Australian Government

Cotton Research and Development Corporation

Cotton Catchment Communities CRC

FINAL REPORT

Part 1 - Summary Details

Cotton CRC Project Numbers: **1.01.64 CRC1003**

Project 1.01.64: Managing weeds and herbicides in a genetically modified cotton farming system

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Project 1.01.64 Commencement Date: 1 July 2009

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Cotton CRC Program: The Farm

Part 2 – Contact Details

Administrator:	Mr. Graham Denney Manager External Funding	
Organisation:	NSW Dept. Primary industries	
Postal Address:	Locked Bag 21, Orange 2800	
Ph: 0263 913219	**Fax:** 0263 913327	**E-mail:** graham.denney@dpi.nsw.gov.au
Principal Researcher:	Mr. Graham Charles, Research Agronomist (Weeds)	
Organisation:	NSW Dept. Primary industries	
Postal Address:	Locked Bag 1000, Narrabri 2390	
Ph: 0267 991524	**Fax:** 0267 991503	**E-mail:** graham.charles@ dpi.nsw.gov.au
Supervisor:	Dr. Peter Fleming	
Organisation:	NSW Dept. Primary industries	
Postal Address:	Locked Bag 6006, Orange 2800	
Ph: 0263 913806	**Fax:** 0263 913899	**E-mail:** peter fleming@ dpi.nsw.gov.au

Abbreviations used in this document:

ACRI	the Australian Cotton Research Institute, situated near Narrabri
CRC	Cotton Catchment Communities Cooperative Research Centre
CPWC	the Critical Period for Weed Control (when period during which weeds must be controlled to prevent yield losses)
WRT	the Weed Removal Time (the start of the critical period)
WFP	the Weed Free Period (the end of the critical period)
UNR	ultra narrow row planting configuration. Eg., 6 rows on a 2 m bed.
WEEDpak	the Integrated Weed Management Guide for cotton. Available in hard copy, on the **COTTONpaks CD** & on the CRC web.

Signature of Research Provider Representative: ____________________

Part 3

Background

Herbicide damage is an ever increasing challenge for much of the cotton industry due largely to:

- the increasing complexity in the farming system (with a wide range of herbicides used),
- the increasing trend to minimum/zero tillage (using more herbicides for fallow weed control),
- difficulties in controlling fallow weeds (eg. fleabane and feathertop Rhodes grass), and
- increasing climatic uncertainty (need to treat weed flushes in a short time frame and maintain soil moisture).

Continuing herbicide damage is threatening the profitability of the cotton industry and in some areas may threaten the viability of the industry. Unfortunately, there is no easy solution. Crops generally will recover from herbicide damage, but in many instances with delayed maturity and reduced yields.

Over the last 3 years, CRC Project 1.01.49 has been developing a valuable herbicide damage data set which will be expanded in the new project. This data set currently gives detailed information on 2,4-D, bromoxynil, dicamba, MCPA, glyphosate, Spray.Seed and Starane damage, with data from other phenoxy herbicides to be added soon. Work is needed on the implications of lower rates of 2,4-D and multiple damage events and to further expand the range of herbicides and rates included in the data base now available on the web.

The 2nd part of the project involves the development of a readily assessable weed control threshold for cotton. The threshold is essential if the industry is to fully realise the value of herbicide tolerant cotton.

The threshold based on the Critical Period for Weed Control was an important outcome from project CRC 126 and a large step forward. The shortcomings of this threshold are that it:

- is based on single weed types and does not integrate across types, and
- is based on a visual estimation of weed species and density which are difficult and time consuming to accurately measure over a whole field, where weeds are often patchy.

The next step is to develop a user-friendly, readily applied weed control threshold based on weed biomass, which integrates weed species and density.

Objectives

The project's aims were:

- to expand and develop the herbicide damage data base, and
- to further develop the weed control threshold.

The herbicide damage data base will assist growers who have suffered damage to:

- identify which herbicide/s is most likely to have caused the damage,
- estimate the herbicide rate and when the exposure occurred,
- understand the likely impact of damage on crop growth and development, and
- based on this information, know how best to manage the crop.

Information on 2,4-D, Spray.Seed, Liberty, dicamba, bromoxynil, MCPA, Starane and glyphosate damage generated in the previous project is available on the web and information on atrazine, glufosinate, Grazon, simazine, Tordon 242 and Tordon 75D damage is being processed at present for inclusion on the web. This new work will concentrate on 2,4-D damage, exploring the effects of lower rates, multiple exposures and post-damage irrigation management.

Work will also evaluate the sensitivity of a range of cotton varieties and genetic material to 2,4-D.

Observations on breeders' lines indicate differing sensitivities and this potential will be explored.

The weed control threshold work will validate the threshold currently available to cotton growers and strengthen the science behind the threshold to improve its application in the field. This project will validate the threshold for mixed weed populations of naturally occurring weeds.

An additional, very important aim of this project will be to provide the resources to continue to deal with the huge amount of data generated in the last project. It has been possible in project CRC 126 to process the data generated by Dr. Ian Taylor's project in the 3 seasons between 2003 and 2006, but much of the data generated in the 2008/9 season will still need to be processed.

With this project, CRDC has the opportunity to build on previous work and obtain an expanded and improved outcome for cotton growers and the industry.

All the objectives have been fully achieved in this project

Obj No.	Objective	No.	Milestone	No.	Performance Indicator
1	Evaluate the effect of 2,4-D damage on cotton development with lower 2,4-D rates	1.1	Undertake field experiment to collect data	1.1	Field experiment 1 completed
	and multiple exposures at a range of growth stages	1.2	Obtain a 2nd years data	1.2	Field experiment 2 completed
		1.3	1st season's sample processing completed	1.3	Exp. 1 data set published on the web
2	Evaluate the effect of water management after 2,4-D damage on cotton recovery and development	2.1	Undertake field experiment to collect data	2.1	Field experiment completed
		2.2	1st seasons sample processing completed	2.2	Initial data set published on the web
3	Evaluate the sensitivity of a range of varieties and genetic material to 2,4-D	3.1	Undertake field experiment to collect data	3.1	Field experiment 1 completed
		3.2	Obtain a 2nd years data	3.2	Field experiment 2 completed
		3.3	1st season's sample processing completed	3.3	Exp. 1 data analysed
4	Complete a 2nd seasons evaluation and validation experiment for the weed control threshold	4.1	Undertake field experiment to collect data	4.1	Field experiment 1 completed
5	Undertake an experiment using the weed control threshold approach using	5.1	Undertake field experiment to collect data	5.1	Field experiment 1 completed
	responsive thresholds on mixed weed populations	5.2	Obtain a 2nd years data	5.2	Field experiment 2 completed
6	Evaluate the damage from a range of fallow and alternative herbicides on	6.1	Undertake field experiment to collect data	6.1	Field experiment 1 completed
	cotton using 3 rates at 4 growth stages	6.2	1st seasons sample processing completed	6.2	Exp. 1 data set published on the web
7	Obtain a 2nd seasons data for a seasons data for the effect of water management	7.1	Undertake field experiment to collect data	7.1	Field experiment 2 completed
	on 2,4-D damage or the fallow herbicides, depending on the outcomes from these				
	experiments				

Methods

A combination of field and glasshouse experiments, laboratory studies and observations in commercial cotton fields were used to achieve the project's aims.

The main experiments were in the field at the ACRI, Narrabri. Treatments were applied at various crop growth stages to plots of 13 - 15 m by 4 rows using a randomized complete block design with 4 replicates on an area of about 8 ha. This is a standard statistical design which is easily analysed. Buffer plots of 4 rows were included to allow for any herbicide drift. Both aims used detailed crop measurements to assess the post-treatment impact of weed competition and herbicide damage on cotton plants, monitoring plant height and development, leaf number and area, squares, flowers and bolls throughout the season, and crop yield, quality and time to maturity. Measurements were taken every 14 days post-treatment through to picking. Photographs of herbicide damage symptoms were also taken throughout the season.

Number of plants, plant height, nodes and wet weight were recorded on all plants. A sub-sample of 5 plants was removed for further processing, recording leaf area, squares, flowers and bolls on each plant. Dry weight was then estimated.

At the end of the season, maturity picks were undertaken on two 1 m strips in each plot. Plots were machine picked and samples ginned and fibre quality tested.

Experiments to validate the weed control threshold used the background weed population, manipulated with a range of timings and number of applications of glyphosate. An infra-red sensor (GreenSeeker™) was used to estimate weed biomass, with regular samples taken for calibration.

Data sets were developed in spreadsheets, analysed with the assistance of statisticians based at Tamworth and published in the Australian CottonGrower and in WEEDpak on the COTTONpaks CD and the Cotton CRC web site.

In addition to the research highlighted in this application, this project allowed the researcher to continue his role in advising cotton growers on weed issues, supporting and updating WEEDpak, giving expert technical advise to the TIMS Herbicide Tolerant Crop Technical Panel and continuing to review pesticide applications for the APVMA which involve the cotton faming system. Weed audits in the Burdekin were an additional part of the researcher's input into TIMS and the development of a sustainable cotton system for the north.

A 2nd funding application was made to the Australian Weeds Research Centre to extend this project more broadly into the farming system by including a module to develop a weed control threshold for Roundup Ready and InVigor canola. This project was undertaken and a copy of the final report has previously been submitted to all funding bodies. Additional copies are available if required.

Results

Obj. 1. Evaluate the effect of 2,4-D damage on cotton development with lower 2,4-D rates and multiple exposures at a range of growth stages

Obj. 1. Background:

This experiment addressed 2 questions, which were raised by growers in response to earlier work.

- Generally growers felt that the 2,4-D damage they were observing was from lower rates than was used in the earlier work (10% and 1% of a typical field rate of 2,4-D at 800 g a.i./ha) and so wanted to see the damage result from lower rates, and
- Growers had too often experienced multiple drift events and wanted to understand the impact of multiple exposures compared to single exposures, as occurred in all the previous work.

Obj. 1.1. Design – 2009/2010:

3 Rates x 11 Treatments x 4 Reps = 132 plots

- Rates were: 0.1%, 0.01% & 0.001% of a typical field rate of 2,4-D, of 800 g a.i./ha
- Plots were 13 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift)

Treatments: plants were exposed at combinations of 4, 8, 12 and 16 nodes as shown below.

		Nominal growth stage at application			
Treatment	**Nodes**	**4 nodes**	**8 nodes**	**12 nodes**	**16 nodes**
1	nil				
2	4	4			
3	4 & 8	4	8		
4	4, 8 & 12	4	8	12	
5	4, 8, 12 & 16	4	8	12	16
6	8		8		
7	8 & 12		8	12	
8	8, 12 & 16		8	12	16
9	12			12	
10	12 & 16			12	16
11	16				16

Obj. 1.1. Details – 2009/2010:

		Nominal growth stage at application			
		4 node	8 node	12 node	16 node
Variety	Sicot 71 BRF				
Planted	8-Oct-09				
Watered	9-Oct-09				
Emerged	23-Oct-09				
Spray		18-Nov-09	25-Nov-09	11-Dec-09	07-Jan-10
Picked	17-Jun-10				

Obj. 1.1. Results – 2009/2010:

Relatively mild symptoms of 2,4-D damage were observed on all treatments in this experiment this season, with few symptoms generally observed at the lighter rates. Visually, there was no indication that multiple exposures compounded the damage story. If anything, it appeared that a plant already damaged by 2,4-D was less sensitive to a 2nd exposure that occurred soon after the initial exposure.

