FINAL REPORT 2008

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

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Part 4 – Final Report Executive Summary

Supporting IPM for future cotton systems

This project has addressed issues that have emerged with the widespread adoption of Bollgard II cotton, and the resulting reduction in insecticide use. Specific objectives and outcomes are described below.

1) *The fit of new insecticides into integrated pest management.* Selection of insecticides can have a big influence on both control of the target pest as well as on beneficials, and the risk of secondary pest outbreaks. We found that low rates of fipronil provided strong efficacy against mirids, with or without salt, and were significantly more selective that the full rates of fipronil against beneficials, though still with a risk of flaring mites. Low rates of indoxacarb alone provided poor efficacy against mirids but the addition of salt or canopy oil boosted this to efficacy equivalent of the full rate with low risk to beneficials or risk of flaring mites. Altacor (rynaxypyr) a new insecticide for *Helicoverpa* control was highly efficacious and selective against many beneficials indicating a good IPM fit. These results have been made available to industry via the Cotton Pest Management Guide, to assist pest manager in spray choices, and to industry to help in registration, thereby ensuring availability of new insecticides or uses of insecticides to industry.

2) *Defining the pest status of emerging pests*

   a) Management of thrips on seedling cotton. Tobacco thrips, *Thrips tabaci*, is still the dominant species. It was controlled moderately well at some sites but poorly at others, which could indicate resistance. At some locations the western flower thrips, *Frankliniella occidentalis*, is also abundant and poorly controlled by available options indicating insecticide resistance. Control of thrips is problematic because damage is often cosmetic, plants will recover without loss, and because thrips are also predators of spider mites. Nevertheless in cooler regions, where control is justified, management of WFT may be difficult. Monitoring of thrips population composition early in the season and determination of resistance profiles for both WFT and *T. tabaci* has been initiated in conjunction with Dr Grant Herron (NSWDPI) and CSD.

   b) Late season pest damage from thrips and jassids. These pests often build to levels causing significant damage to leaves on maturing cotton. We found that late season damage to leaves is only likely to reduce yield in crops with high yield potential and if the damage is very severe and prolonged before cut-out. High yielding crops are likely more affected but even they show strong compensation at yield levels up to 14 b/ha.

   c) The effect of mirid sprays on secondary pests. We found that controlling mirids with the most popular insecticide (fipronil) increases the risk of causing mite outbreaks, which would then require additional control. Our results also suggest that in some situations Bollgard II crops are more at risk – this deserves further investigation. Nevertheless, the results highlight the need to have good mite sampling protocols in place in Bollgard II crops especially if OP's, SP's or fipronil are used to control mirids.

3) *Develop a new aphid sampling strategy and thresholds.* These were developed and extended to industry. They will provide a more rational basis for deciding when the occurrence of this pest justifies control and when beneficials are providing adequate control. This information has been linked with new information on the aphid borne disease cotton bunchy top, to provide pest managers with a holistic approach to managing both the pest and the disease.

4) *Sporadic pests.* Information and publication to help manage the pale cotton stainer was completed and will help industry to manage this pest in the future. In particular thresholds for lint damage are now available. These indicate that for stained locks the threshold is >50% of bolls with all locks damage, and for tight-locked bolls it's > 20% of bolls with all locks damaged. We also studied the feeding behaviour and have a better understanding of the damage symptoms.

This project has provided new information to help pest managers to make better decisions about management of emerging pests. Outcomes have been largely delivered to industry through a range of presentations, published resources and the WWW. Benefits to the industry are more rational decisions on the need to control pests, and awareness of risks for different control options. This will contribute to reduced pesticide use with flow-on economic, social and environmental benefits.

Background

This project built on the outcomes of a series of projects dating back to the late 1980's, most recently CSP147C 'Incorporating aphids, insecticides and early season plant compensation into IPM'. The emphasis throughout these projects was on supporting the development of IPM systems and their practical application by providing knowledge across three main themes (i) the selectiveness of insecticides and their risk of causing pest resurgence, which helps determine their fit in IPM systems, (ii) understanding the capacity of cotton to tolerate damage and hence not require spraying, and (iii) understanding the effect of pests on the yield and fibre quality of cotton, so that accurate pest thresholds and sampling strategies can be developed. This project extended the knowledge gained in these past projects by considering;

a) The economic significance of emerging pests. As the proportion of the cotton industry growing Bollgard II varieties has increased there has been be a corresponding decrease in insecticide use. This helped the survival of beneficial populations, which contributed to the control of pests, but, also allowed some pests such as jassids, thrips (late season) and aphids to establish and increase to levels that may be economically damaging. This situation was further complicated by the invasion of cotton regions by western flower thrips, often in very high numbers late in the season. This species is a mite predator but also causes significant leaf damage.

Little was known about the economic significance of mid season jassid damage or late season thrips damage. Application of insecticides to control these pests may be not be economical and result in reduction in beneficial numbers, in turn leading to secondary pest outbreaks. However, in high yield crops these insecticides may be economically justified but their use needs to be balanced against other risks. Due to the difficulty of obtaining reliable infestations of jassids or thrips late season, we completed experiments simulating a worst case scenario to test if there is any chance that these pests could affect yield. These experiments involved removing leaves from different layers of the plant, simulating total loss of photosynthetic capacity due to extreme jassid numbers. In this case cutting off the top 25cm of the terminal or top 6 main stem leaves only to simulate late season thrips infestation caused extreme damage to the plant terminal. In both cases yield losses occurred, indicating that jassids and thrips could be economic pests under some circumstances.

Recent data collected by Steve Yeates (CSIRO PI) indicates that about 60 % of the crop yield is produced after the last leaf has developed – hence in high yielding crops the upper leaves may be more important in contributing to yield than previously thought. This project researched thresholds for jassids and late season thrips using both actual and simulated pest damage with the ultimate aim of developing thresholds based on pest abundance or damage symptoms. Additionally, during seasons with more winter rainfall and high proportions of cotton planted to BGII a range of other pests have emerged. For instance, the green stink bug, *Plautia affinis*, has shown up as a potential problem in the Gwydir Valley and in 2007-08 the pale cotton stainer (*Dysdercus sidae*) was a widespread problem. As the opportunity permitted we did preliminary investigation of these emerging pests to provide industry with information to help make better decisions about control.

b) The non-target effects of new insecticides and new low beneficial impact options and risk for resurgence of secondary pests. In the early 1990's research in predecessors of this project showed clearly the effect of early spraying with broad-spectrum insecticides on beneficial populations and the increased risk of outbreaks of spider mites or aphids. The research developed into a regular series of experiments to evaluate the efficacy, non-target effects and pest resurgence risk for all current and new insecticides. The outcomes have been used, along with results from other researchers, to develop look up charts showing the effects of each insecticide on non-target species, their pest resurgence risk and their impact on bees (see p. 23 Cotton Pest Management Guide 2004-05). This research was complimented by studies in other projects, such as that of Viliami Heimoana (NSW DPI – DAN160C and new submission) which has ceased. In this project we have added additional value to the experiments by artificially infesting experiments with mites and aphids to provide clearer data on the resurgence risk for these pests.

We also screened new insecticides or miticides and evaluated some of the other softer options such as the petroleum spray oils and salt plus insecticide mixtures for efficacy, non-target impacts and secondary pest resurgence. This was done with input from Moazzem Khan (QDPI&F – mirid control), and added the extra feature of secondary pest resurgence. The data has been used to provide growers and consultants with up-to-date information on the IPM fit of new chemistry, insecticides plus adjuvants and new uses of old chemistry.

c) Factors influencing the abundance of aphids. During a prior project we developed a good understanding of the effect of aphids on cotton yields, and showed that early infestations were capable of causing significant losses if not controlled (30 – 50%). However three areas where there were gaps were (i) the effect of HPR on aphids (ii) the value of beneficials at limiting increase of incipient aphid populations and (iii) the effect of crop nutrition on aphid abundance. Though we intended to investigate these issues, problems prevented completion of this work (discussed below).

This project supported the salary of Simone Heimoana (Senior Technical Officer) and a portion of the salary of Deon Cameron (Technical Assistant), Ammie Kidd (Technical Assistant) and Dee Hamilton (Technical Assistant). It also provided a vehicle and operating costs to complete the research.

Objectives

- Determine the non-target effects of new insecticides and new low beneficial impact options and the risk for resurgence of secondary pests
- Define the economic significance of emerging pests such as jassids and late season thrips.
- Understand the effect of variety, crop agronomy and predation on development of aphid populations.

NB. In the first year of this project we realised that experiments manipulating aphid densities were going to be very difficult. This was because the widespread adoption of Bollgard II cotton led to a dramatic reduction in insecticide use. This allowed beneficial populations to survive and build, making initiating and sustaining aphid outbreaks very difficult. We contacted Dr Ian Taylor (CRDC) and agreed to scale down objective three, and focus more effort in the area of emerging pests in Bollgard II. Hence a new objective could be:

- To define the effect of application of insecticides to emerging pests on the management of secondary pests in Bollgard II dominated cotton systems.

Methods and Results

1. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

a. Determine the non-target effects of new insecticides and new low beneficial impact options and the risk for resurgence of secondary pest

This research used a protocol developed in 1993-94 and used consistently ever since. Large replicated experiments were done in each year of the project. In each experiment seven new insecticides or miticides were evaluated for their efficacy, non-target effects and risk of causing resurgence of secondary pests (mites or aphids). Over the duration of this project we have maintained ongoing communication with the range of Agrichemical companies to keep track of developments. Due to the small cotton insecticide market, the number of new products being considered for registration in cotton has declined dramatically, and many of the products we evaluated in a previous project (CSP147C) have not made it to market. Nevertheless, our research is valuable in helping products through registration and providing industry with independent information so we have to take the risk that some products may not be registered. As a result of these discussions we have evaluated two new compounds;

(i) Altacor (Rynaxypyr – Dupont), a new Lepidotpera targeting insecticide. Our research indicated that this product provides very good efficacy against *Helicoverpa* spp, and is relatively selective against many beneficials. Our report to Dupont has been used in their registration submission and in formulating some of the wording on the label (a copy of the reports can be provided to CRDC / Cotton CRC if requested)
(ii) Movento (BYI 08330 240 SC - Bayer) an experimental product targeting sucking pests. This product has not yet been progressed to market.

