FINAL REPORT 2015
For Public Release

Part 1 - Summary Details
Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: DAN1305

Project Title: Updating and expanding WEEDpak in support of the cotton industry and myBMP

Project Commencement Date: 1-Jul-2012  Project Completion Date: 31 Oct 2015

CRDC Research Program: 1 Farmers

Part 2 – Contact Details

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Signature of Research Provider Representative:

Date Submitted:
1. **Background**

This project built on many years of weeds work supported by CRDC and value added to the earlier work, while providing strategic information to growers in support of MyBMP, based around updating WEEDpak.

WEEDpak, the guide to integrated weed management in cotton, was a collaborative document written in 2001/2 and released in hard-copy in the spring of 2002. It covered a wide range of weed issues, weed identification material, guidelines for developing an Integrated Weed Management (IWM) approach for cotton, and extensive research findings on the management of specific, hard to control weeds. It was released with 37 weeds and 276 pages of information. WEEDpak has gradually been updated and at the time this project was initiated, included 102 weeds and 612 pages of information, including the Herbicide Damage Identification and Information Guide, a totally new section for WEEDpak. This additional information is only available through the cotton website, where WEEDpak has been the most frequently sought information on the site.

Nevertheless, some strategically important parts of WEEDpak were badly out of date and need updating, such as the IWM Guidelines, Section B2, which were written in the early days of Roundup Ready cotton and primarily covered the conventional cotton production system of the 1990’’s. This document needed updating and linking through to the weed components of MyBMP.

The herbicide damage section of WEEDpak is becoming increasingly important, with the spread of cotton into new areas and the growing complexity of the farming system. This guide will need to continue to grow in response to growers seeking information on new herbicides.

The weed threshold work has been a world-class research break-through, but results in the previous project have highlighted limitations to the weed density based approach. The new project will explore the option of going to a weed biomass based threshold to overcome these issues and improve usability.

2. **Objectives**

The project aimed to develop and expand strategic areas of WEEDpak in support of MyBMP and the cotton industry, providing:

- Up-to-date guidelines for Integrated Weed Management in the Roundup Ready Flex system,
- Up-to-date information on key weed questions in MyBMP,
- More and better information on the potential for damage issues from herbicides used in other parts of the farming system, and
- An improved, more user-friendly and more robust weed control threshold for cotton.

To achieve this, the project:

- Updated strategic sections of WEEDpak,
- Added additional information as required in support of MyBMP,
- Updated and expand the Weed Identification Guide,
- Added further herbicides to the Herbicide Damage Information Guide,
• Further evaluated and develop the weed control threshold for cotton, and
• Monitored the health of the Roundup Ready Flex weed management system in the
ger traditional cotton areas of the MIA, and
• Undertook glasshouse studies on desert cowvine, an emerging problem weed.

3. 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 field experiments were conducted at the ACRI, Narrabri. Treatments were applied at
various crop growth stages to plots of 12 m length by 8 rows width (effectively allowing a
4 m buffer between treatments) using a randomized complete block design with 4
replicates, using an area of about 8 ha each season. This is a standard statistical design
which is easily analysed. The experiments used detailed crop measurements to assess the
post-treatment impact of herbicide damage on cotton plants, monitoring plant height and
development, leaf number and area, squares, flowers and bolls throughout the season, and
crop yield, fibre quality and time to maturity. Measurements were taken every 14 days
post-treatment through to picking. Photographs of herbicide damage symptoms were
taken throughout the season.

At each assessment time, 1 m of plants were removed from each plot. A sub-sample of 6
plants were removed for further processing, recording weight, leaf area, squares, flowers
and bolls on each plant.

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 tested for fibre quality with the
assistance of the CSIRO plant breeding team.

Experiments to validate the weed control threshold used the background weed population,
supplemented to ensure strong weed pressure, 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 WEEDpak on the Cotton web site.