Damage from 0.1% of a typical field rate of 2,4-D. The plants were exposed at 8 nodes and the photo was taken 23 days after exposure.

The 2,4-D exposure caused crinkling on some developing leaves, but was relatively mild and didn't result in the rank growth often seen at higher rates.

Damage from 0.001% of a typical field rate of 2,4-D. The plants were exposed at 8 nodes and the photo was taken 23 days after exposure.

Many plants showed little if any damage from this exposure, although some leaf damage is obvious on these plants.

Damage from 0.001% of a typical field rate of 2,4-D. The plants were exposed at 4, 8 & 12 nodes and the photo was taken 36, 29 & 13 days after exposure.

These plants showed little if any damage from this multiple exposure.

Summary tables of the findings of this experiment follow in Appendix 1.

The results show the 2,4-D had no consistent effect on the plant stand, tipping out, plant height or node number.

At the 0.1% rate, the 2,4-D reduced leaf number and leaf area, with the most reduction occurring at the single exposures and less reduction with multiple exposures. There was a 24% reduction in leaf number and 16% reduction in leaf area from the 8 node exposure, for example, but 10% and 0% reductions from 8 & 12 node exposures and no reduction from 8, 12 & 16 node exposures. This trend was reversed for the 0.01% rate, and inconsistent for the 0.001% rate.

Plant weight was affected by the exposures, but the trends were not consistent.

Boll number, the number of mature boll and boll weight were again affected by the exposures, but the trends were not consistent.

The exposures also had no consistent affect on boll position, boll maturity, the proportion of open bolls, ginning % or fibre quality.

Lastly, these lighter rates of 2,4-D didn't reduce lint yield, even when plants were exposed 3 or 4 times during the season.

Obj. 1.1. Conclusions – 2009/2010:

This experiment aimed to explore the damage from lower rates of 2,4-D, but the rates used were too low in this season. Plant leaf number and leaf area were affected by the 2,4-D, but plants were able to recover from the damage caused, resulting in not loss of yield, delay in average maturity or reduction in fibre quality.

Because of the importance of information on low rates and multiple exposures, it was decided to repeat this experiment in the final year of this project, replacing the 0.001% rate with a higher rate.

Obj. 1.1. Outputs – 2009/2010:

No publications came from this experiment due to the inconclusive nature of the findings, but will occur following the repeat of the experiment at higher rates in 2011/12.

Obj. 1.2. Design – 2011/2012:

4 Rates x 8 Treatments x 4 Reps = 128 plots

- Rates were: 5%, 1%, 0.1% & 0.01% of a typical field rate of 2,4-D, of 800 g a.i./ha
- Plots were 13 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift)

Treatments: plants were exposed at combinations of 4, 8 and 12 nodes as shown below.

		Nominal growth stage at application		
Treatment	**Nodes**	**4 nodes**	**8 nodes**	**12 nodes**
1	nil			
2	4	4		
3	4 & 8	4	8	
4	4 & 12	4		12
5	4, 8 & 12	4	8	12
6	8		8	
7	8 & 12		8	12
8	12			12

Obj. 1.2. Details – 2011/2012:

		Nominal growth stage at application		
		4 node	**8 node**	**12 node**
Variety	Sicot 71 BRF			
Planted	10-Oct-11			
Emerged	17-Oct-11			
Spray		21-Nov-11	15-Dec-11	4-Jan-12
Picked	22-Apr-12			

Obj. 1.2. Results – 2011/2012:

This experiment ran well, with strong symptoms of 2,4-D damage observed following the higher rates of exposure. However, the experiment was confounded, to some extent, by excessive mid-season rain which resulted in an extended period of water-logging. This stress resulted in fruit loss, particularly on some of the treatments where additional fruit might have been retained during this period to compensate for the herbicide damage.

The 5% 2,4-D exposure caused considerable damage to these plants, which were exposed at 4 nodes and again at 8 nodes, although the 8 node damage is not yet apparent on these plants exposed 7 days before this photo.

The 2,4-D damage is now readily apparent on the plants 33 days after the 8 node exposure (plants exposed to 2,4-D at 5% both at 4 and 8 nodes).

These plants exposed to 2,4-D at 5% only at 8 nodes were much less damaged 33 days after exposure and might be expected to have suffered less yield loss.

Summary tables of the findings of this experiment follow in Appendix 1. Ginning and the HVI lint testing are yet to be completed.

The damage recorded this season was less extreme than has been observed previously, presumably due to the interaction with prolonged water-logging.

No appreciable yield loss was observed from the lightest rate of 2,4-D at 0.01% of a typical field use rate.

Some yield loss was observed at the 0.1% rate, but there was no clear evidence that the damage was additive, with similar levels of damage observed from single, double and triple exposures. The 2,4-D had no appreciable affects of plant density, tipping-out, plant height or node number. Some other parameters were affected, but the effects were not consistent over the multiple exposures.

Some yield loss was observed at the 1% rate, but again there was no clear evidence that the damage was additive, with similar levels of damage observed from single and double exposures at 4 and 8 nodes, and all combinations including exposure at 12 nodes. The 2,4-D had no appreciable affects of plant density, tipping-out, plant height or node number. Exposure at 4 and 8 nodes reduced leaf number and leaf area, but multiple exposures at 8 & 12 and 4, 8 & 12 nodes caused increases in leaf number and leaf area. Some other parameters were also affected, but the effects were not consistent over the multiple exposures.

Much heavier yield losses were observed at the 5% rate of 2,4-D, but again there was no clear evidence that the damage was additive. Similar levels of damage were observed from single and double exposures at 4 and 8 nodes. Much heavier damage was observed from the 12 node exposures, but there was no additional damage with the double exposures at 4 & 12 and 8 & 12 nodes. However, the triple exposure did cause the heaviest yield loss.

Obj. 1.2. Conclusions – 2011/2012:

It can be concluded from this experiment that there is no strong evidence that 2,4-D exposure events are additive, such that a crop receiving multiple exposures to 2,4-D is going to be much more heavily damaged than a crop with a single exposure.

This observation is consistent with other observations that suggest that the affect of 2,4-D is similar to any other damage or stress events, and that consequently, the plant is less affected by a further stress event while it is growing less vigorously due to the initial stress. Herbicides tend to be most effective on actively growing plants and have less effect on stressed plants. Consequently, cotton plants already stressed by 2,4-D damage are less susceptible to further stress from 2,4-D than are plants which are more actively growing. Nevertheless, multiple exposures will obviously have some additional effect as they extend the length of the stress period. This is consistent with the findings from Objective 2.

Obj. 1. Combined conclusion:

The rates used on this 2nd occasion were appropriate and have given useful results in what was a difficult season. The experiment should be repeated to confirm the findings.

Obj. 2. Evaluate the effect of water management after 2,4-D damage on cotton recovery and development

Obj. 2. Background:

This experiment continued a series of experiments aimed to explore possible management options for cotton following damage from 2,4-D. The idea for the work came from discussion with a Qld. grower who had suffered heavy mid-season 2,4-D damage on a dryland crop that was water stressed, but where water became available later in the season and the crop was finished as an irrigated crop. Harvest was late, but a good crop was achieved in spite of the mid-season damage. The grower felt that the water stress at the time of exposure had lessened the impact of the 2,4-D. This suggestion was consistent with observations in the south, where it has been found over many seasons that 2,4-D is much less effective in controlling thistles when the thistles are stressed by moisture stress, cold stress (a series of frosts) or a lack of sunlight following spraying. Similarly, induced stress may be a way of reducing the impact of 2,4-D on cotton crops.

Obj. 2. Design – 2009/10:

5 Rates x 2 Application stages x 3 Water management options x 4 Reps = 120 plots

- Rates were: 0, 1%. 0.1%, 0.01% & 0.001% of a typical field rate of 2,4-D, of 800 g a.i./ha
- Application stages were: 8 and 16 nodes of crop growth
- Water management options were: normal, miss 1 post-damage irrigation or miss 2 post-damage irrigations.
- The experiment used a split-plot design, with water management as the main plot (field length). Sub-plots were 40 m by 8 rows.

Obj. 2. Details – 2009/10:

		Nominal growth stage at application	
		8 node	16 node
Variety	Sicot 71 BRF		
Planted	8-Oct-09		
Watered	9-Oct-09		
Emerged	23-Oct-09		
Sprayed		27-Nov-09	
Irrigated		3-Dec-09*	
Irrigated		21-Dec-09*	
Sprayed			11-Jan-10*
Irrigated			21-Jan-10*
Irrigated			4-Feb-10
All irrigated		3-Mar-10	3-Mar-10
All irrigated		25-Mar-10	25-Mar-10
Picked	21-Jun-10		

Note* Some treatments missed one or both of these post-damage irrigations.

Obj. 2. Results – 2009/10:

The experiment largely went to plan, but was challenged by the season. The 2009/10 season started out very warm and dry, but a large rainfall event followed the 8 node irrigations, with 254 ml recorded over the 12 days following the 2nd in-crop irrigation, starting on 21-Dec-09. This rainfall resulted in water logging on all irrigated plots, advantaging the plots which had missed irrigation.

Conditions were more favourable following the 16 node spray, although 113 ml fell over 18 days following the 2nd in-crop irrigation, starting on 5-Feb-10. However, the higher water demand of these larger plants meant that this rain had little impact on the treatments.

The crop was actively growing when the 2nd 2,4-D exposure occurred, but plants which didn't receive the following in-crop irrigations became highly stressed .

Symptoms of the phenoxy damage and irrigation stress had largely disappeared late in the season.

Summary tables of the findings of this experiment follow in Appendix 2.

Obj. 2. Results – 2009/10 - 2,4-D applied at 8 nodes of crop growth:

There was a general increase in plant height and node number on the treatments with reduced irrigation (due to the subsequent water-logging on the fully irrigated plots), with the largest plants on the treatments missing the first in-crop irrigation.

The treatments missing the first in-crop irrigation also generally had the highest leaf number and leaf area. The higher 2,4-D rates increased leaf number under the normal irrigation regime, but had less effect when water stress was imposed.

Boll number was generally lowest on the fully irrigated treatments, with the treatments missing the first in-crop irrigation consistently having the most mature bolls at the final assessment on 10th March.

There were no consistent affects of any of the treatments on fibre quality, and no reductions in lint yield from missing the 1st two in-crop irrigations in the absence of 2,4-D damage, with the treatment missing the first two irrigations yielding 9% more lint than the fully irrigated treatment. Surprisingly, none of the 2,4-D treatments resulted in any reductions in lint yield, even though a 21% yield reduction had been recorded for the 1% rate in a previous season. However, there was a delay in crop maturity of around 20 days due to the 2,4-D exposure

While the reason for the lack of yield loss from the 2,4-D is not clear, it might be concluded that the initial moisture stress on the unirrigated treatments and the later water-logging stress, especially on the fully irrigated treatments, masked the 2,4-D damage, which supports the hypothesis behind this work, that stressed plants are less affected by 2,4-D damage. It might also be concluded that environmental effects can have a big impact on the expression of 2,4-D damage.

Obj. 2. Results – 2009/10 - 2,4-D applied at 18 nodes of crop growth:

There was a general increase in plant height and node number on the treatments with reduced irrigation and also from the 1% exposure of 2,4-D, presumably due to late-season compensatory growth in response to this damage.