Over the past 5 years there has been strong interest by industry in options to control sucking pests - especially mirids - that are less expensive, efficacious and more selective. An approach that has been used is to reduce rates and add salt (NaCl) or Canopy oil to help maintain efficacy. The reduced rate is cheaper and theoretically more selective against beneficials. Work by Moazzem Khan (QDPI&F) in cotton and by Hugh Brier (QDPI&F) in pulses and grain legumes suggests that these row rate plus additive compilations also provide better efficacy than the low rates alone. We wanted to include these options in the 'Impact of insecticides and miticides on predators in cotton' table in the Cotton Pest Management Guide, so we evaluated them as well in our standard format. The options considered so far were selected based on common use in the case of fipronil (Regent) or potential to be highly selective in the case of indoxacarb (Steward), and included all of the combinations required:

(i) Low rate Regent (fipronil @ 8 g ai/ha) alone
(ii) Low rate Regent with salt (@ 10g/l)
(iii) Full rate Regent (fipronil @ 25 g ai/ha)
(iv) Low rate Steward (indoxacarb @ 60 g ai/ha)
(v) Low rate Steward + salt
(vi) Low rate Steward + canopy at 2% v/v
(vii) Full rate Steward (indoxacarb @120 g ai/ha)
(viii) Salt alone
(ix) Canopy alone

These combinations were evaluated for two years. We found that the low rates of fipronil provided strong efficacy against mirids, with or without salt, and were significantly more selective that the full rates of fipronil against beneficials. With indoxacarb we found that the low rate alone provided poor efficacy against mirids. However, the addition of salt or canopy oil boosted this to efficacy equivalent of the full rate. A particular outcome is that low rates of indoxacarb plus salt or canopy oil provide good control of mirids with low risk to beneficials or risk of flaring mites. In contrast, low rates of fipronil, either alone or with salt provide good mirid control and are more selective than full rates, but still carry a high risk of flaring mites. The results of these experiments have been reported in detail to Nufarm (fipronil), Dupont (indoxacarb) and to Caltex (Canopy Oil). The report has been used by Dupont in a submission for registration of the lower rates of fipronil plus salt against mirids (copies of the reports can be provided to CRDC / Cotton CRC if requested).

The information summarising effects of the new registered compounds (e.g. Altacor) and the lower rates of fipronil or indoxacarb have been incorporated into the 'Impact of insecticides and miticides on predators in cotton' table and provided to Tracey Farrell (NSWDPI) for inclusion in the Cotton Pest Management Guide (Table 1). This ensured that this reference document was up-to-date each year for the cotton industry. Evaluation of dimethoate at low rates and two new biopesticides is underway, but as only one year of data is available results are not reported yet.

b. Define the economic significance of emerging pests such as jassids and late season thrips.

Thrips early season.

In the early 2000's the western flower thrips (WFT), *Frankliniella occidentalis*, was recorded from cotton at St George, and subsequently other cotton regions. An initial evaluation of resistance in a single strain of WFT from cotton confirmed that it was resistant to a range of control options. Since then we have regularly assisted CSD with counting and identification of thrips in their early season at-planting insecticide and seed treatment evaluations. During the course of this project we have identified the adult thrips species from some of the treatments to better interpret the results, especially where we found high survival of thrips on treatments that we expected to control them effectively. The experiments essentially compare a range of seed treatments and at-planting insecticides, including imidacloprid (Gaucho, Genero), Imidacloprid plus ? (Amparo), thiodicarb plus fipronil (Semevin Super), thiamethoxam (Cruiser) aldicarb (Temik), carbosulfan (Marshall). Here we report on a selected subset of treatments for 2006/07 and 2007/08.

Results are shown in Tables 2 and 3. Summarising these results; at most sites *Thrips tabaci* is the most common thrips species on seedling cotton. WFT is the next most abundant, followed by *F. schultzei*, but both are usually less than about 10% of the population. Across all sites, none of the treatments have provided strong control of either thrips adults or larvae, the best result being Greenbah 07-08 (Table 3), where about 90% control was achieved on one date with phorate (Thimet) and imidacloprid. Poor control of adults is to be expected as there is continual 're-invasion' of treated plots which can mask efficacy. However, the poor control of larvae is surprising and control is certainly poorer than in the past, especially with aldicarb (Temik) e.g. see (Sadras and Wilson 1998) where highly significant control in the range 50 – 95% was often achieved.

The identification of adult thrips suggests that while *T. tabaci* is suppressed by the treatments, at least in some experiments, control of WFT by either aldicarb or imidacloprid is generally poor e.g. ACRI ,Wee Waa 06-07, CSD Moree 06-07 (all in Table 2), Kummerow 07-08, Narromine 07-08 (Table 3). Looking at the larval populations, where adult control was poor, larval control was also generally poor e.g. Wee Waa 06-07 (Table 2) where on some dates larval numbers where higher in insecticide treated plots than in the control. At Kummerow 07-08 (Table 3), larval control was very poor, and larvae were as, or more, abundant in aldicarb or imidacloprid treated plots – probably reflecting the higher proportion of WFT at this site, and poor control of the larvae of this species due to resistance. At Narromine 07-08, WFT constituted about 40% of the adult population, and control of larval thrips, though statistically significant was fairly poor.

The results suggest that (i) at the sites surveyed none of the treatments worked as well as would be expected (ii) *T. tabaci* predominates early season, though WFT can be locally abundant (iii) control of WFT adults and larvae appears to be poor – but this is confounded by the poor performance of the insecticides at almost all sites. Nevertheless, if WFT were to become prevalent early in the season more frequently, the data from Kummerow 07-08 and Narromine 07-08 suggest that this species would be difficult to control with existing seed treatment or at-planting options. There are effective options such as spinosad (Tracer) but this would need to be managed carefully to avoid selecting for resistance. We are following this research up in 2008-09, and we have arranged for samples of thrips from the Darling Downs (Kummerow) to be collected by John Marshall and sent to Dr Grant Herron (NSW DPI) to establish their resistance profile. The cause of poor efficacy is puzzling – it may be related to growing conditions, but the possibility that *T. tabaci* also has some level of resistance would be easy to test and we have discussed this need with Dr Herron.

Table 1. Effect of insecticides and miticides on beneficials and pest resurgence in cotton, based on data derived from this project and from collaborators (Robert Mensah - NSW DPI*, Moazzem Khan – QDPI&*F, Martin Dillon – formerly CSIRO Entomology, Mark Wade – formerly QDPI&F and UQld, Brad Scholz – QDPI&F, Dave Murray – QDPI&F*, Viliami Heimoana – NSW DPI and Richard Lloyd – QDPI&F*, Jonathan Holloway – Formerly NSW DPI). This version will be published in the Cotton Pest Management Guide 2008/09.* Also Cotton Catchment Communities CRC. New additions indicated with **bold** lines.

Insecticides (in increasing rank order of impact on beneficials)	Rate (g ai / ha)	Target Pest(s)						Beneficials																	Pest resurgence [12]			Toxicity to bees [14]
									Predatory beetles				Predatory bugs							Hymenoptera							
		Helicoverpa	Mites	Mirids	Aphids	Thrips	Persistence[8]	Overall Ranking[10]	Total[1]	Red & Blue beetle	Minute 2-spt lady beetle	Other lady beetles	Total[2]	Damsel bugs	Big-eyed Bugs	Other Predatory bugs	Apple Dimpling	Lacewing adults	Spiders	Total (wasps)	Trichogramma	Ants	Thrips	Mite	Aphid	Helicoverpa	
Bt[11]		✓					very short	very low	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL				VL
NP Virus		✓					very short	very low	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	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
Etoxazole	38.5		✓				short	low	VL	VL	-	L	VL	VL	VL	VL	VL	VL	M	L	VL	VL	L				VL
Indoxacarb (low)	80			✓			medium	low	L	L	H	M	VL	L	-	L	H	M	VL	VL	VL	H	VL		+ve		-
Indoxacarb (low+salt)	80			✓			medium	low	L	L	H	M	VL	L	-	L	H	M	VL	L	VL	H	VL				-
Indoxacarb (low+Canopy)	80			✓			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	-	-	-	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	+ve			H[15]
Diafenthiuron	350		✓		✓		medium	low	M	H	VL	M	L	M	VL	L	H	VL	L	L	VL	H	L			+ve	M
Pymetrozine	150				✓		short	low	M	M	M	M	L	L	L	VL	H	M	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]
Abamectin	5.4	✓[6]	✓				medium	moderate	L	M	H	VL	M	L	M	M	H	VL	M	M	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
Endosulfan (low)	367.5	✓		✓	✓	✓	medium	moderate	M	VL	VH	M	M	M	M	L	H	L	M	VL	-	VH	H				M[15]
Propargite	1500		✓				medium	moderate	M	H	H	M	M	H	VL	VL	L	VL	M	M	H	H	M		+ve	+ve	L
Acetamiprid	22.5				✓		medium	moderate	M	M	VH	H	M	M	H	M	VH	L	VL	L	H	VH	VH				M[15]
Amitraz	400	✓	✓[9]		✓[9]		medium	moderate	H	M	VH	H	L	-	-	-	H	VL	M	M	L	H	M				L
Fipronil (low)	12.5			✓		✓	medium	moderate	L	L	H	L	L	H	L	L	VH	L	M	M	M	VH	VH	+ve	+ve	+ve	VH
Chlorfenapyr (low)	200	✓	✓				medium	moderate	M	L	VH	VL	M	VL	H	H	VH	L	L	M	VH	H	M				H
Thiamethoxam	100				✓		medium	moderate	H	H	H	H	M	M	M	H	H	M	VL	M	H	VH	H	+ve		+ve	H
Endosulfan (high)	735	✓		✓	✓	✓	medium	moderate	M	VL	VH	M	M	M	M	M	H	L	M	L	VH	VH	H				M[15]
Fipronil (high)	25			✓		✓	medium	moderate	L	VL	H	L	M	H	H	L	VH	L	M	M	M	VH	VH	+ve		+ve	VH
Imidacloprid	49			✓	✓		medium	moderate	H	L	VH	H	H	M	H	L	VH	L	L	L	M	H	H	+ve		+ve	M
Methomyl	169	✓					very short	high	H	L	VH	VH	M	L	VH	L	VH	M	M	M	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]
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	H	VH	H	+ve			H
Carbaryl[3]							short	high	H	-	-	-	H	-	-	-	-	-	-	-	-	-	H	-	-	-	H
Pyrethroids[4]		✓	✓[7]	✓[7]			long	very high	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; dimethoate, omethoate, monocrotophos, profenofos, chlorpyrifos, chlorpyrifos-methyl, azinophos ethyl, methidathion, parathion-methyl, thiometon
6. *Helicoverpa punctigera* only.
7. Bifenthrin is registered for mite 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.

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.

Table 2. Efficacy of at-planting insecticide treatments against thrips, CSD and CSIRO Experiments, 2006/07. * = significantly different from control at $p < 0.05$.

		Adults/plant								
		T. tabaci			*F.cccidentalis*			Larvae/plant		
Site	Date	Control	Temik	Gaucho	Control	Temik	Gaucho	Control	Temik	Gaucho
ACRI 06/07	1/11/2006	11.0	6.8*	-	1.0	3.3*	-	31.2	5.4*	-
	22/11/2006	1.4	1.6	-	0.1	0.2	-	8.5	4.1	-
	14/12/2006	2.5	2.9	-	0.8	1.0	-	22.9	25.5	-
	P value	0.007			P value	0.039		P value	0.001	
	LSD	2.1			LSD	1.28		LSD	7.1	
Greenbah 06/07	1/11/2006	6.2	6.8	7.8	0.5	0.3	0.6	11.3	5.1	12.1
	8/11/2006	5.4	3.4	7.6	0.6	0.2	0.0	12.6	4.1*	7.6
	15/11/2006	3.8	4.5	3.5	0.3	0.3	0.4	9.7	7.8	12.8
	22/11/2006	1.2	1.8	1.6	0.2	0.2	0.1	28.5	18.7*	38.4*
	29/11/2006	2.3	1.8	2.1	0.0	0.2	0.3	3.5	5.1	4.0
	6/12/2006	2.5	3.1	4.1	0.0	0.0	0.1	4.4	2.9	6.8
	14/12/2006	2.2	3.3	1.9	0.3	0.0	0.9	15.7	14.0	18.0
	20/12/2006	2.6	2.1	3.0	0.2	0.2	0.4	14.5	17.0	19.5
	P value	0.3			P value	0.3		P value	0.028	
	LSD	ns			LSD	ns		LSD	6.9	
WeeWaa 06/07	13/10/2006	3.06	1.58	0.52	0.34	0.45	0.74	0.27	0.30	0.13
	20/10/2006	6.77	5.00	6.70	0.00	0.00	0.00	3.27	2.33	2.53
	27/10/2006	5.27	5.49	4.80	0.17	0.24	0.00	7.17	4.80	10.40*
	6/11/2006	4.53	3.32	4.96	0.00	0.05	0.24	27.97	7.90*	14.90*
	P value	0.4			P value	0.6		P value	0.0001	
	LSD	ns			LSD	ns		LSD	3.9	
CSD Moree	3/10/2006	1.5	1.1	1.1	0.5	0.3	0.2	8.0	2.7	1.8
	19/10/2006	15.6	17.6	15.2	0.6	0.6	0.2	19.1	14.9	6.9
	1/11/2006	1.9	3.1	2.8	0.3	0.3	0.2	18.6	15.0	11.8
	P value	0.9			P value	0.8		P value	0.8	
	LSD	ns			LSD	ns		LSD	ns	

Table 3. Efficacy of at planting insecticide treatments against thrips, CSD and CSIRO Experiments, 2007/08. * = significantly different from control at p < 0.05.

