher than those for *H. punctigera*, at 3 in 100 (0.03, 3%). 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 and F2 screens of 1 in 100 (0.01 or 1%). The estimate of Vip3A resistance frequency for *H. punctigera* based on F1 and F2 screens is also 1 in 100 (0.01 or 1.0%).

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. Note that the RMP will continue to be the document that informs growers of their responsibilities in managing Bollgard II cotton while the contingency plan will contain other mitigation strategies that may be introduced into the RMP.

1. Refuges

What is the purpose of refuges?

The aim of refuge crops is to generate significant numbers of susceptible moths (SS) that have not been exposed to selection pressure from the Bt proteins. 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% unsprayed cotton was considered as the reference point. On average pigeon pea produced twice as many moths as the same area of unsprayed cotton, hence a 5% refuge, half that of an unsprayed cotton refuge, is required for this crop. Initially, sorghum and corn were included as refuge options in the RMP because they were effective at producing *H. armigera* 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?

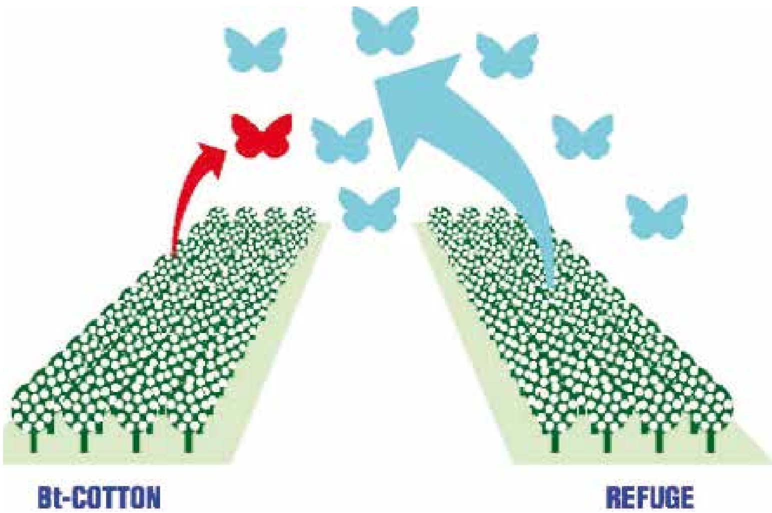
It is possible to combine more than one type of refuge, provided that the total requirements for area equivalence are met. For example, 1 hectare of pigeon pea can be grown alongside 1 hectare of unsprayed cotton, rather than 2 hectares of either. Each type of refuge must be managed so that it is productive 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 dryland Bollgard II and irrigated Bollgard II?

For dryland Bollgard II crops the only available dryland refuge options are sprayed or unsprayed cotton.The reason for this



Moths produced from refuges dilute resistance genes in the population.

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 dryland 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 dryland conventional cotton treated and not treated by slashing as a potential refuge option. There are also irrigated refuge options for dryland Bollgard II cotton. These options are sprayed or unsprayed irrigated cotton and unsprayed irrigated pigeon pea, and were chosen because to date they have been the most widely adopted refuges for irrigated Bollgard II.

How can the 'effectiveness' of an individual refuge be evaluated?

The productivity of refuges will vary considerably across regions and seasons. It is not possible to place a value on the effectiveness of each refuge. Looking after refuges, including nutrition, weed control, timely irrigation and all factors that make the refuge 'attractive' to female moths laying eggs, is the key to ensuring that they are effective. Managing resistance is a population level activity, and every refuge makes an important contribution to the overall RMP for the valley, and because *Helicoverpa* spp. disperse widely, on a larger scale for the whole industry. 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. This measure effectively restricts the selection pressure on *H. armigera* to develop resistance to Bollgard II.

Is it possible to vary the Bollgard II planting window?

Where exceptional circumstances exist, requests for a variation to the planting window will be considered. In the past Monsanto approached the APVMA on behalf of a grower or Cotton Grower's Association to consider requests. From 2006–07 onwards, the TIMS Committee will consider requests. Requests must satisfy a number of criteria as outlined in the 'Request for variation to the Bollgard II planting window' document, found on page 74. If a request is approved, the variation only affects the planting window component of the RMP for the requestee/s for the current season. All other components of the RMP remain the same.

4. No Bt sprays

Why is it important that foliar Bt sprays are not used on refuges?

By preventing the use of foliar Bt on all refuges (sprayed and unsprayed), the likelihood of producing moths that are susceptible (SS) rather than resistant (RR) to Bt is maximised. This is an important part of the RMP because susceptible refuge moths are presumed to mate with any resistant moths in the population to produce heterozygotes (RS) that are killed by Bollgard II.

With regard to refuge crops, what does the term 'unsprayed' mean?

The term 'unsprayed' encompasses all management activities which are likely to reduce the survival of Helicoverpa in these crops. Insecticides with activity against Helicoverpa cannot be used in unsprayed refuges. Food sprays cannot be used in unsprayed refuges as these aim to reduce Helicoverpa survival through increased predation and parasitism. Similarly, Trichogramma and other biolocial control agents cannot be released in unsprayed refuges as they too aim to reduce Helicoverpa survival.

5. Pupae destruction

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

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

Am I required to pupae bust in my refuges?

Refuges must produce moths during the cotton season when Bollgard II is grown but unsprayed refuges can continue to provide benefits for resistance management by being left in place until the following spring. By doing this any pupae produced in the autumn may be carried over the spring and provide additional genetic dilution of resistant survivors. Once Bollgard II crops begin flowering and are highly attractive to Helicoverpa moths, the corresponding refuge should not be cultivated (e.g. 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 2010–11 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% square loss at early flowering, up to 100% square removal alone or in combination with 30% boll damage at peak flowering, and 30% 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 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 59–67). The predator/pest ratio (described on page 11) 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.

Our last line of defence.

Pupae bust in winter to slow down resistance
Because we are in this together
www.mybmp.com.au

Best Practice

GUIDELINES FOR AMENDING BOLLGARD II PLANTING WINDOWS 2013–14

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

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

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

Process

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

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

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

Criteria for assessing the application to change a planting window

1. The Cotton Growers Association (CGA) must request and approve the change with a majority vote (an absolute majority is more than 50% of all CGA members eligible to vote).
2. The majority decision affects TUA compliance for all licensed growers. This means that all growers, even the minority that voted against the change, must abide by the majority decision. The CGA must advise all growers of the outcome of the vote, and their obligation to abide the decision. Evidence in writing of this process will be required from the CGA, together with the information requested below.
3. The region (or individual grower) requesting the variation is more than 100 kms from any other significant Bollgard II® planting.
4. Planting of Bollgard II® in the region requesting the variation has not exceeded 10% of the anticipated Bollgard II® cotton area.
5. No Bollgard II® cotton has been planted in excess of 21 days prior to the opening of the new window.
6. There are no known threats to the efficacy of refuges in the region (e.g., plague locust pressure).
7. The requested planting window variation must be a 42 day window that falls entirely within the period September 1 to December 31.

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

1. Detailed description of the reasons for the request.
2. Proposed new window start and finish dates.
3. Map or description of the region concerned.
4. Distance of the relevant region to nearest neighbouring cotton.
5. Time of first Bollgard II® cotton planted in the region.
6. Area of Bollgard II® already planted in the region.
7. Projected total area to be planted to Bollgard II® in the region.
8. Statement confirming that all cotton growers in the region, even those that voted against the change, will abide by the requested changes to the window.
9. Statement confirming that all cotton growers in the region acknowledge that they must meet the pupae busting requirements in the RMP even when a later planting window is requested.

TIMS Committee, C/- Greg Kauter, Cotton Australia Ltd. Suite 4.01, 247 Coward St., Mascot NSW 2020.
Ph: 02 9669 5222 M0b: 0429 700 711 E: gregk@cotton.org.au

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2013–14

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.

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% unsprayed cotton refuge or its equivalent, as determined by the relative production of *Helicoverpa* spp. from each of the refuge types as described in Tables 1 and 2, for irrigated and dryland production scenarios respectively. 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 1: Irrigated Bollgard II cotton refuge options

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

TABLE 2: Dryland Bollgard II cotton refuge options

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

No other refuge options are approved for dryland 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. moths.

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2013–14

New South Wales, Southern Queensland & Central Queensland (continued)

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.

Dryland: A dryland 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 2km 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.

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

(i) Refuges for dryland 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 dryland Bollgard II crop, then that refuge may be planted in a solid configuration. Dryland cotton is measured as green hectares (calculated as defined in the Technology User Agreement).

2. Control of volunteer and ratoon cotton

Volunteer and ratoon cotton may impose additional selection pressure on *Helicoverpa* spp. to develop resistance to the Bt 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 2013–14

New South Wales, Southern Queensland & Central Queensland (continued)

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.

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. Dryland 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% 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% 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 **	35kg/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% 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% 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 10cm 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 (e.g. before November) or too late (e.g. 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% 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 68–73).

SCHEDULE A – RESISTANCE MANAGEMENT PLAN FOR BOLLGARD II COTTON 2013–14

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% 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:

TABLE 1: 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 2013–14

Ord River Irrigation & Burdekin Bowen Basin & Richmond areas (continued)

(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 2km 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. Table 2 shows the requirements for the chick pea trap crop.

TABLE 2: End of season chick pea trap crop requirements

Criterion	End of season chick pea trap crop
Minimum area & dimensions	A trap crop of 1% 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

Establishing and growing an attractive, refuge is a critical, mandatory component in the Resistance Management Plan for Bollgard II. The aim 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 ll cotton crops.

The following information is intended to assist growers establish and maintain effective pigeon pea refuges. It is not part of the Resistance Management Plan (RMP) and growers should also refer to the RMP for guidance on refuge requirements.

While pigeon pea is a hardy, deep-rooted crop typically grown in dryland situations, it is not currently offered as a dryland refuge option because establishment and timing and duration of flowering can be problematic. Research is exploring the use of pigeon pea within a dryland environment as a refuge option.

Planting

Field selection

Pigeon pea can be grown on a wide range of soils, however is very susceptible to waterlogging, so select fields with good surface and internal drainage. Avoid areas where water tends to back up after irrigation and/or heavy rainfall.

The presence of Bollgard II volunteers/ratoons cannot be tolerated in refuge crop areas. This will diminish the value of the refuge and may impose additional selection pressure to *Helicoverpa* species. All refuges should preferably be planted into a fallow or rotation fields that have not been planted to cotton in the previous season so as to avoid the likelihood of ratoon or volunteer cotton in refuges. Avoid fields where Bollgard II was the most recent crop and there is a high risk of ratoon cotton (ie there were difficulties with crop destruction).

Refuges should be planted on one side of, or next to, a Bollgard ll field. 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. To minimise the possibility of herbicide drift, pigeon pea refuges should be separated from herbicide tolerant Bollgard ll cotton crops by a sufficient distance to minimise drift but not more than 2km from the Bollgard ll cotton.

Nitrogen fixation by legumes such as pigeon pea is optimal in soils with very low residual soil N. Field selection should take this into consideration.

As with many other legumes, pigeon pea has been shown to have allelopathic properties which may inhibit the growth and performance of the following season's crop. This should be taken into account if large fields are planted.

Timing

Pigeon pea requires a minimum soil temperature of 17°C and rising (similar to mungbeans and soybeans). Depending on location, this will normally occur in October-November. Pigeon pea is a photoperiod sensitive plant, and there is a wide range of flowering times among varieties. Therefore, choice of variety and sowing date will strongly affect when it flowers.

Variety

Quest is currently the only variety available for refuge purposes. There is on going research to identify improved varieties, particularly for Northern cotton growing areas.

Given the usual planting time for cotton refuges, Quest takes 65 to 80 days to flower. With the right conditions it will continue to flower for a long period. To ensure Quest is attractive to *Helicoverpa* spp. during the same period of time that cotton is attractive (flowering), refuges should be planted 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*.

*See RMP for details.

Row spacing

As pigeon pea is only available for use as a fully irrigated refuge option in the RMP, the maximum row spacing is 1.0 metre.

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

Unsprayed pigeon pea refuge agronomy

Where cotton is grown on a row spacing narrower than 1.0 metre, the row spacing for pigeon pea should match that of the cotton for which it is a refuge.

Seeding rates

To maintain attractiveness, it is important to comply to the required plant stand of not less than 4 plants per square metre. Higher plant populations tend to produce plants with thinner stalks, making crop residues easier to handle. Evenly spaced, lower plant populations can still be attractive and tend to produce larger plants that flower for longer and can cope better with water stress.

Seed germination percentages can vary greatly (<30% to >80%). Growers are advised to have a current germination test for either purchased or farm-saved seed. The proportion of hard seed can also influence the number of plants established, often above expectations.

Seed size is normally in the range of 6,000–10,000 seeds/kg. Generally a sowing rate of 25–40 kg/ha is used, but allowances must be made for planting conditions and seed quality.

Seed bed preparation and planting

Ensure seedbed preparation is reasonable to avoid replants. Reasonable preparation is described as that in which seed is sown to a depth of no more than 5cm. 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 choosing to water up the refuge with the rest of the field, then replant into this moisture if a replant is required.

Inoculum and fertiliser

Pigeon pea requires inoculation with Group J inoculant. To ensure efficacy of inoculant, follow all label requirements and directions regarding storage, handling and application. Nodulation will be limited in high nitrogen soils. A well-grown crop of pigeon pea can add up to 38kg/ha of nitrogen. However grown in soils with moderate to high background nitrogen, pigeon pea can leave the soil depleted 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.

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 or Uptake at 500 mL/100L 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)
Flumetsulam	B	800 g/kg	25–50 g/ha + wetter	Post plant, pre emergent. Minimum spray volume 150 L water.
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 mL/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.

Weed management

Pigeon pea grows slowly, particularly when planted into low soil temperatures. Therefore will be a poor competitor with weeds.

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 ll cotton begins to flower the corresponding refuge should not be cultivated. The presence of Bollgard ll volunteers/ratoon cotton in any refuge will diminish the value of the refuge and must be removed as soon as possible.

Irrigation

Pigeon pea is extremely sensitive to waterlogging, and flood irrigation is generally not ideal for this crop. However it is the most common form of irrigation and growers need to be manage this carefully, for example, it is advisable to delay irrigating if heavy rain is predicted. Practices such as watering every second row, can be useful in supplying water to the crop, while reducing the risk of waterlogging by leaving room in the soil profile to make use of rainfall.

While pigeon pea generally requires less irrigation water than cotton, it is important to ensure crops do not become water stressed as this will impact on attractiveness. Flowering will be delayed under periods of extreme moisture stress and this situation appears to be one of the biggest problems facing an efficient refuge system. If there is moisture present, pigeon pea will respond very quickly with attractive regrowth after insect attack.

Destruction and harvest of pigeon pea refuge crops

Harvest or destruction of aerial parts of a pigeon pea refuge should only be carried out after Bollgard ll lint removal has been completed. 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 ll 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.

The pigeon pea refuge can be harvested with the aim of recouping refuge planting seed for the following season. No crop product or crop residue is to be fed to livestock. To ensure viability for planting, focus on preserving quality. Harvest at 13.0% grain moisture for optimum seed quality. Rotary harvesters with low drum speeds (350-400 rpm) give best results. Crop dessication may be required.

**Every refuge counts.
Moths don't recognise farm boundaries.**

Photo: Annie Johnson

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Herbicide resistance in Australian cotton farming systems

Susan Maas, Ian Taylor, Tracey Leven, CRDC
Jeff Werth, David Thornby, DAFF Qld
Graham Charles, NSW DPI I

Introduction

Herbicide resistance is now a real issue for the Australian cotton industry, with glyphosate resistant weeds being detected in both irrigated and dryland cotton situations. Throughout the world there are currently 218 species (129 dicots and 89 monocots) of weeds with herbicide resistance and resistance in 21 of the 25 known herbicide modes of action (International survey of herbicide resistant weeds, 2013). Herbicide resistance continues to impact Australian agriculture since it was first reported in annual ryegrass in 1982. Resistance to many modes of action have been documented in Australian production systems and is now a key constraint to crop production.

Resistance has been confirmed in thirty-six weeds in Australia. In the cotton growing areas populations of 4 common grass weeds – awnless barnyard grass, liverseed grass , windmill grass and annual ryegrass – and one broadleaf species -flaxleaf fleabane have resistance to glyphosate. Cases of multiple resistance have also been reported where for example, annual ryegrass proves resistant to two or more chemical groups. Research undertaken in two recent projects on herbicide resistance, has reviewed the propensity of 200 weed species to evolve and change in response to continued selection by herbicides. The top ten weeds relevant to most cotton systems have been summarised in Table A.

Several species that aren't important in-crop are at high risk of resistance in other situations on cotton farms, such as in dams and channels. Cumbungi (*Typha* spp, score 7.0) and arrowhead (*Sagittaria montevidensis*, score 6.9) are the most important of these. Parthenium weed (*Parthenium hysterophorus*, score 6.9) can occur in non-crop areas and is also at risk. It is important to

TABLE A: Top 10 species at risk of developing herbicide resistance with relevance to cotton farming systems.

Common name	Botanical name	Score (out of 10)
Sweet summer grass	*Brachiaria eruciformis*	8.1
Flaxleaf fleabane	*Conyza bonariensis*	7.6
Liverseed grass	*Urochloa panicoides*	7.2
Feathertop Rhodes grass	*Chloris virgata*	7.0
Awnless barnyard grass	*Echinochloa colona*	6.9
Barnyard grass	*Echinochloa crus-galli*	6.9
Cobbler's pegs	*Bidens pilosa*	6.9
Common sowthistle	*Sonchus oleraceus*	6.9
Milkweed	*Euphorbia heterophylla*	6.9
Crowsfoot grass	*Eleusine indica*	6.3

Adapted from Weeds to watch out for!: 200 Australian weeds and their risk of evolving herbicide resistance; David Thornby, Jeff Werth, and Joe Vitelli (Qld DAFF) http://glyphosateresistance.org.au/media%20releases/article_120703_Weeds%20to%20watch%20out%20for.pdf.

remember that there is no relationship between resistance risk and weediness, invasiveness, or ease of control. Despite being at low risk of resistance, some low scoring species are nevertheless important and highly prevalent weeds, both of cropping (eg nutgrass, bladder ketmia) and non-cropping areas (eg salvinia, alligator weed).

No major new mode of action herbicide has been discovered for over 30 years., but a number of older products are being withdrawn for a variety of reasons. As the number of effective products is reduced, it is now more important than ever to approach weed management with a strategy that invests in successful weed control this year and for the long term.

How does herbicide resistance occur

Weed populations can contain a large amount of natural genetic diversity and it is likely that within the population a small number of individuals exist that are able to survive exposure to a particular herbicide group due to their genetic makeup. When a herbicide from this group is used, many of these individuals survive and set seed, whereas the majority of susceptible plants are killed. Continued use of the same type of herbicide will result in an ever-increasing proportion of the population being able to survive those herbicide applications. Herbicides have been grouped according to their mode of action (the way they work) and the resistance risk. Some of the factors that can influence the evolution of resistance include:

- **How often an herbicide or mode of action group is applied to a weed population –** The higher the frequency of use, the higher the selection pressure and the greater the risk of herbicide resistance developing.
- **The biology and density of the weed –** Weed species that produce large numbers of seed, emerge in dense populations, and have a large amount of natural diversity are more likely to evolve to resistance.
- **Mode of action –** The frequency of genes with resistance to some herbicide groups, such as Groups A and B is quite high, and therefore resistance risk is quite high. Refer toTable B.
- **Intensity of selection pressure –**The more weeds that are present, the more likely that an individual containing herbicide resistance genes will be present and hence likely to become a problem. The fewer times a different method of weed control (another type of herbicide or a non-herbicide tactic) is used, the more pressure there is for the weed population to evolve resistance to the most commonly-used herbicide.

TABLE B: Years of herbicide application before resistance evolves.

Herbicide group	Years of application	Herbicide resistance risk
A (Fops, Dims, Dens).	6-8	High
B (SUs: Glean, Ally. IMIs: Flame, Spinnaker)	4	High
C (atrazine, prometryn, fluometuron).	10–15	Medium
D (trifluralin, pendamethalin)	10–15	Medium
F (norflurazon)	10	Medium
I (phenoxies)	not known	Medium*
L (paraquat/diquat)	15+	Medium*
M (glyphosate)	15+	Medium*
N (glufosinate)	not known	Medium*

Adapted from Preston et al, 1999

- **Preventing seed set of survivors by effective control with a different tactic –** after the application of a herbicide, the control of survivors through use of a follow up tactic such as cultivation, chipping, or alternative mode of action herbicide, will prevent or significantly delay resistanceevolution.

How long does herbicide resistance last?

The challenge with herbicide resistant weeds is that you can't tell by just looking that they are resistant. This means that if a survivor of a herbicide spray is allowed to set seed, then the resistance will last at least until all those seeds either germinate and are controlled before they can set seed, or remain in or on the soil and die. Where germination does not necessarily occur all in the same flush, this can mean that groups of resistant weeds are germinating over a season, or over years. If this next generation is able to set seed, the resistance will continue through to a third generation, even if selection pressure isn't applied again.

What does herbicide resistance look like?

Herbicide resistance is normally present at very low frequencies in weed populations before the herbicide is first applied. Using

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)

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

the herbicide creates the selection pressure that increases the resistant individuals' likelihood of survival compared to 'normal' or susceptible individuals. The underlying frequency of resistant individuals within a population will vary greatly with weed species and herbicide mode of action. Resistance can begin with the survival of one plant and the seed that it produces. Early in the development of a resistant population, resistant plants are likely to occur only in 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. Options are much more limited if resistance has spread over large areas before it is diagnosed. 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. Evaluate your risk of resistance, the higher your risk the more a further investigation of possible resistance is warranted.