The plants exposed to the 1% rate of 2,4-D also had a large increase in leaf number (33%, 37% & 38% for the fully irrigated, 1 missed and 2 missed irrigations, respectively). There was no corresponding increase in leaf area on the fully irrigated plots, indicating the typical post-phenoxy damage response of a flush of vegetative growth with small, distorted leaves. However, there was a corresponding increase in leaf area on the treatments missing irrigations, showing that although a flush of vegetative growth occurred, the typical leaf expression of the phenoxy damage had been greatly reduced.

Large increases in leaf number were also recorded for the normal and miss 1 irrigation treatments for 2,4-D at 0.1%. There were no corresponding increases in leaf area on these treatments and no consistent damage was obvious for the lower rates of 2,4-D.

Boll number was highest on the treatments that missed 1 irrigation, but lowest on the treatments that missed 2 irrigations, and was reduced on the plots exposed to 2,4-D at 1%.

There were no consistent affects of any of the treatments on fibre quality. However, there were large reductions in lint yield from both the irrigation and 1% 2,4-D treatments, with no effects from the lower 2,4-D rates. Lint yield was reduced by 34% on plots that missed 2 mid-season irrigations (no 2,4-D), and by 19%, 16% and 9% on the plots exposed to 2,4-D at 1%, missing none, 1 or 2 irrigations, respectively. These results showed that 2,4-D damage could be reduced by imposing post-exposure stress (reducing the yield loss from 19% to 9% by missing 2 irrigations when compared to undamaged plots that missed 2 irrigations), but that this would rarely be a practical approach to managing herbicide damage due to the large yield reduction due to the stress alone (a 34% yield loss), with the combination of stress and 2,4-D exposure resulting in a 40% yield loss. The grower would be better off suffering the 19% yield loss from the 2,4-D exposure on a fully irrigated crop in most situations, rather than the 40% yield loss from a stressed and damaged crop. Nevertheless, cutting post-phenoxy damage irrigations could be a viable strategy in a low water season, where it would clearly be more beneficial to apply water to undamaged crop than to damaged crop. The results also suggest that the strategy of applying additional inputs post-damage to assist damaged crops may be counter-productive, exacerbating the phenoxy damage.

Obj. 2. Observations – 2009/10:

- It is interesting to note that the level of damage seen from the 18 node spray was in line with the level of damage previously reported, unlike the 8 node spray, where no yield loss was recorded.
- No yield loss was recorded for the lower rates of 2,4-D (0.1% to 0.001%), consistent with the observations in the multiple low rates experiment (Objective 1).

Obj. 2. Conclusions – 2009/10:

The theory that imposing stress following phenoxy damage could reduce the expression of the damage was supported by these results. However, is appears that the stress needs to be reasonably severe, and may well do more damage to the crop than the phenoxy damage it was aimed to ameliorate.

Imposing post-damage water stress would not be a useful strategy in most situations, but could be a viable approach with limited water.

Conversely, the results indicate that applying additional inputs to a damaged crop may exacerbate the damage.

A caveat to these conclusions is that it is generally around 15 to 20 days between when a crop is exposed to 2,4-D and when the first obvious symptoms of damage are apparent. Consequently, a grower would often not have the option of imposing stress until long after the damage has occurred, and the stress is unlikely to have any benefit at all.

It would be valuable to repeat this work, examining both the value of imposed stress and additional inputs, and the impact of a delay in response, with the response occurring after visible symptoms are observed.

Obj. 2. Outputs – 2009/10:

A CottonGrower article was published from this work.
Charles G. (2011). Recovering from herbicide damage – induced water stress. *The Australian Cottongrower* **32 (4):** 21-22.

A copy of the article is included in Appendix 8.

The article is also available in the Herbicide Damage Guide on the CRC website.

Obj. 3. Evaluate the sensitivity of a range of varieties and genetic material to 2,4-D.

Obj. 3. Background:

Many growers have reported that they have observed some varieties to appear to be less sensitive than other to 2,4-D damage. Similar observations were made in the CSIRO breeder's block beside ACRI, although any conclusions were confounded by differences in plant height at the time of exposure (potentially leading to differences in exposure to the 2,4-D drift).

We assessed a commercial block that had been damaged in 2008/9 and found that in this block Sicot 71BRF and DP210BRF did appear to respond differently to phenoxy drift, but gave much the same yield in the end (the observation was confounded by a lack of replication and slightly different sowing dates for the varieties).

Nevertheless, on the basis of this anecdotal information, I decided to explore 2 hypothesis:

1. That the severity of crop damage from 2,4-D (yield loss) was proportionally symptomatic of the extent of the visual symptoms of damage, and
2. That some varieties of cotton were less sensitive to 2,4-D damage, displaying milder damage symptoms and less yield loss (assuming hypothesis 1 is proven).

Obj. 3.1. Design – 2009/2010:

1 Rate x 4 Application stages x 5 Varieties x 4 Reps = 80 plots

- Application rate was 1% of a typical field rate of 2,4-D, of 800 g a.i./ha
- Application stages were: nil, 4, 8 and 12 nodes of crop growth
- Varieties were: Sicot 71BRF, Sicot 75, Coker 315, Sipima 280 and a breeder's line, L64411 B. Single lines of 3 additional breeder's lines were included in the experiment. These lines appeared to be interesting on the basis of damage previously observed in the breeder's block.
- Plots were 13 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift)

Obj. 3.1. Details – 2009/2010:

		Nominal growth stage at application		
		4 node	8 node	12 node
Planted	8-Oct-09			
Watered	9-Oct-09			
Emerged	23-Oct-09			
Sprayed		18-Nov-09	25-Nov-09	11-Dec-09
Picked	21-Jun-10			

Obj. 3.1. Results – 2009/2010:

The varieties established poorly, especially on the southern side of the experiment, resulting in a poor plant stand. Approximately half the experiment was replanted, but still produced a gappy plant-stand. The poor plant stand and variations in plant size as a result of the replanting confounded the experiment. The single rows of additional breeder's lines established very poorly and no extra seed was available for these lines. Consequently, there was insufficient of this material established to be fully included in the final results.

Sicot 71 BRF 53 days after being exposed to 2,4-D at 1% of a typical field rate at 12 nodes of plant growth. Moderate levels of 2,4-D damage were observed on these plants, with some deformed leaves still obvious in this photo.

Sicot 75 53 days after being exposed to 2,4-D at 1% of a typical field rate at 12 nodes of plant growth. Moderate to low levels of 2,4-D damage were observed on these plants, with some deformed leaves still apparent in this photo.

Breeder's line L64411 BII 53 days after being exposed to 2,4-D at 1% of a typical field rate. This line appeared to be very sensitive to 2,4-D, and was severely damaged, developing a mass of distorted leaves, as seen from the damage still obvious in this photo.

Breeder's RIL 041 53 days after being exposed to 2,4-D at 1% of a typical field rate at 12 nodes of plant growth. This line appeared to be relatively unaffected by the 2,4-D exposure, with little damage obvious in this photo.

Sipima 280 53 days after being exposed to 2,4-D at 1% of a typical field rate at 12 nodes of plant growth. This variety appeared to be relatively unaffected by the 2,4-D exposure, with little damage obvious in this photo.

A series of photos were taken on most varieties throughout the season, allowing a comparison of the onset, duration and extent of visual symptoms over the varieties. A summary of this data is shown below, averaged over the 4, 8 and 12 node exposures.

Damage Summary				
Variety	Average damage[1]	First symptoms (DAE)[2]	Last symptoms (DAE)	Duration of symptoms (days)
Sicot 75	2.3	6.5	68.1	62
Sicot 71 BRF	2.9	5.3	77.8	73
Line L64411 BII	3.3	5.2	90.9	86
Sipima 280	1.4	6.8	56.9	50

Note[1]. A visual rating of damage from 1 (no damage) to 5 (severe damage).

Note[2]. Days after exposure to 2,4-D at 1% of a typical field rate.

Comparison of these photos shows that the breeder's line L64411 BII had more acute visual symptoms of the 2,4-D damage than Sicot 71 BRF or Sicot 75, and that the symptoms were apparent for longer in the season than occurred for the other varieties. By contrast, Sipima 280 had very mild symptoms, which were apparent for a shorter duration.

Summary tables of in-season and final measurements for the varieties and lines are shown in Appendix III.

Obj. 3.1. Results for Sicot 71BRF – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Leaf number and area were affected by the exposure to 2,4-D with increases in leaf number from exposure at 4 and 12 nodes, but reductions in leaf area from the 8 and 12 node exposures. Area per leaf declined.

Boll number and the number of mature bolls were reduced by the later exposures, but there were no consistent trends in the patterns of boll retention or reductions in average boll maturity.

The herbicide had no consistent impact on lint quality.

The lint yield data must be viewed with some caution, due to the poor establishment of this experiment. Nevertheless, there was a yield increase from the 4 and 8 node exposures, with a yield decrease only from the 12 node exposure.

Obj. 3.1. Results for Sicot 75 – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Sicot 75 responded to the 2,4-D exposures with large increases in leaf number and area. Area per leaf only declined following the 12 node exposure.

Boll number and the number of mature bolls increased following the 4 and 8 node exposures but not the 12 node exposure. There were no consistent trends in the patterns of boll retention or lint quality.

The lint yield data must be viewed with some caution, due to the poor establishment of this experiment. Nevertheless, there was a yield increase from the 4 node exposure, with a yield decrease only from the 12 node exposure.

Obj. 3.1. Results for Coker 315 – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand or tipping out, but reduced plant height and node number for the earlier exposures.

Leaf number and area were not affected by 4 and 12 node exposures, but there were reductions from the 8 exposure..

There were no consistent effects on boll number, the number of mature bolls, the patterns of boll retention, average boll maturity or lint quality.

The lint yield data must be viewed with some caution, due to the poor establishment of this experiment. Nevertheless, there was only a yield decrease from the 12 node exposure.

Obj. 3.1. Results for breeder's line L64411 – 2009/2010:

This line, which had the strongest visual symptoms of 2,4-D damage, had a very different response to the damage, compared to the previous varieties.

The 2,4-D exposures had no consistent impact on the plant stand, tipping out or node number, but the exposures increased plant height from the post-exposure production of elongated top growth.

Leaf number and area were increased by all exposures.

Boll number and the number of mature bolls were also increased by all exposures, with additional bolls retained on the outer fruiting positions, with corresponding reductions in average boll weight and delays in average boll maturity.

The herbicide had no consistent impact on lint quality.

The lint yield data must be viewed with some caution, due to the poor establishment of this experiment. Nevertheless, there was a yield increase from all exposures, even though the plants had shown strong symptoms of 2,4-D damage.

Obj. 3.1. Results for RIL 041 – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height, or node number.

Leaf number was decreased by the exposures. Insufficient plants of this line established to allow an assessment of leaf area.

There were no consistent impacts on boll number, the number of mature bolls and the patterns of boll retention.

The herbicide had no consistent impact on lint quality.

The lint yield data must be viewed with caution, due to the poor establishment of this line. Nevertheless, there was a yield increase from the 8 node exposure.

Obj. 3.1. Results for RIL 056 – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height, or node number.

Leaf number was increased by the 8 and 12 node exposures. Insufficient plants of this line established to allow an assessment of leaf area.

Boll number and the number of mature bolls were reduced by both exposures, but there were no apparent changes in the patterns of boll retention.

Obj. 3.1. Results for RIL 104 – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height, or node number.

Leaf number was increased by the 12 node exposure. Insufficient plants of this line established to allow an assessment of leaf area.

Boll number and the number of mature bolls were reduced by both exposures, but there were no apparent changes in the patterns of boll retention.

The herbicide had no consistent impact on lint quality.

The lint yield data must be viewed with caution, due to the poor establishment of this line. Nevertheless, there was a yield decrease from both exposures.