		Adults/plant											
		T. tabaci			*F. occidentalis*			*F. schultzei*			Larvae/plant		
Site	Date	Control	Temik	Gaucho	Control	Temik	Gaucho	Control	Temik	Gaucho	Control	Temik	Gaucho
Kummerow 07/08	15/11/2007	0.7	0.3	1.0	3.2	3.9	3.5	-	-	-	9.1	15.6	6.9
	22/11/2007	4.5	2.1	3.4	0.5	1.3	1.7	-	-	-	8.5	8.2	17.3
	P value	0.6			P value	09					P value	0.03	
	LSD	ns			LSD	ns					LSD	8.9	
			Thimet			Thimet			Thimet			Thimet	
Greenbah 07/08	23/10/2007	1.0	0.7	0.7	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0
	30/10/2007	4.3	2.1	2.4	0.1	0.1	0.2	0.7	0.4	0.2	12.4	1.3*	0.8*
	6/11/2007	1.2	1.4	1.7	0.0	0.0	0.1	0.1	0.5	0.2	9.2	3.0*	1.9*
	P value	0.3			P value	0.7		P value	0.3		P value	0.001	
	LSD	ns			LSD	ns		LSD	ns		LSD	2.6	
Boolooroo 07/08	30/10/2007	1.0	1.3	1.0	0.1	0.0	0.0	0.0	0.2*	0.1*	0.8	0.6	0.1
	8/11/2007	0.1	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	1.2	1.0	0.3
	14/11/2007	0.2	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.7	1.3
	23/11/2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
	P value	0.8			P value	0.4		P value	0.031		P value	0.8	
	LSD	ns			LSD	ns		LSD	0.08		LSD	6.9	
ACRI 0708	6/11/2007	1.9	0.2		2.1	2.4		0.4	0.2		5.2	4.3	
	13/11/2007	1.3	0.9		0.8	1.2		0.1	0.2		3.7	4.6	
	21/11/2007	5.7	5.2		1.4	1.5		0.1	0.8		1.5	1.7	
	P value	0.17			P value	0.9		P value	0.017		P value	0.34	
	LSD	ns			LSD	ns		LSD	0.44		LSD	3.9	
Narromine 0708	11/11/2007	9.0	10.8		6.2	7.7		6.0	7.6		14.0	4.9*	
	18/11/2007	5.6	7.3		2.4	0.0		3.3	2.3		2.8	1.9	
	27/11/2007	2.0	0.3		0.3	0.7		0.0	0.0		1.2	0.5	
	P value	0.6			P value	0.6		P value	0.3		P value	0.008	
	LSD	ns			LSD	ns		LSD	0.44		LSD	3.7	

Late season damage due to thrips.
Since the advent of Bollgard II we have received frequent calls from consultants about late season populations of thrips on cotton. In general these late season populations, which are mostly WFT or *F. schultzei*, are not regarded as a problem and they actually assist in reducing the risk of mite outbreaks as both adults and larval thrips consume mite eggs. However, damage can sometimes be severe, especially to the upper leaves, which receive the most sunlight and which are most photosynthetically active (see Figure 1a-c). Some consultants (e.g. Mike Stone, Moree) have also expressed concern that high numbers of thrips larvae in flowers may cause flower abortion.

Figure 1. Leaves showing damage from late season thrips populations (a) from Mal Pritchard at Hillston (b) from Geoff Rudd at Dalby (c) from Togo, Wee Waa. In all cases these were upper leaves and the crop manager had expressed concern about the level of damage.

We have investigated this in several ways. Firstly we completed a small field experiment as part of a previous project that showed that loss of upper leaves late in the season could affect yield. Secondly, we established that thrips damage does reduce photosynthesis and could therefore potentially affect yield. Thirdly we set up experiments where portions of leaf area were removed to simulate severe damage to leaves and finally we developed a spray, based on spray-rig applied glacial acetic acid, which causes burns on the leaf that simulate the effects of thrips feeding. The latter two approaches both simulate a loss of photosynthetic activity which could then affect yield. These experiments are reported on below:

<u>Effect of leaf removal on yield</u>
Experiments were conducted over three years in collaboration with Stephen Yeates who provided valuable discussions on the treatments to be imposed. Our aim was to test how much leaf area needed to be removed in order for yield to be affected. We hypothesised that crops with high yield potential would be more likely to be at risk from yield loss due to late damage. This strategy was taken because experiments to manipulate thrips densities in field crops failed as thrips populations were variable at the particular sites chosen.

In the first year, 2005-06 we did two experiments focussing on damage after cut-out. In the first experiment we removed the leaves from the top 6 mainstem nodes at cutout, cutout plus 10 days, plus 20 days, plus 30 days and plus 40 days and had an undamaged control (6 treatments x 5 replicates, RBD). In the second experiment, damage treatments were superimposed on an experiment where flower retention had been manually manipulated to generate higher (85%) and lower (74%) retention levels. The results of Experiment 1 (Table 4) showed that none of the damage treatments affected maturity or yield, and those of Experiment 2 showed no significant effect of damage on yield regardless of retention level (though there was a trend for plots receiving damage at 40 days after cut-out to have higher yield).

Table 4. Effect of removal of all leaves from the top 6 nodes of cotton plants at cut-out and dates after that, ACRI, 2005/06.

Treatment	Experiment 1		Experiment 2	
			Yield (b/ha)	
	Yield (b/ha)	Maturity (DAS)	High retention	Low retention
Control	10.9	162.5	9.716	10.112
Cutout	10.4	158.1	9.939	10.058
Cutout + 10d	10.3	157.7	9.952	9.604
Cutout + 20d	10.4	161.6	9.712	9.832
Cutout + 30d	10.3	161.9	-	-
Cutout + 40d	11.2	161.7	10.682	10.696
P value	0.68	1.12	P retention	0.76
LSD (0.05)	ns	ns	P time	0.03
			(LSD 0.05)	0.64
			P R x T	0.82

Based on the results of the earlier experiments we realised that some more extreme damage treatments would be required to determine the point at which leaf damage translated into yield loss – important in defining a threshold. We decided to implement two damage levels (i) removal of all leaves from the top 6 nodes or (ii) removal of all leaves from the top 9 nodes (Figure 2). In both cases this included leaves on the mainstem and fruiting branches.

Figure 2. Plots from damage experiments (a) undamaged (b) leaves removed from top 9 nodes (c) thrips in flower, Field A3, ACRI, 2007-08.

We also decided to refocus the timing of damage to include some earlier treatments with the first damage at peak flowering, the second three weeks later (end of flowering), the third at cut-out and the fourth at cut-out plus two weeks. This experiment was completed in 2006-07 and 2007-08 using a randomised block design with four replications, see Figure 3. The two experiments were analysed in a single ANOVA with year, node and time as terms. As there was only a single control treatment this was replicated in the analysis to provide a control for each node level, allowing for a balanced design.

Figure 3. Layout of simulated thrips damage experiments in 2006-07 and 2007-08.

The results are shown in Table 4, but because the analysis is complex the results are reported more fully below. ANOVA showed significant effects of year as 06-07 had a lower yield than 07-08 (2006-07, 9.0 bales/ha; 2007-08;12.5 bales/ha, $p = 0.016$). Node ($p < 0.001$) and time of damage ($p < 0.001$) also had significant effects, but also strong contributions to interactions. Year by node was just significant, indicating a marginally different response between years ($p = 0.05$). The difference in yield between damage to six or nine nodes was bigger in 07-08, due largely to the difference in yield levels between years. The effect of time of damage varied between years ($p = 0.002$), with the earlier damage reducing yield more significantly as expected, but the effect being more significant in 07-08 when yields were higher (Figure 4). The interaction of time of damage by nodes damaged was also significant ($p < 0.001$). As expected, removal of the leaves from the top 6 nodes affected yield less than removal of leaves from the top 9 nodes and later damage did not significantly affect yield (Figure 5). Maturity was not affected by any of the treatments and did not differ between years (Table 4).

Overall the results indicate that cotton yield is sensitive to damage to the upper leaves, though it requires quite high damage. It is interesting that at the times when thrips are most likely to be in high abundance on cotton (end of flowering, cut-out, cutout plus 2 weeks) the higher yielding crops appear more sensitive, and damage quite late, can be important. These experiments allow us to focus in future on later damage timings and partial leaf removal which will more accurately simulate real damage.

As an additional component in this experiment we also included some extra treatments in spare rows of some plots. These treatments included flower removal, which was in response to suggestions that high densities of thrips may cause flower abortion. There is evidence for this overseas so we asked the question "Assuming thrips do cause flower abortion what would be the consequences for yield?". This was applied at the second damage timing (end of flowering) where 3 days worth of flowers were removed from both controls, and the 6 and 9 node leaf removal treatments. We removed tomorrow's flowers (candle wick stage square), today's flowers, and yesterday's flowers at the same time as the leaves were removed and again 3 days later, simulating complete flower abortion for a week.

The results (Table 5) showed that removal of flowers for 1 week did not affect yield ($p = 0.12$), but node of damage did affect yield (control, 9.71; 6 nodes, 9.22; 9 nodes, 7.57 b/ha). The interaction was not significant. This suggests that crops were able to compensate for flower loss, whether they had leaf damage or not. Crop maturity was not affected by flower removal, or the interaction between flower removal and node, but node alone was significant with the lower yielding node 6 and node 9 damage treatments maturing significantly earlier (control, 160.68; 6 nodes, 158.44; 9 nodes, 152.70 days after sowing to 60% bolls opened) (Table 5). Some of this effect could be due to the more open canopy which would allow more light and heat into the crop.