What are my glyphosate resistance risks?

Start by taking the self assessment on this page. The more questions to which you have confidently answered 'Yes', the more a further investigation of possible resistance is warranted.

You can now assess the level of risk of your own practices via the online risk assessment tool. 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 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 Glyphosate Resistance Toolkit is available online through www.myBMP.com.au or Qld DAFF website. The toolkit also contains a herbicide resistance quiz which explains the important drivers in herbicide resistance development.

If you have answered 'Yes' to most of the questions, including 8–10 on field history, or the glyphosate resistance toolkit has indicated your practices and/or species are at high risk, take action:

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

Note that a low risk level only means that resistance is unlikely to develop in this scenario. Resistant weeds can still come in through contaminated machinery, water, seed etc. Resistance doesn't need high-risk practices to occur, it can just be a result of bad luck, like a header breakdown that introduces resistant seeds!!

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

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

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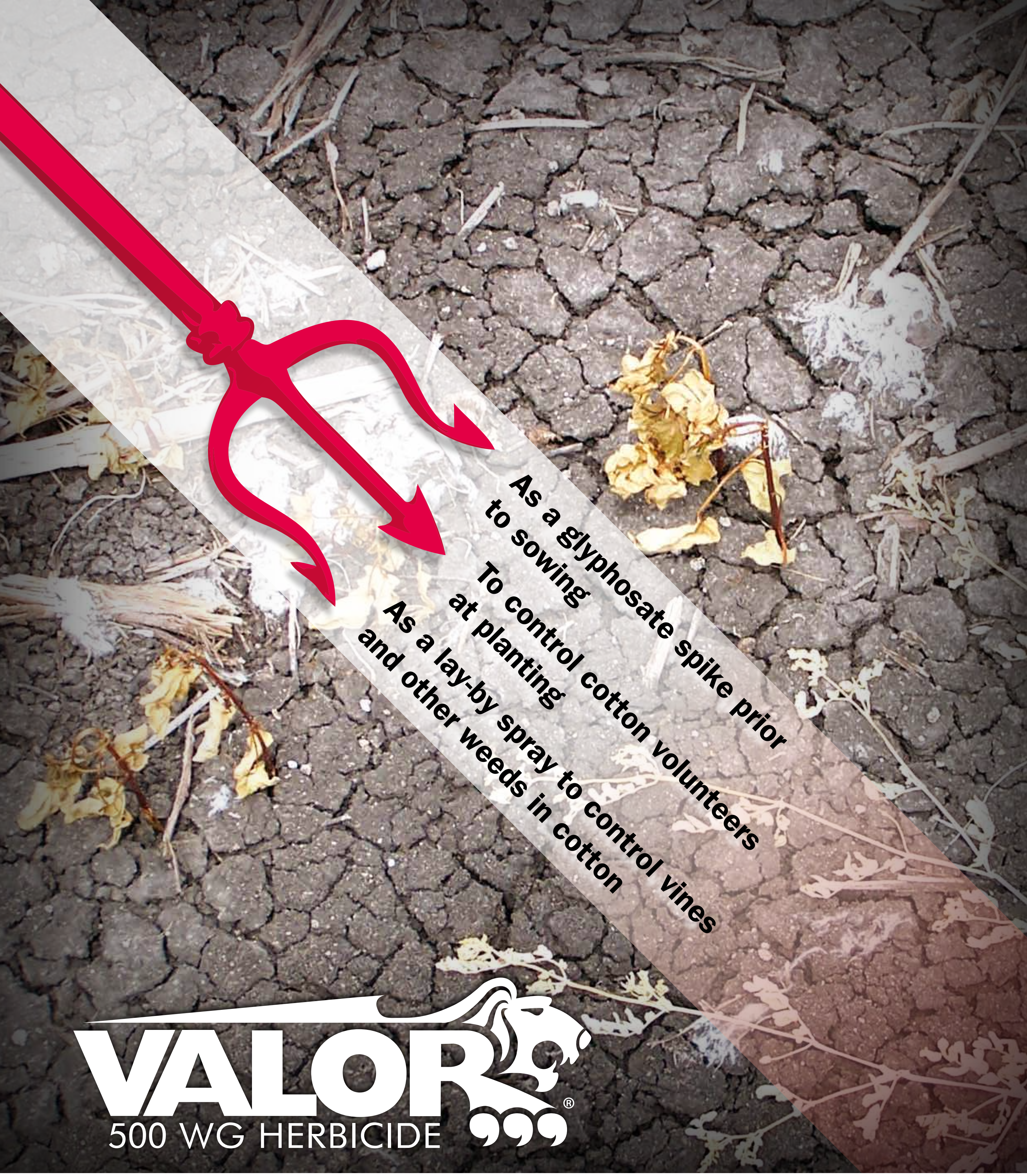

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and is sent for testing. However, the dormancy mechanism in some species, such as barnyard grass, creates problems with this process. It is difficult to get sufficient quantities of seed to germinate uniformly in short time frames. An alternative sampling 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.

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.
- Bash seed heads into a bucket to ensure only ripe seed in collected.
- Store samples in a paper bag at room temperature, away from sunlight, moisture and heat. Post as soon as possible.

Collecting plant samples for the Quick test:

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

Sending samples to resistance testing services

Follow the instructions above and send samples together with 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@plantscience consulting.com
Website: www.plantscienceconsulting.com

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

What is species shift?

Species shift refers to a change in the spectrum of problem weeds in a system due to reliance on a particular tactic. For example no-till systems favour small seeded weeds that germinate from on or near the soil (top 20mm). such as fleabane and sow thistle. These weeds become problematic as they are no longer being controlled by cultivation and seed burial. While species shift is different to herbicide resistance, it can be an early sign that the system is too reliant on a small number of tactics.

How do I manage glyphosate resistant weeds?

Experience tells us that even where some species have developed resistance to glyphosate, glyphosate remains an important weed management tool in the system. The key is to focus on how glyphosate is supported by other tactics. 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 seedbank, and prevent further seed set/recruitment.

Integrated weed management (IWM) is the term used to describe the strategy to not only manage existing herbicide resistance and prolong the use of life of each herbicide, but also reduce the rate of species shift, manage the cost of future weed control by depleting the number of weed seeds in the soil, and of course help to improve crop productivity through effective weed management. Refer to Weed management tactics – tool box for Australian cotton for more information.

For more information:
Australian glyphosate sustainability working group http://www.glyphosateresistance.org.au/
CropLife Australia Mode of actions http://www.croplifeaustralia.org.au/default.asp?V_DOC_ID=1954

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Weeds to watch out for!

Common weeds of cotton with a high risk of developing herbicide resistance

Make herbicide decisions early – target young growth stages

Too late for glyphosate – control before seed set

SWEET SUMMER GRASS

FLAXLEAF FLEABANE

LIVERSEED GRASS

FEATHER TOP RHODES

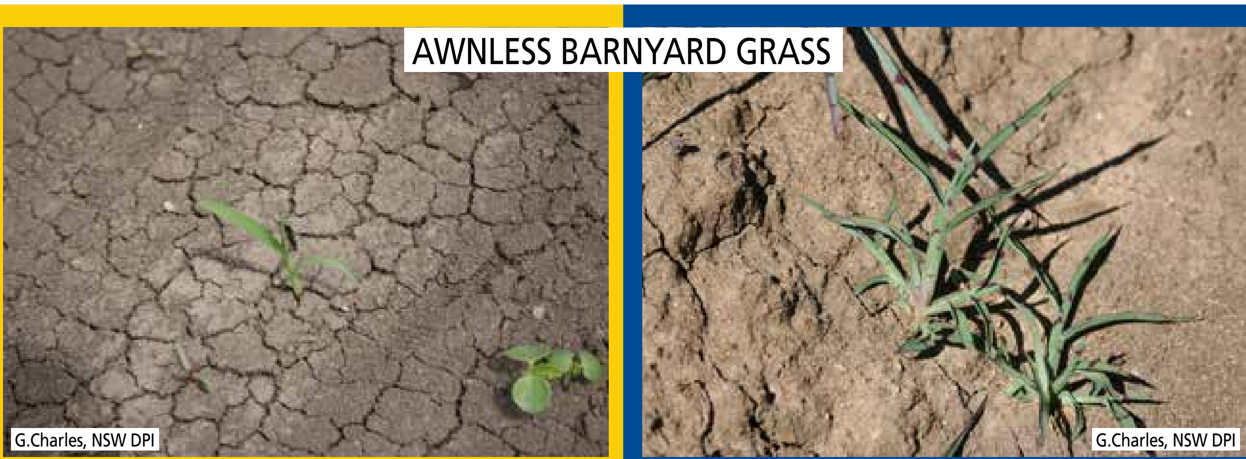
Weeds to watch out for!

Common weeds of cotton with a high risk of developing herbicide resistance

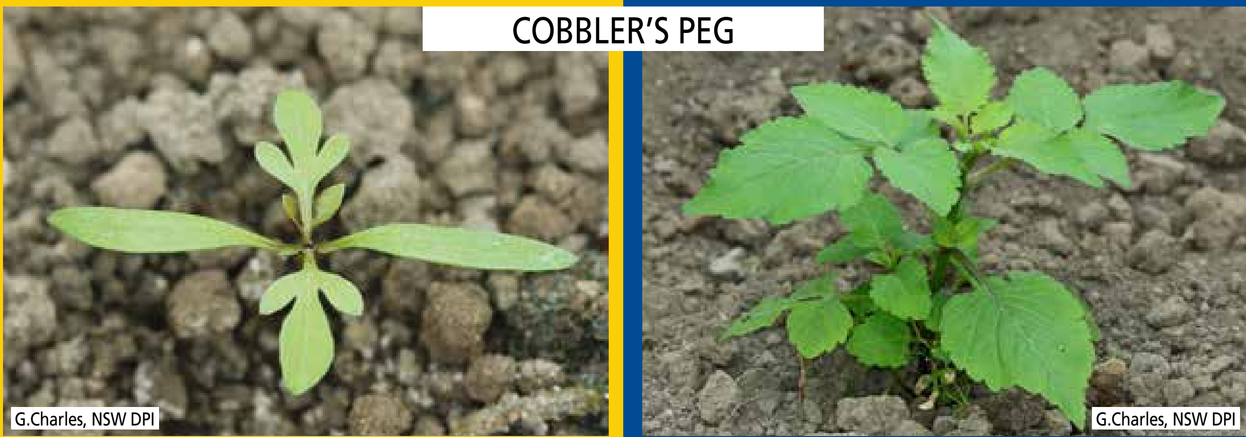
Make herbicide decisions early – target young growth stages

Too late for glyphosate – control before seed set

AWNLESS BARNYARD GRASS



COBBLER'S PEG



COMMON SOWTHISTLE

MILKWEED

Weed management tactics for Australian cotton

Susan Maas, Ian Taylor, Tracey Leven, CRDC
Jeff Werth, David Thornby, DAFF Qld
Graham Charles, NSW DPI I

Formula to prevent manage/delay glyphosate resistance (2+2+0)

Extensive modeling of potential glyphosate resistant risks has found that irrespective of whether a farm is irrigated or dryland, 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 fallow targeting both grasses and broadleaf weeds

+

0 glyphosate survivors allowed to set seed

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

Develop a strategy

It is important to strategically plan how the 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.

There are five principles in developing a successful long term approach to weed management:

- Know the weed spectrum and conduct monitoring.
- Use a diversity of in-crop and fallow management tactics to actively reduce seed bank, as well as prevent emerged weeds from surviving through to seed set (see 2+2+0 formula).
- Rotate herbicide mode of action.
- Monitor and follow up to ensure weeds that survive a herbicide are controlled by another tactic before they are able to set seed.
- Come Clean Go Clean to prevent movement of weeds seeds on, off or around the farm.

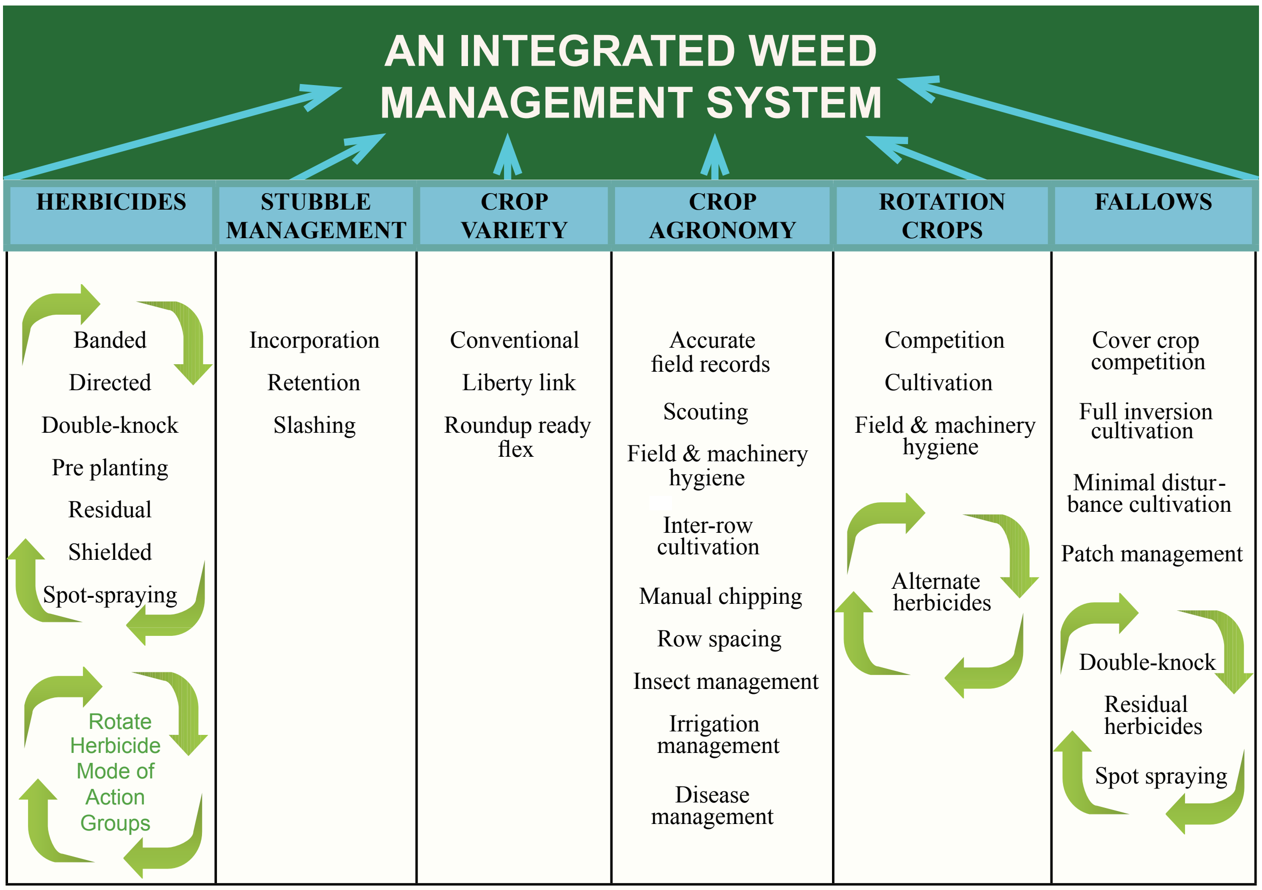
Deployment of tactics recognises the full range of farming system's inputs that impact on weeds and the interactions of these inputs, as shown diagrammatically in Figure 7.

Critical success factors for using tactics

Correct weed identification

Ensure that weeds are correctly identified before deciding upon

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



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USE ROUNDUP READY® HERBICIDE WITH PLANTSHIELD®

TO PROTECT AN OVER-THE-TOP COTTON YIELD.

Weed control in the first 8 weeks following emergence maximises the yield potential of a cotton crop. Roundup Ready® Herbicide with PLANTSHIELD® is the only product registered for over-the-top use in cotton that is covered by Monsanto's warranty as part of the Technology User Agreement (TUA).

Roundup Ready Herbicide with PLANTSHIELD is:

- **An easy to use 690g/kg dry glyphosate formulation**
- **Does not require additional surfactant**
- **Specially formulated to reduce spray drift and limit off target application**
- **Made in a dedicated glyphosate production facility which meets Monsanto's manufacturing specifications and quality assurance testing, avoiding the risk of contamination and reduced crop safety**

To ensure sustainable results and an over-the-top yield, Roundup Ready Herbicide with PLANTSHIELD should be used as part of an Integrated Weed Management (IWM) program.

Sinochem Australia are proud supporters of the Weedsmart Initiative

WEED smart
every weed every seed
every farm every year

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a response. Similar species may respond differently to control measures. For example, the strong seed dormancy mechanisms of cowvine (*Ipomoea lonchophylla*) make it less responsive to a tactic like the spring tickle than bellvine (Ipomoea plebeia) which has very little seed dormancy. Herbicide susceptibility can also differ between similar species.

The Weed Identification and Information Guide through the www.mybmp.com.au is a powerful tool to assist weed identification. Unknown weeds can be identified by scrolling through the collections of pictures and the supporting text. The picture collections include seedling, flowering and mature growth stages as well as close up images of seeds for over 100 of the weeds that commonly occur in cotton. Additional weeds and more detailed biology and ecology information are added to the collections as material becomes available.

Scouting

Scouting fields before weed control is implemented enables the weed control option to be matched to the species present. Soon after a control is implemented, scouting should be repeated to assess efficacy. Weed audits are a requirement of growing Liberty Link and Roundup Ready Flex cottons. See pages 102 and 105 for details. These auditing techniques can also be used to scout weeds in conventional cotton and rotation crops.

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

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

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. 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. Information on the growth and development of some of the more common weeds is available in the Weed Growth & Development Guide in WEEDpak through www.myBMP.com.au

Identify and closely monitor areas where machinery such as pickers and headers breakdown. Weeds seeds are often inadvertently released when panels are removed from machines for repairs. There have been many instances where weeds such as parthenium weed have been spread this way. Long-term monitoring of breakdown sites is the best way to prevent these problems. Whenever possible, it is best practice to ensure that all machinery maintenance occurs in a centralized area, such as around the farm sheds, so that any new weed incursions will be readily observed and managed.

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

GUIDE TO THE CRITICAL PERIOD FOR WEED CONTROL TO PREVENT 2% YIELD LOSS

Weed Type	Weed Density/ 10 m row	Cotton Growth Stage (day degrees) To prevent yield loss, control weeds			
		From		To	
Large broadleaf weeds such as; noogoora burr, thornapple, volunteer sunflower, sesbania	1	1–2 leaf	(145)	3 leaf	(189)
	2	1–2 leaf	(144)	5–6 leaf	(275)
	5	1–2 leaf	(143)	first square	(447)
	10	1–2 leaf	(141)	squaring	(600)
	20	1–2 leaf	(139)	squaring	(738)
	50	1–2 leaf	(131)	early flowering	(862)
Medium broadleaf weeds such as; bladder ketmia, mintweed, Boggabri weed	1	1–2 leaf	(145)	2–3 leaf	(172)
	2	1–2 leaf	(144)	4–5 leaf	(244)
	5	1–2 leaf	(143)	pre-squaring	(387)
	10	1–2 leaf	(141)	early squaring	(514)
	20	1–2 leaf	(139)	squaring	(627)
	50	1–2 leaf	(131)	squaring	(729)
Grass weeds such as; awnless barnyard grass, liverseed grass, Johnson's grass	20	–	–	–	–
	30	1 leaf	(122)	1–2 leaf	(139)
	50	1 leaf	(122)	2–3 leaf	(174)
	100	1 leaf	(122)	4–5 leaf	(248)
	200	1 leaf	(122)	7–8 leaf	(357)
	500	1 leaf	(122)	early squaring	(531)

Good record keeping

Good record keeping will help to develop strategies. and are invaluable for mitigating problems if they occur. For all fields, maintain records of cropping history and weed control methods and their effectiveness after every operation. Consider the records from past years in this year's decisions, particularly in relation to rotating herbicide modes of action.

Timely implementation of tactics

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

Timing to protect yield potential

In addition to targeting weeds in a timely manner, after planting, it is important to manage weeds to prevent yield loss, as young cotton is not a strong competitor with weeds. The critical times when weed competition can cause yield loss are provided in guide below for a range of weed densities and weed types. Irrespective of the type of weeds, early season control is critical to prevent yield loss. The higher the weed population, the longer into the season weed control is required. Preventing yield loss as well as preventing weed seed set ensures there is an economic return from weed control both today and in the future.

Rotate herbicide groups

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

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fortunate to have registered herbicides in the majority of the mode of action groups.

Closely follow herbicide label recommendations

Herbicide efficacy is highly dependent on the use of correct application techniques. Always follow label directions, including ensuring that the rate you are about to use is right for the growth stage and condition of the target weeds, whether a wetter or crop oil is required to maximise herbicide performance and that the application set up you are about to use is consistent with the label – water volume, water quality, droplet spectrums and operating pressure. Always consider the suitability of weather conditions. Refer to pages 142–150 for additional information about herbicide application and weather conditions for spraying.

Stop seed set, and actively management the seedbank

Managing the weed seed bank is the most important component of weed management. This applies to resistance management as well as general weed management. Use a range of selective tactics – inter-row cultivation, lay-by herbicides, chipping and spot spraying – to prevent seed set in weeds that survived early-season tactics or have germinated late.

Consider other aspects of crop agronomy

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

Cultural control

Cultural controls provide opportunities to incorporate different tactics and suppress weed populations.

Rotation crops

Rotation crops provide an opportunity to introduce a range of different tactics into the system including:

- Herbicide options not available in cotton.
- Producing stubble loads that reduce subsequent weed germinations.
- Varying the time of year non-selective measures can be used and the time of year that crop competition suppresses weed growth.
- Rotation between summer and winter cropping provides opportunities to use cultivation and knockdown herbicides in-fallow at all times of the year.