In addition to this research, the project allowed the researcher to continue his role in
advising cotton growers on weed issues and giving expert technical advice to various
groups, including the TIMS Herbicide Tolerant Crop Technical Panel.
4. Results

Obj. 1.1: Update and expand WEEDpak

Obj. 1.1: Background

WEEDpak, the guide to integrated weed management in cotton, was a collaborative document written in 2001/2 and released in hard-copy in the spring of 2002. It covered a wide range of weed issues, weed identification material, guidelines for developing an Integrated Weed Management (IWM) approach for cotton, and extensive research findings on the management of specific, hard to control weeds. It was released with 37 weeds and 276 pages of information.

WEEDpak has gradually been updated and at the start of this project included 102 weeds and 612 pages of information, including the Herbicide Damage Identification and Information Guide, a totally new section for WEEDpak. This additional information is only available through the Cotton website, where WEEDpak remains the most frequently sought information on the site.

Nevertheless, some strategically important parts of WEEDpak were badly out of date and need updating, such as the IWM Guidelines, Section B2, which were written in the early days of Roundup Ready cotton and primarily covered the conventional cotton production system of the 1990’s. This document needed updating and linking through to the weed components of MyBMP.

Most of the newer material that has been added to WEEDpak didn’t need updating at this time. All the original material was updated, with the exception of section G. The Best Management Guide, and section D2., the Herbicide and Formulation List. These sections are outdated and should be removed from WEEDpak. Section G was a compilation of grower’s and consultant’s best guesses as to which herbicides were most effective on some of the more common weeds. Much of this information has been replaced by the expanded Managing Problem Weeds section in WEEDpak, or is no longer relevant, in the new world of Roundup Ready Flex cotton. The Herbicide and Formulation List is useful information, but is more appropriately provided in the Australian Cotton Production Manual where it is updated annually.

Obj. 1.1: Output

All major sections of WEEDpak have been updated, with additional information included where it is required in support of MyBMP. The updated WEEDpak is available on the Web.

The updated and expanded sections are:

- B2. Managing Weeds in Cotton,
- B3. Integrated Weed Management (IWM): Guidelines for Australian Cotton Production,
- C2. Managing Herbicide Resistance in Cotton,
- C3. Herbicide Resistance and the Crop Management Plan,
- D3. SPRAYpak/Spray Application,
- F2. Farm Hygiene in Integrated Weed Management,
- F3. Managing Weeds on Roads, Channels and Water Storages,
- F4. Controlling Volunteer Cotton,
F5. Plant Protection Interactions with Weeds,
H3. Managing Nutgrass in Cotton,
H4. Managing Polymeria (Take-all) in Cotton, and
H10. Managing Feathertop Rhodes Grass in Cotton has been added to the
guide.

These sections are presented in Appendix 1.1

**Obj. 1.2: Update and expand the Weed Identification Guide**

**Obj. 1.2: Background**

**WEEDpak** was launched with just 37 weeds in the weed identification section,
roughly half supported with detailed Biology and Ecology information. Since 2002, the
**Weed Identification Guide in WEEDpak** has been upgraded to 100 weeds, all
supported with biology and ecology information.

This project has doubled this section to 200 weeds and updated the existing
information where necessary. These new weeds are a combination of weeds commonly
found in cotton, weeds found in the cotton farming system, and weeds found in the
areas surrounding cotton.

**Obj. 1.2: Outcome**

The weed identification section of **WEEDpak** has been doubled to 200 weeds, with
full ecology and biology information for each of the new weeds, and many of the
existing identification pages were also updated. The major thrust has been in the
grasses, increasing this section from 8 grasses to 43 grasses, and with the inclusion of
some water weeds.

**Obj. 1.2: Output**

The material for **WEEDpak** ID Guide has also been migrated to a data base (thanks to
David Larsen) and a new seedling identification key has been introduced.