Obj. 3.1. Results for Sipima 280 – 2009/2010:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Leaf number and area were increased by all exposures.

Boll number and the number of mature bolls were unaffected by the exposures, although fewer bolls were retained on the primary fruiting positions, with a corresponding delay in average boll maturity.

The herbicide had no consistent impact on lint quality.

The lint yield data must be viewed with some caution, due to the poor establishment of this experiment. Nevertheless, there was a yield decrease from the 4 and 12 node exposures, but no impact from the 8 node exposure.

Obj. 3.1. Conclusions – 2009/2010:

As a broad observation, all lines and varieties appeared to give similar visual responses to the 2,4-D exposures, albeit with different degrees of response, from Line L64411 showing the strongest damage symptoms, to Sipima 280 with the least. However, analysis of the plant data shows a wide range of plant responses in most measurements, which were not necessarily consistent with the visual symptoms, from yield increases from all exposures to Line L64411 (the line showing the strongest damage), to yield reductions for Sipima 280 (which had the least visual damage).

Some conclusions drawn from this experiment (based on only a single season's results):

1. The extent of visual symptoms of 2,4-d damage was not well related to the severity of crop damage as measured in yield loss (hypothesis 1 disproven).

2. Some cotton varieties appeared more able to compensate for damage from 2,4-D than others, but this compensatory ability was not related to the expression of visual symptoms of damage.

3. The 1% field rate may not have caused sufficient damage in this season to fully evaluate the material used. A heavier rate may have given more insight to differences.

4. The cotton damaged at the 4 node stage was best able to compensate for the damage, consequently giving comparatively little useful information

5. Inclusion of the RIL's in the experiment was of little value due to the limited amount of seed available and the poor establishment of this material.

Obj. 3.2. Background – 2010/2011:

On the basis of the 2009/2010 results, the experiment was repeated in 2010/2011, with some changes to the field design:

- The RIL lines were dropped, as little seed was available for these lines,
- A second, 5% rate of 2,4-D was included to increase the level of damage, and
- The 4 node exposure was dropped.

Obj. 32. Design – 2010/2011:

2 Rates x 3 Application stages x 5 Varieties x 4 Reps = 120 plots

- Application rates were 1% and 5% of a typical field rate of 2,4-D, of 800 g a.i./ha
- Application stages were at: nil, 8 and 12 nodes of crop growth
- Varieties were: Sicot 71BRF, Sicot 75, Coker 315, Sipima 280 and a breeder's line, L64411 B.
- Plots were 13 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift)

Obj. 3.2. Details – 2010/2011:

		Nominal growth stage at application	
		4 node	12 node
Planted	13-Oct-10		
Emerged	27-Oct-10		
Sprayed		21-Dec-10	16-Jan-11
Picked	23-May-11		

Obj. 3.2. Results – 2010/2011:

The experiment established well, with large differences apparent between the varieties during the season.

Sicot 71 BRF 34 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate levels of 2,4-D damage were observed on these plants, with deformed leaves obvious at the tops of the plants in this photo.

Sicot 75 34 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate levels of 2,4-D damage were observed on these plants, with deformed leaves obvious at the tops of the plants in this photo.

Coker 315 34 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate to heavy levels of 2,4-D damage were observed on these plants, with deformed leaves and elongated growth obvious at the tops of the plants in this photo.

Breeder's line L64411 BII 34 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. This line appeared to be very sensitive to 2,4-D, and was severely damaged, developing a mass of distorted leaves and elongated growth obvious at the tops of the plants in this photo.

Sipima 280 34 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate levels of 2,4-D damage were observed on these plants, with deformed leaves obvious at the tops of the plants in this photo.

Sicot 71 BRF 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. Strong levels of 2,4-D damage were observed on these plants, with deformed leaves obvious and elongated growth at the tops of the plants in this photo.

Sicot 75 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. Strong levels of 2,4-D damage were observed on these plants, with deformed leaves obvious and excessive growth at the tops of the plants in this photo, which contrast with the unsprayed Sicot 71 BRF plants in the left row.

Coker 315 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. Strong levels of 2,4-D damage were observed on these plants, with deformed leaves obvious and excessive growth at the tops of the plants in this photo, similar to the Sicot 71 BRF plants in the left row.

Breeder's line L64411 BII 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. This line appeared to be very sensitive to 2,4-D, and was severely damaged, developing a mass of distorted leaves and elongated growth obvious at the tops of the plants in this photo.

Sipima 280 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. This variety appeared to be relatively unaffected by the 2,4-D exposure when exposed at 8 nodes, but was severely affected by the 14 node exposure, developing a mass of distorted leaves and elongated growth obvious at the tops of the plants in this photo.

Summary tables of in-season and final measurements for the varieties and lines are shown in Appendix 3.2.

Obj. 3.2. Results for Sicot 71BRF – 2010/2011:

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Leaf number and area were affected by the exposure to 2,4-D with increases at both rates and both times of exposure, but no consistent decrease in leaf size.

Boll number and the number of mature bolls were reduced by the 5% exposures and the 1% exposure at 14 nodes (the biggest reduction was at 5% at 14 nodes), with fruit lost from on the primary fruiting positions following the 14 node exposures. There was a substantial delay in average boll maturity at the 5% rate at 14 nodes, with few bolls mature at picking.

The herbicide had no consistent impact on lint quality, although most treatments had low mic.

There was a substantial yield loss on all treatments, with the yield loss doubling from the 1% to the 5% exposure, and a 6-fold increase from the 14 node compared to the 8 node exposure.

Obj. 3.2. Results for Sicot 75 – 2010/2011:

The Sicot 75 treatments followed a similar general pattern to Sicot 71 BRF.

The 2,4-D exposures had no consistent impact on the plant stand, tipping out or node number, but there was an increase in plant height on all treatments.

Sicot 75 responded to the 2,4-D exposures with large increases in leaf number, but a decrease in average leaf size, resulting in a relatively smaller change in total leaf area.

Boll number and the number of mature bolls were reduced by all exposures, with fruit shed from on the primary fruiting positions following the 14 node exposures.

There was a substantial delay in average boll maturity at the 5% rate at 14 nodes, with few bolls mature at picking.

The herbicide had no consistent impact on lint quality, although most treatments had low mic.

There was some yield loss on all treatments, with substantial yield loss from the 5% rate at 14 nodes.

Obj. 3.2. Results for Coker 315 – 2010/2011:

2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Leaf number and area were not heavily affected by the exposures, but there were reductions in leaf size from the 14 node and 5% exposures.

Boll number and the number of mature bolls were reduced by all exposures, with a reduced proportion of fruit retained on the primary fruiting positions. There was a delay in average boll maturity at the 5% rate at 14 nodes, with few bolls mature at picking.

The herbicide had no consistent impact on lint quality, although most treatments had low mic.

There was some yield loss on all treatments, with substantial yield loss from the exposures at 14 nodes.

The Coker 315 treatments again followed a similar general pattern to the Sicot 71 BRF, with the exception of leaf number and area, where the exposures had comparatively little impact.

Obj. 3.2. Results for breeder's line L64411 – 2010/2011:

The L64411 treatments followed a similar general pattern to Coker 315.

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Leaf number and area were reduced by most exposures, but there was no reduction in average leaf size.

Boll number and the number of mature bolls were reduced by all exposures, with bolls shed from the primary fruiting positions from the 5% and 14 node exposures. The 14 node exposure resulted in a reduction in average boll weight and a delay in average boll maturity at the 5% rate.

The herbicide had no consistent impact on lint quality, although most treatments had low mic.

There were substantial yield losses on the 5% and 14 node exposures.

Obj. 3.2. Results for Sipima 280 – 2010/2011:

The Sipima treatments followed a similar general pattern to Sicot 71 BRF and Sicot 75.

The 2,4-D exposures had no consistent impact on the plant stand, tipping out, plant height or node number.

Leaf number was increased by most exposures, but leaf area was only increased by the 8 node exposures, with leaf size declining on the 14 node exposures.

Boll number and the number of mature bolls were reduced by all exposures, with bolls shed from the primary fruiting positions from the 5% and 14 node exposures and corresponding delays in average boll maturity.

The herbicide had no consistent impact on lint quality, although all treatments had low mic.

There were yield losses on from all exposures.

Obj. 3.2. Conclusions – 2010/2011:

For whatever reason(s), all varieties were far more severely affected by the 2,4-D exposures this season compared to last, particularly from the 14 node applications, with similar levels of yield loss occurring on all varieties. The only exception occurred with Line L64411 at the 1% rate at 8 nodes, where there was no yield loss, but this line had substantial yield losses from the other exposures.

Again, it is difficult to draw strong conclusions from a single season's data, but it appears that:

1. Any differences in varietal sensitivity may be more apparent at lower rates of exposure to 2,4-D, with severe damage affecting all varieties similarly.

2. There appears to be an environmental factor in the 2,4-D damage equation, with the extent of plant damage related to the rate of exposure, stage of plant growth and an environmental factor.

3. The level of visual damage is not necessarily a good indicator for comparing damage across varieties, but may be a reasonable general guide to the level of plant damage within a variety.

4. The photographic information from the 2 seasons needs to be reassessed in more detail to check the correlation between visual damage and yield loss within a variety (the information from last season was averaged over the 3 application times).

On the basis of these results, the experiment will be repeated in 2011/2012 when it was hoped to achieve both good establishment and less severe damage levels (this experiment is an addition to the project's objectives).

Obj. 3.3. Background – 2011/2012:

On the basis of the previous results, the experiment was repeated in 2011/2012, with some changes to the field design:

- Siokra 24 was added to the design, to look at potentially different leaf responses from an okra variety, and
- The in-crop measurements were made on only 1 replicate to reduce the labour requirements for this experiment, which was an addition to the project's objectives.

Obj. 3.3. Design – 2011/2012:

2 Rates x 3 Application stages x 6 Varieties x 4 Reps = 144 plots

- Application rates were 1% and 5% of a typical field rate of 2,4-D, of 800 g a.i./ha
- Application stages were at: nil, 8 and 12 nodes of crop growth
- Varieties were: Sicot 71BRF, Sicot 75, Coker 315, Siokra 24 BRF, Sipima 280 and a breeder's line, L64411 B.
- Plots were 13 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift)

Obj. 3.3. Details – 2011/2012:

		Nominal growth stage at application	
		4 node	**12 node**
Planted	13-Oct-11		
Emerged	21-Oct-11		
Sprayed		15-Dec-11	12-Jan-12
Picked	Yet to be picked		

Obj. 3.3. Results – 2011/2012:

Commercial seed of Sipima 280 and Siokra 24 BRF were not available at planting, but seed of these varieties was procured from the breeders, as well as seed for Coker 315 and L64411. The commercial varieties (Sicot 71 BRF and Sicot 75), treated with Dynasty Complete + Cruiser established well this season, but unfortunately the varieties obtained from the breeders suffered heavy seedling losses, again leading to gappy stands for this material (the L64411 seed had been retained from the previous season's experiment and seed quality may also have been an issue).

Not withstanding this problem, the experiment has run well this season, although weed control was an issue following excessive mid-season rain.

Sicot 75 33 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate to severe levels of 2,4-D damage were observed on these plants, with deformed leaves obvious at the tops of the plants in this photo.

Coker 315 33 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate to severe levels of 2,4-D damage were observed on these plants, with deformed leaves and elongated growth obvious at the tops of the plants in this photo.