When summer crops, such as maize, are planted earlier than cotton, there is an opportunity to use crop competition and inter-row cultivation for cotton volunteer control rather than relying on herbicides, as can occur when cotton follows cotton.

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.

Herbicide tolerant cotton traits

Incorporating this tactic into the strategy allows for more responsive, flexible weed management. Weeds need only be controlled if and when germinations occur, meaning herbicide application can be timed to have maximum impact on weed populations. Even where glyphosate resistant weed species are present, Roundup Ready® cotton is still likely to be a useful part of the farming system. However the use of other tactics, especially control of all weed survivors will be critical to the long-term value of the traits. Avoid using the same herbicide to control successive generations of weeds. Rotating to glufosinate tolerant cotton (Liberty Link), provides an opportunity to use a different mode of action in-crop, and can help to manage cotton volunteers. Refer to pages 97 and 102–106 for more information.

Crop competition

An evenly established, vigorously growing cotton crop can compete strongly with weeds, especially later in the season. Competition reduces the number of seeds each weed can produce. Factors such as uneven establishment (gappy stands) and seedling diseases reduce crop vigour, and increase the susceptibility of the crop to competition from weeds. Close attention to crop agronomy will increase crop yields and can help reduce weed problems. 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. Row closure in irrigated cotton is important to maximise light interception for optimum cotton yield but also provides a very important method of minimising light for weeds growing below the crop canopy. Many weeds will fail to germinate once row closure occurs, and many small weeds will not receive enough light to compete with cotton plants and produce few seeds.. Research has shown that in irrigated crops, weed-free periods of 8-9 weeks from planting cotton provide enough time for the crop to out-compete later emerging weeds and significantly reduced seed production

Irrigation

Weed emergence is often stimulated by rainfall and irrigation events. Irrigation should be planned to reduce the impact of weeds by coordinating irrigation with planting, cultivation

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, DAFF);

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 (e.g. 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 (e.g. 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 (e.g. 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 (e.g. paraquat)	7 to 10 days.	Only target small rosettes
	glyphosate plus saflufenacil	Group L (e.g. 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 (e.g. paraquat)	4 to 14 days. Optimal timing is generally 5 to 7 days	
Feathertop Rhodes grass (*Chloris virgata*)	haloxyfop	Group L (e.g. 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 (e.g. paraquat)	5 to 14 days. Optimal timing is generally 7 to 10 days	Refer to APVMA permit 13460 (NSW ONLY)
SOURCE: ICAN				

and herbicide events. Pre-irrigation allows a flush of weeds to emerge and be controlled before cotton emergence. Irrigation during the season will cause another weed flush, providing another opportunity for a planned control tactic, as well as reducing moisture stress for existing weeds, making these more easily controlled by herbicide applications.

Post-harvest management

Some weeds will 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.

Herbicides

Herbicides continue to play a vital role in weed management. Understanding how the herbicide works can help to improve its impact and sustainability.

Mode of action (MOA) – Refers to how the herbicide acts against the weed to kill it. Avoid relying too heavily on herbicides with the same mode of action. Repetitive use of the same mode of action group over time is closely associated with the evolution of herbicide resistance within weed populations.

Contact herbicides – have limited movement within the plant. While results are usually quite rapid, coverage of the target weed is critical. Target small weeds, and optimise application technique and conditions.

Translocated herbicides – move within the plant using the xylem, where water and nutrients are transported from soil to growth sites, and/or the phloem, which moves products of photosynthesis to growth and storage sites. Response to the herbicide can appear quite slow. Understanding how the herbicide is translocated can help identify suitability for a situation. For example, atrazine is only translocated in an upwards direction, and so can be unsuitable to apply post-emergence, as very little herbicide gets to the roots.

Herbicide uptake – will vary with product (foliar, root absorption, coleoptile and young shoots absorption). Herbicides generally require the weed to be actively growing. It is important to refer to label for directions on the need for additives such as ammonium sulphate, wetters and oils.

Selective herbicides – have a limited range of target weed(s). This can help to target problem weeds under different scenarios. It is important to follow label recommendations about use or otherwise of adjuvants and avoid use in stressed crops. If only grass weeds are targeted by the use of a selective herbicide, consider how broadleaf weeds will be controlled.

Non selective herbicides – such as glyphosate or paraquat will damage most plants they contact with. However, these herbicides are not effective on all species and it is essential to check the label and not just assume a given species will be controlled.

Herbicide mixtures – refers to application of more than one herbicide in a single operation, which can reduce application costs. It is important that full label rate of each component is used. Refer to the label or manufacturer to determine suitable mix partners, as some products are antagonistic, reducing weed control, damaging the crop when mixed together or through physical incompatibility (form sludge).

Shielded spraying – the practice in which shields are used to protect the crop-rows while weeds in the inter-row area are sprayed with a non-selective herbicide.

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Band spraying – the practice in which a given area (band) of selective herbicide is applied to weeds in either the crop-row or inter-row area.

Double knock tactic

A double knock is where two weed control tactics, with different modes of action, are used on a single flush of weeds to stop any survivors from the first application setting seed. The tactics do not need to be herbicides. Cultivation, heavy grazing or fire could also be used as the second knock.

When executed well (right products, right rates, right timing, right application) the double-knock tactic can provide excellent control of the target weeds (see Table above or below?). In cotton systems there are several ways the technique can be applied to improve control of weeds such as flaxleaf fleabane and simultaneously reduce the risk of resistance developing in other key weed species such as liverseed grass and awnless barnyard grass. It is important to remember that total control won't always be achieved, so fields will still need to be monitored and survivors dealt with an alternative method.

Originally the technique was developed to maximise weed control at planting by using Spray.Seed or Roundup CT followed by the sowing operation which included full soil disturbance. This has application at cotton planting time for effective management of volunteers, provided that full disturbance is achieved.

When using two herbicides, the basis of the double-knock is to apply a systemic herbicide, allow sufficient time for it to be fully translocated through the weeds, then return and apply a contact herbicide, **from a different mode of action group,** that will rapidly desiccate all of the above ground material, leaving the systemic product to completely kill the root system.

Most commonly, glyphosate is followed with a Group L product. The optimum time between the treatments is dependent on the weed targets. Small, rapidly growing grasses respond best when the second application occurs 3–5 days after the first. When slightly larger fleabane is the target, separate the applications by 7–10 days. Examples of double-knock treatments and their efficacy on flaxleaf fleabane compared to a standard fallow application of glyphosate are shown on the previous page.

Generally, glyphosate is relied on more in the fallows than in-crop. No-till is now adopted widely in both cotton and grains systems, putting severe pressure on glyphosate to keep weeds, particularly grasses, under control. Awnless barnyard grass can have five or more emergences over the summer fallow period. If glyphosate alone was used to control each of these flushes, the time frame for resistance development would be even lower than using glyphosate alone in Roundup Ready Flex.

The fallow creates an opportunity to use different herbicide groups. The double knock tactic has been proven to be effective on glyphosate-resistant awnless barnyard grass and can ensure that survivors of glyphosate applications are controlled.

Knockdown herbicides

A number of non-selective, knockdown herbicides can be used to control germinating weeds while they are young and actively growing. Glyphosate (Group M), Basta (Group N), Spray.Seed® and Gramoxone® (Group L), Pledge® and Hammer® (Group G), as well as some combinations of these herbicides can be used. Where cotton with Roundup Ready® technology is to be planted this is an excellent opportunity to rotate herbicide mode of action by using the Group L or Group G products prior to planting. These alternate mode of action products can also be used to control herbicide tolerant cotton volunteers. Depending on the weed spectrum, more selective products from other modes of action may be used. Refer to Table 29 page 108. For additional information regarding the plant-back restrictions of these products for cotton, refer to Tables 24 and 25 on page 101.

Spot spraying

Spot sprayers may be used as a cheaper alternative to manual chipping for controlling low densities of weeds in-crop. Ideally, weeds should be sprayed with a relatively high rate of a herbicide from a different herbicide group to the herbicides 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 label for plant-back limitations relevant to rate applied. Refer to Permit Per11163 and follow manufacturer recommendations for speed and nozzle type, as well as allowable products to ensure that application is effective.

Herbicide tolerant cotton traits

Herbicide tolerant cottons allow the use of non-selective herbicides for summer weed control in-crop. In relatively clean fields, the reliance on residual herbicides for in-crop management is reduced. In fields known to have heavy weed burdens, using non-selective together with residual herbicides can achieve very high levels of control. Avoid using the same herbicide to control successive generations of weeds.

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

Refer to pages 102–106 for more information.

Residual herbicides

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. Residual herbicides must be absorbed through either the roots or shoots, or through both Residual herbicides can provide good control of difficult to control weeds, especially when used in conjunction with other tactics. For example when targeting feather top Rhodes grass in fallow, adding a residual to the second paraquat knock, 10-14 days after the first glyphosate knock, improves the paraquat knockdown and extends the period of control. Research has also found that where residuals such as pendimethalin and trifluralin are used for grass control, feather top Rhodes grass declines, especially if the grass escapes are then targeted and controlled in-crop with glyphosate or the Group A chemicals such as haloxyfop and fluazifop.

The use of residuals in the farming system requires good planning as:

- They must be applied in anticipation of a weed problem, and so usage should consider potential weed species and density for at least the previous 12 months.
- 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 which may conflict with other farming practices such as minimum tillage and stubble retention. 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. The risk to crop needs to be minimised. Always refer to the label for instructions on how to apply each residual herbicide.
- While advantageous to weed management, the persistence of residual herbicides needs to be considered within the farming system in terms of rotation cropping sequence. 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. Table 23 to 26 provides information on some plant-back limitations. Refer to product label for more information. If growers are concerned 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 an 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.
- Persistence in the environment can also be a concern for industry, and it is important to ensure that best practice is followed in terms of capture and management of runoff water.

Tillage and cultivation

Inter-row cultivation

Inter-row cultivation can be used mid-summer to prevent successive cohorts of weeds from being targeted by post-emergent herbicides. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the soil damage caused by tractor compaction and soil smearing from tillage implements. However, letting the soil dry down too much will result in poor implement penetration, bringing up clods, require excessive horsepower and be hard on equipment.

EFFECT OF TILLAGE TYPE ON EMERGENCE OF FLEABANE

Tillage type	% Untreated
Zero tillage	100.0
Harrows	9.0
Tynes	8.1
Off set discs	2.6
One-way disc	1.3
Source Widderick/Mclean, DAFF Queensland, 2011.	

'Spring tickle' (flush & cultivate)

The spring tickle uses shallow cultivation in combination with a non-selective, knockdown herbicide. The aim of the spring tickle is to promote early and uniform germination of weeds prior to sowing to ease weed pressure in-crop. Some weed species are more responsive to the spring tickle than others. Highly responsive weeds include bellvine and annual grasses – liverseed grass and the barnyard grasses. Weeds that are less responsive include; cowvine, thornapple, noogoora burr and bathurst burr. No till specialist weeds such as Fleabane and feather top Rhodes grass are discouraged from germination by these types of operation.

The shallow cultivation (1–3 cm) can be performed using implements such as, lillistons or go-devils.

Best results are achieved when the cultivation follows a rainfall event of ≥ 20 mm. Adequate soil moisture is needed to ensure that weed germination immediately follows the cultivation. Where moisture is marginal, staggered germination may result in greater weed competition during crop establishment.

Bury seed of surface–germinating species

Use strategic cultivation to bury weed seeds and prevent their germination. Some weed species, such as common sowthistle (milk thistle), flaxleaf fleabane, and feathertop Rhodes grass are only able to germinate from on or near the soil surface (top 20 mm). Tillage operations such as pupae busting, where full disturbance of the soil is required, can be timed to assist in situations where these species have set seed. Burying the seed more than 20 mm below the surface will prevent its germination. This tactic is most successful when used infrequently as seed longevity of common sowthistle and flaxleaf fleabane will be extended from ~12 months to ~30 months by seed burial, meaning that a cultivation pass burying seed which is on the surface could at the same time expose older but still viable seed buried in a previous operation.

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.

Control survivors before they set seed.

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 the IWM strategy that survivors not be allowed to set seed.

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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.

Putting it all together

When preparing a weed management plan it is important to consider the following points:

- What are the key weed species in each field, and how dense are they? Different species may require specific management.
- What is the history of herbicide use in the field? Although glyphosate-tolerant cotton may have only been used in a field for a couple of years, it is important to know what herbicides have been used in other crops and fallows prior. Glyphosate may have been heavily relied upon in fallows long before the introduction of glyphosate-tolerant cotton.
- What herbicides are effective on the key weeds in each field, and when is the best time to use them? In the case of awnless barnyard grass, it is controlled well by glyphosate, paraquat, group A herbicides such as Verdict and some residual herbicides. In a rotation containing glyphosate-tolerant cotton, glyphosate will be used in-crop. However to minimise the glyphosate selection pressure, residual or post-emergent herbicides can also be used. It should also be noted that glyphosate should not be solely relied upon in fallow: this is an opportune time to use paraquat (group L) or perhaps even a residual (keeping in mind they have a medium resistance risk). The table on page 84 shows that Verdict (group A) has a high risk of developing resistance, so its use should be limited to in-crop applications rather than in fallow.
- Any extraneous factors. The presence of a glyphosate resistant weed such as flaxleaf fleabane on a neighboring field or property, for example, would mean there is a high likelihood of the resistant weed being present even if there have been no past indications of resistance. Strategies to deal with resistance need to be implemented before a full-blown problem occurs.
- Last but not least, when can tillage be used? 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. It is possible that these operations can be timed to combine with weed control measures.
- The weed management requirement of the Roundup Ready Flex and Liberty Link Crop Management Plans (CMP's) are designed to ensure that the technology is used as part of an integrated strategy. It is essential that industry follows the CMPs and is proactive in managing the risk of herbicide resistance.

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 100mm 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 1.4kg/ha
			18 months	Following treatments of 1.4kg/ha to 3.3kg/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 30g/ha are used.
			6 months	When rates of 30–120g/ha are used.
			24 months	When rates above 120 g/ha are used. For all rates at least 100mm rain required during plant back period.

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
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	6 months(NNSW, QLD) Not stated SNSW	When rates up to 25g/ha are used. Dependent on rainfall (Soil wetness for at least 1 week) and soil type.
			9 months (NNSW, QLD) Not stated SNSW	When rates of up to 50g/ha are used Dependent on rainfall (Soil wetness for at least 1 week) and soil type.
			2 years	On shallow duplex, low organic matter soils with impermeable sub-horizon within root zone (30cm deep or less) and alkaline
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 + 150mm 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.	Dryland cotton.,
			18 months.	Irrigated only. (Providing rainfall and irrigation exceeds 2000mm)
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 2.5kg/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 (0.2L/ha) 6 months (0.4L/ha)	During drought conditions (<100mm rainfall in a 4 month period) the plant back is significantly longer
Hussar	mefenpyr-diethyl + iodosulfuron-methyl sodium	Cereal Crops: wheat.	12 months	Rainfall of less than 500mm following Hussar use may result in extended re-cropping intervals for summer crops sown in the following season.
Sencor 700	metribuzin	Cereal Crops: wheat, barley, oats Legume Crops: chickpeas, faba beans, lentils, vetch, lupins, field peas, soybeans (irrigated) Other Field Crops: potatoes	12 months	This could be longer if there have been long dry periods between crops.
Sencor 480			6 months for rates <1.5L/ha; 12 months for rates > 1.5L/ha	
Atlantis	metsulfuron methyl + mefenpyr-diethyl	Cereal Crops: wheat	12 months.	Rainfall of less than 500mm 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 333g/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
Raptor	imazamox	Legume Field Crops: field peas, soybeans Other Field Crops: peanuts Pastures: lucerne, legume-based pastures
Intervix	Imazamox + imazapyr	Clearfield crops 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	Cow pea	Fab bean	Field pea	Lab Lab	Lupin	Lucerne	Mungbean	Pigeon pea	Soybean	Canola	Safflower	Linseed	Sunflower
chlorthal dimethyl	8	8	8	8	8	8	8	8	8	8	8	8	8	8	FH	FH	8	FH	8	8	8	8
diuron	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 expresses a protein that blocks the action of Liberty 200 Herbicide. The protein, known as phosphinothricin acetyltransferase (PAT) attaches an acetyl group to the glufosinate ammonium molecules, rendering them ineffective. The expression of PAT allows Liberty Link cotton to continue producing glutamine when glufosinate-ammonium is present.

How tolerant is Liberty Link cotton to Liberty 200 herbicide?

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

Weed management with Liberty Link

Before growing Liberty Link cotton, develop and document a weed control strategy for each field, including a rotation program for crop and herbicide 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

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

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 118.

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

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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 102. 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 31 December. 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%.)

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 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 Roundup Ready Herbicide with PLANTSHIELD by Monsanto. Roundup Ready Flex cotton plants produce the modified form of EPSPS, so are able to continue producing amino acids and proteins after Roundup Ready Herbicide with PLANTSHIELD by Monsanto 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. Roundup Ready Herbicide with PLANTSHIELD by Monsanto may be applied over the top (OTT) of Roundup Ready Flex cotton up to four times between emergence and 22 nodes, while one application is allowed between 60% bolls open and harvest. However, the total amount of herbicide applied to any one crop must not exceed 6 kg/ha in a total of 4 applications as illustrated in Figure 10. Crops that are intended for seed production must not have an application of Roundup Ready herbicide past the 60% bolls open stage.

The full-plant glyphosate tolerance of Roundup Ready Flex means that applications of glyphosate can be made irrespective of the rate of crop growth or the number of days between applications 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 Roundup Ready Herbicide with PLANTSHIELD by Monsanto, 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 92–101 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 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 Roundup Ready Herbicide with PLANTSHIELD by Monsanto 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 (over-the-top) 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 Roundup Ready Herbicide with PLANTSHIELD by Monsanto based upon the most difficult to control weed species in each field.

Inter-row cultivation

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

Lay-by residual application

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

Pre-harvest application

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

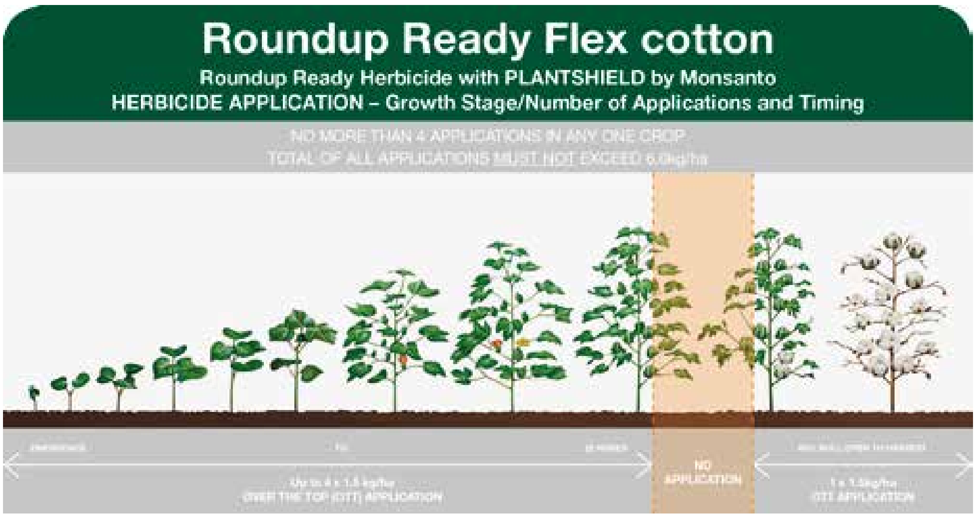
Audit requirements in the Roundup Ready Flex crop management plan

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 the Crop Management Plan (CMP). Within the CMP, there are the requirements for a Planting Audit and a Weed Management Post Spray Survey.

Planting audit

The Technology Service Provider (TSP) is responsible for completion of the planting audit by no later than 5th December,

FIGURE 10: Roundup Ready Flex cotton allows you to spray Roundup Ready® herbicide with PLANTSHIELD by Monsanto over the top (OTT) of your cotton from emergence through to 22 nodes.



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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 CMP

Weed management Post Spray Survey

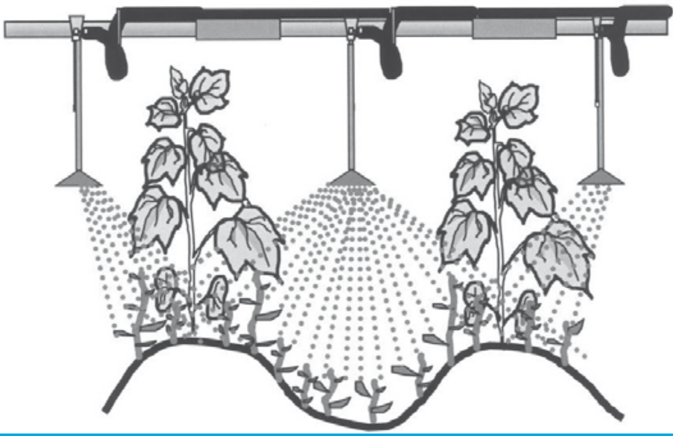
Only accredited TSPs will be able to conduct the Weed Management Post Spray Survey.

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 Roundup Ready Herbicide or Roundup Ready Herbicide with PLANTSHIELD by Monsanto 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:



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

- 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 Monsanto as soon as it is identified. Monsanto must report any cases of confirmed resistance to the APVMA.