The following weeds have been added to **WEEDpak** and are available on the Web:

<table>
<thead>
<tr>
<th>Common name</th>
<th>Botanical name</th>
<th>Common name</th>
<th>Botanical name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td><strong>Grasses</strong></td>
<td></td>
</tr>
<tr>
<td>African lovegrass</td>
<td><em>Eragrostis curvula</em></td>
<td>Paspalum</td>
<td><em>Paspalum dilatatum</em></td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td><em>Lolium rigidum</em></td>
<td>Purple wire-grass</td>
<td><em>Aristida personata</em></td>
</tr>
<tr>
<td>Bahia grass</td>
<td><em>Paspalum notatum</em></td>
<td>Queensland blugrass</td>
<td>* Dichanthium sericeum ss.</td>
</tr>
<tr>
<td>Barbed-wire grass</td>
<td><em>Cymbopogon refractus</em></td>
<td></td>
<td>* sericeum*</td>
</tr>
<tr>
<td>Barley grass</td>
<td><em>Hordeum leporinum</em></td>
<td>Red Natal grass</td>
<td><em>Melinis repens</em></td>
</tr>
<tr>
<td>Barnyard grass</td>
<td><em>Echinochloa crus-galli</em></td>
<td>Rhodes grass</td>
<td><em>Chloris gayana</em></td>
</tr>
<tr>
<td>Blowgrass</td>
<td><em>Lachnagrostis filiformis</em></td>
<td>Rigid panic</td>
<td><em>Walhalleya prolata</em></td>
</tr>
<tr>
<td>Buffel grass</td>
<td><em>Lachnagrostis filiformis</em></td>
<td>Ringed wallaby grass</td>
<td><em>Austrodanthonia caespitosa</em></td>
</tr>
<tr>
<td>Coolati grass</td>
<td><em>Hyparrhenia hirta</em></td>
<td>Shatter cane</td>
<td><em>Sorghum bicolor ss. x</em></td>
</tr>
<tr>
<td>Cotton panic grass</td>
<td></td>
<td></td>
<td><em>almum</em></td>
</tr>
<tr>
<td>Couch</td>
<td><em>Digitaria brownii</em></td>
<td>Slender bamboo grass</td>
<td><em>Austrostipa verticillata</em></td>
</tr>
<tr>
<td>Creeping bluegrass</td>
<td><em>Digitaria sanguinalis</em></td>
<td>Spiny burrgrass</td>
<td><em>Cenchrus incertus</em></td>
</tr>
<tr>
<td>Drooping lovegrass</td>
<td><em>Bothriochloa insculpta</em></td>
<td>Spring grass</td>
<td><em>Eriochloa procrea</em></td>
</tr>
<tr>
<td>Feathertop Rhodes grass</td>
<td><em>Eragrostis leptocarpa</em></td>
<td>Sugarcane</td>
<td><em>Saccharum officinarum</em></td>
</tr>
<tr>
<td>Handsome lovegrass</td>
<td><em>Chloris virgata</em></td>
<td>Tall cupgrass</td>
<td><em>Eriochloa crebra</em></td>
</tr>
<tr>
<td>Japanese millet</td>
<td><em>Eragrostis speciosa</em></td>
<td>Two row barley</td>
<td><em>Hordeum distichon</em></td>
</tr>
<tr>
<td>Ludo wild oat</td>
<td><em>Echinochloa esculenta</em></td>
<td>Warrego summer grass</td>
<td><em>Paspalidium jubiflorum</em></td>
</tr>
<tr>
<td>Native oatgrass</td>
<td><em>Avena ludoviciana</em></td>
<td>Western rat's tail grass</td>
<td><em>Sporobolus creber</em></td>
</tr>
<tr>
<td>Oat</td>
<td><em>Themeda avenacea</em></td>
<td>Wild oat</td>
<td><em>Avena fatua</em></td>
</tr>
<tr>
<td></td>
<td><em>Avena sativa</em></td>
<td>Windmill grass</td>
<td><em>Chloris truncata</em></td>
</tr>
</tbody>
</table>
This section is presented in full in Appendix 1.2a and 1.2b.

**Obj. 1.2: Conclusion**

It must be noted that this portion of the project required far more input than was anticipated. Each weed was grown in the glasshouse, with measurements and photographs taken regularly over time. (On many occasions the weeds failed to germinate from the collected seed, or seedlings died and the process had to be restarted). Once the adult stage was completed, the plant was then identified to species level and the identification material compiled. This process took around 2 days per plant, with the full 100 plants requiring nearly 12 months, 1/3rd of the project’s life.