Breeder's line L64411 BII 33 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. This line appeared to be very sensitive to 2,4-D, and was severely damaged, developing a mass of distorted leaves and elongated growth obvious at the tops of the plants in this photo.

Sipima 280 33 days after being exposed to 2,4-D at 5% of a typical field rate at 8 nodes of plant growth. Moderate to severe levels of 2,4-D damage were observed on these plants, with deformed leaves and elongated growth obvious at the tops of the plants in this photo.

Siokra 24 BRF 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. Severe levels of 2,4-D damage were observed on these plants, with deformed leaves obvious and elongated growth at the tops of the plants in this photo.

Sicot 71 BRF 33 days after being exposed to 2,4-D at 5% of a typical field rate at 14 nodes of plant growth. Moderate levels of 2,4-D damage were observed on these plants, with deformed leaves obvious at the tops of the plants in this photo.

Summary tables of in-season and final measurements for the varieties and lines are shown in Appendix 3.3. Ginning has not yet been completed and there are no HVI results as yet.

Obj. 3.3. Results for Sicot 71BRF – 2011/2012:

The 2,4-D exposures had no consistent impact on the plant stand or node number. The 5% exposure increased tipping out at 9 nodes and plant height at both times.

Leaf number and area were both reduced by the exposure to 2,4-D.

Boll number and the number of mature bolls were increased by the 1% exposure at 9 nodes, but reduced by the 5% exposure at 15 nodes, with fruit lost from the primary fruiting positions. There was no consistent delay in average boll maturity following the exposures, but there were proportionally fewer mature bolls at picking the 5% rate at 15 nodes.

There was a substantial yield loss from the 5% exposure at 15 nodes, but no loss (actually a 19% yield gain) from the lighter rate at 15 nodes and only small losses from the 9 node exposures.

Obj. 3.3. Results for Sicot 75 – 2011/2012:

The 2,4-D exposures had no consistent impact on the plant stand or node number, but the 5% exposure increased tipping out at 8 nodes and there was an increase in plant height on most treatments.

Sicot 75 responded to the 2,4-D exposures inconsistently, with increases in leaf number, leaf area and plant size on 2 treatments, but a decreases on the other treatments.

Boll number was slightly increase by all exposures but the number of mature bolls were reduced by the 5% rate at 13 nodes, with fruit shed from on the primary fruiting positions following the 5% exposures. There was a substantial delay in average boll maturity from all exposures, with fewer bolls mature at picking from the 13 node exposures.

There were no yield losses from the 8 node treatments, but substantial yield losses from the 13 node treatments.

Obj. 3.3. Results for breeder's line L64411 B – 2011/2012:

2,4-D exposures had no consistent impact on the plant stand, plant height or node number, but the 5% exposure increased tipping out at 9 nodes.

The leaf number and leaf area responses to the 2,4-D exposures were again quite inconsistent, with no impact on leaf number from the 9 node exposures but a large increase in leaf area from the 5% exposure at 9 nodes, large reductions and increases from the 1% and 5% exposures respectively at 14 nodes, but no corresponding change in leaf area following the 1% exposure.

Boll number and the number of mature bolls were increased by the 5% exposure at 9 nodes but reduced by the 14 node exposures, with a reduced proportion of fruit retained on the primary fruiting positions from the 5% exposures. The 5% exposures also caused a small delay in average boll maturity and proportionally fewer open bolls at picking.

There were substantial yield losses on all treatments, with the largest loss from the 5% exposure at 14 nodes.

Obj. 3.3. Results for Coker 315 – 2011/2012:

2,4-D exposures had no consistent impact on the plant stand, plant height or node number, but the exposures at 9 nodes increased tipping out.

Plants responded to the 2,4-D exposures with large increases in leaf number and leaf area on most treatments and a corresponding increase in plant size.

There was little impact on boll number, with small reductions in the number of mature bolls on most treatments. There were no consistent changes in boll retention positions and no delay in average boll maturity, although there were proportionally fewer open bolls at picking on the 5% exposure at 14 nodes.

There were substantial yield losses on both treatments exposed to the 5% rate of 2,4-D.

Obj. 3.3. Results for Siokra 24 BRF – 2011/2012:

2,4-D exposures had no consistent impact on the plant stand, but the 5% exposure increased tipping out at 9 nodes. Plant height and node number were increased on some treatments.

Leaf number and leaf area were reduced by the 5% exposures. The responses were less consistent from the 1% exposures, although average leaf size was reduced on all treatments.

Boll number and the number of mature bolls were reduced by all treatments, with proportionally fewer fruit retained on the primary fruiting positions. There were no consistent delays in average boll maturity or reductions in the proportion of bolls open at picking.

There were substantial yield losses on most treatments, although the trends were inconsistent.

Obj. 3.3. Results for Sipima 280 – 2011/2012:

The 2,4-D exposures had no consistent impact on plant height or node number, although the 5% exposure at 10 nodes increased tipping out. The plant stand was very patchy for this variety.

Leaf number and leaf area were decreased by the 5% exposure at 10 nodes, but increased by the heavy exposure at 13 nodes.

Boll number and the number of mature bolls were substantially reduced by the 5% exposures, and the boll weights were down on all treatments, indicating the very small size and lack of maturity of most bolls. There was no impact on boll positions, with all treatments, including the untreated control, retaining relatively few early bolls. Average boll maturity was substantially delayed by the 5% exposures, with proportionally bolls open at picking on these treatments.

There were yield losses on from all exposures, with substantial yield losses from the exposures at 13 nodes.

Obj. 3.3. Conclusions – 2011/2012:

Unfortunately, this 3rd season's results were confounded by poor establishment and the large amount of rain which fell in late-January, with 230 mm falling between 27th Jan and 3rd Feb. Water logging from this event continued until about the 10th Feb, as the river was too high to allow tail water to be released. Cotton at the tail end of the field was sitting in water for much of this period. Consequently, the damage caused by the herbicides was to some extent masked by the damage from water logging during boll fill.

Similar visual levels of damage were observed on all varieties this season, with the exception of Siokra 24 BRF, which exhibited stronger damage symptoms. However, plant responses to the damage varied widely, from large reductions in leaf number and leaf area, through to large increases. Simialrly, there were large variations in responses in boll numbers, boll size, boll maturity and yield.

Again, it is difficult to draw strong conclusions from a single season's data, but it appears that:

1. The varieties responded in different ways to the 2,4-D damage, with early damage causing little or no yield loss in some varieties. Responses in vegetative growth differed between the varieties

2. The responses to 2,4-D damage were not consistent with the previous seasons, and may have been masked by the period of stress during boll fill caused by water logging. This would be consistent with the observation from Objective 2 of this project which found that stress (in this case moisture stress) reduced the plants expression of 2,4-D damage.

Obj. 3. Combined Conclusions:

When considering the combined data set from the three seasons, it appears that:

1. The extent of visual symptoms of 2,4-d damage is not well related to the severity of crop damage as measured in yield loss.

2. Plants which initially produce a mass of vegetative growth may be at an intial disadvantage, but may be able to use this increased photosynthetic area to retain more later-season bolls.

3. Some cotton varieties appeared more able to compensate for damage from 2,4-D than others, but this compensatory ability was not related to the expression of visual symptoms of damage.

4. Yield compensation did not occur in all seasons, with seasonal conditions determining the ability of the variety to set a later crop.

5. Apparent differences in response to 2,4-D damage may not be due to differences in sensitivity to 2,4-D per se, but to differences in the varieties' ability to compensate from damage (of any kind).

6. In line with the conclusion from Objective 2, in practical terms it appears that the varieties which are best able to compensate for damage (including 2,4-D damage) are those which will normally produce the highest yields.

This work has raised a number of questions, especially the possible influence of environmental factors in the expression of 2,4-D damage. However, the inconsistency of the results suggests that there would be little value in screening varieties for their apparent sensitivity to 2,4-D. Consequently, the work will not be continued, although aspects of the work will be continued when opportunity allows.

Obj. 4. Undertake a 2nd season's evaluation and validation of the weed control threshold.

Obj. 4. Background:

A weed control threshold was developed in the previous project and released to cotton growers in 2008. This threshold was developed in order to:

- Enable cotton growers to confidently identify fields with low weed pressure where weeds only need to be controlled to prevent seed set (eliminating the over-use of weed management inputs), and
- Ensure in-crop glyphosate use is optimised, eliminating potential over-use of glyphosate, or yield losses due to weed competition.

Further testing, evaluation and validation of the threshold was undertaken in the previous project and is now particularly focussing on the potential to use remote sensing to estimate weed pressure in a more reliable and more easily undertaken way. The use of remote sensing has the potential to enhance the threshold by making sampling far more reliable and accurate, eliminating a major hurdle to the adoption of the current threshold.

An experiment evaluating the use of remote sensing and the threshold was undertaken at the end of the last project and was repeated in the first season of the current project.

Obj. 4. Design – 2009/2010:

25 treatments x 4 Reps = 100 plots

- Application rate was 1.5 kg of Roundup Ready Herbicide 690g a.i./ha
- Timing of the herbicide applications is indicated in the following table. Treatments received a range of applications based on growing day degrees, regardless of the weed pressure present, ranging from Treatment 1, which was sprayed every 100 day degrees from emergence to 1200 DD, to Treatment 24, which was sprayed only at 300 DD.
- Where possible, the GreenSeeker sensor was run over the plots the same day as the sprays.
- Manual calibration cuts were undertaken at the same time to calibrate the GreenSeeker.
- A weekly visual assessment of the weed pressure was also undertaken.
- Plots were 20 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift.

									Crop day degrees since emergence									
Treatment		**100**	**150**	**200**	**250**	**300**	**400**	**450**	**500**	**600**	**700**	**750**	**800**	**900**	**1000**	**1050**	**1100**	**1200**
1	1 - 100	1 - 100		1 - 100		1 - 100	1 - 100		1 - 100	1 - 100	1 - 100		1 - 100	1 - 100	1 - 100		1 - 100	1 - 100
2	1 - 150		1 - 150			1 - 150		1 - 150		1 - 150		1 - 150		1 - 150		1 - 150		1 - 150
3	1 - 200			1 - 200			1 - 200			1 - 200			1 - 200		1 - 200			1 - 200
4	1 - 250				1 - 250				1 - 250			1 - 250			1 - 250			1 - 250
5	1 - 300					1 - 300				1 - 300				1 - 300				1 - 300
6	1 - 400						1 - 400						1 - 400					1 - 400
7	1 - 600									1 - 600								1 - 600
8	2 - 100	2 - 100		2 - 100		2 - 100	2 - 100		2 - 100	2 - 100	2 - 100		2 - 100	2 - 100				
9	2 - 150		2 - 150			2 - 150		2 - 150		2 - 150		2 - 150		2 - 150				
10	2 - 200			2 - 200			2 - 200			2 - 200			2 - 200					
11	2 - 250				2 - 250				2 - 250			2 - 250						
12	2 - 300					2 - 300				2 - 300				2 - 300				
13	2 - 400						2 - 400						2 - 400					
19	2 - 600									2 - 600								
14	3 - 100	3 - 100		3 - 100		3 - 100	3 - 100		3 - 100	3 - 100								
15	3 - 150		3 - 150			3 - 150		3 - 150		3 - 150								
16	3 - 200			3 - 200			3 - 200			3 - 200								
17	3 - 250				3 - 250				3 - 250									
18	3 - 300					3 - 300				3 - 300								
25	3 - 400						3 - 400											
20	4 - 100	4 - 100		4 - 100		4 - 100												
21	4 - 150		4 - 150			4 - 150												
22	4 - 200			4 - 200														
23	4 - 250				4 - 250													
24	4 - 300					4 - 300												

Obj. 4. Details – 2009/2010:

	Nominal day degrees	Date	Spray	GreenSeeker	Visual
Planted		8-Oct-09			
Watered		9-Oct-09			
Emerged		23-Oct-09			
Activity	100	26-Oct-09	108		
	150	30-Oct-09	148		
	200	3-Nov-09	200	200	
	250	9-Nov-09	265	265	
		10-Nov-09			277
	300	12-Nov-09	307	307	
	400	16-Nov-09			371
		18-Nov-09	408	408	
	450	20-Nov-09	452		
	500	23-Nov-09	513		
		26-Nov-09			560
	600	30-Nov-09	610	610	
		1-Dec-09			620
	700	7-Dec-09	706		
	750	9-Dec-09	743	743	
		10-Dec-09			760
	800	14-Dec-09	815	815	
		16-Dec-09			853
	900	21-Dec-09	928	928	
	1000	24-Dec-09			972
		8-Jan-10	1162		
	1050		1162		
	1100		1162	1162	
	1200	11-Jan-10	1213	1213	1213
	1300	18-Jan-10			1324
Picked	7-Jun-10				

Obj. 4. Results – 2009/2010:

2009/10 was a relatively easy season for field work, with very little rain occurring between planting and 900 day degrees. Consequently, most sprays and measurements went on fairly much as planned. An irrigation on the 21st Dec delayed the 1000 DD spray and GreenSeeker measurements. More rain over Christmas delayed this and the following inputs till the 8th January 2010.