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

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 118–119 for more information

Application guidelines

Timing options

The Roundup Ready Herbicide with PLANTSHIELD by Monsanto label permits:

- Applications in fallow, prior to sowing the Roundup Ready Flex crop, with the maximum rate applied dependent on the targeted weed/s. Application may be made by ground rig sprayer or by aircraft.
- Up to four applications of Roundup Ready Herbicide between crop emergence and 22 nodes of crop growth, with a maximum of 1.5 kg/ha being applied in any single spray event.
- An option for a pre-harvest application, alone or in tank mix with Dropp, once the crop is 60% open and immature bolls cannot be cut with a sharp knife. The maximum herbicide rate for pre-harvest use is 1.5 kg/ha. Application may be made by ground rig sprayer or by aircraft.
- Not more than four applications and 6.0kg of Roundup Ready Herbicide with PLANTSHIELD by Monsanto 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 Roundup Ready Herbicide with PLANTSHIELD by Monsanto due to the potential for reduced weed control or crop injury to result. (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 Roundup Ready Herbicide with PLANTSHIELD by Monsanto by aircraft at temperatures above 30°C or if relative humidity falls below 35%.

Other Sources of Information:
Roundup Ready Flex Cotton Technical Manual, Monsanto Australia Ltd.
Technical enquiries: 1800 804 479

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Cotton Weed Control Guide

Tracey Leven, CRDC

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 DAFF, cost $7.50 plus postage and handling. Contact Qld DAFF 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	MSolC = Soluble concentrate
DF = Dry flowable granule	SP = Soluble powder
EC = Emulsifiable concentrate	WDG = Water dispersible granule
L = Liquid	WP = Wettable powder
SC = Suspension concentrate	

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 plantback to cotton.
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
Bromoxynil	C	200 g/L EC	1.4–2.1 L/ha	Controls peachvine, climbing buckwheat and cotton volunteers. Spray volumes above 50 L/ha are recommended. Complete coverage is essential.
Carfentrazone-ethyl	G	240 g/L EC	0.025–0.0.75 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 ONL Refer to label.
	M	Various	Various	Controls most annual grasses and broadleaf weeds. Refer to label for rates on specified weeds and recommendations.
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.
Fluometuron	C	500 g/kg WG, AC, SC 900 g/kg GR, WG	2.8 – 5.6L/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.
		690 g/kg WG	0.265–1.5 kg/ha	In fallows and prior to sowing Roundup Ready Flexcotton only
Glufosinate-ammonium	N	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.
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.
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.

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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 960g/L EC	2.0 L/ha 1.5L/ha	Controls certain annual grasses and Wandering Jew. Rain or irrigation needed within 10 days of application or incorporate mechanically
Paraquat	L	250 g/L 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 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% bolls are open.
		690 g/kg WG	0.710–1.5kg/ha	Registered for use in Roundup Ready Flex cotton. Apply when 60% 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 30cm 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.
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.
Glyphosate	M	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.

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TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013

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 AV	2,4-D 300 IPA	Sabakem, Agro-Alliance, Ezycrop, Agspray Chemical Co, Crop Smart, New Australia Agricultural Development Company, Farmalinx, Ospray, Agrimart Industries, Agcare, Landmark Operations, Ravensdown, Accensi, Novaguard, Spalding Holdings, Easyfarm, Ozcrop, Shandong Rainbow International Co, Profeng Australia, Pacific Agriscience, Halley International Enterprise, FMC
			Amine 300	Titan Ag, Ruralchem, Goobang, Hextar Chemicals, Conquest
			Aminex 300	Australis Crop Protection
			Aminoz Ct 300	Sanonda
			Applause 300	Agri West
			Basilica 300	Chemtura
			Cobber	Crop Care
			Glymate 300	Macspred
			Inca 300 Herbicide	Proterra
			Ken-Star	Kenso
			Smash 300	Imtrade
			Surpass 300	Nufarm
			Weeds Out 300	Biotis Life Science
			Zulu 300	Farmoz
		400 g/L	Abound	Dow Agrosciences
			2,4-D 400 IPA	FMC
		450 g/L	2,4-D 450 IPA	Apparent, Farmalinx, Shandong 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
Amitrole + ammonium thiocyanate	Q	250 g/L + 220 g/L SL	Amitrole 250	Imtrade
		250 g/L + 220 g/L SL	Amitrole T	Nufarm
		250 g/L + 220 g/L SL	Amitat	Farmalinx
		250 g/L + 220 g/L SL	Aggrav8	Agri West
		250 g/L + 220 g/L SL	Weedeath	Cyndan
Amitrole + paraquat	Q + L	250 g/L + 125 g/L	Alliance	Crop Care
Bromoxynil	C	200 g/L EC	Bromicide 200	Nufarm
			Bromo 200	Agri West, Conquest
			Bromox 200	Imtrade
			Bromoxy 200	Farmalinx
			Bromoxynil 200	Imtrade
				FMC, Ozcrop, Ezycrop, Novaguard, Shandong Rainbow, Apparent., Kenso, Sanonda, Accensi, Landmark Operations, Titan Ag Pty Ltd, 4 Farmers Pty Ltd
			Bronco	Farmoz
			Bronx 200	Hextar
			Firefighter	Ospray
Butroxydim	A	250 g/kg WG	Factor WG	Crop Care
Carfentrazone-ethyl	G	240 g/L EC	Hammer	FMC
			Punch	Osspray
			Nail	Crop Care
		400 g/L Ec	Hammer 400	Crop Care
Carfentrazone-ethyl + Glyphosate	G + M	7.2 g/L + 432 g/L	Broadway	FMC
Chlorthal dimethyl	D	750 g/kg WG	Clorthal dimethyl 750WG	Macphersons, Novaguard, FMC, Ezycrop
		750 g/kg WG	Prethal 750 WG	KD Plant Care
		900 g/kg WG	Dacthal 900 WG	Crop Care
			Chlor-Dime	Mission
		900 g/kg WG	Pterodactyl	Imtrade

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed by
Clethodim	A	240 g/L EC	Akodim	Aako
			Blade 240EC	Ravensdown
			Carbine 240	Axichem
			Cleodim 240	Grow Choice
			Clethim 240 EC	Farmalinx
			Cletho 240	Ozcrop
			Cletho 240 EC	Kenso
			Clethodim 240 EC	4 Farmers, Agcare, Agricultural Product Services, Agrimart Industries, Agro-Alliance, Apparent, Australian Progressive Supplies, Australis Crop Protection, Biotis Life Science, Chemforce 2010, Crop Smart, Easyfarm, Echem, Ezycrop, Fmc, Goobang, Imtrade, Landmark Operations , Macspred , Mission Bell Holdings, Nisso Basf Agro Co , Novaguard, Ospray, Pacific Agriscience, Profeng Australia, Sabakem, Sanonda, Shandong Rainbow , Spalding, Titan Ag, Wellfarm
			Cluster 240 EC	Hextar Chemicals
			Coerce 240EC	Agri West
			Eco Cletho 240 EC	Sanplus
			Genie	Chemtura
			Grasidim	Sipcam
			Havoc	Crop Care
			Nissodim 240 EC	Nisso Basf Agro Co
			Nitro 240	Conquest Crop Protection
			Platinum	Farmoz
			Scalpel 240 EC	Sinochem Agro
			Select	Arysta
			Sequence	Nufarm Australia
			Status	Sumitomo Chemical Australia
			Uproot 240 EC	United Phosphorus .
Dicamba I	C	500 g/L AV	Camquesta 500	Conquest
			Cutlass 500	Farmoz
			Dicam 500	Farmalinx
			Dicamba 500	Ozcrop, Apparent, Chemtura, Grow Choic, Accensi, FMC, Landmark Operations, Imtrade, Kenso, Ospray, Ozcrop, Shandong Rainbow, Ravensdown, Australis Crop Protection
			Dicer 500	Hextar
			Ditch 500 Herbicide	Agri West
			Kamba 500	Nufarm
			Titan Dicamba 500 Herbicide	Titan Ag
		700 g/kg SG	Cadence	Syngenta
			Cambagran	Agritech Bioscience
			Dicamba 700	Ospray, Rallis, Titan Ag
			Kamba Dry	Nufarm
			Volley	Sipcam
		700 g/kg WG	Dicam 700	Farmalinx
			Dicamba 700wg	Kenso, Shandong Rainbow, Titan Ag
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
		212 g/L EC	Flazz	Agriwest
		212 g/L EC	Fluazifop-p 212	4Farmers, Apparent, Ezycrop, Novaguard,
		212 g/L EC	Fuzilier	Ospray
		212 g/L EC	Resilience	Farmoz
		212 g/L EC	Rootout 212	Sinon
		212 g/L EC	Rootout 212	Sinon

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TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed by
Fluometuron	C	500 g/kg WG, AC, SC	Cotoran Wg, Sc	Farmoz
			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	Farmoz, 4Farmers, Ozcrop, Shandong Rainbow, Sabakem, Titan Ag
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	Farmoz
		440 g/L + 440 g/L DF	Convoy DF	Nufarm
		440 g/L + 440 G/L WG	Cotogard WG	Farmoz
		450 g/L + 450 g/L WG	Flupromix	Sipcam
Flumioxazin	G	500 g/kg WG	Pledge	Sumitomo Chemical Australia
Fluroxypyr	I	200 g/L EC	Acclaim	Sipcam
			Comet 200	Nufarm
			Dozer	Axichem
			Flagship 200	Farmoz
			Flotilla	Ospray
			Floxor 200 EC	Farmalinx
			Fluroken 200	Kenso
			Fluroxypyr 200EC	4Farmers, Accensi, Agrimart Industries, Apparent, Australis Crop Protection, Chemtura, Crop Smart, Ezycrop, FMC, Landmark Operations, Novaguard, Ospray, Ozcrop, Pacific Agriscience, Profeng Australia, Sabakem, Shandong Rainbow, Titan Ag, Value Chem
			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	United Phosphorus
		333 g/L EC	Fluroken 333	Kenso
			Starane Advanced	Dow Agrosciences
		400 g/L EC	Comet 400	Nufarm
			Decoy 400	Crop Care
			Fluroxypyr 400	Accensi, Australis Crop Protection, Titan Ag
			Neon 400	Conquest
Glufosinate–ammonium	N	200 g/L SL	Liberty 200	Bayer CropScience
			Basta 200	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, 875g/L WG, 840g/L WG, 900g/L WG	various for multiple products	various for multiple products
Halosulfuron–methyl	B	750 g/kg DF, WG	Halo 750 Wg	Imtrade
			Halosulfuron 750 Wg	Enviromax Technologies, Ozcrop, Apparent, Shandong Rainbow
			Kenpra 750 Wg	Kenso
			Nut-Buster	Ospray
			Nutless	Axichem
			Sedgehammer	Amgrow

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed by
Halosulfuron–methyl	B	750 g/kg DF, WG	Sempra	Nufarm
			Tuffnut	Freezone
			Sedgehammer	Amgrow
			Yowler	Agriwest
Haloxyfop-p	A	130 g/L	Judgement 130	Imtrade
		520 g/L EC	Halfback 520	Axichem
			Haloxyfop 520EC	Agricultural Product Services, Apparent, Crop Smart, Easyfarm, Grow Choice, Landmark, Macspred, Mission Bell, Opal, Ruralchem, Sabakem
			Harpoon 520	Agri West
			Hermes 520	Titan Ag
			Inquest	Sipcam
Haloxyfop-r	A	130 g/L	Gallant West	Dow Agrosciences
		520 g/L E	Convict	Ospray
			Asset	Nufarm
			Convict	Ospray
			Decree 520 EC	Sinochem
			Exert 520	Crop Care
			Firepower	Farmoz
			Halomac 520	Macspred
			Halox 520	Echem
			Haloxyfop 520 EC	4 Farmers, Accensi, Agro-Alliance, Australis Crop Protection, Chemforce 2010, Chemtura, Ezycrop, Farmalinx, FMC, Novaguard, Ozcrop, Profeng, Shandong Rainbow
			Haloxyken 520	Kenso
			Recon 520	Conquest Crop Protection
			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	Nufarm
Metolachlor	K	720 g/L EC	Bouncer	Australia Limited
			Clincher	Farmoz
			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, Shandong Rainbow
			Scrimmage 720	Agri West
			Strada	Sipcam
Metolachlor	K	960 g/L EC	Chaser	Ospray
			Clincher Plus	Farmoz
			Metal Plus 960	Imtrade
			Metolachlor 960	Accensi, Apparent, Australis Crop Protection, FMC, Landmark Operations, Mission Bell Holdings, Proterra, Titan Ag
			Metolamax 960	Conquest
			Metor 960	Farmalinx
			Smasha 960	Agritrading
			Strada Xtreme	Sipcam
MSMA	Z	720 g/L LQ	Arena	Agricorp
		720 g/L SL	Monopoly	Barmac
			MSMA 720	Agspray, Ancom
			Armada 720 SL	Hextar
			Vesta	Campbell
		800 g/L LQ	Daconate	CropCare
			Megalith	Agriwest
			MSMA	Imtrade

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TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed by
Norflurazon	F	800 g/kg DF	Zoliar 800DF	Agnova Technologies
Oxyfluorfen	G	240 g/L EC	Cavalier	Farmoz
			Conversion 240	Australis Crop Protection
			Convert 240 Ec	Ospra
			Encore	Conquest
			Goaltender	Dow Agrosciences
			Gowel 240 Ec	Sinon
			Offend 240	Grow Choice
			Olright 240ec	Agri West
			Ox 240	Kenso Corporation (M) Sdn. Bhd.
			Oxen	Imtrade
			Oxxel 240 Ec	Axichem
			Oxydox 240 Ec	Hextar Chemicals
			Oxyfan 240 Ec	Farmalinx
			Oxyfluorfen 240 Ec	4Farmers, Accensi, Agrismart, Agro-Alliance, Apparent, Landmark Operations , Opal Australasia, Ozcrop, Profeng , Ravensdown, Ruralchem, Titan Ag
			Point	Kendon
			Striker	Nufarm
		480 g/L EC	Goaltender	Dow Agrosciences
Paraquat	L	250 g/L SL	Agroquat 250	Agrogill
			Explode 250	Conquest
			Gramoxone 250	Syngenta
			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	Farmoz
			Uniquat 250	United Phosphorus
		334 g/L SL	Para-ken 334	Kenso
Paraquat + diquat	L	135 g/L + 115 g/L AV	Alarm	Sipcam
			Blowout	Ozcrop
			Brown Out	4 Farmers
			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 , Australia Generic Crop Protection , Easyfarm , Ezycrop , FMC , Forward , Fosterra , Mission Bell Holdings , NAADC , Novaguard , Pacific Agriscience , Sanonda , Shandong Rainbow
			Premier 250	Halley
			Ravensdown Wildfire 250	Ravensdown
			Revolver	Nufarm
			Scorcher 250	Conquest Crop Protection
			Smart Combination 250	Crop Smart
			Spalding Exocet 250	Spalding Holdings.

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed by
Paraquat + diquat	L	135 g/L + 115 g/L AV	Speedy 250	Kenso
			Spray & Sow	Farmoz
			Spray.Seed 250	Syngenta Australia
			Spraykill 250	Imtrade
			Spray-Out 250	Ospray
			Spray-Plant 250	Sipcam Pacific Australia
			Titan Eos	Titan Ag
			Tombstone	Goobang
			Uni-Spray 250	United Phosphorus
Pendimethalin	D	330 g/L EC	Charger 330 EC	Conquest
			Charger 330 EC	Conquest
			Cyclone 330 EC	Imtrade
			Fist 330	United Phosphorus
			Ipimethalin 330	Finchimica
			Pendant	Amgrow
			Pendi 330	Kenso
			Pendimethalin 330EC	4Farmers, Halley, Rallis, Ravensdown, Sabakem, Shandong Rainbow, Titan Ag
			Rifle 330	Nufarm
			Stomp 330e	Basf
		435 g/L EC	Panda 435	Farmalinx
			Panida Grande	Sipcam
			Pendimethalin 330EC	FMC
			Pendimethex	Farmoz
		440 g/L EC	Argo 440EC	Colin Campbell
			Cyclone 440EC	Imtrade
			Rifle 440	Nufarm
			Romper 440EC	Crop Care
			Stomp 440	BASF
		455 g/L AV	Stomp*Xtra	BASF
		475 g/L	Panida Max	Rallis
Prometryn	C	500 g/L SC	Gesagard 500 SC	Syngenta
			Gesagard 500 SC	Syngenta
			Promesip 500	Sipcam
			Prometrex 500	Farmoz
			Prometryn 500	Accensi, Ospray, Ozcrop
			Proton	Crop Care
		900 g/kg DF	Prometryn 900 DF	Nufarm
		900 g/kg WG	Gesagard 900 WG	Syngenta
			Prometrex 900 WG	Farmoz
			Prometryn 900	Ozcrop
Propaquizafop	A	100 g/L EC	Shogun	Farmoz
Saflufenacil	G	700 g/kg WG	Sharpen	Nufarm
s-Metolachlor	K	960 g/L EC	Dual Gold	Syngenta
			Dualis 960	United Phosphorus
			Metoken Gold	Kenso
			s-Metolachlor	Genfarm
Triclopyr	I	600 g/L EC	Axeman 600	Apparent
			Biosorb 600	Biotis Life Science
			Garlon 600 Herbicide	Dow Agrosciences
			Gerlan 600 Ec	Sinon
			Grando 600	Crop Care
			Hurricane 600	Imtrade
			Invader 600	Nufarm
			Maca 600	Conquest
			Ranger 600	Hextar
			Redeem 600	Sipcam
			Safari 600ec	Farmoz
			Tricky 600	Axichem

TABLE 33: Herbicide trade names and marketers – Registered chemicals as at June 30, 2013 (continued)

Active ingredient	Mode of Action group	Concentration and formulation	Trade name	Marketed by
Triclopyr	I	600 g/L EC	Triclon 600	Grow Choice
			Triclops	Crop Culture
			Triclopyr 600 EC	4 Farmers, Accensi, Agri West, Agrimart, Agro-Alliance, Aimco, Apparent, Ausagri, Australian Progressive Supplies, Australis Crop Protection, Chemforce, Crop Smart, Ezycrop Pty Ltd, Farmalinx, FMC, Halley, Kenso, Landmark Operations, Macspred, Mission Bell Holdings, Novaguard, Opal, Ospray, Ozcrop, Pacific Agriscience, Profeng, Ravensdown, Western Stock Distributors, Ruralchem, Sabakem, Sabero, Shandong Rainbow, Spalding, Titan Ag
			Tripyr	Farmalinx
			Uni-Lon 600	United Phosphorus
			Weedpro Tryclops	PCT Holdings
		755 g/L EC	Garlon Fallow master	Dow AgroSciences
Trifloxysulfuron sodiumta	B	750 g/kg WG	Envoke	Syngen
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
			Triflen 480	Sinon
			Triflur X 480	Nufarm
Trifluralin	D	480 g/L EC	Triflur Boost	Extol
			Trifluralin 480 EC	
			Multiple	
			Trifluralinx 480	Farmalinx
			Triflurasip	Sipcam Pacific Australia
			Triflurex	Farmoz, Nufarm
			Trigen 480	Landmark Operations
			Trilogy	Farmoz
			Unitry	United Phosphorus .
		500 g/L EC	Trilogy Xtra	Farmoz
		530	Trifluralin 530 Ec	Accensi
		600 g/L EC	Tricon Maxi 600	Conquest Crop Protection
			Trifluralin 600 Ec	4Farmers , Landmark Op
			Trilogy 600	Farmoz

Volunteer and ratoon cotton

Frank Taylor, Nufarm
Susan Maas, CRDC

The control of unwanted cotton in the farming system is an essential part of good integrated pest and disease management. 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.

Reasons why ratoon and volunteer cotton must go

1. Mealybugs survive from one season to the next on these food sources, infesting crops earlier in the following season.
2. Cotton aphids with resistance to neonicotinoids survive between seasons on these plants, reducing insecticide effectiveness.
3. Bunchy top disease can be transmitted by cotton aphids from infected ratoons to new cotton crops.
4. Silverleaf whitefly survive between seasons on these plants, resulting in earlier infestation in the following season.
5. They provide a winter host for pale cotton stainers and solenopsis mealybugs.
6. Inoculum of soil-borne diseases such as black root rot, Fusarium and Verticillium builds up in ratoons.
7. Ratoon plants place extra selection pressure on Bt
8. Ratoon cotton can be used as a host by the earliest and latest Helicoverpa generations.
9. Ratoon plants may only express sub-lethal doses of the Bt proteins, therefore increasing resistance selection pressure.
10. Fields with ratoons from Bt cotton are unsuitable for planting refuge crops, as the refuges cannot be effective if contaminated with Bt cotton plants.
11. Removing ratoons may be a costly exercise, but it is cheaper than the costs of dealing with the problems resulting from not removing them.
12. They are a biosecurity risk. Ratoons harbour pests and are a potential point of establishment for exotic pests.

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 a 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 is extremely effective.
- In crop cultivation with sweeps that lift or till out volunteers and other weeds are effective tools for control when volunteers are small.

Chemical

- The broad spectrum herbicide glyphosate has often been used extensively to control seedling volunteer cotton. Control has either been deliberate or inadvertent when targeting other weeds prior to cotton planting as a fallow spray or within-crop as a shielded spray. Glyphosate rates of 1.2 L/ha (450 g/L.) will easily control seedling cotton at the 1st and 2nd true leaf stage.
- The release and widespread adoption of Roundup Ready Flex® cotton, which has a gene allowing the tolerance of over-the-top applications of glyphosate, eliminates the use of glyphosate as a potential control herbicide for seedling volunteer Roundup Ready Flex® cotton. 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 (e.g. 100L/ha) water volumes per hectare. Coverage can often be compromised due to shading, stubble & lint. Ensure appropriate spray quality which may vary depending on the product selected, but generally a medium-coarse spray quality would be adequate at 100L/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. Double knock technique may be useful for these plants.
- Ensure label directions are followed, especially where volunteers are located near water ways.