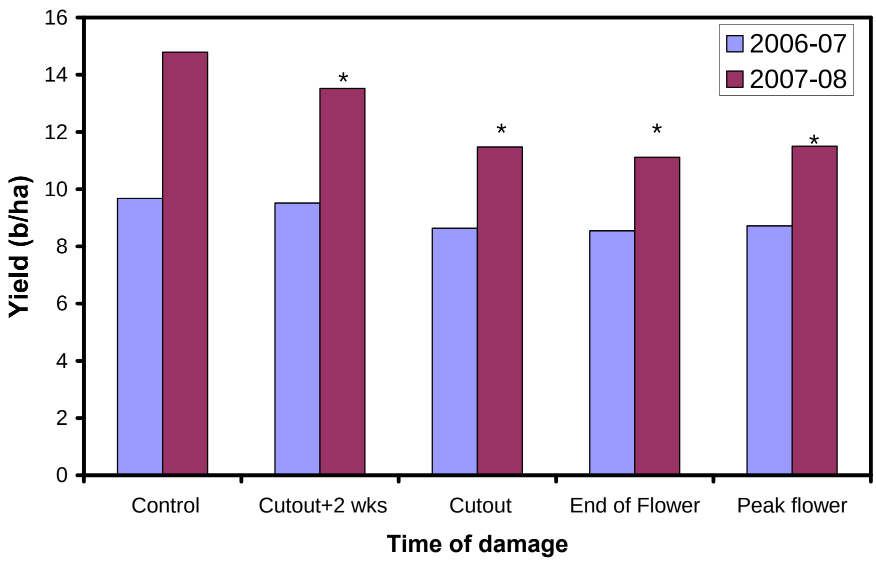

Figure 4. Earlier imposition of damage reduces yield more. This effect was stronger in 2007-08 when yield was higher. Asterisks indicate treatments significantly different from the control for each year separately.

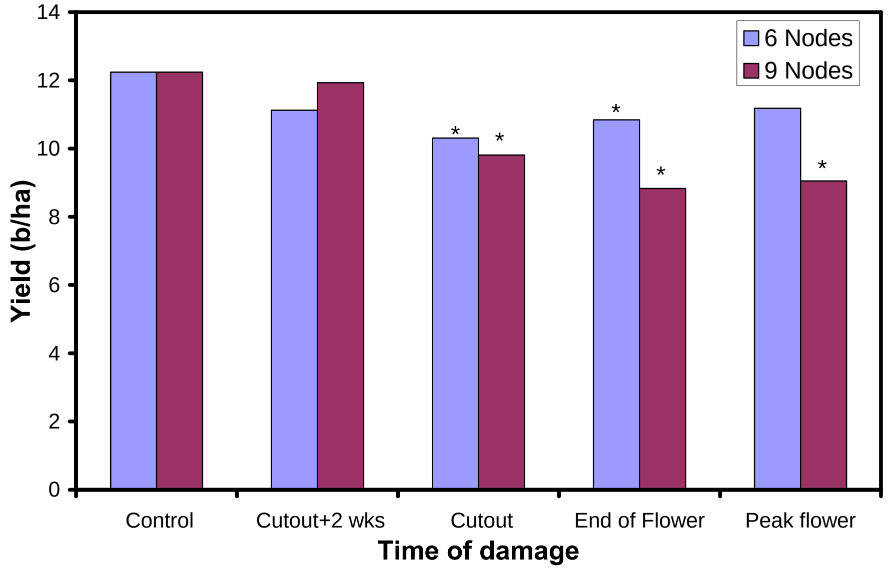

Figure 5. Earlier imposition of damages reduces yield more when imposed for 9 nodes than 6 nodes. Asterisks indicate treatments significantly different from the control for each year separately.

Table 4. Effect of removal of all leaves from the top 6 or top 9 nodes of cotton plants at a range of growth stages, ACRI, 2006-07 and 2007-08.

Treatment		Yield (b/ha)		Maturity DAS	
Timing	Nodes removed	2006-07	2007-08	2006-07	2007-08
Control (undamaged)	0	9.7	14.8	158.3	159.8
Peak Flower	6	9.9	12.5	157.9	155.4
Peak Flower	9	7.6	10.5	157.2	162.9
End flowering	6	9.1	12.6	158.2	157.5
End flowering	9	8.0	9.6	151.7	153.3
Cutout	6	8.8	11.8	157.5	162.6
Cutout	9	8.5	11.1	160.5	159.6
Cutout plus 2 weeks	6	8.6	13.7	159.4	162.3
Cutout plus 2 weeks	9	10.5	13.4	155.4	158.4

Table 5. Effect of flower removal near the end of the flowering period on yield of cotton with or without leaves removed from the top 6 or 9 nodes ACRI, 2007/08

	Flowers removed					
	Yes	No	Yes	No	Yes	No
Nodes damaged	Mean number of flowers removed/m		Yield b/ha		Maturity (days after sowing to 60% bolls open	
0	16.2	0	10.8	8.6	161.6	159.8
6	18.0	0	9.7	8.8	159.4	157.5
9	18.1	0	7.4	7.7	152.1	153.2

Effect of 'burn spray' on yield

This experiment, the first in a series, was also designed to mimic the effect of late thrips damage (i.e. loss of photosynthetic activity of leaves), given that we were unable to do this with actual thrips populations. The aim was to overcome a deficiency of the leaf removal experiments – when leaves are removed completely more light is allowed into the lower canopy. Real thrips damage does result in smaller and less functional leaves, so there would be less shading of lower leaves, but still more shading than complete leaf removal. We used a spray consisting of diluted glacial acetic acid (10%) and Canopy crop oil (10%), plus xantham gum (0.25%) as a sticker to cause damaged areas on leaves by creating burns. This reduced leaf area would have reduced photosynthetic activity, similar to thrips damage, but without the leaves falling off completely, In a preliminary experiment this approach was quite effective. (Figure 6)

Figure 6. Effect of 'burn spray' on cotton leaves, Field A3, ACRI, 2007-08.

The experiment was set up to mimic possible field damage, with sprays being applied on three dates: (2 weeks before cut-out, at cutout and 2 weeks after cutout. We used a progression where on the first date we had the combination of sprays x dates (see Table 6). We established that the burned areas have significantly reduced photosynthetic capacity as do areas of leaf damaged by thrips – hence this technique is a reasonable approximation of pest damage (Figure 7).

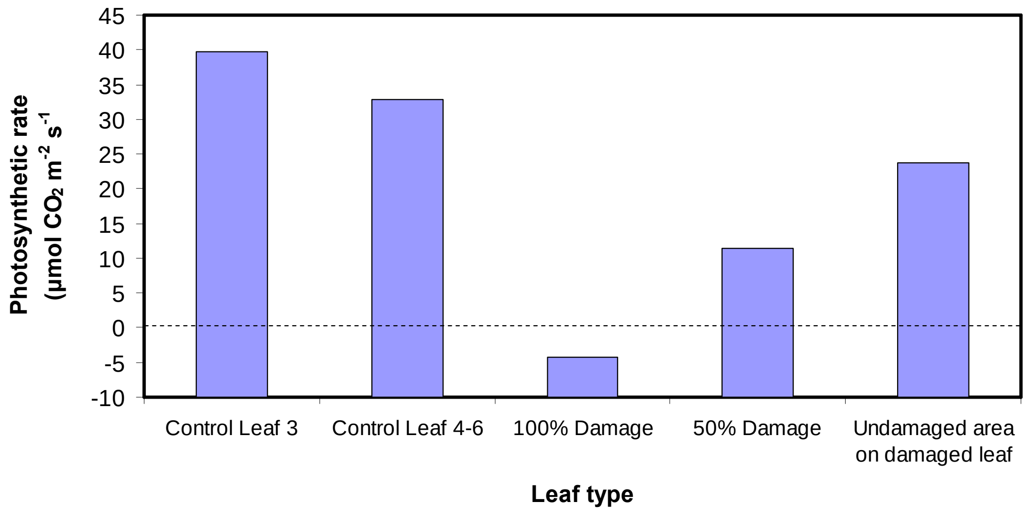

Figure 7. Effect of leaf burn damage on photosynthesis. Control leaves have no damage.

The sprays were applied with a spray rig using 5 flat fan nozzles per row. We quantified carefully the amount of leaf area damaged for each different treatment and also assessed if the damage caused differences in light penetration (data not shown). We also developed a system using a digital imaging program to select the different coloured damaged areas and automatically estimate the leaf area and damaged area for leaves sampled from each plot – this allowed us to calibrate our damage scores in the field to an actual leaf area damaged (data not shown).

The results were similar to the leaf removal experiment and show that earlier damage causes a greater reduction in yield (Table 2), especially with high yield (e.g. controls had 12.9 b/ha). Interestingly even the late damage with a single spray caused a reduction in yield – similar to the leaf removal experiment. A further experiment with a reduced spray rate or coverage would be valuable in helping to define the interaction between damage severity and timing.

Table 6. Effect of single and repeated 'leaf burn' sprays at different stages of growth on yield (b/ha) of cotton, ACRI, 2007/08. Asterisk indicates treatment significantly different to Control (ANOVA, LSD 0.05).

	Sprays applied			
Date of first spray	0	1	1 + 2	1 + 2 + 3
Control	12.9			
2 weeks before cutout		10.1*	9.2*	9.3*
Cutout			12.0	12.0
2 weeks after cutout				12.3

Late Season Jassid Damage

These experiments were designed to help understand the outcomes of damage from mid to late season jassids. These pests typically begin in the lower canopy, progress through the mid canopy and, when severe, cause damage to upper leaves. We have previously shown that severe jassid damage (80%) of upper leaf area damaged, can reduce photosynthesis of upper leaves by about 20%. However, the same damage on mid canopy leaves produced a much smaller decline of about 3%, mainly because photosynthesis in the shaded leaves is lower to start with. We tried to manipulate jassid population in the field on several occasions but were unable to generate sufficient differences in jassid density. However, when later sampling field for aphids and mites for resistance testing at a range of locations throughout the industry we frequently encountered fields with pronounced jassid damage especially along the edges.

As a backup method to obtain some understanding we carried out two experiments where we removed all of the leaves from the lower 1/3 of the crop, the middle, the top, and combinations of these strata e.g. bottom+middle, bottom+top, middle+top, and bottom+middle+top (see Figure 8 and 9). This essential asks the question 'if jassid damage was so severe that a particular strata was not contributing to photosynthesis what would be the effect on yield?'. The damage was implemented in early January in the first experiment in 2005-06, and in early January and early February (separate treatments) in 2006-07. We collected the leaves we removed from each stratum and measured the total leaf area removed for each treatment, and also harvested the bolls separately from each stratum so we could understand how loss of leaf area affected the bolls in each stratum, single or in combination (data not shown here). In 2006-07 we used longer plots of 6m which were machine harvested to provide a more accurate estimate of damage effects.

	D1 BT		**D1 BMT**		**D1 MT**		**D1 Bottom**
	D2 Top		**Control**		**D2 Bottom**		**D2 BM**
	D1 MT		**D2 Middle**		**D2 BT**		**D1 BT**
	D2 BMT		**D1 BM**		**D1 Middle**		**Control**
	D1 Bottom		**D2 BM**		**D1 BMT**		**D2**
	D2 MT		**D1 BT**		**D2 BMT**		**D 2 Top**
	D2 Middle		**D2 Bottom**		**D1 Bottom**		**D1 BM**
	D1 Top		**D1 Middle**		**Control**		**D2 BMT**
	D2 BM		**D2 BMT**		**D2 MT**		**D1 Top**
	D2 BT		**D1 MT**		**D2 Middle**		**D2 BT**
	D1 BMT		**D1 Top**		**D2 Top**		**D1 MT**
	Control		**D2 MT**		**D1 BM**		**D1 Middle**
	D1 BM		**D2 BT**		**D2 BM**		**D2 Bottom**
6m	**D2 Bottom**		**D1 Bottom**		**D1 BT**		**D2 MT**
long	**D1 Middle**		**D 2 Top**		**D1 Top**		**D1 BMT**
	Rep 1 (8 rows wide, central 3 damaged)		**Rep 2**		**Rep 3**		**Rep 4**

Figure 8. Layout of simulated jassid damage experiments in 2006-07 and 2007-08.