Results from the experiment are presented in Appendix 4. Very large differences in weed biomass were observed between the various treatments up till 928 days degrees post-crop emergence. At, and beyond 928 day degrees it was not possible to separate the biomass of the crop from the weed biomass with the sensor running along the rows.

To assess the value of the GreenSeeker® to estimate weed biomass from NDVI, dry matter cuts were taken every time the GreenSeeker was used and calibration curves generated. In previous seasons, the calibration curves remained relatively stable throughout the first half of the season, but lost accuracy at around 1000 day degrees. However, the biomass calibrations did not remain stable in this season, dropping progressively thought the season.

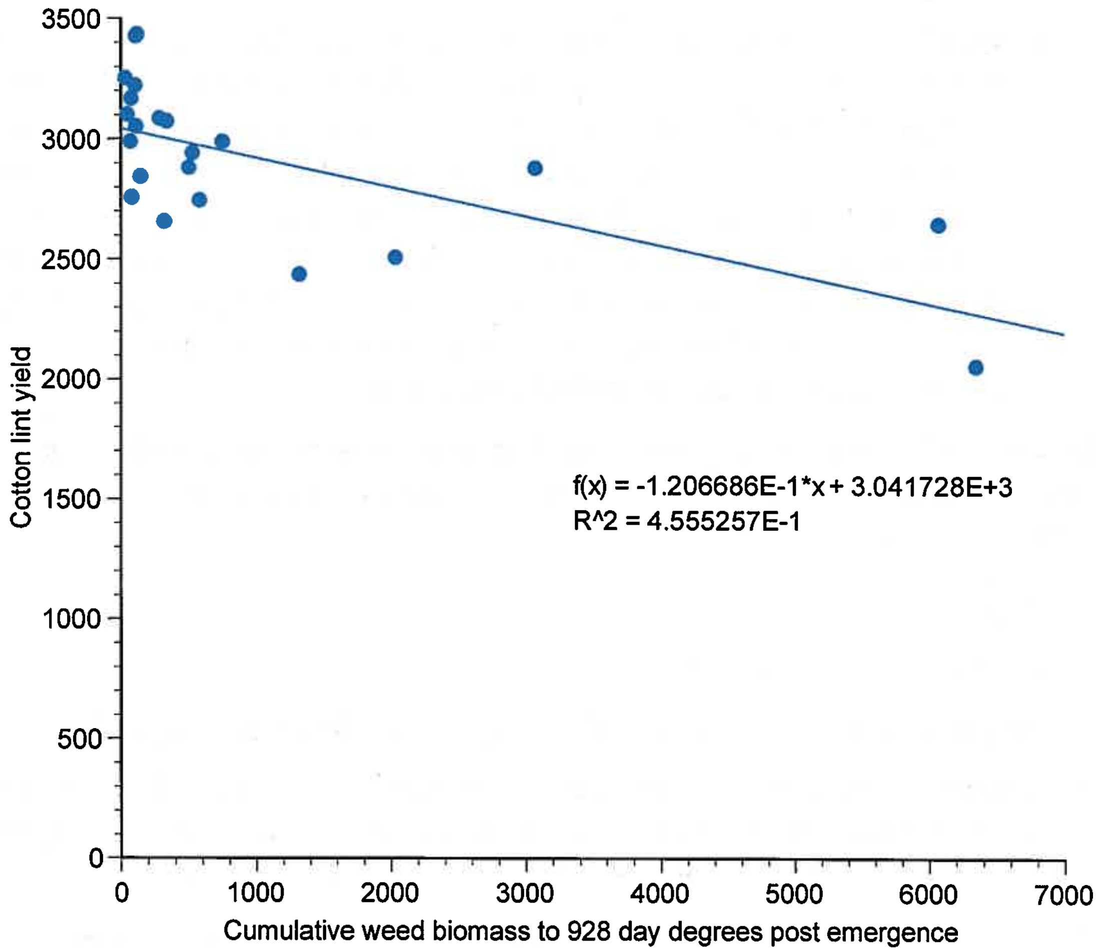
The reason for this change partly relates to the way the calibration curves were generated. In previous seasons, calibration cuts have been taken from a random selection of plots throughout the experiment. This approach had some advantages, but it was difficult to relate the NDVI readings taken from a full plot to the dry matter taken from a single metre square in the plot, due to the variability in weed density over a plot, which is typical of natural weed populations. To overcome this problem, smaller calibration plots were set aside this season. The data generated from these plots was more accurate, but with improved accuracy, the calibration decline over the season became more apparent.

The second reason for the changing calibration curves is fundamental to the nature of NDVI, which records the amount of greenness. This greenness is correlated to green matter and dry matter and this is in tern correlated with weed competitiveness, but the correlations are not perfect. Five issues became apparent this season:

1. Not all weeds have the same amount of greenness, so NDVI underestimates some weeds compared to others.
2. Stressed weeds are less green. This characteristic is used to assess things such as nitrogen status in a field, but also confounds the estimate of biomass, so that the estimate will be higher or lower depending on temperature, water status, nitrogen status, etc.
3. Most plants lose their greenness as they mature. Grass weeds, for example, typically become yellow as they hay off. These, potentially large, mature weeds are largely not seen by the GreenSeeker, but can contribute a large amount of biomass to the calibration cuts.
4. Small green weeds that are beneath a sward of weeds killed by a herbicide are not visible to the GreenSeeker, and
5. Dead plant matter is not seen by the sensor but still contributes to the weed biomass measurement. This is not a problem with the sensor, but a problem with the use of total weed biomass to estimate weed competitiveness.

While these issues may limit the absolute accuracy of NDVI for estimating weed biomass, the ability of the sensor to quickly assess and developing an integrated estimate over large arrears still makes this approach very valuable. It also may be argued that NDVI is in fact more closely correlated with weed competitiveness than is weed biomass.

The cotton lint yield results (Appendix 4) from this season give good support to the critical period for weed control approach, with the highest yields on the treatments receiving the higher levels of weed control, and lower where weed control was less frequent, resulting in more weed biomass and more weed competition (see figure below).



Further analysis of this data and the entire critical period for weed control data mass will be undertaken in the new (2012-2015) project.

Obj. 5. Undertake an experiment using the weed control threshold approach using responsive thresholds on mixed weed populations.

Obj. 5. Background:

Validating the weed control threshold has proven to be a difficult task due to a range of factors including:

- The "normal" variability observed in the field, with both variable weed populations and variability in cotton yields. It has been difficult to separate the relatively subtle effects of weed competition from background variability.
- Weed competition can't be directly measured, but is correlated with factors such as weed and crop biomass. NDVI measurements appear to be a practical and valuable way to assess weed competition, but this is based on a correlation between NDVI and plant green matter, green matter and biomass, and biomass and competition. The errors in these correlations are more than made up for by the ability to assess and integrate measurements over large areas in a short time frame, but when applied to small plots, the correlation errors make it difficult to assess the accuracy of the critical period predictions.

Results from experiments over the last few seasons have supported the threshold concept, but a new field design will be used this season in an attempt to further tease out the data.

Obj. 5. Design – 2010/2011:

14 treatments x 6 Reps = 84 plots

- Application rate was 1.5 kg of Roundup Ready Herbicide 690g a.i./ha
- Timing of the herbicide applications is indicated in the following table. Treatments received a range of applications based on growing day degrees, weed pressure or weed biomass, depending on the treatment.
- Where possible, the GreenSeeker sensor was run over the plots every 100 day degrees.
- Manual calibration cuts were undertaken from calibration plots at the same time as the GreenSeeker assessment to calibrate the sensor.
- A weekly visual assessment of the weed pressure was also undertaken.
- Plots were 50 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift.
- Six replicates were used to reduce the field effects.

	Nominal day degrees
1	No weed control
2	Kept clean
3	At 500 day degrees post emergence only
4	At 500 and 1000 day degrees post emergence only
5	At 1000 day degrees post emergence only
6	The 1st time the control threshold is reached*
7	The 1st & 2nd times the control threshold is reached*
8	Only when treatment 7 receives its 2nd spray
9	The 1st three times the control threshold is reached*
10	Only when treatment 9 receives its 3rd spray
11	Whenever the GreenSeeker detects 100 kg of weed biomass
12	Whenever the GreenSeeker detects 200 kg of weed biomass
13	Whenever the GreenSeeker detects 300 kg of weed biomass
14	Whenever the GreenSeeker detects 400 kg of weed biomass

Note* Based on the weed control threshold as determined from visual assessments.