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Ratoon cotton

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 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 minimize the number of ratoons that survive.

Ratoon cotton is extremely difficult to control with herbicides as there is a small leaf area for herbicide absorption compared to the large root system available for carbon and nutrient supply. Table 3 in WEEDpak section F4.4 shows that for selected herbicides on ratoon cotton 20 days after treatment. there was greater than 90% regrowth on all treatments.

Table 34 (below) 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.

ALWAYS FOLLOW LABEL DIRECTIONS

TABLE 34: Herbicides that have registration for control of volunteer cotton

Actives	MOA	Conc & forumulation	Appl rate	Stage	Comment
Amitrole + Ammonium Thiocyanate	Q	250 g/L + 220 g/L SL	4.3–5.6L/ha	Cotyledon – 8 leaf	See label for rain fastness. Apply in 50–100L/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	2–4 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	1.5L/ha or 1–1.5L/ha with glyphosate	Cotyledon – 6 leaves	Apply in minimum of 80L/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	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 150L/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 up to 24 hours prior to sowing. Can be tank mixed with glyphosate. Refer to label for adjuvant details.
Glufosinate-Ammonium	N	200 g/L SL	3.75 L/ha in 100L water	2–6 leaf	Only apply to Liberty Link cotton varieties. Max 2.25kg a.i./ha/season (3 applications). As a contact herbicide coverage is critical to effectiveness. Will not control Liberty Link cotton volunteers.
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	333g/L	0.45 L/ha 0.6 L/ha	2–6 leaf 5–7 leaf	Summer fallow.
Saflufenacil	G	700 g/kg	9-26 g/ha plus Bonza 1%	2–6 leaf	May be tank mixed with Roundup Attack herbicide. Apply in 80–250L water per ha. Mandatory down wind no spray zone 100–250m

Integrated disease management

Stephen Allen, Cotton Seed Distributors
Linda Smith, Linda Scheikowski, Cherie Gambley, Murray Sharman, Qld DAFF
Karen Kirkby and Peter Lonergan, NSW DPI

Introduction

A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. When a virulent pathogen is dispersed onto a susceptible host and the environmental conditions are suitable then a plant disease develops and symptoms become evident.

Disease control strategies must therefore focus on the host, the pathogen and/or the environment. 'Integrated Disease Management' involves the selection and application of a harmonious range of control strategies that minimise losses and maximises returns. Each of the disease control strategies by itself is not able to provide adequate control. However, when several such strategies are used in combination then acceptable control is achieved.

Effective disease management must be integrated with management of the whole farm. The absence of symptoms does not indicate an absence of disease. Basic strategies should be implemented regardless of whether or not a significant disease problem is evident. These basic strategies should focus on the host, the pathogen and the environment.

The host

A particular plant may be immune, resistant or susceptible. Breeders also use the term 'tolerance' to imply good performance (yield) despite the presence of the disease. Examples of disease control strategies that focus on the host include:

The use of resistant varieties

Australian upland cotton varieties are completely resistant to Bacterial blight. Some have good resistance to Verticillium wilt and some have some resistance to Fusarium wilt. Use varieties with good seedling vigour.

Cotton symptoms guide app now available.

When the Black root rot pathogen is present, use the more indeterminate varieties that have the capacity to catch up later in the season. Avoid growing susceptible varieties in fields that contain infected residues.

Balanced crop nutrition

A healthy crop is more able to express its natural resistance to disease. Adopt a balanced approach to crop nutrition, especially with nitrogen and potassium. Both deficiencies and excesses provide better conditions for the development of diseases such as Verticillium and Alternaria. For more information on cotton nutrition see NUTRIpak available from the Cotton CRC.

Replanting

Replanting decisions should be made on the basis of stand losses, not on the size of the seedlings.

The pathogen

A pathogen must be present in the area, capable of surviving the inter-crop period and adapted for effective dispersal between host plants if a disease is to occur. Disease control strategies that focus on the pathogen include:

Monitoring

Be aware of what diseases are present, where they are present and whether or not the incidence is increasing. Do your own disease survey in November and February of each season. Train farm staff to be observant and report back on possible disease occurrences.

Practice good farm hygiene

Minimise the movement of pathogens onto and off your farm, and between fields within your farm. Clean down machinery and vehicles of mud, crop and weed residues between fields and farms. Minimise movement of crop residues in tailwater recirculation systems. Encourage all visitors to 'COME CLEAN' and 'GO CLEAN'. For more information refer to myBMP.

Use rotation crops that are not hosts

Develop a sound crop rotation strategy. Successive crops of cotton can contribute to a rapid increase in disease incidence – especially if susceptible varieties are used. Use rotation crops that are not hosts for the pathogens present. The Verticillium wilt pathogen has a large host range and most legume crops are hosts of the Black root rot pathogen.

Control alternative hosts and volunteers

The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, Tobacco Streak Virus and Alternaria leaf spot can also infect common weeds found in cotton growing areas. Control alternative hosts to prevent build up of inoculum and carry over of disease from one season to the next.

Cotton volunteers and cotton ratoons can significantly increase the risk of disease carry over between seasons. Ensure weed management strategies for fallows and rotation crops consider the need for volunteer control, particularly in systems where herbicide tolerant crops are grown. Manage cotton stubble to avoid the occurrence of ratoon cotton as herbicides are rarely cost effective or highly efficacious.

Crop residues

Manage crop residues to minimise carryover of pathogens into subsequent crops. The pathogens that cause Verticillium wilt,


Aerial photo of fusarium damage.

Fusarium wilt, Black root rot, boll rots, seedling disease and Alternaria leaf spot can all survive in association with crop residues. Incorporate cotton crop residues as soon as possible after harvest, except where Fusarium wilt is present. Where Fusarium is present residues should be slashed and retained on the surface for at least one month prior to incorporation.

The Fusarium wilt pathogen can also survive and multiply on the residues of non-host crops such as cereals. Currently recommendations are that residues should be buried or baled as soon as possible after harvest.

Application of fungicides

Examples include seed treatments for seedling disease control and foliar sprays for the control of Alternaria leaf spot on Pima cotton. For more details see Tables 35 and 36 on page 131.

Biofumigation

In addition to fixing substantial quantities of nitrogen, vetch has a biofumigation effect against Black root rot. As the vetch breaks down in the soil, ammonia is released in sufficient quantities to kill spores of the Black root rot pathogen. In contrast, vetch residues can increase the activity of Fusarium wilt in the following cotton crop.

The success of biofumigation depends on the growth of the biofumigant crop and good incorporation (at least 4 weeks before planting). Biofumigant crops can been grown and incorporated a year before planting the following cotton crop.

Control of insect vectors

Diseases caused by a virus or phytoplasma can often be prevented by controlling the vector that carries the pathogen.

Cotton Bunchy Top (CBT) can be transmitted by aphids feeding on infected plants then migrating to healthy plants. Transmission of Tobacco Streak Virus (TSV) to plants relies on the virus from infected pollen entering plant cells through the feeding injury caused by thrips. Many species of thrips are potentially capable of transmitting TSV. For more information on these diseases, see the following section. Aphid and thrip thresholds can be found on pages 14 and 30.

The environment

Pathogens have optimum temperature, relative humidity, leaf wetness and/or soil moisture content requirements for infection to occur and for the disease to spread and multiply in the host plant. When environmental conditions are not optimal then the rate of disease development is reduced.

It may appear difficult to manipulate the environment but it can be achieved by altering row or plant spacing, irrigation method or frequency or by changing the sowing date. Possible disease control strategies that focus on the environment include:

Good bed preparation

Plant into well prepared, firm, high beds to optimise stand establishment and seedling vigour. Carefully position fertiliser and herbicides in the bed to prevent damage to the roots. Fields should have good drainage and not allow water to back-up and inundate plants.

Sowing date

Delay sowing as late as possible within the planting window to avoid cool, wet conditions that favour disease. Sowing when the soil temperature is above 20°C would be best for reducing cotton's susceptibility to disease, but generally this is not practical. Time planting to coincide with soil temperatures of at least 16°C and rising. Refer to *Cotton Production Manual* for more information on crop establishment.

Irrigation scheduling

Applying water prior to planting provides better conditions for seedling emergence than watering after planting.

Watch for signs of water stress early in the season if the root system has been weakened by disease (eg. Black root rot) and irrigate accordingly. Avoid waterlogging at all times, but especially late in the season when temperatures have cooled. Irrigations late in the season can result in a higher incidence of Verticillium wilt.

Agronomic management

High planting rates can compensate for seedling mortality however a dense canopy favours development of bacterial blight, Alternaria leaf spot and boll rots. Avoid rank growth and a dense canopy with the use of growth regulators. Manage irrigations, nutrition and insects for early maturity as many pathogens are favoured by cool conditions at the end of the season.

In fields where Fusarium wilt is present avoid inter row cultivations after seedling stage as mechanical damage to the roots provide a site for infection by the pathogen.

Soil health

Fields where soil borne pathogens cause chronic disease in cotton are not 'unhealthy' as healthy cereal crops could be grown in the same field. These diseases are not present because the soil has been mistreated, the presence of the pathogen creates a problem with the health of the plants but not a problem with the health of the soil.

Come clean. Go clean.

Common diseases of cotton

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Seedling diseases

There have been over 30 species of fungi isolated from dying cotton seedlings. Death of seedlings is often referred to as 'damping off' but is mainly caused by
Rhizoctonia solani; Pythium spp. and Fusarium spp. (not Fusarium wilt)

Symptoms

Pre-emergent seed rots. Post emergent wilting, collapse and death (damping off). Slow early season growth, small cotyledons and reddened hypocotyls, lesions on roots.

Favoured by

Anything that slows down germination and seedling growth favours infection by seedling disease. This includes cool and/or wet weather, poorly formed beds, compaction, waterlogging, incorrect planting depth, fertiliser under the plant line, excessive rates of planting herbicide, movement of herbicide into root zone (ie by rain) and infection by other pathogens.

Host range

These pathogens have wide host ranges and can survive on residues of many crops and weeds.

IDM tactics

- Delay sowing if possible, until soil temperature is 16°C and rising.
- Use a variety with good seedling vigour.
- Use effective seed treatment fungicides.
- Avoid freshly incorporated rotation crop residues.
- Plant into well prepared, high, firm beds.
- Carefully position fertiliser away from the plant line.
- Pre-irrigate and/or plant into moisture.
- Take care with use of herbicides at planting.

Rhizoctonia seedling disease. (Alison Seyb, formerly DPI NSW)

Black root rot

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 *T. basicola* does not kill seedlings by itself. Severe black root rot opens the root up for infection by Pythium or Rhizoctonia. Plants that are badly affected early in the season may not continue to show symptoms later in the season as the dead cells of the root cortex are sloughed off when growth resumes in warmer weather.

Host range

The host range of *T. basicola* includes all varieties of cotton, most legumes including faba bean, soybean, cowpea, field pea, chickpea, mung bean, lablab and lucerne. Datura weeds (thornapple, caster oil) are also hosts, but little is known about other weeds. Non hosts include all the cereal crops, sunflower, canola and vetch.

IDM tactics

- Choose varieties that can 'catch up'.
- Use Bion seed treatment.
- Prepare beds well ('high and firm' not 'low and loose')!
- Pre-irrigate and/or plant into moisture.
- Delay sowing if possible, until soil temperature are 16°C and rising.
- Rotate with biofumigation crops such as vetch or mustard.
- Avoid legumes and control weeds.
- Minimize your tailwater.
- Always practice good farm hygiene.
- Summer flooding if possible.

Black root rot. (Stephen Allen, CSD)

Verticillium wilt
Verticillium dahliae

Symptoms
Leaf mottle – yellowing between the veins and around the leaf margins, vascular discolouration or browning extending throughout the stem and into the petioles, root system otherwise healthy, some defoliation may occur if cool.

Internal symptoms can be checked by cutting the stem. The vascular tissue of an infected plant will reveal flecking brown discolouration extending throughout the stem and into the petioles. Under Australian conditions with Australian strains of the pathogen, all plants with vascular symptoms will also display foliar symptoms,

The discolouration is similar to that of Fusarium wilt but usually appears as flecking rather than continuous browning. Severe cases often need to be tested by a pathologist to determine whether the pathogen is Fusarium or Verticillium.

The root system appears otherwise healthy.

Favoured by
Resistance to the disease is temperature sensitive. Varieties that are resistant at 25°–27°C are susceptible at 20°–22°C. The disease is most severe during extended wet weather and/or waterlogging and in late maturing crops. The disease is favoured by excessive use of nitrogen which results in late season growth and also by potassium deficiency.

Host range
V. dahliae has a large host range which includes sunflower, soybean, noogoora and bathurst burr, saffron thistle, thornapple, caustic weed, bladder ketmia, burr medic, black bindweed, pigweed, devils claw, turnip weed, mintweed, blackberry nightshade and others.

Non-host crops include sorghum and cereals.

IDM tactics
- Select varieties with a high V.rank.
- Manage for earliness, including optimizing nutrition and water inputs.
- Avoid late season irrigations.
- Incorporate cotton residues soon after harvest.
- Rotate with non-hosts such as cereals or sorghum.
- Control alternative weed hosts.
- Minimize your tailwater.
- Always practice good farm hygiene.

Verticillium wilt. (Stephen Allen, CSD)

Fusarium wilt
Fusarium oxysporum var. vasinfectum (FOV)

Symptoms
External symptoms include stunted growth and dull and wilted leaves followed by yellowing or browning of the leaves and eventual death from the top of the plant. Some affected plants may reshoot from the base of the stem. External symptoms can appear in the crop at any stage. Most commonly they become apparent in the seedling phase when plants are beginning to develop true leaves, or after flowering during boll fill. Symptoms can appear as only a few, individual plants or as a small patch, often but not always in the tail drain or low-lying areas of the field.

Internal symptoms can be checked by cutting the stem. An affected plant will reveal continuous brown discolouration of the stem tissues running from the main root up into the stem. The discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecking.

Favoured by
Use of susceptible varieties. Stresses in the crop such as waterlogging, root damage through cultivation and cool, wet growing conditions. Spores surviving in soil and on crop residues can be spread by overland flows, in irrigation water and attached to people and machinery.

Host range
The FOV pathogen is specific to cotton but can live on the residues of most non-host crops. Known alternative weed hosts include bladder ketmia, sesbania pea, dwarf amaranth, bellvine and wild melon.

IDM tactics
- Select varieties with a high F.rank
- Delay planting if possible until soil temperatures are 16°C and rising.
- Ideally root pull, with crop residues slashed and retained on the surface for at least one month prior to incorporation.
- 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.
- 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.
- Avoid inter-row cultivation

Fusarium wilt. (Linda Smith, Qld DAFF)

Alternaria leaf spot

Alternaria macrospora
Alternaria alternata

Most commercial varieties of cotton are relatively resistant to Alternaria and the impact of the disease on yield is insignificant, unless the crop is severely affected with premature senescence associated with potassium deficiency. Pima cotton is very susceptible.

Symptoms – *A. macrospora*

Brown, grey brown or tan lesions 3–10 mm in diameter on lower leaves, sometimes with dark or purple margins. Circular dry brown lesions on bolls.

Pima varieties can defoliate rapidly when the environment favours the disease.

Symptoms – *A. alternata*

Purple specks or small lesions with purple margins on bolls and leaves.

Favoured by

Heavy dews or extended periods of wet weather resulting in long periods of free moisture on the leaf. Suppressed by hot dry weather. Nutritional stress can favour development. Pima varieties are quite susceptible.

Host range

Cotton, bladder ketmia, sida and anoda weed.

IDM tactics

- Manage crop to avoid extremely rank growth.
- Foliar fungicide sprays are available for the control of Alternaria leaf spot on Pima cotton.

Alternaria leaf spot. (Chris Anderson, NSW DPI)

Boll rot and Tight rock

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.

Symptoms

Bolls infected by Phytophthora nicotiane var parasitica appear dark brown to black, sometimes with areas of white mould on the surface. 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. Fusarium boll rot (not Fusarium wilt) causes similar boll rots, with mould sometimes having a pink discolouration. Diplodia boll rot starts as dark brown lesions which rapidly expand to cover the whole boll as rot progresses. In the later stages of development, bolls become covered in a black smut-like fungal growth which can easily be rubbed off the boll surface.

Sclerotinia boll rot characteristically has black sclerotia (2 to 10mm 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 bolls may be affected. The sclerotia germinate to produce apothecia (small cream coloured 'golf tees' – not to be mistaken for bird's nest fungi) which release clouds of microscopic spores that can only infect the plant through dead or dying tissue. The fungus then grows into healthy plant tissue such as the developing boll and down the fruiting branch towards the main stem. Several other fungi can cause secondary boll rots in cotton, taking advantage of wounds in boll wall.

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.

Host range

There are a broad range of fungi and bacteria involved in boll rots and host range varies between species.

IDM tactics

- Manage crop to avoid extremely rank growth.

Cotton bunchy top (CBT)

It has been reported from the Macquarie Valley (south) to the Emerald region (north). CBT, a viral disease, is spread by the cotton aphid (*Aphis gossypii*, Glover).

Symptoms

Symptoms include reduced plant height, leaf size, petiole length, internode length and boll size. Leaf symptoms are usually an angular pattern of pale green leaf margins with darker green centres. The angular patches turn red as leaves age. Leaves are leathery and brittle compared to leaves on

CBT has a distinctive leaf mottling. (Stephen Allen, CSD) healthy plants. Usually a period of 3–8 weeks lapses between infection and when symptoms first appear. Affected plants often occur in patches or crop edges and are associated with areas of highest aphid activity. When plants become infected very early, the growth of the whole plant is affected taking on a compact, stunted, 'climbing ivy' appearance. Early infection has the greatest potential to reduce yield. The extent to which yield is affected also depends on the proportion of plants infected. If the proportion infected is high (>50%), yield may be reduced.

Favoured by

CBT 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 is probably higher after wet winters and lower after dry winters. 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

The most critical alternative host plant is ratoon volunteer cotton. They survive between seasons, retaining leaves through winter and supporting infected aphid populations from one season to the next. Seven natural field hosts and one experimental host CBT have been identified. These include cotton, *Malva parviflora* (Marshmallow weed), *Abutilon theophrasti* (Velvetleaf), *Anoda cristata* (Spurred anoda), *Hibiscus sabdariffa* (Rosella), *Sida rhombifolia* (Paddy's lucerne), *Chamaesyce hirta* (Asthma plant) and *Gossypium australe*. 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 like asthma plant (family Euphorbiaceae).

IDM tactics

1. Avoid the problem

- Break the green bridge. Elimination of hosts, particularly over winter, is the most effective means of minimising recycling CBT risk.
- Good crop destruction and control of ratoons and volunteers is critical for controlling CBT and cotton aphid.
- Good farm hygiene to control broad leaf weeds will reduce the risk of cotton aphid.

2. Manage the risk

- Don't over-react to aphids. Excessive use of aphicides will select resistance and restrict control options.
- 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

Reniform nematodes *(Rotylenchulus reniformis)* have been confirmed as affecting cotton in some fields in Central Qld.

Symptoms

Feeding causes damage to the plant resulting in stunting and generally poor plant growth. Populations can be quite uniform in their distribution across a field, making detection of early plant symptoms difficult.

Presence/absence sampling

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.

1. Mark patches with GPS or on a map so that they can be monitored next season.
2. Scrape off the dry top soil and sample 10-15cm deep using a small trowel or soil corer.
3. If there is more than one patch in a field, collect multiple samples from these areas in a bucket, and mix through.
4. Place approximately 400g in a clearly labelled plastic bag.
5. Postage and handling - The extraction process relies on live nematodes so please keep cool in an esky without an ice brick, and do not store samples in the fridge. Never send a sample on a Thursday or a Friday. Label samples with permanent marker towards the bottom of the bag. Include a sample sheet with:
   - Sample site (farm/field name and GPS references);
   - Date and time sampled; and,
   - Contact name, number and email address.

Contact Linda Smith, DAFF Qld, 07 32554356 for details.

IDM tactics

- Rotating with non-host crops such as wheat or sorghum reduces nematode levels.
- Management of cotton stubble is important. Cotton stalks should be cut and soil tilled through the stubble zone immediately after harvest (or as soon as is feasibly possible) to destroy these breeding sites.
- Ensure root-cutting is successful and there is no re-growth.
- Bare fallows are a very good management option. However success depends on having no host plants in the fallow (cotton or weedy hosts), and the length of the fallow because the longer the better.
- Plant into good conditions including optimum soil temperature, no water stress and well formed beds.

Cotton pathology 2012–13

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Commercial cotton crops across NSW and Queensland were inspected in October-December 2012 and February-April 2013. 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 112 and 48 fields that were surveyed in NSW and Queensland respectively. This represents the 30th consecutive season of quantitative disease surveys of cotton in NSW and the 11th consecutive season of cotton disease surveys in Queensland.

Daily maximum temperatures were well above average from planting through to the end of January, 2013 and then average or below average from February to harvest. The daily maximum temperature exceeded 45°C in many areas in mid-January, 2013. At Bourke, in western NSW, temperatures exceeded 35°C on 111 days and over 45°C on 24 days between 1st October, 2012 and 20th April, 2013.

In contrast the cold spell and rainfall that occurred in NSW cotton production areas on 11th and 12th October, 2012 interrupted planting and produced problems with stand establishment. Widespread rainfall in late January, associated with Cyclone 'Oswald,' was accompanied with a drop in daily maximum temperatures. The cooler weather was further accompanied by above average rainfall in February and March, 2013.