Figure 9. Examples of treatments in jassid damage simulation experiments (a) control (b) removal of leaves from bottom, middle and top strata (c) removal of leaves from bottom and top strata, leaving the middle – removed leaves can be seen in the furrow. A 1m section of removed leaves was retained to estimate the leaf area removed. Block 18, ACRI, 2006-07.

Analysis of the total yield for each treatment (Figures 10 and 11) showed that the experiments gave very similar results. Loss of leaf area from the bottom has almost no effect on yield. Loss from the top or middle reduced yield. Additional loss of bottom leaves to loss of middle or top leaves maked little difference. This suggests jassid damage to lower leaves is unlikely to reduce yield no matter how severe. However, damage to middle or top leaves, singly or in combination is more significant. However, these results must be tempered by the fact that jassid damage doesn't reduce photosynthesis very much, even when severe. Earlier research by Lei, Reddall and Wilson found that leaves in the upper canopy, with 80% of the upper leaf surface area damaged had photosynthesis reduced by only 20%. This appeared to be because the jassids only damage part of the way through the leaf, leaving the lower half of the leaf still functional. In contrast leaves in the lower canopy with similar damage levels had photosynthesis reduced by about 5%, because the rates were low already. So, damage would need to be very severe and prolonged to reduce yield, even at high yields (as obtained here).

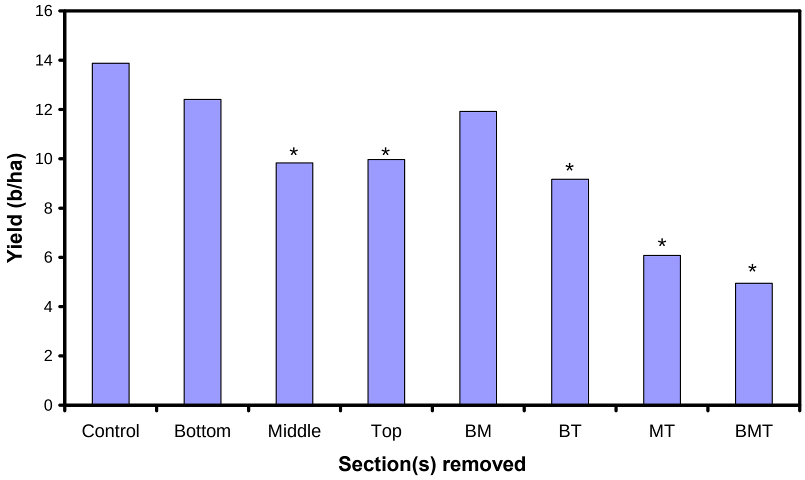

Figure 10. Effect of removing all of the leaves from a section of the crop canopy on yield, ACRI, 2005-06. Damage imposed on 4 January, early flowering. Asterisk indicates significantly different from control (ANOVA, LSD 0.05).

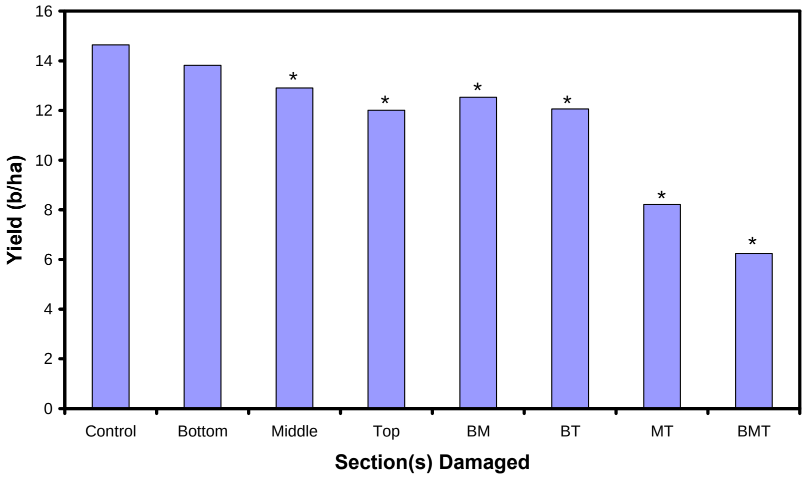

Figure 11. Effect of removing all of the leaves from a section of the crop canopy on yield., ACRI, 2006-07. There were 2 damage times (8 January early flowering, and 7 February late flowering) but the effect of damage timing was not significant ($p > 0.05$) so the combined values are shown. Asterisk indicates significantly different from control (ANOVA, LSD 0.05).

Real jassid damage

We had difficulty locating suitable sites for experiments with jassids in advance of a problem – usually we heard about sites after damage had already occurred. When we decided on a predetermined site the jassid population invariably failed to develop to the extent we wanted. Nevertheless, we persevered and complete an experiment in 2006-07. In this experiment, Dr Mary Whitehouse indicated that she had seen areas with jassid damage in her cotton, and was prepared to allocate us a section. We set the experiment up on the 18th January, with four treatments: no control, control now, control 3 weeks later and control 5 weeks later. Diafenthiuron (Pegasus) was used to control jassids. This design was chosen to allow progressive accumulation of damage. We sampled immediately before the first spray event, then each week thereafter. From each plot we scored the damage on the upper and lower surfaces of leaves at node 3, 6, and 10 on 10 plants per plot (see Figure 12 and Table 7), and also sampled the jassids in each plot with a sweep net (12 sweeps across the centre two rows). At the end of the season we machine harvested the central two rows of each plot (each plot was 10m long and 8 rows wide).

Figure 12. Left, the section of field including the jassid damage experiment and right, the damage scoring system used.

Table 7. Damage score used to rank jassid damage to leaves.

Percentage Damage	Score
0 to 10	1
11 to 20	2
21 to 40	3
41 to 60	4
61 to 80	5
81 to 100	6

The jassid damage built slowly, and then declined. Analysis showed a significant overall difference in scores but only between the Control 1 (1.4) and the rest (≈ 1.72)($p = 0.004$), and an overall increase then decline in scores from 0.7 to 2.2 to 1.7 ($p < 0.001$) (Figure 13). The interaction between treatment and date was not significant. The sweep netting indicated differences between treatments with a peak of ≈ 80 jassids per 12 sweeps in the Control 1 treatment and up to ≈ 140 in the no control treatment ($p = 0.001$)(Figure 14). Analysis of yields (machine harvested) showed no effect of jassids on yield, suggesting that at these low levels of damage (average high score about 2.2 about 20 % of leaf surface damaged (see Figure 12) there was no effect on yield.

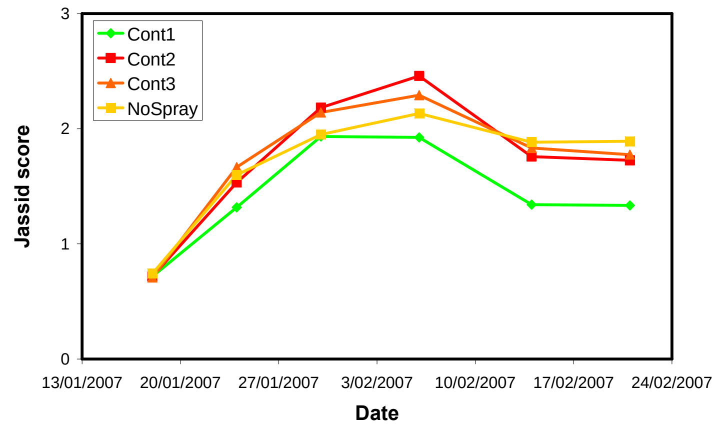

Figure 13. Build up of jassid damage in plots, River Block 5, ACRI, 2006-07.

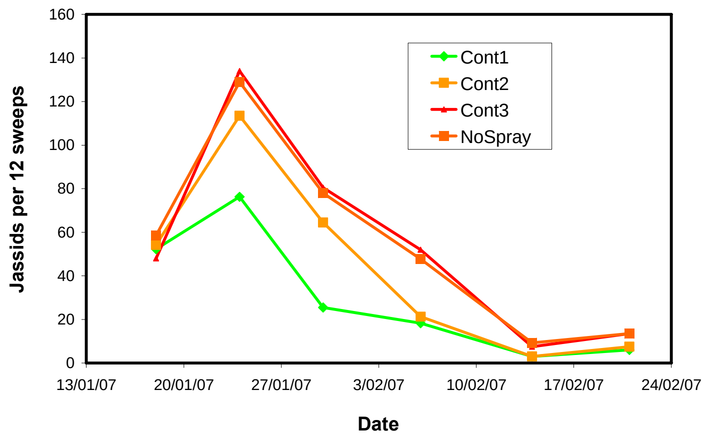

Figure 14. Build up of jassid damage in plots, River Block 5, ACRI, 2006-07.

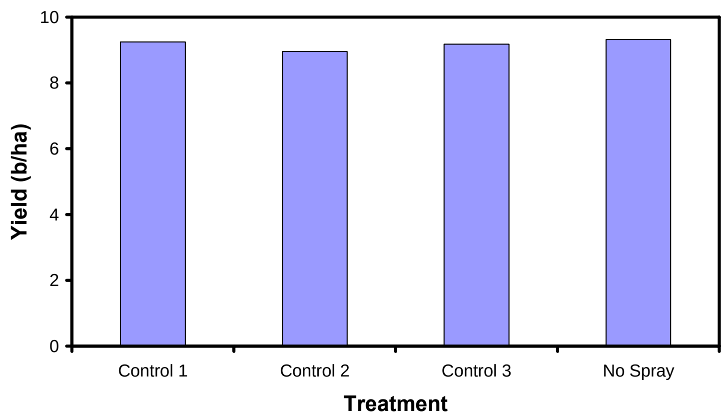

Figure 15. Effect of jassid damage on yield, River Block 5, ACRI, 2006-07.

b. Mirid management

Mirids have emerged as the major pest in Bollgard II cotton, which now accounts for about 80+ % of the planted area. Crops are regularly sprayed 1 or more times to control mirids, with an average of 2-3 but as many as 5 applications in a season. Fipronil (Regent) and dimethoate (Rogor) are the most commonly used insecticides, often at lower rates with the addition of salt or Canopy oil. We know from the work of our earlier projects that the use of these insecticides can potentially lead to increases in abundance of secondary pests, especially mites, but also whitefly and OP resistant cotton aphids in the case of dimethoate.

Consultants often note that they spray their Bollgard II crops first for mites. We have put this down to the fact that Bollgard II crops are sprayed with products that 'flare' mites, whereas conventional crops are sprayed with endosulfan, abamectin and emamectin especially early season which would tend to suppress mites. However, in the glasshouse and in other research with CSIRO funded Summer Scholarship students (Lauren Cave, 2005-06; Petra Norman, 2006-07) we have seen indications that mite populations may develop faster in Bollgard II cotton, though we are uncertain as to the mechanism – it does not appear to be related to differences in food quality of Bollgard or conventional cotton.