Obj. 5.1. Details – 2010/2011:

	Nominal day degrees	Date	Spray	GreenSeeker	Visual
Planted		12-Oct-10			
Emerged		27-Oct-10			
Activity	100	13-Nov-10		160	123
	180	15-Nov-10	1st threshold		180
	200	24-Nov-10		266	266
	300	29-Nov-10		321	
	400	9-Dec-10		Too wet	434
	500	20-Dec-10		539	561
	574	23-Dec-10	2nd threshold & 500 DD		
	600	30-Dec-10		667	684
	700	4-Jan-11		748	748
	800	10-Jan-11		824	
		14-Jan-11			882
	900	17-Jan-11		930	
	1000	21-Jan-11	1000 DD	984	970
	1100	30-Jan-11	3rd threshold	1138	1158
	1300	7-Feb-11		1282	
		21-Feb-11	All plots		
Picked	16-May-11				

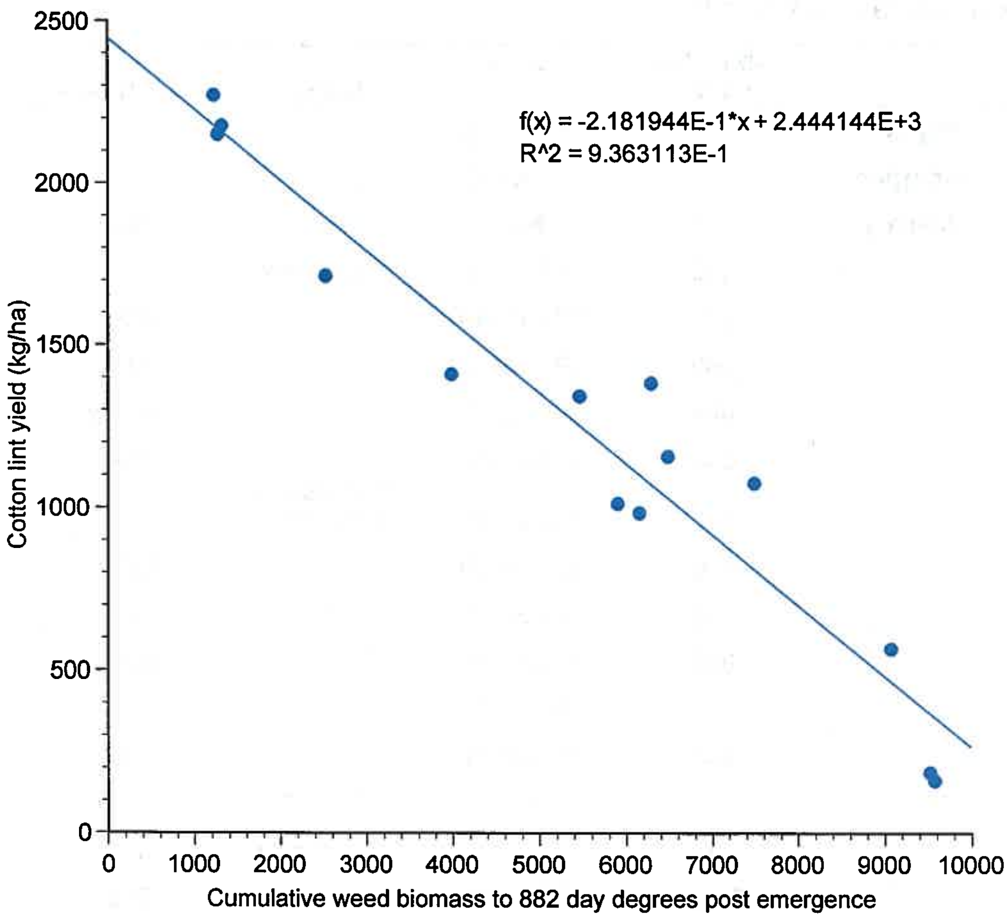
Obj. 5.1. Results – 2010/2011:

The early part of 2010/11 was relatively wet, making it difficult to complete the GreenSeeker assessments and sprays in a timely fashion. 216 mm fell in November, followed by 139 mm in December, mainly falling in the early part of the month. Consequently, weeds grew very vigorously and were highly competitive but some assessments and treatments were delayed by rain or a wet tail ditch. The season was also quite cool, delaying crop growth and development.

Results from the experiment are presented in Appendix 5. Very large differences in weed biomass were observed between the various treatments up till 970 days degrees post-crop emergence. At, and beyond 970 day degrees it was not possible to separate the biomass of the crop from the weed biomass with the sensor running along the rows.

Weed dry matter cuts were taken every time the GreenSeeker was used and calibration curves generated. As in previous seasons, the calibration curves changed (dropping) progressively thought the season.

The cotton lint yield results (Appendix 5) were very strongly correlated with the NDVI estimates in this season (see figure below).



Further analysis of this data and the entire critical period for weed control data mass will be undertaken in the new (2012-2015) project.

Obj. 5.2. Details – 2011/2012:

	Nominal day degrees	Date	Spray	GreenSeeker	Visual
Planted		10-Oct-11			
Emerged		17-Oct-11			
Activity	100	28-Oct-11		106	
		4-Nov-11			164
	200	8-Nov-11	1st threshold	215	
		11-Nov-11			254
	300	16-Nov-11		334	
	400	21-Nov-11		401	401
	500	30-Nov-11	2nd threshold & 500 DD	496	496
		5-Dec-11			538
	600	17-Dec-11		649	638
	700			Too wet	
	800	29-Dec-11	3rd threshold	784	784
	900	5-Jan-12		878	
	1000	12-Jan-12	1000 DD	964	964
	1100	20-Jan-12		1057	
	1200	2-Feb-12		1196	
	1300	13-Feb-12	All plots	1327	
Picked	2-May-12				

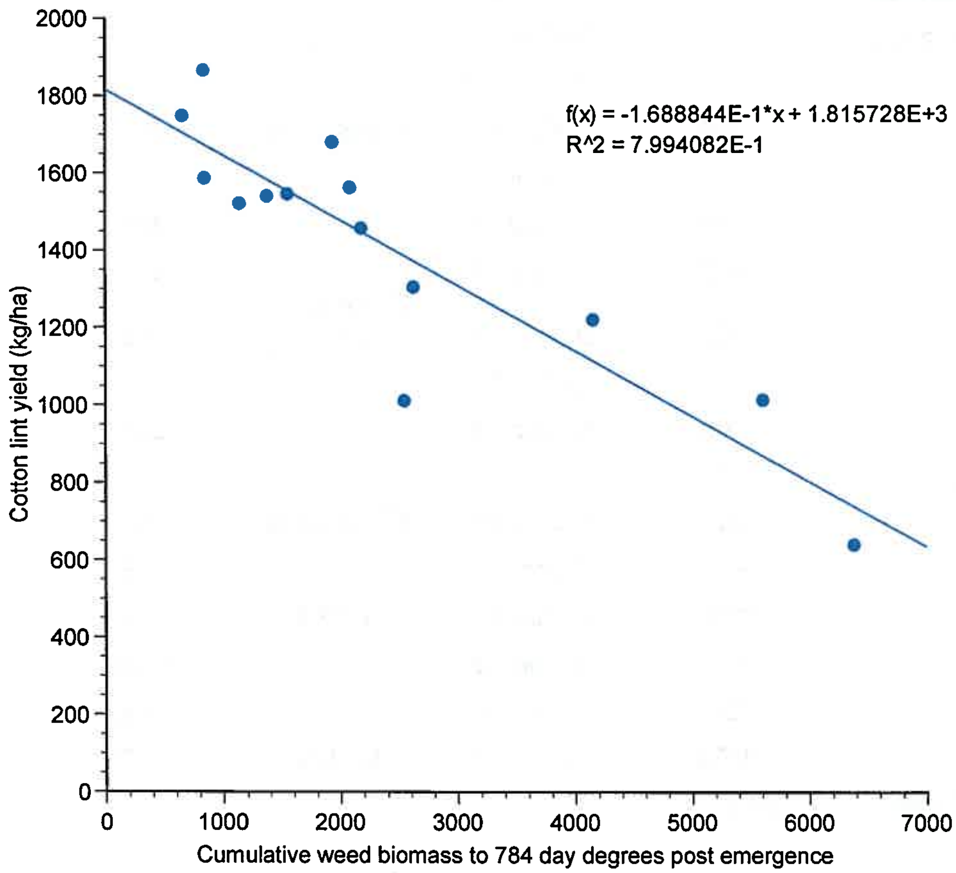
Obj. 5.2. Results – 2011/2012:

Much of the 2011/12 season was again relatively wet, making it difficult to complete the GreenSeeker assessments and sprays in a timely fashion. 231 mm fell in November, followed by 155 mm in December. This was followed by 252 mm in late January/early February, resulting in water logging in early boll fill, with plants losing a lot of fruit. Consequently, although the weeds grew very vigorously and were highly competitive, some assessments and treatments were delayed by rain or a wet tail ditch, and the lint yields were well down, particularly disadvantaging the better treatments.

Results from the experiment are presented in Appendix 5. Very large differences in weed biomass were observed between the various treatments up till 878 days degrees post-crop emergence. At, and beyond 878 day degrees it was not possible to separate the biomass of the crop from the weed biomass with the sensor running along the rows.

Weed dry matter cuts were taken every time the GreenSeeker was used and calibration curves generated. As in previous seasons, the calibration curves changed (dropping) progressively thought the season.

The cotton lint yield results (Appendix 5) were very strongly correlated with the NDVI estimates in this season (see figure below), although the absolute yields were well down on what might have been expected.



Further analysis of this data and the entire critical period for weed control data mass will be undertaken in the new (2012-2015) project.

Obj. 6. Evaluate the damage from a range of fallow and alternative herbicides on cotton using 3 rates and 4 growth stages..

Obj. 6. Background:

Herbicide damage has been an issue in cotton production since the earliest days of herbicide use, as cotton is readily damaged by many of the herbicides commonly used on fallows and other crops in the farming system.

Herbicide damage can occur through a number of pathways, including:

- Herbicide residues in the soil from herbicides applied prior to the cotton crop,
- Herbicide residues in spraying equipment not adequately decontaminated following an earlier spray,
- Off-target drift of spray applied to another crop or fallow,
- Inadvertent spray contamination through using the wrong product,
- Poor spray application, and
- Adverse weather conditions leading to increased crop sensitivity.

As well as the direct issues of herbicide damage, the cotton industry has been faced with the difficulty of not necessarily being able to identify the herbicide/s with might have caused damage and not knowing the likely impact of damage.

To address these issues, a series of experiments has been undertaken in previous projects where cotton was exposed to known rates of known herbicides to determine the damage symptoms and the crop impacts of these herbicides.

A further 4 herbicides were be examined in objective 6 of this project. These herbicides were expected to have some residual effects on cotton, so were applied both at-planting and during crop growth.

Obj. 6. Design – 2010/2011:

4 herbicides x 2 rates x 5 application times x 4 Reps = 172 plots

- The herbicides were: Ally, Balance, Flame and Glean
- Herbicides were applied at 50% and 10% of a typical field rate.
- Herbicides were applied at planting, 4, 8, 12 and 16 nodes of crop growth.
- Plots were sampled every 2 weeks from the time of exposure to picking.
- Maturity picks, plant mapping and lint yield were also recorded.
- Plots were 12 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift.

Obj. 6. Details – 2010/2011:

	Date	Nominal growth stage at exposure			
		4 nodes	8 nodes	12 nodes	16 nodes
Planted	13-Oct-10				
Emerged	27-Oct-10				
		25-Nov-10	15-Dec-10	13-Jan-11	31-Jan-11
Picked	9-May-11				

Obj. 6. Results – 2010/2011:

Metsulfuron-methyl

Damage from Ally caused mild to strong visual symptoms and yield losses, especially from the heavy rate at 16 nodes. This work clearly shows that Ally and cotton are not a good mix, and growers should carefully consider their options before using this product in any fields that might be planted to cotton in later years.

Isoxaflutole

Damage from Balance caused relatively mild symptoms, with no yield losses from the early exposures. Symptoms were more apparent from the 12 and 16 node exposures and there were substantial yield losses from both rates at these stages. It might be concluded from this work that Balance could have a place in fallow weed control prior to cotton (allowing the recommended plant-back period), but care must be exercised to ensure Balance does not drift onto cotton crops.

Imazapic

Damage from Flame caused mild to strong visual symptoms and yield losses, especially from the heavy rate at 12 and 16 nodes. Combined with a very long soil half-life, this work clearly shows that Flame and cotton are not a good mix, and growers should carefully consider their options before using this product in any fields that might be planted to cotton in later years.

Chlorsulfuron

Damage from Glean caused strong visual symptoms and heavy yield losses at the heavier rate, especially at 12 and 16 nodes. Combined with a very long plant-back period, this work clearly shows that Glean and cotton are not a good mix, and growers should carefully consider their options before using this product in any fields that might be planted to cotton in later years.