The incidence and severity of plant diseases is determined by environmental conditions. The cooler and wetter 2011/2012 season favoured the appearance of Sclerotinia stem and boll rot, severe Verticillium and Fusarium wilt and problems with boll rot in central Queensland. The hot and dry conditions experienced during much of 2012/2013 suppressed the development of most diseases of cotton. However, the cooler and wetter autumn weather did allow late development of severe Verticillium wilt.

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 54 farms in NSW and 21 farms in Queensland during October and December of 2012 (Table A). 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.

The presence of volunteer plants surviving over from the previous season enables pests and pathogens such as aphids, mealy bug and cotton bunchy top to overwinter and initiate new outbreaks in the spring. Volunteer cotton plants were observed on 59 of the 75 farms visited during the disease surveys (79%).

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. None of these diseases and/or pathogens were observed.

Seedling mortality

As part of the disease survey an estimate of the number of seeds planted per metre is compared to the number of plants established per metre. This comparison produces an estimate of seedling mortality which includes the impact of seedling disease (Rhizoctonia and Pythium etc.) as well as seed viability, the activity of soil insects such as wireworms, physical problems such as fertiliser or herbicide burn and the effects of adverse environmental conditions.

Mean seedling mortality (Figure 1) for the crops inspected in NSW and Queensland was 32.1% and 26.6% respectively in the 2012–13 season, (32.3% and 29.6% in 2011–12 and 31.9% and 25.8% in 2010–11).

Mean seedling mortality was lowest (21.1%) in the Tandou and St George/Dirranbandi areas and highest in-crops in the Macquarie Valley (39.1%) and Bourke/Walgett (37.6%). Problems with crop establishment included wireworm, symphlids, 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.

In southern NSW the most affected fields were those that were either sown into moisture or watered up on 5th and 6th October, 2012 and then received rainfall on 11th and 12th October along with daily minimum soil temperatures < 12°C between 11th and 14th October. The mean seedling mortality in these fields was approximately double (50.5%) that observed in other fields planted either before or after 5th and 6th October, 2012.

TABLE A: The occurrence of volunteer cotton plants surviving from the previous season on farms in NSW and Queensland in the spring of 2012

	1. Along channels, roads, fences	2. In fallows and rotation crops	3. In the current crop (regrowth from stubs)	TOTAL
In NSW	22/54 (41%)	13/49 (26%)	40/54 (74%)	44/54 (81%)
In Qld	11/21 (54%)	2/21 (9%)	11/21 (54%)	15/21 (71%)
Total	33/75 (44%)	15/70 (21%)	51/75 (43%)	59/75 (79%)

FIGURE 1: Mean seedling mortality in the 2012/13 season. Seedling mortality is derived from the difference between the number of seed planted and the number of plants established.

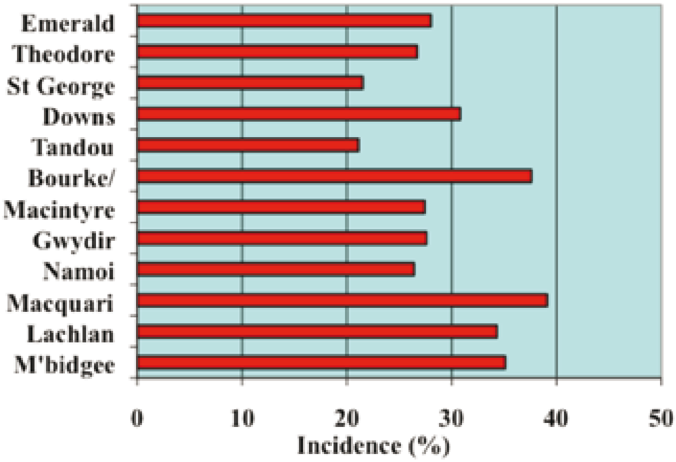
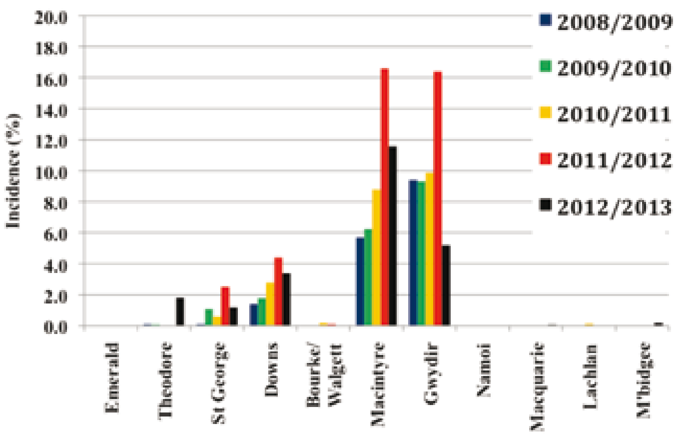


FIGURE 2: The mean incidence of Fusarium wilt of cotton in the five seasons from 2008-09 to 2012–13. Fusarium wilt is present in all cotton production areas listed.



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 – as was experienced during the 2011–12 season. 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 again obvious during early season surveys. 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 was one new report of Fusarium wilt ('Downs' strain) on a farm in the Murrumbidgee Valley. This new report was confirmed by Dr Linda Smith (DAFF Queensland) who provides a free, confidential diagnostic service for Fusarium wilt of cotton funded by the Australian cotton industry. This represents the first report of Fusarium wilt of cotton in the Murrumbidgee Valley.

Fusarium wilt was observed in 18 of the 112 crops surveyed in NSW including nine of the 12 crops inspected in the Macintyre Valley and seven of the 14 crops surveyed in the Gwydir Valley. The incidence of Fusarium wilt (Figure 2) averaged 11.6% and 5.2% (respectively), for these two production areas (16.6% and 16.4% in 2011–12; 8.8% and 9.9% in 2010–11) and exceeded 30% of plants affected in two of the 18 fields. Though Fusarium wilt is known to be present and widespread in the Macquarie Valley and the upper Namoi Valley it has not been prevalent in fields surveyed in any of the last four seasons.

It is interesting to note that black root rot was also present in 17 of the 18 fields in NSW where Fusarium wilt was recorded. The incidence of black root rot exceeded 40% in 11 of the 18 fields.

The disease was observed in 20 of the 48 crops surveyed in Queensland including 11 of the 12 irrigated crops inspected on the Darling Downs. Fusarium wilt was not observed in the rain grown crops that were inspected. The incidence of Fusarium wilt averaged 3.4% and 1.2% respectively, for the Darling Downs and St George areas compared to 4.4% and 2.4% in the previous season (Figure 2).

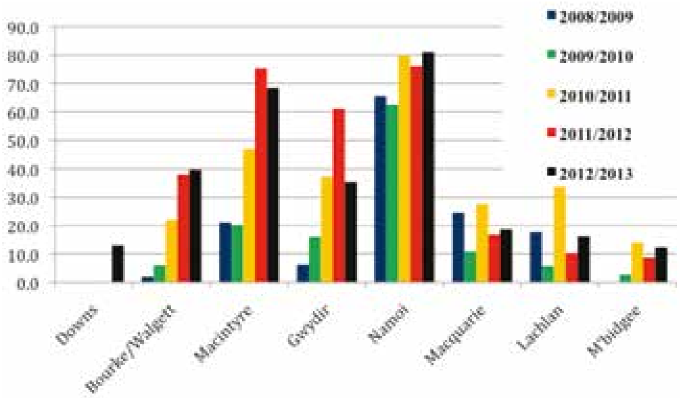
Disease survey results over the last five seasons (Figure 2) reveal the impact of favourable weather conditions in the 2011–12 season and the trend in increasing disease incidence that is particularly evident in-crops surveyed in the Macintyre Valley and on the Darling Downs.

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. Assessments during the 2012–13 season showed a decrease in disease incidence in eight of the ten transects. Factors contributing to this observed decrease include the use of varieties with the highest level of resistance and the less favourable hot seasonal weather conditions during the 2012–13 season compared to the cooler and wetter 2011–12 season.

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 2012–13 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.

FIGURE 3: The incidence of black root rot of cotton in the five seasons from 2008-09 to 2012–13.



Disease survey results over the last five seasons (Figure 3) reveal the impact of favourable weather conditions in the 2011–12 season and the trend in increasing disease incidence that is particularly evident in-crops surveyed in the Bourke/Walgett area, Macintyre Valley, Gwydir Valley and Namoi Valley.

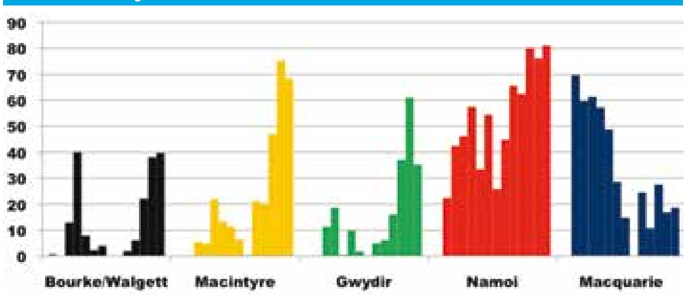
The average incidence of black root rot within fields was 40% for NSW. This included 48 fields where more than 50% of plants were affected and four fields in the Namoi Valley, three fields in the Macintyre Valley, one field in the Murrumbidgee Valley and one field at Tandou where all plants were infected. The disease was found in all of the fields visited in the Namoi and Macintyre Valleys, 86% of fields surveyed in the Gwydir Valley; 64% of fields in the Bourke/Walgett area, 50% of fields in the Tandou area, Macquarie Valley and Lachlan Valley and 21% of fields in the Murrumbidgee Valley. Verticillium wilt was present in seven (78%) of the nine fields that had a high incidence of black root rot.

Assessment of disease severity is based on the proportion of each tap root that is blackened where '0' indicates healthy and '10' indicates 100% of the tap root blackened. The mean severity of black root rot for fields in the Namoi, Gwydir and Macintyre Valleys was 3.6, 1.1 and 3.5 respectively (3.0, 2.4 and 3.1 in 2011–12).

Black root rot has previously been recorded in all Queensland cotton production areas except the Burdekin. The disease was observed in eight of the 14 fields surveyed on the Darling Downs and two of the 15 fields surveyed in the St. George/Dirranbandi area. The mean incidence of black root rot in-crops on the Darling Downs was estimated to be 13.1%.

A review of the mean incidence of black root rot in the established cotton production areas of NSW since the 2000–01 season (Figure 4) indicates that black root rot was more prevalent in the Macquarie Valley than in the Namoi Valley prior to the drought years between 2003 and 2010. The reduced cropping and enforced long fallows during the drought resulted in a dramatic reduction in the mean incidence of black root rot. The impact of the drought was least severe in the Namoi Valley and most severe in the Bourke/Walgett area. As mentioned previously – during the last five seasons since the drought the incidence of black root rot has increased significantly.

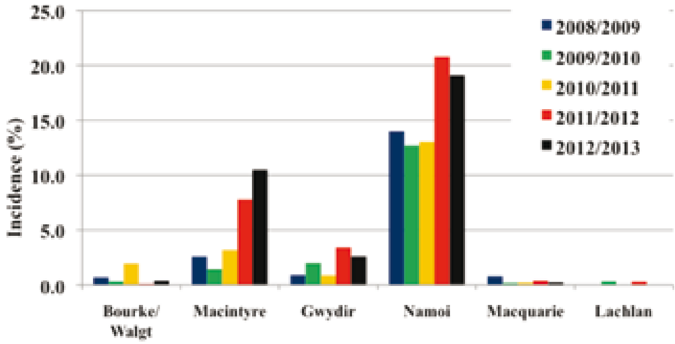
FIGURE 4: The incidence of black root rot of cotton in NSW production areas in the 13 seasons from 2000-01 to 2012–13. The impact of the drought between 2003 and 2010 is very obvious.



Verticillium wilt

Verticillium wilt (*Verticillium dahliae* Klebahn) is also favoured by cooler weather and is rarely observed in Queensland production areas. The disease was observed in 38% of fields surveyed in NSW during the 2012–13 season. However, the average incidence was only 5.3% of plants infected (Figure 5). This can be compared with average incidences of 6.8%, 3.7%, 3.8% and 4.1% in the 2011–12, 2010–11, 2009–10, and 2008-09 seasons (respectively). Symptoms of Verticillium wilt observed during the 2012–13 season were not as severe as those seen in the cooler and wetter 2011–12 season.

FIGURE 5: The distribution and incidence of Verticillium wilt of cotton 2008–09 to 2012–13. The disease was present in many areas but the incidence was generally low.



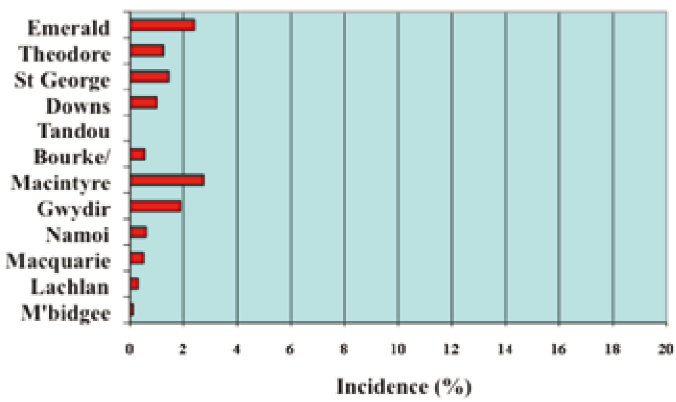
Verticillium wilt was observed in all of the fields surveyed in the Macintyre Valley during the 2012–13 season and the average incidence was 10.5% of plants affected (Figure 5). The disease was observed in 86% of fields surveyed in the Namoi valley, 57% of fields in the Gwydir Valley and 21% of fields in the Bourke/Walgett area where the average incidence of the disease was 19.5%, 2.6% and 0.6% (respectively). Two fields in the Namoi Valley had over 75% of plants with symptoms and both of these fields had been severely affected by black root rot earlier in the season.

The distribution and incidence of Verticillium wilt has increased significantly in-crops in the Namoi, Gwydir and Macintyre Valleys in the 2011–12 and 2012–13 seasons (Figure 5). The disease was observed for the first time in the Murrumbidgee Valley during the 2011–12 season.

Boll rots

The average incidence of boll rots in the 2012–13 season was recorded as 0.9% for NSW and 1.5% for Queensland; (1.6% and 6.8% in 2011–12; 0.7% and 2.7% in 2010–11; 9.7% and 7.3% in 2009–10). Only 2.6% of bolls were affected in-crops in the Macintyre Valley and 2.4% of bolls in-crops in the Emerald area. It should be remembered that the disease surveys are completed in February and the final incidence of boll rots at harvest may be significantly higher.

FIGURE 6: The average incidence of boll rots in each of the cotton production areas for the 2012–13 season.



The most common boll rot in NSW production areas is Phytophthora boll rot, which develops when soil is splashed up onto low opening bolls. 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.

Rainfall in Emerald exceeded 2.0mL on only three days in January, 2013 and five days in February, 2013 compared to eleven days in January, 2012 and seven days in February, 2012. Despite the fact that many of the crops in the Emerald area were planted in September and early October, 2012 and bolls were maturing and opening in January, 2013 the mean incidence of boll rots (2.4%) was well below the mean incidence of boll rots observed in the previous season (16.7%).

Reniform nematode

Stunted seedlings and roots with 'nodules' (Figure 7) were collected from fields near Theodore in Queensland during the annual disease survey in November, 2012. Nematologist Jenny Cobon of DAFF Queensland confirmed the presence of the reniform nematode (*Rotylenchulus reniformis*).

Subsequent intensive sampling has found the nematode to be widespread in the Theodore area. The reniform nematode had previously been observed in a field near Emerald during the November, 2003 disease survey and was still present in this and other adjacent fields in 2012–13. Reniform nematode is considered to be a major pest of cotton in parts of the USA.

Other diseases and disorders

Bunchy top was observed in only two (4.2%) of the fields surveyed in Queensland production areas and in 31% of fields surveyed in NSW with the average incidence only 0.01% in Queensland and 1.7% in NSW. It was estimated that 24.5% of plants were affected in one field in the Walgett area of NSW.

FIGURE 7: Egg sacks of the reniform nematode on seedling roots. (Photo: Damien Erbacher)

Seed rot was observed in 23 of the 48 (48%) crops inspected in Queensland. The average incidence was only 0.4% although 4.5% of bolls were affected in one field near Emerald.

Tobacco Streak Virus was observed in two of the 11 crops inspected in central Queensland in November 2012. The incidence of the virus was very low.

Alternaria leaf spot was present at low levels in almost all crops and was generally of minor significance.

Premature senescence was noted in 29% of the crops surveyed in Queensland. However, the average incidence was only 0.7%.

Sclerotinia boll and stem rot was not observed during disease surveys in the 2012–13 season.

Acknowledgments: These surveys were made possible with the financial support of the Cotton Research & Development Corporation, Cotton Seed Distributors Ltd., NSW Department of Primary Industries and the Department of Agriculture, Fisheries and Forestry Queensland. 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: (e.g. Cotton Extension Officer)	Address/Email/Fax/Telephone:
Property name and field number:	Date collected:
Grower/Agronomist	Grower's address or area/locality:

Mark (X) as appropriate

SYMPTOMS	DISTRIBUTION	INCIDENCE/SEVERITY	CROP GROWTH STAGE
☐ Poor emergence or seedling depth	☐ One field only	☐ All plants	☐ Irrigated
☐ Leaves: spots or dead areas	☐ In several fields	☐ Scattered single plants	☐ Dryland/rain-grown
☐ Leaves: discoloured	☐ In all fields	☐ Scattered patches of plants	☐ Seedling stage
☐ Leaves: mottled	☐ One variety only	☐ In a large patch (>5 m)	☐ Setting squares
☐ Leaves or shoots: distorted or curled	☐ Several varieties affected	☐ In a small patch (1–5 m)	☐ Early flowering
☐ Plants stunted	☐ Some rows more affected	☐ In a small patch (<1 m)	☐ Peak flowering
☐ Plants wilting	☐ On lighter soil types	☐ Plants dead	☐ First bolls open
☐ Premature plant death	☐ On heavier soil types	☐ Plants defoliating	☐ Defoliated
☐ Bolls: spots or dead areas	☐ In poorly drained area(s)	☐ One to a few plants only	☐ Ready to pick
☐ Roots: discoloured, bent, pruned, etc.	☐ Other: (please specify)		

OTHER INFORMATION

- Cultivar ....
- Paddock History ....
- Nearby crops ....
- Rainfall in last 10 days ....
- Average temperature range over the last 10 years ....
- Date of last irrigation ....
- Date of last cultivation ....

Please contact 02 6792 4088 for an Australian Cotton Industry Development and Delivery team member or district agronomist to determine the appropriate Pathologist and address for submitting sample

IF FUSARIUM WILT IS SUSPECTED, SAMPLES MUST BE SENT TO:
Qld DAFF Ecoscience Precinct – contact Linda Smith, Ph 07 32554356, Email: linda.smith@daff.qld.gov.au

When sending samples:

- Send multiple samples (e.g. more than 1 leaf, stem or plant).
- If possible include a healthy plant as well as the diseased plant material.
- It is better to despatch samples early in the week rather than just before the weekend.
- Never wrap samples in plastic. Dry or slightly dampened newspaper is better.
- When collecting seedlings – dig them up rather than pull them out. Include some soil.
- Several sections of stem (10–15 cm long) are usually adequate for wilt diseases.
- Keep the sample cool and send as soon as possible.

Cotton Disease Control Guide

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

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

- Planning your crop layout to avoid sensitive areas, including homes, school bus stops, waterways, grazing land and non-target crops.
- Ensuring that all spray contractors have details of any sensitive areas near spray targets.
- Carefully following all label directions.
- Consulting with neighbours to minimise risks from spraying near property boundaries. Keep neighbours informed of your spraying intentions

Spray Log Books

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

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

ABBREVIATIONS USED IN TABLES 35–36

EC = Emulsifiable concentrate	WDG = Water dispersible granule
FC = Flowable concentrate	WP = Wettable powder
SC = Suspension concentrate	

TABLE 35: Control of cotton diseases

Active ingredient	Fungicide chemical group	Concentration and formulation	Application rate of product	Comments
Alternaria leaf spot				
mancozeb	Y	750 g/kg WG	2.5 kg/ha	Pima varieties only. Do not apply before flowering. Begin applications as soon as disease symptoms appear and before each infection period. DO NOT apply more than 4 sprays per season.
***Rhizoctonia solani* (Damping off)**				
tolclofos-methyl	X	500 g/L SC	0.12 L/ha or 0.12 L/10km row	QLD and NSW only. Apply as an in-furrow spray or by water injection at time of planting.
		100g/L	40g/kg of seed	Put with seed immediately before planting
***Pythium* spp. and *Phytophthora* spp. (Damping off)**				
metalaxyl-m	D	350 g/L EC	0.1 L/100 kg seed	Commercial application recommended.
***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				
acibenzolar-s-methyl		500 g/L FC	1.2 mL/100 kg seed	Seed treatment for suppression of Fusarium wilt and Black root rot.
metalaxyl-m	D	350 g/L	0.043 L/100 kg seed	For Fusarium wilt disinfection. Commercial application recommended.

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	Dynasty	Syngenta
mancozeb	750 g/kg DF, WG	multiple	multiple
tolclofos-methyl	100 g/kg	Rizolex	Sumitomo Chemical Australia
	500 g/L SL	Rizolex liquid	Sumitomo Chemical Australia
	500 g/L SL	Tolex	Genfarm

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. To determine if growth regulators are required see Cotton Seed Distributors' website (www.csd.net.au) to calculate vegetative growth rates. For more information refer to 2013 *Cotton Production Manual.* Cottassist provides support in calculating vegetative growth rates.