To help answer this question we designed two field experiments, in collaboration with Dr Mary Whitehouse and Dr Sharon Downes (CSIRO Entomology). Dr Whitehouse undertook detailed beatsheet sampling of the beneficial complex (data not reported here) and Dr Downes carried out detailed sampling of *Helicoverpa* abundance (data not reported here). In 2007-08 the plots were also used by PhD student Lu Baoqian as part of his research into thresholds for *Helicoverpa* spp. in Bollgard II cotton.

The experiments were laid out as a randomised block designs with two treatments specified as crop type and insecticide. Crop type was either Sicot 80RF or Sicot 80BRF while insecticide was either untreated or sprayed with fipronil (@ 25 g ai/ha) in 2006-07)(see Figure 16) and in 2007-08 was untreated or sprayed with either fipronil or thiodicarb (Larvin @ g ai/ha). We mass reared two-spotted spider mites in a glasshouse on cotton seedlings and used these to infest all plots with a moderate density of mites (2-3 seedlings /m). We sampled immediately before the first spray, then at least once between sprays. Sprays were applied 3 times with an interval of about 7-10 days depending on conditions (irrigation, rain, wind).

13 **Conventional**	**14 SPRAY BG II**	15 SPRAY **Conventional**	**16 BG II**
9 SPRAY **BG II**	**10 Conventional**	11 SPRAY **BG II**	**12 Conventional**
5 **BG II**	**6 SPRAY Conventional**	7 **Conventional**	**8 SPRAY BG II**
1 SPRAY Conventional	**2 BG II**	3 **BG II**	**4 SPRAY Conventional**
12 rows wide and 20 m long	**12 rows**	**12 rows**	**12 rows**

Figure 16. Layout of Mirid management x Mite experiments, ACRI, 2005-06.

The results for the 2006-07 experiment are quite surprising as in the sprayed plots the build up of mites was significantly faster in the Bollgard II plots than in the conventional plots. In 2007-08 there were also strong effects due to spraying, with plots treated with thiodicarb or fipronil having significantly more mites; however, there were no variety effects or variety by treatment interactions (Figure 17).

Across all of our experiments we have sometimes found more mites in insecticide treated Bollgard II plots than in conventional plots (2/5 experiments), but this has not been consistent. We are uncertain as to the cause of this inconsistency, but it does suggest that factors other than just insecticide application are, at least in some situations, also important. However, the results do highlight the tremendous biological control of mites – despite us infesting all plots with mites the populations were naturally controlled in the unsprayed plots. In contrast, if cotton was sprayed regularly with fipronil to control mirids it is likely that there will be mite outbreaks. Many consultants are already anticipating this problem and adding abamectin, which is very effective and inexpensive, to pre-emptively control mites. Such applications, however, do increase the risk of selection for resistance in mites and an approach that did not increase the risk of mite outbreaks in the first place would be better.

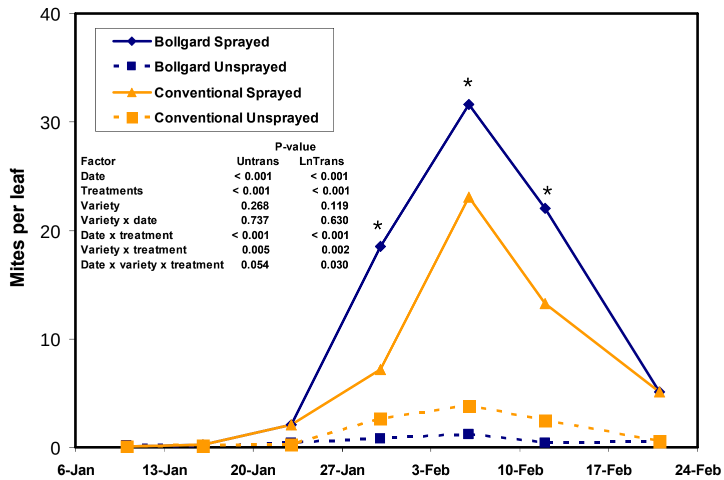

Figure 17. Build up of spider mites in plots of conventional or Bollgard II cotton either unsprayed or sprayed with fipronil 3 times at about 7-10 d intervals, Block 18, ACRI, 2006-07. Asterisks indicate treatments significantly different according to the untransformed analysis for the 3 way interaction, e.g. sprayed Bollgard II and conventional differ on 3 dates, unsprayed treatments don't.

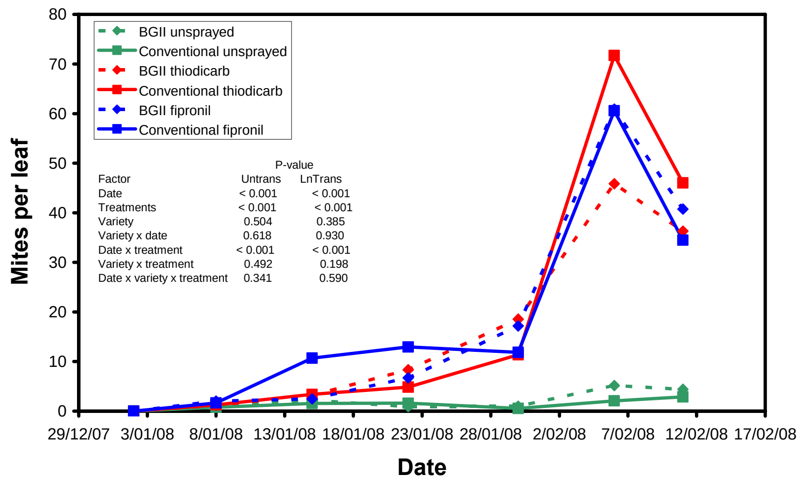

Figure 18. Build up of spider mites in plots of conventional or Bollgard II cotton either unsprayed or sprayed with fipronil or thiodicarb 3 times at about 7-10 d intervals, Field 1, ACRI, 2007-08.

c. Pale cotton stainer (*Dysdercus sidae*)

In 2007-08 the pale cotton stainer (PCS) emerged as a significant pest, for the first time in the modern cotton industry in Eastern Australia. This problem was detected through consultants requesting information from Tracey Farrell (NSW DPI) or Lewis Wilson early in January. Inspection of fields revealed significant densities of PCS in some fields (e.g. up to 6-7/m) and significant damage to some bolls – as indicated by distortion and staining of early open bolls.

We did a quick search of the available literature – especially 'Insect Pests of Cotton' by Tunstall and Matthews, and realised that this pest could be quite damaging – causing significant damage to lint. Particularly significant is that this pest feeds on both developing and mature seeds and will attach to bolls too mature for other sucking pests (e.g. mirids), and will also attack open bolls – hence the period of potential damage is wide. To help industry deal with this problem we assembled some information on the life cycle of the pest, control options, sampling issues, thresholds (based on data by Dr. Moazzem Khan), thresholds for lint damage to cause discounts (see below). This was compiled into a 'Pest Profile' on this pest and was sent widely throughout the industry.

The thresholds for lint damage were derived by collecting damaged and undamaged bolls. Separating the damaged bolls into stained, tight-locked or undamaged locks. We ginned these locks in a micro gin and took the samples to Australian Classing Services. The classing produced clear evidence of potential for discounts from stainers (Table 8). Allowing for the ratio of damaged to undamaged lock we developed two tables that indicate the proportion of bolls that need to be damaged to have potential for an overall discount.

Following this research we wanted to investigate the symptoms of the damage caused by this pest as this would help consultants to detect it early in the field. We found we could distinguish between male and female PCS by the presence of bands on the abdomen. We caged adult stainers on relatively mature bolls in the field (bolls > 20 days old) which would not be attractive to other sucking pests.

We found that the symptoms of damage are difficult to see – the PCS pierces the boll wall with a very fine stylet that leaves only a very tiny puncture mark on the outside of the boll – almost impossible to see even with a hand lens. On the inner boll wall the damage is evident as small black marks, easily missed. Shortly after feeding the lint appears undamaged, but if the seed are dissected out and cut open there is clear evidence of damage by female stainers but not by males. This information has been extended to industry via the CCA AGM and the CRC Science Forum in 2008. It makes managing stainers more difficult because damage is difficult to detect without opening bolls and inspecting the internal walls very carefully as well as cutting seeds open to check for damage. We intend to follow this up in 2008-09 by caging different ages of bolls undamaged by other sucking pests with known numbers of stainers and developing a better understanding of the damage symptoms and rate.

Figure 19. Clockwise from top right, adult pale cotton stainer, undamaged boll (left) and damaged boll (right) showing staining, nymphal stage of PCS, damaged boll being fed on by a mating pair of PCS.

Table 8. Effect of PCS on grade of lint.

Boll type	Lock type	Colour	Spotting
Damaged	Stained	3	2
	Tight	4	4
	Undamaged	2	1
Undamaged	Undamaged	1	1

Discounts
22 = $15
32 = $48
33 = $78
43 = $120
44 = >$120

Table 9. Lint grade as affected by proportion of bolls and locks per boll by pale cotton stainer damage.

	Staining				Tight locked (damage + disease)			
	Damaged locks per boll				Damaged locks per boll			
Proportion of bolls affected	1	2	3	4	1	2	3	4
0.00	11	11	11	11	11	11	11	11
0.10	11	11	11	11	11	11	11	11
0.20	11	11	11	11	11	11	11	22
0.30	11	11	11	21	11	11	22	22
0.40	11	11	21	21	11	11	22	22
0.50	11	21	21	22	11	22	22	33
0.60	11	21	21	22	11	22	22	33
0.70	11	21	21	22	21	22	22	33
0.80	11	21	21	32	21	22	33	33
0.90	11	21	21	32	21	22	33	44
1.00	21	21	22	32	21	32	33	44