Obj. 6. Conclusions – 2010/2011:

The value of the results from this and previous damage work can not be underemphasised and deserve to be more strongly promoted. These results are of enormous value to potential new growers who may have used some of these products in previous years or to growers who may be tempted to use these products in the future.

The message is clear. Many of the alternative herbicides can cause heavy yield losses if they are used inappropriately, and should be used with extreme caution around cotton.

Obj. 6. Outputs – 2010/2011:

All of this information has been incorporated into the Herbicide Damage Guide, a component of WEEDpak on the cotton internet site. In addition, information generated in the previous project (1.01.49) on atrazine glufosinate, Grazon, simazine, Tordon 242 and Tordon 75D damage has been compiled and incorporated into the Herbicide Damage Guide.

Copies of the data sheets are included in Appendix 6.

During this three year period, the information already contained in the Herbicide Damage Guide on the internet was also updated, with a new-look format and inclusion of HVI results in the data sheets, increasing the amount and value of the data included on these sheets.

Obj. 7. Evaluate the damage from an additional range of fallow and alternative herbicides on cotton using 3 rates and 4 growth stages.

Obj. 7. Background:

It was decided to evaluate an additional set of herbicides in Objective 7 because:

- The results from the water management experiment (Objective 2), showed that while this strategy was effective, water stress caused more crop damage than it alleviated. Consequently, there is little perceived value in repeating this work, and
- With the rapid growth of cotton into the southern farming area, there is increasing concern regarding the potential for damage from some of the herbicides not traditionally used in the cotton area. Some of these herbicide have no established plant-back periods to cotton.

Obj. 7. Design – 2011/2012:

4 herbicides x 2 rates x 5 application times x 4 Reps = 192 plots

- The herbicides were: Hussar, Intervix, Lontrel and Spinnaker
- Herbicides were applied at 50% and 10% of a typical field rate.
- Herbicides were applied at planting, 4, 8, 12 and 16 nodes of crop growth.
- Plots were sampled every 2 weeks from the time of exposure to picking.
- Maturity picks, plant mapping and lint yield were also recorded.
- Plots were 12 m long by 8 rows (effectively allowing a 4 row buffer between treatments to allow for any herbicide drift.

Obj. 7. Details – 2011/2012:

		Nominal growth stage at exposure			
	Date	**4 nodes**	**8 nodes**	**12 nodes**	**16 nodes**
Planted	10-Oct-11				
Emerged	17-Oct-11				
		20-Nov-11	15-Dec-11	4-Jan-12	18-Jan-12
Picked	30-May-12				

Obj. 7. Results – 2011/2012:

The results from this work are presented in Appendix 7.

Idosulfuron + mefenpyr

Damage from Hussar caused only mild visual symptoms but resulted in large yield losses, especially from the heavy rate pre-planting, and at 4 and 16 nodes. Hussar is reported to have a short half-life in the soil, but the extent of the damage suggests this herbicide should be used with caution and growers should carefully consider their options before using this product in any fields that might be planted to cotton.

Imazamox + imazapyr

Damage from Intervix caused mild to strong visual symptoms, with substantial yield losses from most of the heavier exposures. The size of the yield losses, combined with a very long soil half-life for imazapyr, clearly shows that Intervix and cotton are not a good mix, and growers should carefully consider their options before using this product in any fields that might be planted to cotton in later years. There are several other options containing similar herbicide combinations and it is likely that these would be equally damaging to cotton.

Imazethapyr

Damage from Spinnaker caused mild to strong visual symptoms and yield losses, especially from the heavy rate pre-planting and at 8, 12 and 16 nodes. Combined with a long soil half-life, this work clearly shows that Spinnaker and cotton are not a good mix, and growers should carefully consider their options before using this product in any fields that might be planted to cotton in the following year.

Clopyralid

Few damage symptoms were obvious from exposure to Lontrel, although there were still heavy yield losses at the heavier rate, especially at 12 and 16 nodes. Combined with a long soil half-life, this work shows that growers should be cautious when using Lontrel and should carefully consider their options before using this product in any fields that might be planted to cotton in the following year.

Obj. 7. Conclusions – 2011/2012:

The value of the results from this and previous damage work can not be underemphasised and deserve to be more strongly promoted. These results are of enormous value to potential new growers who may have used some of these products in previous years or to growers who may be tempted to use these products in the future.

The message is clear. Many of the alternative herbicides can cause heavy yield losses if they are used inappropriately, and should be used with extreme caution around cotton.

Obj. 7. Outputs – 2011/2012:

This information will been incorporated into the Herbicide Damage Guide, a component of WEEDpak on the cotton internet site over the next few weeks.

Ginning% and HVI results will be added to the data as soon as they become available.

Project Outcomes

The project has taken a further step in understanding herbicide damage and its consequences. The information generated by the project has been presented in readily understood form in WEEDpak on the cotton website, in CottonGrower articles and at conferences, allowing growers, consultants and others easy access to the information.

The information from the weed control threshold component of the project has not been translated into grower information at this point, but has been valuable in validating the threshold which was released to growers in 2008 and will be an important part of the data set to be explored and developed in the new (2012-2015) project.

There has been no commercially significant developments from the work or information requiring changes to the Intellectual Property register.

Conclusion

Adoption of the weed control threshold has the potential to lift the management of weeds in cotton from an art to a science, where management inputs are directly related to the damage done by the weeds. As with other pest thresholds, the weed control threshold has the potential to improve the management on properties which are already well managed, taking much of the guess work out of management decisions. As with other thresholds, it also gives managers an understanding of when weeds can be present without causing economic damage, and when weeds must be controlled to prevent yield loss or to prevent a build up in the seed bank. Optimizing of weed management inputs also has benefits for the management of species shift and herbicide resistance, and reduces the potential to overuse these pesticides. Adoption of the threshold will optimize pesticide inputs and support the push to higher crop yields.

An understanding of the herbicide damage information should have a large impact on those growers unfortunate enough to suffer herbicide damage. The data:

- Highlights the potential impact on cotton from exposure to a range of herbicides,
- Gives growers information to allow them to assess the type of damage they have suffered and the likely effect on the crop, and
- Enables growers to make informed decisions regarding the future management of damaged crops.

An understanding of this information should also:

- Encourage growers to be extra vigilant with the use of some herbicides,
- Give growers independent information they can discuss with neighbours highlighting the importance of avoiding herbicide drift, and

- Ensure damaged crops are not unnecessarily terminated, or resources waisted on damaged crops which are unlikely to adequately respond.

Take home messages:

Species shift and herbicide resistant weeds, and herbicide damage are becoming increasingly important issues for the Australian cotton industry, although the importance of species shift and resistance may not yet be recognised by some cotton growers.

The information from this project is directly applicable to the cotton industry and will need to be applied if the industry is to achieve best management of weeds in cotton and make informed decisions regarding the management of herbicide damaged cotton.

The take home messages from this work are that:

- Herbicide resistance and species shift is no longer a threat, but a reality of the farming system. This is not a cotton specific issue, but a symptoms of a breakdown in the whole farming system. That breakdown being the replacing of an integrated weed management system with a glyphosate centric system.
- The weed control threshold enables glyphosate use to be optimized and is an essential step in the IWM system to deal with resistance and species shift. Adoption of a weed control threshold is a superior best-management practice, which optimizes inputs, reduces selection pressure on weeds and reduces the potential problems with herbicide drift and contamination by ensuring that pesticides are only used when they are economically justified.
- Herbicide damage is a serious issue for the cotton industry, but that crop response is not a simple story. The degree of crop damage depends on a range of factors, including crop growth stage, herbicide type and herbicide rate. Decisions on the management of herbicide damaged crops need to be based on an understanding of the likely scenario for each damage situation.

Extension Opportunities

1. **Detail a plan for the activities or other steps that may be taken:**
   (a) to further develop or to exploit the project technology.

Analyses and developing of the weed control threshold data will be the major focus of the new project (2012-2015), where this work will be publishing as a series of scientific papers and a PhD.

The new project will also undertake an update of **WEEDpak**, which will include adding the new data set from Objective 7 to the **Herbicide Damage Guide**, publishing the 2,4-D damage by varieties information and publishing the multiple 2,4-D exposure information.

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

The herbicide damage information is presently being undervalued by the industry, with many growers unaware of the information and its potential uses and importance. The current presentation of the information in the **Herbicide Damage Guide** is valuable and will be continued and expanded, but there is a need to sit down with the D&D team and look at other opportunities for promoting this information, such as a Ute Guide format.

(c) for future research.

As identified in Objective 1, there is a need to repeat the work on multiple 2,4-D exposures, as this information has important implications for cotton growers with crops suffering from multiple damage events. The feeling amongst many growers is that after the 2nd or 3rd damage event the crop is a write-off, whereas the results from Objective 1 suggest that this may not be the case, with damage being additive only in the most extreme cases. It is essential to double-check this finding before the results are widely promoted.

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

Yes – all material is on the Cotton CRC website, under **Industry/Publications/Weeds** and either **WEEDpak**, **Weed Identification Tools**, or **Herbicide Damage Identification and Information Guide**.

- Charles G. (2012). **Herbicide Damage Identification and Information Guide**. The full guide was updated, with the inclusion of new material (see Appendix 6) and updating of the existing material to include HVI results. Available through the web & **COTTONpaks CD**..
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Cotton CRC Project Title (1.01.64): Managing weeds and herbicides in a genetically modified cotton farming system

Principal Researcher: Mr. Graham Charles, Research Agronomist (Weeds)
Organisation: NSW Dept. Primary Industries
Postal Address: Locked Bag 1000, Narrabri 2390
Ph: 0267 991524 **Fax:** 0267 991503 **E-mail:** graham.charles@dpi.nsw.gov.au

Tremendous advances in weed management have occurred over the past decade with the almost universal adoption of cotton varieties including the Roundup Ready Flex® trait and the development of a glyphosate based system which gives excellent weed control alongside superior cotton yields. However, for many growers, the realities of species shift and glyphosate resistant weeds are starting to impact and there is a growing need to broaden the weed management system to ensure its sustainability.

The project had two primary aims:

1. To explore and document the potential for herbicides to damage cotton, and
2. To validate and further explore the weed control threshold for cotton using remote sensing to develop a simpler, more user-friendly threshold.

The project provided cotton growers with information on the potential for damage of a further 10 herbicides (with 4 more to be extended to growers shortly), allowing them to assess the likely effects of herbicide damage on cotton crops in terms of crop growth, yield and maturity, and subsequently to make better informed management decisions for damaged crops.

Three aspects of 2,4-D damage were also explored:

1. the value of post-damage water stress on crop expression of damage and recovery. The water stress caused more yield loss than the 2,4-D!
2. the effect of low, multiple exposures on the crop, where it appears that multiple exposures are no necessarily much more damaging than single exposures, and
3. varietal sensitivity and response to 2,4-D damage, where, unfortunately, differences in the extent of visual symptoms did not translate to consistent differences in plant responses in yield.

Much of the information from the project has already been disseminated to the industry though **WEEDpak** and the **Herbicide Damage Guide** on the cotton internet site, the CottonGrower, conferences and meetings. Further information will be released soon as part of an update to WEEDpak to be undertaken in the next project. Weed control threshold work will also form the basis of an extensive re-analysis and publication push to be undertaken in the next project.

The principle researcher has had an important additional role in other aspects such as biosecurity, the TIMS herbicide committee and the management of other projects.

These outcomes significantly progress the science of weed management in the Australian cotton industry, providing guidelines for best practices for weeds and contributing to the sustainability of the glyphosate based system.