Defoliation

The safe timing of defoliation is when the youngest boll expected to reach harvest is physiologically mature. This usually occurs when 60–65% of bolls are open. The other method of assessing physiological maturity is when there are 3–4 nodes of first position bolls above the highest cracked first position boll (last harvestable boll), known as nodes above cracked boll (NACB). For more information on defoliation see FibrePak and 2013 *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	SC = Suspension concentrate
L = Liquid	WDG = Water dispersible granule
LC = Liquid concentrate	

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. Apply no more than 1.5 L/ha in total. See label for application times.
		0.75–2.0 L/ha	Single application rate. Use high rate where crop growth is excessive, between 1st flower and cut out. Check label.

TABLE 38: Plant growth regulators trade names and marketers

Active ingredient	Concentration and formulation	Trade name	Marketed by
Mepiquat	38 G/L Ac	Fix 38	Chemtura
		Adjust 38	Rotam
		Chemquat	Imtrade
		Concorde	Nufarm
		Cot-Trol 38	Hextar
		Fortune	Syngenta
		Mepi-C	Miller
		Mepidef	Farmalinx
		Mepiquat 38 Plant Growth Regulator	Ozcrop, Shandong Rainbow, Agri West, Pacific Agriscience , Accensi , Titan Ag, Landmark Operations, Ospray , Kenso, Conquest, Echem
		Piqme 38	United Phosphorus
		Pix	Nufarm
		Reign	Bayer Cropscience
		Reward	Farmoz

PGRs & DEFOLIANTS – *sponsored by* eChem crop protection

eChem, providing quality crop protection products for the Australian Cotton Industry

Defoliation Products

Ethephon
Thidiazuron 500 SC
Thi-Ultra SC
Mepiquat 38

Insecticides

Diafenthiuron 500
Abamectin
Alpha-Cyp 100 Duo
Amitraz 200 EC/ULV

Cotton Seed Treatment Insecticides

Genero 600

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Phone: 1300 781 649 or Fax: 1300 781 650

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TABLE 39: Cotton defoliation products

Active ingredient	Concentration and formulation	Application rate of product	Comments	
Carfentrazone-ethyl	240 g/L EC	0.08 – 0.1L/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	See critical comments on label. May damage green bolls.	
Ethephon	720 g/L AC	0.5–1.0L/ha 1.3L/ha 2.0-3.0L/ha	Accelerated boll opening in combination with a defoliant Pre conditioning Acceleration of boll opening	
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 1.3L 0.33 – 0.67 L/ha	Acceleration of boll opening and enhancement of defoliation. Pre conditioning. Enhancement of defoliation	
Paraffinic oil	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 dryland 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 apecified on the label. Apply with Dropp Ultra in accordance with the Drop Ultra label.	
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	0.04–0.08L/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/kgWG or 500 g/L SL	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 SL	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
	240g/L + 120g/L SL	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
Cotton seed oil	860 g/L LQ	Intac Cotton Spray Oil	Nipro
Diquat	200 g/L AC	Desi-Tex 200	Ronic International
		Dia-Kill 200	Sinon
		Diquat 200	Accensi, Farmalinx, Imtrade, Kd Plant Care, Kenso, Landmark Operations, Ospray, Ozcrop, Shandong Rainbow, Titan Ag
		Hydrogel D	Better Safe
		Reglone	Syngenta Australia
		Sanction 200	Conquest Crop Protection
Ethephon	720 g/L AC, SC, EC	Advancer 720	Redchem
		Boll Cracker 720	Australis Crop Protection

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TABLE 40: Defoliation products trade names and marketers (continued)

Defoliant	Concentration and formulation	Trade name	Marketed by
Ethephon	720 g/L AC, SC, EC	Ethephon 720	Proterra, Novaguard, Pacific Agriscience, Accensi, Ospray, Landmark Operations, Conquest Crop Protection, Kenso, Echem, Apparent, Ezycrop, 4 Farmers, Agro-Alliance, Ozcrop, Shandong Rainbow, Agri West, Titan Ag, Imtrade
		Ethon 720	Farmalinx
		Galleon	Nufarm Australia
		Prep 720	Bayer Cropscience
		Promote 720	Farmoz
		Sentral 720	Hextar Chemicals
Ethephon + AMADS	275 g/L + 873 g/L AC	CottonQuik	Nufarm
Ethephon + Cyclanilide	720 g/L + 90 g/L LC	Finish 720¬¬¬	Bayer CropScience
Adjuvants	582 g/L LQ	Paraffinic Oil	Apparent
		AC Para Spray Oil	AxiChem
		Infuse	Rygel
		Penatrol	Alphachem
		Pro Stickup	5 heads
		Smartup	Crop Smart
		Uptake Spraying	Dow AgroSciences
	598 g/L EC	Oil Enhance Spray Adjuvant	Sacoa
		PowerSurge Spray Adjuvant	Conquest
		Sticka Sprayoil	ACP
	792 g/L SC	Canopy Insecticide	Caltex Australia
	815 g/L EC	Biopest Paraffin Oil	Sacoa
	815 g/L EC	Bioclear	Caltex
	830 g/L EC	Trump	Victorian Chemicals
Paraquat + diquat	135 g/L + 115 g/L AV	Refer to Table 33	Refer to Table 33
Petroleum oil	827 g/L L	D-C-Tron	Caltex
	844 g/L EC	Sacoa Summer	Sacoa
	846 g/L EC	Broadcoat	Caltex
	859 g/L L	Cottoil	Sacoa
	861 g/L	Empower	Innovative Chemical Services
Pyraflufen-ethyl + n-methyl-2-pyrrolidone	25 g/L + 102 g/L EC	ETee	Sipcam Pacific
Sodium chlorate	300 g/L L	Total Ag Leafex	Total Ag
Thidiazuron	490g/kg WP	Lanceadrop	Lances Link
	500 g/L SC	Dropp Liquid	Bayer Cropscience
		ESCalate 500 SC	Farmoz
		Mace 500 SC	Conquest Crop Protection
		Reveal Liquid	Nufarm Australia
		Tentacle SC	Agri West
Thidiazuron	500 g/L SC	Thidiazuron 500DC	Accensi, Apparent, Echem, Kenso, Landmark Operations, Ospray, Proterra, Sabakem, Titan Ag
		Thiron	Farmalinx
		Timezone 500	Australis Crop Protection
Thidiazuron + diuron	120 g/L + 60 g/L SC	Do Away	Ospray
		Escalate Ultra	Farmoz
		Thidiazuron + diuron	Titan AG
		Thi-Ultra	eChem
		Dropp UltraMAX	Bayer CropScience
	120 g/L + 60 g/L SC	Do Away	Ospray
	120 g/L + 60 g/L SC	Escalate Ultra	Farmoz
	120 g/L + 60 g/L SC	Thidiazuron + diuron	Titan AG
	120 g/L + 60 g/L SC	Thi-Ultra	eChem
	240 g/L + 120 g/L SC	Dropp ultramax	Bayer CropScience

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Best Practice

Biosecurity – we all have a responsibility

Brad Siebert, Plant Health Australia
Susan Maas, CRDC

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.

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 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 washed before returning. 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.

Cotton Australia Ltd is a member of Plant Health Australia (PHA), the national coordinator of the government-industry partnership for plant biosecurity in Australia. PHA is a not-for-profit company funded by subscriptions—one-third by the Australian Government, one-third by state and territory governments and one-third by plant industry members. Research bodies including the Cotton Research and Development Corporation have associate membership of PHA.

As part of its preparedness initiatives for the cotton industry, PHA released the second version of the Cotton Industry Biosecurity Plan (IBP) in February 2010. PHA coordinated the production of the plan with expertise provided by Cotton

Cotton growers are the key to protecting Australia's crops from exotic insects and diseases like cotton leaf curl virus.

It is important that you are aware of the risk, and if you spot anything unusual on your crop you should always check it out and call your local entomologist, pathologist or the Exotic Plant Pest Hotline on 1800 084 881. The call is free (except from mobiles) and early detection will help protect your industry.

Visit www.planthealthaustralia.com.au for further information.

Australian Government Department of Agriculture, Fisheries and Forestry
Australian Cotton Growers Research Association Inc.

This project has received funding from the Australian Government through the Department of Agriculture, Fisheries and Forestry.

Plant Health AUSTRALIA

LOOK. BE ALERT. CALL AN EXPERT. 1800 084 881

Australia, CSIRO, Cotton Seed Distributors, the Cotton Research and Development Corporation, Cotton Catchment Communities Cooperative Research Centre as well as DAFF Queensland and NSW Department of Primary Industries

A risk assessment carried out during the development of the IBP identified 12 high priority pests that currently don't exist in Australia, that could establish in our farms and threaten production. These include **cotton leaf curl virus and exotic races of Fusarium Wilt** that are predicted to have an 'extreme' economic impact on the cotton industry in the case of an incursion in Australian cotton growing areas.

The other high priority pests are:

- **Cotton boll weevil;**
- **Indian green jassid;**
- **Exotic species of spider mites;**
- **Tarnished plant bug;**
- **Biotypes of silverleaf whitefly;**
- **Melon aphid ;**
- **Defoliating strains of verticilium wilt;**
- **Texas root rot; and,**
- **Blue disease.**

Industries that join PHA are permitted to sign the Emergency Plant Pest Response Deed (the EPPRD) which is the formal legally binding agreement between PHA, the Australian Government, all state and territory governments and national plant industry peak-body signatories, which sets out how eradication responses to EPP incidents are to be managed and funded. Cotton Australia became a signatory of the EPPRD in May 2006 which provides following benefits:

- The procedure for dealing with an emergency plant pest incursion is agreed before one occurs, allowing a swift, coordinated and effective response. This gives us the best chance of preventing the incursion from spreading from farm to farm.
- Potential liabilities are known and funding mechanisms agreed in advance.
- In the event of an incursion affecting cotton crops, Cotton Australia will immediately be at the table side-by-side with government representatives, contributing to decision making about any EPP response.
- Growers whose crops or property is directly damaged or destroyed in the course of response plan are eligible for the payment of owner reimbursement costs, under certain circumstances.

For more information on prevention and control of pests, visit the Cotton CRC website at www.cottoncrc.org.au.

Further information on cotton industry biosecurity contact Greg Kauter 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, control of cotton boll weevil using insecticides costs hundreds of millions of dollars.

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

Spider mites

Tetranychid mites

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

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

BIOSECURITY – *sponsored by* eChem crop protection

Indian green jassid
Amrasca devestans

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

Indian green jassid. (NSW DPI)

Tarnished plant bug
Lygus lineolaris

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

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

Whitefly
Bemisia tabaci B-type or Q-type

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

***Bemisia tabaci* B-type.** (Neil Forester)

Melon aphid
Aphis gossipyi – exotic strains

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

Melon aphid. (Lewis Wilson, CSIRO)

Verticillium wilt

Defoliating strains

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

Exotic Verticillium wilt. (Vert_Jack Kelly Clark, UC Statewide IPM Program)

Cotton leaf curl disease (CLCuD)

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

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

Leaf curl disease. (Cherie Gambley, QPIF)

Fusarium wilt

Fusarium oxysporum f. sp. vasinfectum – exotic strains

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

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

Fusarium wilt causing vascular discolouration and root knots caused by nematodes. (Chris Anderson, 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% 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

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

Blue disease. (Murray Sharman DAFF QLD)

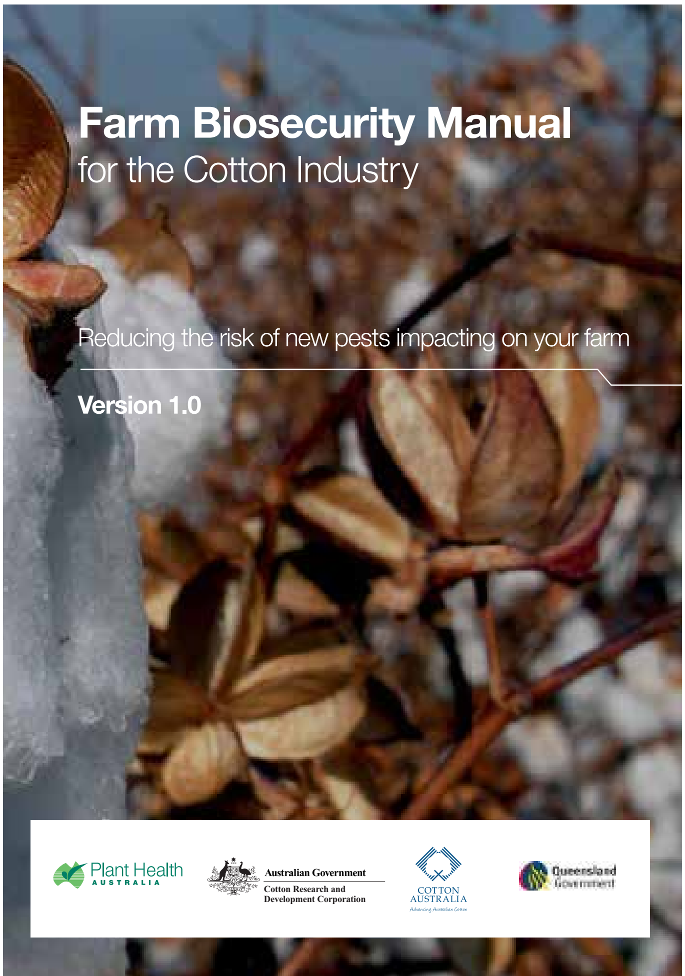
Bacterial blight

Xanthomonas Axonopodis or *X. Campestris PV Mavacearum* – exotic strains

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

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

Bacterial blight.



Cotton Farm Biosecurity Manual
Available from www.planthealthaustralia.com.au

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 DAFF
Tracey Leven, CRDC

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 guidance on factors to be considered in optimizing spray application. New technologies and information are continually becoming available, so this is meant as a summary guide only. 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 and 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 risk assessments to be completed, in addition to maintaining a manifest and Safety Data Sheets for those chemicals deemed to be hazardous.

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, 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 ASABE or BCPC 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.

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 minimize the likelihood of a surface temperature inversion being present.

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. 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**

What aren't your crops telling you?

Sometimes, it's what you can't see that can cost you. For instance, you know your moisture levels vary from field to field, but knowing when yield-robbing variances occur isn't as easy to determine. Until now.

With John Deere Field Connect in-field soil moisture monitoring, you can instantly see whether your soil moisture levels are balanced. Field Connect uses field-installed probes to monitor moisture levels at various depths. It then sends the information to a web-based interface where you can see the data on your computer or mobile device.

Without delay or guesswork, you can make the adjustments needed to protect your yields and reduce costs. It's all part of the advanced solutions and services available through John Deere FarmSight™ and your John Deere dealer.

JOHN DEERE

JohnDeere.com.au/FarmSight

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), i.e. 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 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. This map will be used by spray contractors, resellers, agronomist and neighbours to identify crops.

Monitoring weather conditions

Weather conditions need to be checked regularly during spray applications (this means continual visual observations and actual measurement at least every 20-30 minutes) 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 (e.g. Kestrel 3000, 3500, 4000 or equivalent) or portable weather stations. Alternatively on-board weather stations that provide live weather information while the sprayer operating (such as the Watchdog systems) are available.

FIGURE 11: 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.	✗

Best practices for aerial and ground spray

***my*BMP resources: Fact sheet on weather monitoring equipment.**

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. Refer to Fact sheet on Tips to reduce spray drift for a Delta T chart.

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**

Vegetative buffers

Effective vegetative buffers can reduce drift by as much as 60 to 90 per cent. A good buffer 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. 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 buffers where airflow will be obstructed by adjacent objects such as turkey's nests, water storages or large banks.

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 155 for more information.

The optimum height for a vegetative buffer is 1.5 times the release height of the spray. Trees and shrubs are able to act as an effective barrier for ground applied sprays from early in their development. Most guidelines suggest that the optimum width of the barrier is 20 m with a 10 m maintenance strip on either side.

***my*BMP resources: DNR planning guidelines.doc**

For more information on best practice for aerial and ground spray application go to www.myBMP.com.au.
(Photo: Cotton Australia – Jack Hawkins)

Adopting best spray practice

Bill Gordon, Bill Gordon Consulting

Summary of factors that influence spray drift and best practice

Setting appropriate spray release height

The amount of chemical left in the air may increase by up to 8 to 10 times as nozzle height increases from 50 cm above the target to 1 m above the target. It is important to set the height of the boom at the minimum practical height to achieve the correct spray pattern for the nozzles. Vertical movement (boom bounce) of the spray boom should be minimised.

Vertical movement can be limited by tuning the boom suspension and matching travel speed to release height. Alternatively consider fitting auto boom height. Auto boom height devices use ultrasonic sensors to detect the height of the boom above the target. These adjust the boom hydraulically to maintain the nozzles at a constant height above the target. Generally these systems will require a machine with good hydraulic capacity, but allow the machine to maintain boom height at travel speeds up to 28 km/h.

***my*BMP resources: Factsheet on boom height control**

Travel speed for ground rigs

Speeds above 15 km/h have been shown to increase the risk of drift for boom spraying and speeds above 10 km/h increase the risk from shielded sprayers. Higher speeds reduce deposition of spray droplets in the wheel track and behind stubble, and also increase the drift potential due to droplets being drawn into the machine's wake. When considering operating at higher travel speeds, greater attention must be paid to the potential risk of spray drift and ways of reducing that risk, such as nozzle selection.

***my*BMP resources: Factsheet on managing wheel tracks**

Pressure at the nozzle

Never operate nozzles outside of the pressure range recommended by the manufacturer. Higher or lower than recommended pressures changes the droplet spectrum and the spray pattern, affecting both the risk of drift and the efficacy of the spray application.

Be aware that many air induction nozzles will require slightly more pressure than the minimum indicated on the manufacturers spray chart. Always assess the spray pattern at various pressures, to determine an appropriate minimum operating pressure.

Where automatic rate controllers are fitted to the machine, carefully consider the true range of speeds the machine is likely to operate, from the slowest field to the fastest field. Identify what the pressure at the nozzle will be at your lowest speed and your fastest speed and identify a nozzle that will produce the required spray quality across that range of speeds. Operating at recommended pressures can also minimise wear and tear on nozzles.

***my*BMP resources: Factsheet PRE-SEASON SPRAYER CHECKS, Back pocket guide to nozzle selection**

Suitable water volumes and quality

Always follow label recommendations for water volumes for application. Typically in-crop applications to cotton will require application volumes of 100 L/sprayed hectare or more.

Whereas, for fallow spraying in low stubble situations with translocated herbicides (such as glyphosate and the phenoxys) equivalent efficacy has been shown for medium, coarse and even extremely coarse spray qualities at 50 L/ha and above. Equivalent efficacy in fallow spraying situations has also been shown at 70 L/ha and greater for products with minimal translocation, such as Spray.Seed®.

When using larger than a medium spray quality for translocated products, increasing water rate does not necessarily increase efficacy, and in some situations may actually reduce performance in the field.

Higher water rates with fully translocated products can reduce efficacy when a low rate of product is used, when water quality may be marginal or where diluting the adjuvants included in the product reduces the products performance.

***my*BMP resources: Factsheet Water Quality, Fact Sheet: Spray Mixing Order**

Nozzle selection

Spray nozzles produce a range of droplet sizes called the droplet size spectrum. Nozzle manufacturers now use internationally recognised classifications for droplet size spectrums referred to as the Spray Quality. These are Ultra Fine,Very fine, Fine, Medium, Coarse, Very Coarse, Extremely and Ultra Coarse (according to the ASABE or BCPC standards). As a guide, each time you move from one classification to the next coarser classification you approximately half the driftable fraction (e.g. from medium to coarse, or from coarse to very coarse). Hence it is always advisable to use the largest spray quality classification that will provide acceptable efficacy. Nozzle selection for the correct volume and spray quality requires careful consideration. Always follow label/permit directions in relation to spray drift including nominated droplet size category.

***my*BMP resources: Backpocket Guide Nozzle Selection for Booms and Bands**

Maintenance and hygiene

Calibration – replace worn nozzles

The output of each nozzle should be checked pre-season and regularly during the season. Nozzles that vary more than 10% from the manufacturer's specifications should be replaced. Regularly check wheel sensors and flow meters for accuracy, check pressure across the boom for evenness and monitor total volumes against areas on your GPS logs to indicate when things may have changed since your last calibration.

Decontamination

Application equipment that has been used to apply herbicides should be thoroughly decontaminated before being used to apply any product to a susceptible crop. Strictly follow the method of decontamination recommended on the label. No matter how much time is spent decontaminating the equipment there is always a risk of herbicides residues causing a problem.

***my*BMP resources: Decontamination Guide (Nufarm spraywise)**

Spray Application – *sponsored by* JOHN DEERE

Adopting best spray practice

Tank mix considerations

Always follow the manufacturers' recommendations for mixing. Where multiple product tank mixes and adjuvants are added to the one tank, incorrect mixing order can reduce the efficacy of those products.

Using adjuvants to manipulate droplet size

More can be done to manipulate droplet size (spray quality) with nozzle selection, than with the addition of an adjuvant. Many adjuvants, especially non-ionic wetters (wetter 1000 products) increase the amount the spray volume existing as droplets that are likely to drift, whereas some adjuvants can increase droplet size, care should be taken in ensuring that there is a decrease in small driftable droplets with diameter below 100–200µm, and not just an increase in the average or volume median diameter (VMD) of the spray. When considering adjuvants, compatibility with the tank mix and spraying system should also be considered, since some adjuvants do not perform as well when combined.

Product choice

Where a range of products are available for a particular job, try to select products that have the lowest impact on the environment or sensitive areas. To compare the relative toxicities of insecticides to non-target insect species such as beneficials and bees, refer to Table 3, pages 8–9.

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 kilometers away from the intended target. 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 145.

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% 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:

"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, available from CRDC.