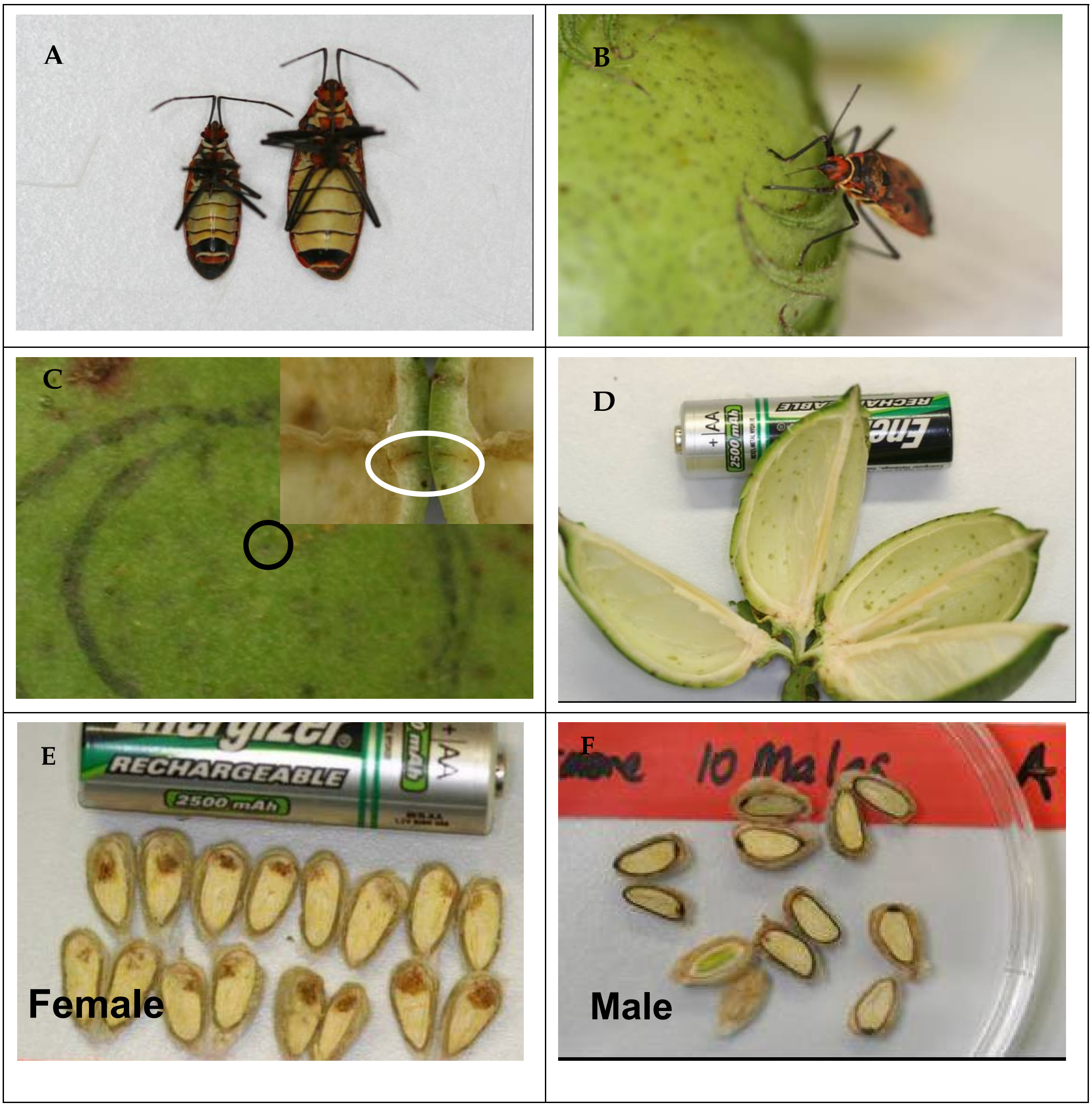

Figure 20. A. male (left) and female (right) adult pale cotton stainers (*Dysdercus sidae*) B. adults stainer feeding, showing fine stylet C. tiny puncture mark D. tiny black marks on inside boll wall caused by feeding of males and females E. seeds fed on by females showing brown damaged areas F. seeds from bolls fed on by males show no sign of damage.

d. Aphids and yield

As part of the previous project (CSP147C) the effect of aphids on yield of cotton was further quantified in an experiment in 2005-06. However, due to the difficulty in generating outbreaks of aphids reliably in small plots this work was curtailed. Effort was then put into developing a relationship between aphids and yield loss from previous years' data that could be used to assist consultants and growers in the field. Data from the 2005-06 season was used to validate the equation, then included in the data set and used to improve the equation slightly.

We developed a new sampling technique as aphids are challenging to sample; they are patchy in distribution, small and too numerous to count quickly. The current recommendation for aphid sampling uses a presence/absence sampling system. We found that this technique provides a poor estimation of the actual aphid population in fields. To overcome this problem we developed a simple scoring system which involves scoring the density of aphids on the 3rd or 4th main-stem node below the terminal as;

0 = no aphids
1 = 1-10 aphids
2 = 11-20 aphids
3 = 21-50 aphids
4 = 51-100 aphids
5 = >100 aphids

An illustration showing these aphid densities is given in Figure 1. After counting aphids the first few times we quickly became confident at estimating abundance. About 20 leaves are required for accurate estimates of aphid density within a region of a field. In most fields at least 4 samples should be taken.

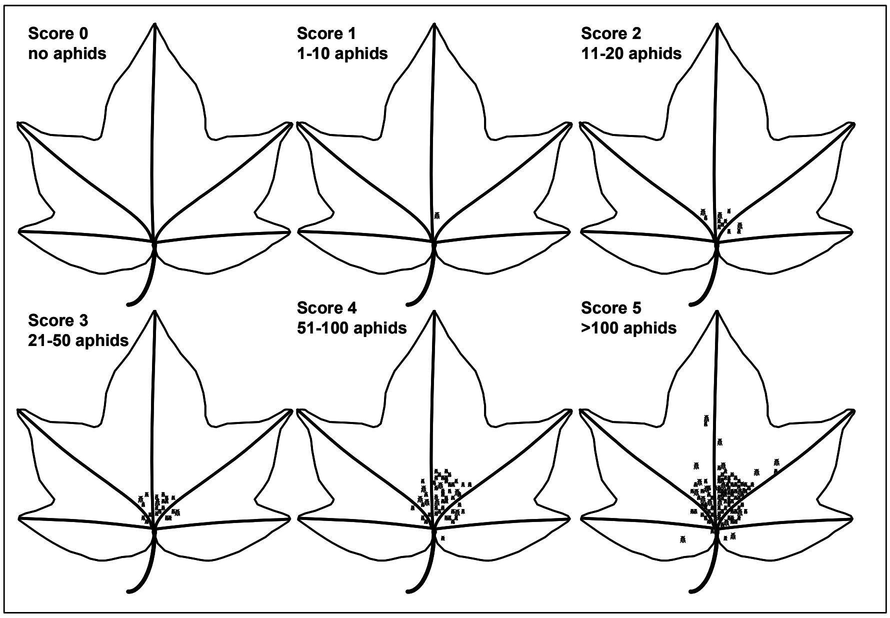

Figure 1. Representation of the aphid scoring system

Using score data from four years of experiments we calculated the average aphid score (AAS) for each sample date (total score / number of leaves sampled). To account for the build up of aphids over time we used the following formula to calculate the sample aphid score (SAS);

SAS = (Previous score x days since last score) + ((current score – previous score) x days since last score/2)

We accumulated this score across dates to give a 'cumulative season aphid score' (CSAS). A statistical equation was developed that predicted the % yield loss from the CSAS and the time remaining from the date the aphid population was first found until 60% bolls open.

Yield loss = 100 – $((-0.0369 \times CSAS \times (TRem/SL) + 10.11))^2$

Where Trem – is the time remaining in the season from the current sample date to 60% of boll open in days and SL – is the season *l*ength in days from planting to defoliation. This relationship predicted yield loss with a high degree of accuracy, accounting for approximately 85% of the variability.

We developed simple guidelines, with help from Tracey Farrell, Simone Heimoana and Tanya Smith to use the sampling strategy and threshold equation to help improve aphid management:

(i) Fields should be sampled in several locations as aphids tend to be patchy. At each location collect 20 leaves from the 3 or 4th mainstem node below the terminal, taking one leaf per plant. Score each leaf using Figure 2 as a guide. The same leaves could also be used to score for mites and whitefly. When counting, do not include the pale brown bloated aphids as these are parasitized.

(ii) Sum the scores and divide by the number of leaves sampled to calculate the average aphid score (AAS). A hand tally counter helps with tallying the score (enter ‘hand tally counter’ into Google, check ‘Australian sites’). Use Table 10 to convert the AAS into a SAS. For the first assessment of the season assume the ‘score last check’ was ‘0’. Find the value in the table where ‘this check’ and ‘last check’ intersect. Multiply this value by the number of days that have lapsed between checks. If this is the first assessment of the season, this value is the first CSAS. The CSAS is a cumulative score, so as the season progresses add the checks value to the previous value to give the updated CSAS.

(iii) Table 11 shows the potential yield loss from aphid populations beginning at different stages of the season for a range of CSAS. Use the date that you first found aphids, expressed as days from 60% of bolls open, as your ‘Time remaining’. For that ‘Time remaining’ look down until you reach the line that approximates your current CSAS – this is the yield loss that the aphid population has caused (a worked example is given in Table 3). The value of the crop and the cost of control should be used to determine how much yield loss can be tolerated before intervention is required. Not controlling non-economic aphid populations saves money and also allows beneficials the chance to build and control aphids and other pests. Crop sensitivity to yield loss from aphids declines as the crop gets older, e.g. a higher CSAS is required before yield is affected. If aphids are controlled, either by a spray applied for aphids or against another pest, or if there are two aphid checks in a row with no aphids found, reset the CSAS to zero. Begin accumulating again when sampling recommences and you first get a non-zero aphid score, using this date as the new ‘Time remaining’. This information has been captured in the Cotton Pest Management Guide, in an article in the Australian Cottongrower and in a webtool under development ‘The Aphid Yield-Loss Estimator’ (with Loretta Clancy).

Table 10. Look-up chart to help convert the average aphid score (AAS) to a sample aphid score (SAS). Look up the appropriate value for the current and previous score. Multiply this number by the number of days between the checks to give the SAS (e.g. a score of 1 last week and a score of 2 this week would be 1.5 x 7 days = 10.5).

Average aphid score *last* check	Average aphid score *this* check								
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0
0	0.0	0.3	0.5	0.8	1.0	1.3	1.5	2.0	2.5
0.5	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.3	2.8
1.0	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.5	3.0
1.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.8	3.3
2.0	1.0	1.3	1.5	1.8	2.0	2.3	2.5	3.0	3.5
2.5	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.3	3.8
3.0	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.5	4.0
4.0	2.0	2.3	2.5	2.8	3.0	3.3	3.5	4.0	4.5
5.0	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.5	5.0

Table 12. Predicted % yield loss based on time remaining in the season from the time aphids were first found in regular checks and the cumulative seasonal aphid score. This table is for a central region with a season length of 165 days from sowing to 60% of bolls open. The decision to control should take into account potential yield loss as well as control costs, impact on beneficials and selection for resistance. In the table a yield loss threshold of ≥4% is used so aphids would be controlled once the red zone is reached. * If aphids are controlled, either by a spray applied for aphids or against another pest, or if there are two aphid checks in a row with no aphids found, reset the CSAS to zero. Begin accumulating again when sampling recommences and you first get a non-zero aphid score, using this date as the new 'Time remaining'.

Cumulative Season Aphid Score*	Time Remaining (days) (Time from when aphids were first recorded until 60% of bolls open)*									
	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	2.3	1.8	1.4	0.9	0.5	0	0	0	0	0
15	4.5	3.8	3.1	2.5	1.8	1.2	0.5	0	0	0
20	6.6	5.8	4.9	4.0	3.1	2.3	1.4	0.5	0	0
25	8.8	7.7	6.6	5.5	4.5	3.4	2.3	1.2	0	0
30	10.9	9.6	8.4	7.1	5.8	4.5	3.1	1.8	0.5	0
35	13.0	11.5	10.1	8.6	7.1	5.5	4.0	2.5	0.9	0
40	15.1	13.4	11.7	10.1	8.4	6.6	4.9	3.1	1.4	0
50	19.1	17.1	15.1	13.0	10.9	8.8	6.6	4.5	2.3	0
60	23.1	20.7	18.3	15.9	13.4	10.9	8.4	5.8	3.1	0.5
80	30.8	27.8	24.7	21.5	18.3	15.1	11.7	8.4	4.9	1.4
100	38.0	34.4	30.8	27.0	23.1	19.1	15.1	10.9	6.6	2.3
120	44.8	40.8	36.6	32.2	27.8	23.1	18.3	13.4	8.4	3.1

Outcomes

2. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

a. The effect of insecticides on target and non-target species has been quantified and made available to industry.

b. The effect of seed treatments on thrips and the abundance of western flower thrips has been quantified.

c. We have made progress in understanding the effect of late season thrips or jassid populations on yield of cotton.

d. The studies regarding the effect of mirid control options on mites illustrate the risk of flaring mite populations very clearly.

e. Information and publication to help manage the pale cotton stainer was completed.

f. A new aphid sampling strategy and thresholds were developed and extended to industry.

3. Please describe any:-
   a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

      (i) Development of look-up tables for establishing if aphids will affect yield loss and a new webtool.

      (ii) Development of look up charts to understand effects of insecticides on beneficials.

   b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and

      (i) Development of relationship between aphid population dynamics and yield loss is a first for cotton, and is significant because it takes into consideration the time of the crop cycle at which the aphids occur. This problem has challenged pest managers for many years.

      (ii) Development of the 'burn spray' is a novel solution to a problem – it may have other applications, such as in knock down of regrowth and in other studies considering the effect of leaf damage on yield or fibre quality.

      (iii) The application of digital imaging to estimate leaf area and area damaged is a first for Australian cotton. This was done using off-the–shelf software by Simone Heimoana and Dr. Xavier Sirault (CSIRO Plant Industry, Canberra),

   c) required changes to the Intellectual Property register.
      Nil

Conclusion

4. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

   1. Selection of insecticides can have a big influence on both the control of the target pest as well as beneficials, and the risk of secondary pest outbreaks. We have provided tools to help with the decision making process, helping pest mangers in understanding the fit of each insecticide in IPM, and the likely consequences for beneficials and flaring of secondary pests. Better selection of the available control options will be the outcome. A particular outcome is that low rates of indoxacarb plus salt or canopy oil provide good control of mirids with low risk to beneficials or risk of flaring mites. In contrast, low rates of fipronil, either alone or with salt provide good mirid control, are more selective than full rates, but still carry a high risk of flaring mites.

   2. Poor control of thrips early in the season may be affected by the presence of WFT. This has some important implications, especially poor performance of some control options, and the likely failure of the available 'at-planting' options (seed treatments) to provide adequate control of western flower thrips. One outcome of this research will be

the ongoing monitoring of thrips population composition early season and determination of resistance profiles.

3. Late season pests that damage leaves are only likely to reduce yield in crops with high yield potential and if the damage is very severe. Our research shows that late season damage can reduce yield if it is extreme. High yielding crops are likely more affected but even they show strong compensation at the yield levels studied (up to 14 b/ha).

4. Management of mirids can affect the risk of mite outbreaks. However, they also suggest that in some situations Bollgard II crops are more at risk – this deserves further investigation. Never-the-less the results highlight the need to have good mite sampling protocols in place in Bollgard II crops especially if OP's, SP's or fipronil are used to control mirids.

5. The provision of existing and new research data on the pale cotton stainer will help industry to manage this pest in the future. In particular thresholds for lint damage are now available and we have a better understanding of the damage symptoms and outcomes.

6. The provision of a new aphid sampling strategy and threshold will provide a more rational basis for deciding when occurrence of this pest justifies control and when beneficials are providing adequate control. This information has been linked with new information on the aphid borne disease cotton bunchy top, to provide pest managers with a holistic approach to managing both the pest and the disease.

Extension Opportunities

5. Detail a plan for the activities or other steps that may be taken:

(a) to further develop or to exploit the project technology.

Extension of key component of this project has been ongoing via active communication with individuals in the Cotton CRC Extension Network, the CCA, TIMS and CSD. Information on non-target effects of insecticides was used to update the 'Effect of insecticides and miticides on beneficials' table published annually in the Cotton Pest Management Guide. Further, reports provided to agrichemical companies have been used in registration packages – helping the industry to access these new products. We have developed new thresholds and sampling strategies for aphids and these are being extended to industry via a new webtool, the Cotton Pest Management Guide, updated aphid reviews and the Cotton Grower magazine. Information on pale cotton stainer was developed into a review and distributed widely within the industry.

(b) for the future presentation and dissemination of the project outcomes.

We will continue to make use of the wide range of approaches we are currently using. Constant turn-over of extension staff is a major problem as good working relationships just get developed then the process starts again.

(c) for future research.

Goals for future research have been expanded on in a new Cotton CRC project, funded by CRDC, 'IPM in Bollgard II: coping with changes in pests and climate', which has the goals:

1. Research the seasonal abundance and ecology of GVB and WFT to better understand

and improve management.

2. Investigate the efficacy and IPM fit of biopesticides (with Dr Mensah, NSWDPI), new chemistries, reduced rates with adjuvants and novel technologies.

3. Develop understanding of the effect of emergent pests, such as late season jassids, thrips and pale cotton stainers on cotton productivity using techniques developed in CRC89 and develop guidelines for industry.

4. Finalise field experimentation with CBT spread in cotton and explore the transmissibility of some of the apparent 'diseases' that are sporadically found in cotton.

The project will also ensure the cotton industry maintains core skills with aphid identification and cotton bunchy top epidemiology (Ms Tanya Smith) and in identification of thrips, plant responses to pest damage and manipulation of mite populations (Ms Simone Heimoana). This project will also allow ongoing collaboration with Dr Grant Herron and Dr Martin McLoon (NSW DPI) and Dr Flavie Vanlerberge-Massutti and Jerome Carletto (CIRAD France) to use microsatellite markers to characterise the aphid clones in cotton and link with resistance.

8. A. List the publications arising from the research project and/or a publication plan.
(NB: Where possible, please provide a copy of any publication/s)

A selection of the publications below is included with this report.

Journal Papers

- Whitehouse, M.E.A., **Wilson, L.J.** and Fitt, G.P. (2005) A comparison of arthropod communities in transgenic Bt and conventional cotton in Australia. Environmental Entomology 35: 1224-1241
- Whitehouse, M.E.A., **Wilson, L.J**. and Constable, G.A. (2007) Target and non-target effects on the invertebrate community of VIP cotton, a new insecticidal transgenic. Aust. J. Agric. Res. 58: 273-285.
- Ali, A., Reddall, A., Roberts, J., **Wilson L. J**. and M. A. Rezaian (2007) Cytopathology, mode of aphid transmission and search for the causal agent of cotton bunchy top disease. Journal of Phytopathology 155, 220–227.
- Reddall, A.A., **Wilson, L.J.**, Gregg, P.C. and Sadras, V.O. (2007) Photosynthetic response of cotton to spider mite damage: Interaction with light and compensatory mechanisms. Crop Science 47: 2047-2057.
- **L. J. Wilson**, T. T. Lei, V.O. Sadras, L.T. Wilson and **S. C. Heimoana** (2008) Undamaged cotton plants yield more if their neighbour is damaged: implications for pest management. Bulletin of Entomological Research (in press).

Invited Reviews

- Naranjo, S.E., Ruberson, J.R., Sharma, H.C., **Wilson, L.J.** and Wu, K. (2008) Chapter 6**.** The present and future role of insect-resistant GM crops in cotton IPM. In; Integration of Insect-resistant GM crops within IPM Programs. Edited by J. Romeis, A. M. Shelton, and G. G. Kennedy. 159-194.
- **Wilson, L.J**. and Plant health Australia (2006) Pest Risk Review: Cotton Aphid (*Aphis gossypii*). In, Appendix 3 Pest Risk Reviews, pp 24-25. National Cotton Industry Biosecurity Plan. Plant Health Australia, Deakin.
- **Wilson, L.J**. and Plant health Australia (2006) Pest Risk Review: Spider mites (*Tetranychus* spp.). In, Appendix 3 Pest Risk Reviews, pp 59-66. National Cotton Industry Biosecurity Plan. Plant Health Australia, Deakin

Book Chapters

- **Wilson, L.J.**, Fitt, G.P., Deutscher, S., Khan, M., and Pyke, B.A. (2007) Cotton: Pests. In, Pests of field crops and pastures: Identification and control. (P.T. Bailey, ed), CSIRO Publishing, pp 63-101.
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- Duggan, B.L. and **Wilson, L.J**. (2007). The response of cotton to real and simulated mirid damage in Australia. Proceedings of the World Cotton Research Conference-4, Lubbock TX, Sept 10-14, 2007. M Stephens (Ed), Lubbock, TX.
- **LJ Wilson** (2008) IPM in Bt-cotton: Australia as a case study. International Congress of Entomology, Durban South Africa, July 2008-09-27 (abstract only)
- PG Gregg and **LJ Wilson** 'The changing climate for pest management', 14th Australian Cotton Conference, Broadbeach, Qld, 12-14th August 2008

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- **Wilson, L.J.**, Whitehouse, M., Herron, G. and **Heimoana, S**. (2005) Aphids and mites in the Bollgard II era. Cotton Consultants Australian AGM paper, May 16-17, Goondiwindi, 2005.
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- Downes, S., Rossiter, L., Farrell, T., **Wilson, L.** and Kauter, G. (2005) Managing resistance: Your IRMS and RMP questions answered. Australian Cottongrower 26(6): 10-14
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- **Wilson, L.J.** (2006) Where have the mites and aphids gone? CSD Trial results booklet pp 98
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- **Wilson, L.J.** (2007) Secondary pests: what risks for 2007-08? CSD Trial results booklet pp 89
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- **Wilson, L**., Mensah, R., Johnson, A. and Deutscher, S. (2007) Integrated Pest Management (IPM) guidelines for Australian cotton. Cotton Pest Management Guide 2007-08, pp 16 – 29. CRC and NSW DPI Publication.
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- **Wilson, L.**, Mensah, R., Khan, M., Dillon, M., Wade, M., Scholz, B., Murray, D., Lloyd, R., Heimoana, V. and Holloway, J. (2007) Impact of insecticides and miticides on beneficials in Australian cotton. Cotton Pest Management Guide 2004-2005, 2005-06, 2006-07, 2007-08, pp 29-30. CRC and NSW DPI Publication.
- **Wilson, L.,** Khan, M. and Farrell, T. (2008) Pest profiled: Pale cotton stainer, *Dysdercus sidae*. Cotton Catchment Communities CRC, On farm series: IPM, February 2008.
- **Wilson, L**., **Heimoana, S.**, Farrell, T. and **Smith, T.** (2008) Setting thresholds for aphids in cotton. Australian Cottongrower 29(6): 12-16.

B. Have you developed any online resources and what is the website address?

Cotton pest and beneficial guide (http://www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/CottonInsectPestandBeneficialGuide.aspx)

Cotton pest management guide (http://www.dpi.nsw.gov.au/agriculture/field/field-crops/fibres/cotton/cotton-pest-management-guide)

Mirid ecology in Australian cotton (http://www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/Sucking_Pest_Publications.aspx)

Mirid management in Australian cotton (http://www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/Sucking_Pest_Publications.aspx)

Integrated pest management guidelines for cotton production systems in Australia (http://www.cotton.crc.org.au/Assets/PDFFiles/IPMGL05/IPMGLFor.pdf)

Pests Profiled: Pale Cotton Stainer (http://www.cottoncrc.org.au/content/Industry/Publications/PestsandBeneficials/Sucking_Pest_Publications.aspx)