Spraywise – Broadacre Application Guide – Available through Croplands Distributors.

The spray drift model 'AgDRIFT', is available for free download from www.agdrift.com

Fact sheets on droplet size classification, and drift management in aerial and ground applications are also available at this website.

For more information about using vegetative barriers in spray drift management, see the Queensland guidelines: Anon (1997) Planning Guidelines: Separating Agricultural and Residential Land Uses. Dept of Natural Resources, Queensland and Dept of Local Government and Planning, Queensland. DNRQ 97088. Available for free download at www.nrm.qld.gov.au/land/planning/pdf/public/plan_guide.pdf

Comprehensive information about droplet spectrums of nozzles under aerial application conditions is available from the United States Dept. of Agriculture at http://apmru.usda.gov/downloads/downloads.htm For aerially-applied 2,4-D sprays, from wind tunnel research, see www.aerialag.com.au

All additional resources can be found at www.myBMP.com.au

CottonInfo *Mobile Apps*

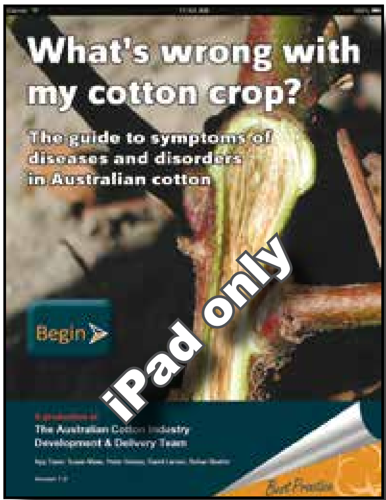
Cotton Calendar

A list of current Australian cotton events. The app enables you to RSVP to listed events and to manage your RSVP's. It also includes a 'Bee Alert' tab that improves communication between hive owners and cotton growers. This free service allows beekeepers to regularly update information about their hives, and alert relevant growers.

https://play.google.com/store/apps/details?id=au.com.crdc.CottonCalendar
http://www.mybmp.com.au/calendarapp/

Google PLAY

mobile website



Cotton Symptoms

An updated and expanded guide to the symptoms of most of the diseases and disorders that may be observed in Australian cotton crops. It also provides descriptions of those diseases identified as 'priority pests' or 'biosecurity threats' in our Farm Biosecurity Manual for the cotton industry.

https://itunes.apple.com/au/app/crdc-cotton-symptoms/id650186511

Apple iTunes

EnergyCalc Lite

A tool for assessing on farm energy use, specifically designed for the cotton industry. By completing an assessment of energy consumption on farm, users can identify where energy and cost savings can be made.

https://itunes.apple.com/au/app/energycalc-lite/id646710320

Apple iTunes

For further information contact Peter Verwey, peter.verwey@dpi.nsw.gov.au or 02 6799 2476

Legal responsibilities in applying pesticides

Mark Scott, formerly NSW DPI
Lisa Dixon, ChemClear

Pesticides Act

This section summarises requirements for NSW. While Qld requirements are similar, differences are spelt out in the box on this page.

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, i.e. all farmers and spray contractors, to keep records of their pesticide application.

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

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

An example form that captures all the information required by the Pesticides Regulation 2009 is provided on the following page. Notes on how to fill it in, can be downloaded from the NSW DPI website. A self-carbonating record book is available for purchase through the Qld DAFF 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.

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

Covered by the regulation is pest control by/on:

- Public authorities, e.g. State Rail,
- Golf courses, sporting fields and bowling greens,
- Agricultural, horticultural, aquacultural and forestry operations,
- Businesses, educational institutions, and hospitals.

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

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

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. The Chemical Usage Act requires users 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 approved label instructions, including any use instructions or restraints that may be listed that relate to droplet size, wind speed and direction, mandatory downwind no-spray zones and other off-target drift restriction controls. There are significant penalties imposed on anyone found to have breached the Chemical Usage Act by failing to observe label instructions.

Under the Agricultural Chemicals Distribution Control Act 1966 (ACDC Act) aerial distribution contractors in the business of aerial distribution (application) of agricultural chemicals and ground distribution contractors in the business of ground distribution of herbicides must be licensed. In addition agricultural pilots and ground spray operators working for or engaged by these contractors must undergo prescribed training and also be licensed. In most instances, agricultural producers applying agricultural chemicals on their own land do not need to undertake training or to hold a licence. However, Queensland growers are strongly encouraged to undergo some form of vocational training or further training a registered training organisation so their skills and knowledge in application technology and handling, storing and transporting chemicals are maintained and kept up to date.

In Queensland cotton growers are required to keep records of spraying activities where specified on the product label or under the conditions of a permit. This differs to the situation in NSW. However it is considered good farming management practice to keep records and therefore all Queensland growers are strongly encouraged to keep records of all their chemical applications along the same lines as NSW growers are required to do so by law.

Licensed 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., Biosecurity Queensland 13 25 23.

PESTICIDE APPLICATION RECORD SHEET

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Location, Applicator, Date of Application					
Property/holding (residential address):					Date:
Applicator's full name:			Owner (if not applicator):		
Address			Address		
		Phone:			Phone:
Mobile:	Fax:	Email:	Mobile:	Fax:	Email:
Sensitive areas (including distances, buffers): N W E S			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, e.g. Teejet AI 11002.

Hazardous Chemicals Legislation

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.

The Work Health and Safety Act 2011, and the Hazardous Chemical section of the Work Health and Safety Regulation 2011, detail the legal requirements of suppliers, workers and persons conducting businesses or undertakings in the workplace for hazardous chemicals management. The Act and accompanying Regulations are intended to protect workers from both the short and long term health effects of exposure to hazardous chemicals and to improve current health and safety practices by:

- Provision of health and safety information to workers (including a list or register of all hazardous chemicals and an SDS (safety data sheet) for each hazardous chemical);
- Consultation with workers;
- Training of workers;
- Minimising the risks arising from hazardous chemicals exposure; and,
- Health surveillance (if warranted by the risk assessment in respect to organophosphates).

Both storage and use are covered by WHS legislation.

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

WorkCover NSW's Code of practice for the safe use and storage of chemicals (including pesticides and herbicides) in agriculture is an approved industry code of practice and provides practical guidance for farm chemical users to comply with the legislation mentioned here.

*my*BMP provides guidance and resources to meet your requirements for handling, storage and application of chemicals.

Pesticides and The Environment

The cotton industry's guidelines for minimising risk to the environment are another component of myBMP.

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

Protecting bees

The cotton growing environment is a high risk environment for bees. Bees are particularly susceptible to many of the insecticides used on cotton farms, such as abamectin, fipronil, indoxacarb 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 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.

Bees are generally active between 7:00 am and 4:00 pm and most bees forage within a 2 to 4 km radius of their hive. They may travel up to 7 km 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:

- Applying pesticides toxic to bees in the evening when bees are not foraging;
- 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;

Protect bees when using Regent Insecticide

The Regent Insecticide label states:

'Dangerous to bees. DO NOT apply where bees from managed hives are known to be foraging, and crops, weeds or cover crops are in flower at the time of spraying, or are expected to flower within 28 days (7 days for pastures and sorghum).

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

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

'Bee Alert'

The CottonInfo team Cotton Calendar app includes a 'Bee Alert' (Industry Events/Regional Events/My Events/Bee Alert/RSVP Settings) tab that aims to improve communication between hive owners and cotton growers. This free service allows beekeepers to regularly update information about their hives, with information automatically linked to relevant growers. Bee hives are entered as special event type, with GPS co-ordinates of hives as well as start date, likely duration, number of hives and contact details. Calendar App users in the vicinity will be advised of the risk. Communication with growers and aerial operators can then be coordinated locally. When communicating with beekeepers, encourage them to use this service, particularly when apiaries are being placed within bee flight range of flowering crops.

For more information on how to access the Cotton Calendar App or to use the 'BEE Alert' tab contact Dave Larsen, NSW DPI 02 6799 1534.

BEE Alert with Cotton Calendar

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 DAFF
Patricia Swift, Apiary officer
Ph: 07 5466 2216
patricia.swift@daff.qld.gov.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;

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 above.
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.

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

Protecting birds

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

Risks to birds from granular products can be managed by:

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

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

- Ensuring even bait distribution, with no locally high concentrations;
- Not baiting over bare ground or in more open situations, such as near crop perimeters, where birds may see the baits;
- Not baiting near bird habitat such as remnant native vegetation;
- Use of bait stations which prevent access by birds, particularly near bird habitat;
- Only baiting where pest pressure is high;
- Baiting late in the evening when birds have finished feeding;
- Prompt collection and burial of rodent carcasses where these occur in open situations; and,

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

- Minimising drift into remnant vegetation, wildlife corridors, nesting sites, or other bird habitats;
- Actively discouraging birds from feeding in-crops which are to be sprayed;
- Spraying late in the day when birds have finished feeding; and,
- Using only low toxicity chemicals when large concentrations of birds are nesting nearby. The best way to manage any long term adverse environmental risks is to follow the protection statements on labels, minimise spray drift, and to dispose of chemical containers and waste in accordance with label directions and codes of practice.

Recycle chemical containers

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

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

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

Preparing chemical drums for recycling

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

- 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.
- 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 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 containers are rejected the user is responsible for ensuring that the container is taken back to the property and cleaned

Birds can make a significant contribution to pest management. (Photo: Cotton Australia – Julie Reardon) using all rinsate to make up an application of the same chemical according to the label recommendations.

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/container-recycling/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

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

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

Registering to use the ChemClear program

There are six simple steps in using the program;

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

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

IMPORTANT: USE OF PESTICIDES

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

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

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

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

APVMA review and changes to use of common cotton products

The Australian Pesticides and Veterinary Medicines Authority (APVMA) has a Chemical Review Program which can reconsider the registration of agricultural and veterinary chemicals in the marketplace if potential risks to safety and performance have been identified. The following actives that are registered for use in cotton are currently under review:

- 2,4 D Current and Spray Drift
- Chlorpyrifos
- Diazinon
- Dimethoate
- Diquat
- Fipronil
- MCPA - Spray Drift
- Methidathion
- Omethoate
- Paraquat

Refer to www.apvma.gov.au for more information about the chemical review program including all current, completed and nominated chemical reviews.

The following information is provided to highlight some new restrictions on products used in cotton, however as the APVMA continues to review registration conditions refer to www.apvma.gov.au for the most up to date information.

Diuron restrictions

In 2002 the APVMA began a review of diuron because of environmental and human health concerns, specifically regarding the potential for diuron to contaminate the marine environment through agricultural runoff. Based on the outcomes of the diuron review significant changes to the way diuron products can be used have been made. **Refer to the label and always follow label direction.**

Restrictions include:

- DO NOT apply more than 1.8 kilograms of diuron active per hectare in any 12 month period.
- DO NOT use in cotton UNLESS ALL irrigation tailwater and/or up to 25 mm rainfall can be captured and held on farm.
- DO NOT use in water-logged areas.
- DO NOT apply if greater than 50 mm rainfall is expected within 3 days of application.
- DO NOT irrigate within 3 days of application.
- DO NOT apply to fields where the slope exceeds 3%.
- DO NOT spot spray more than 5% of total farm area.
- DO NOT apply more than once per calendar year.
- DO NOT replant treated areas within 2 years of application of diuron except when otherwise stated on label. Refer to label for further replant restrictions.
- Do not use in non-crop areas. Uses no longer permitted include driveways, paths, lanes, drains, ditches, fence lines, car parks, tennis courts and non-crop areas.
- DO NOT use in irrigation channels or drains UNLESS ALL irrigation tailwater and rainfall can be captured and held on farm.

Spray drift restraints

- DO NOT apply by air.
- DO NOT apply with spray droplets smaller than COARSE spray droplet size category according to nozzle manufacturer specifications that refer to the ASAE S572 Standard or the BCPC Guideline.
- Users of this product MUST make an accurate written record of the details of each spray application within 24 hours following application and KEEP this record for a minimum of 2 years.
- MANDATORY NO-SPRAY ZONES.
- DO NOT apply when there is non-target vegetation downwind from the application area and within the mandatory no-spray zones. For cotton terrestrial downwind buffer zone is 200m.
- DO NOT apply when there are aquatic and wetland areas including aquacultural ponds, surface streams and rivers downwind from the application area and within the mandatory no-spray zones. For cotton aquatic downwind buffer zone is 100m.

Dimethoate restrictions

On 6 October 2011 the APVMA suspended the use of dimethoate on a number of food crops due to potential dietary risks. The suspension period has now been extended – refer to www.apvma.gov.au to 5 October 2013. Under this suspension, dimethoate can still be used in cotton under permit PER13155 with the following restrictions:

- DO NOT harvest for 14 days after application.
- DO NOT feed cotton fodder, stubble or trash to livestock.

Refer to http://www.apvma.gov.au/products/review/current/dimethoate.php for the most recent status on dimethoate usage.

Cancellation of 2,4-D High Volatile Esters registration

As part of the ongoing review of 2,4-D, the Australian Pesticides and Veterinary Medicines Authority (APVMA) has determined the risks of the use of 2,4-D HVE products under the suspended label instructions are unacceptable and cannot be mitigated. The decision means:

- Supply of the cancelled 2,4-D HVE active constituent is to cease immediately (21 August 2013).
- From 31 August 2013 the supply of product containing 2,4-D HVE manufactured up to 21 August 2013 is to cease.
- People can use products they have already purchased up until 31 August 2014 under the same permit instructions (PER14329) which restricts use to winter only and under strict conditions.
- Use of these products after 31 August 2014 will be illegal.

Refer to www.apvma.gov.au/products/review/current/2_4_d.php for the most recent status of 2,4-D review.

Neonicotinoid review

In August 2012 APVMA commenced a study to look at the use of neonicotinoid insecticides (or 'neonics') in Australia to see if they present more of a risk to honey bee health than other pesticides that have been in use for many years. The APVMA preliminary study of the science will include consideration of the European Food Safety Authority risk assessments of three neonicotinoids (clothianidin, imidacloprid and thiamethoxam) that were part of the European Commission decision to suspend for two years (from 1 December 2013) the use of neonicotinoid insecticides on flowering crops such as corn, canola and sunflowers and cotton.

Refer to page 151 for more information on protecting bees.

Fipronil review

The APVMA commenced the review of fipronil in September 2003, over concerns over toxicity, primarily related to skin irritation and induction of skin sensitisation, but also the potential for fipronil to form toxic photodegradation products, occupational health and safety issues, animal safety, and the adequacy of label instructions. In 2007 fipronil was nominated as a priority 1 chemical for environmental review, following the identification of new information, considered by international regulatory authorities (primarily the European Food Safety Authority in 2006), showing that fipronil and its metabolites are very highly toxic to organisms in the environment, particularly aquatic and terrestrial insects.

The APVMA are reviewing the following environmental aspects of product registrations for fipronil including, but not limited to:

- Aquatic degradation.
- Persistence in environmental media (soil, water and sediment).
- Partitioning in the environment e.g. deposition, adsorption.
- Toxicity to fish and aquatic invertebrates, sediment organisms, bees and non-target arthropods.

Refer to page 151 for more information on protecting bees.

The cotton growing environment is a high risk environment for bees. 'BEE Aware' by using the bee tab of the Cottoninfo Cotton Calendar. Refer to page 151 for more information on protecting bees. (Photo: Lance Pendergast, DAFF QLD)

Re-entry periods after spraying

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 day's use.

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

Refer to Table 18, page 42 for the trade names of active ingredients.

INSECTICIDES WITHOUT LABEL RE-ENTRY PERIODS

Active ingredient	Hazard Classification (WHO 2009)
Spinosad, Bt, Chlorantraniliprole, clothianidin	Unlikely to present acute hazard in normal use
Dicofol, Propargite	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.
Beta-cyfluthrin	Do not allow entry into treated areas until spray has dried.
Chlorfenapyr	Do not allow entry into treated areas for 12 hours after treatment.
Chlorpyrifos	Do not allow entry into treated areas until spray deposits have dried.*
Deltamethrin	Do not allow entry into treated areas until the spray deposits have dried.
Diafenthiuron	Do not allow entry into treated areas for 24 hours after treatment.*
Emamectin benzoate	Do not allow entry into treated areas for 12 hours after treatment.
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
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(R)	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.
Methoxyfenozide	Do not allow entry into treated areas until spray has dried.
NPV	Do not allow entry into treated areas until spray has dried.
Omethoate	Do not allow entry into treated areas until at least 24 hours after treatment.
Profenofos	Do not enter treated areas without protective clothing until 24 hours after spraying.
Pymetrozine	Do not allow entry into treated areas until spray has dried.
Pyriproxyfen	Do not allow re-entry into treated area until the spray has dried.
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

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.

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

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.
Alphamethrin	14 days	not stated
Alpha-cypermethrin	14 days	not stated
Amitraz	21 days	not stated
Amorphous silica	0	0
Bacillus thuringiensis	0	0
Bifenthrin	14 days	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
Chlorfenapyr	28 days	Do not graze or cut for fodder
Chlorpyrifos-methyl	28 days	Do not graze crop or stubble
Clothianidin	5 days	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 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 food for 14 days after application. (Per13155)
Disulfoton	70 days	70 days
Emamectin benzoate	28 days	Do not harvest, graze or cut for stock for 4 weeks after application. Do not feed trash to animals including poultry.
Esfenvalerate	7 days	not stated

TABLE 43: Withholding period after application for common chemicals (continued)

Active ingredient	Crops not to be harvested for:	No grazing or cutting as stock fodder for:
Insecticides/miticides		
Ethion + Zeta-cypermethrin	28 days	Not stated
Etoxazole	21 days	Do not graze treated area or cut treated area for stock feed
Fipronil	28 days	Do not graze or cut for fodder
Gamma-cyhaldthrin	21 days	See label for the Export Slaughter Interval (ESI).
Imidacloprid	91 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(R)	Insecticide WHP + 7 days	Insecticide WHP + 7 days
Methidathion	3 days	not stated
Methomyl	0	Do not graze or feed crop to animals
Methoxyfenoziole	28 days	Do not graze or cut for fodder
NPV	0	0
Omethoate	21 days	not stated
Paraffinic oil	1 day	not stated
Parathion	14 days	Do not graze or cut for fodder
Pirimicarb	21 days	21 days
Phorate	70 days	70 days
Profenofos	28 days	not stated
Propargite	28 days	Do not graze or cut for fodder
Pymetrozine	28 days	Do not graze crop stubble or gin trash
Pyriproxyfen	28 days	Do not graze on or cut for stock feed. Do not feed treated cotton trash to livestock
Spinosad	28 days	Do not graze or cut for fodder
Spirotetramat	21	Do not feed cotton fodder, stubble or trash to livestock.
Thiamethoxam	28 days	Do not graze or feed cotton trash to stock
Thiodicarb	21 days	21 days
Growth regulator and defoliant chemicals		
Dimethipin	7 days	7 days
Endothal	1 day	Do not graze
Ethephon	7 days	Do not graze
Mepiquat	28 days	Do not graze
Paraquat + diquat	7 days	1 day
Pyraflufen-ethyl	7 days	Do not feed cotton trash or stubble
Sodium chlorate	0	0
Thidiazuron	0	Do not graze or cut for fodder
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.

Spray Application – *sponsored by* JOHN DEERE

*my*BMP – best practice benefits the whole industry

The Cotton industry's *my*BMP program is one of the key plank's behind cotton's reputation as an innovative and proactive Australian agricultural industry.

*my*BMP is the web-based best practice management system freely provided to all Australian cotton growers as a centralised location for access to important information, or to conduct a farm self-assessment against industry developed best practice standards. It provides tools to:

- Better manage business risk;
- Help improve on-farm production performance;
- Maximise potential market advantages; and,
- Demonstrate responsible and sustainable natural resource management.

As well as meeting future challenges early, *my*BMP supports continual industry improvement.

While most Australian cotton growers already meet the majority of industry best practice principles, grower participation in *my*BMP also helps deliver a powerful information-based platform which can help industry influence and achieve positive outcomes when working to protect important cotton industry farming rights.

After consultation with growers, researchers and industry bodies, in August 2010 *my*BMP was relaunched in a program that completely rejuvenated and extended the original BMP system.

The new *my*BMP is fully supported by Cotton Australia, the Cotton Research Development Corporation and Cotton Seed Distributors through the CottonInfo joint venture, and is a cornerstone component in delivery of industry extension work.

Over the past year the *my*BMP program has undergone a major update, the result of feedback received since launching in 2010. These changes make *my*BMP even easier and faster to use and includes even more comprehensive information, resources and tools.

For more information or help in getting started call the *my*BMP team on 1800 268 866, visit the website at www.myBMP.com.au or send an email to admin@myBMP.com.au

Best practice where the whole industry benefits

www.myBMP.com.au

To arrange your personal introduction to *my*BMP, contact *my*BMP Service Manager, 1800 COTTON

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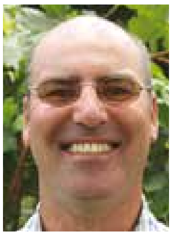

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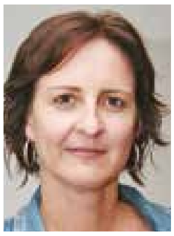

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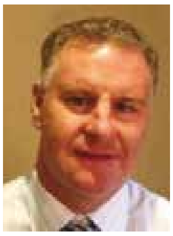

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FRONT COVER PHOTOS:
Main: Beat Sheet – Cotton Australia: Daniel Skerman
Top left: Linda Scheikowski & Bartley Bauer researching nematodes in cotton – QDAFF
Top circle: BEE Alert for Bees – Johnelle Rogan
Middle circle: Glyphosate resistant weeds – Tony Cook, NSW DPI
Bottom circle: Magnet and moth – Peter Greg UNE

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