**Obj. 1.3: Update and expand the Weed Growth and Development Guide**

**Obj. 1.3: Background**

The *WEED Growth and Development Guide* was added to *WEEDpak* in 2009, providing the best available information to growers on the details of expected growth rates of many of the major weeds of the cotton industry.
This data was compiled from work undertaken primarily by Dr. Stephen Johnson and myself over a number of years. However, much of this work was undertaken in the glasshouse and may underestimate the potential growth rate of some weeds.

The aim of this section was to collaborate with a PhD student, accessed via UNE, who would collect field data for as many of the major weeds as possible.

**Obj. 1.3: Outcome**

Unfortunately, UNE was unable to procure a student for this work and, after consultation with Tracey Leven for CRDC, this part of the project was dropped.

**Obj. 1.4: Provide material for and facilitate the development of a Weed ID App.**

**Obj. 1.4: Background**

The **WEED Identification Guide** in **WEEDpak** was the most heavily used section of the Cotton CRC website, and is likely to be even more important now that it has grown to 200 weeds. However, the bigger it gets, the more difficult it is to rapidly find unknown weeds.

Some years ago the idea of a WEEDS ID APP was launched but did not come to fruition. However, there is ongoing interest in the development of an APP and it has been an aim of the work undertaken in the current project to ensure that identification material can be made available to the developers of an APP.

**Obj. 1.4: Outcome**

The first month of this project was invested in ensuring that all the photographic material that had been collected over many years was scanned and catalogued so that it could be made available for the developers of a WEED ID APP. However, to date there has been no request for the use of any of this material.

**Obj. 1.4: Output**

Identification material from this work was provided to the Sydney Herbarium for their use during the project’s life, and small numbers of images have also been made available to other individuals on request.

**Obj. 2.1: Add a further 12 herbicides to the Herbicide Damage Information Guide**

**Obj. 2.1: Background**

The **Herbicide Damage Information Guide** has been an evolving document, first added to **WEEDpak** in 2006, enabling growers to identify the likely culprit herbicide/s when crop damage has occurred and also enabling them to estimate the likely extent of damage and develop an appropriate post-damage management strategy.

This work initially only covered 2,4-D and glyphosate, but was expanded over time to cover much of the extensive range of herbicides likely to be encountered in the cotton farming system, with new herbicides added over time as issues were observed or these herbicides came to be more commonly used in the system.

By the start of the project, 18 herbicides had been included in the **Herbicide Damage Information Guide**, available on the internet. These were:
**J3. Herbicide Damage Information by date**

| J3.24. 2,4-D | Group I | 2005/6 |
| J3.40. Glyphosate | Group M | 2005/6 |
| J3.35. 2,4-D & glyphosate | Groups I & M | 2005/6 |
| J3.27. Fluroxypyr (Starane) | Group I | 2007/8 |
| J3.28. MCPA | Group I | 2007/8 |
| J3.41. Glufosinate (Liberty) | Group N | 2007/8 |
| J3.17. Simazine | Group C | 2008/9 |
| J3.30. 2,4-D & picloram (Tordon 75D) | Group I | 2008/9 |
| J3.32. MCPA & picloram (Tordon 242) | Group I | 2008/9 |
| J3.34. Triclopyr & picloram (Grazon) | Group I | 2008/9 |
| J3.1. Chlorsulfuron (Glean) | Group B | 2010/1 |
| J3.4. Imazapic (Flame) | Group B | 2010/1 |
| J3.9. Metsulfuron (Ally) | Group B | 2010/1 |
| J3.23. Isoxaflutole (Balance) | Group H | 2010/1 |

Note. The prefix “J3.*” refers to each section’s placement in the combined document.

**Obj. 2.1: Output**

Over the life of the project, a further 17 herbicides were added to the Herbicide Damage Information Guide (the 2011/2 information sheets were developed as part of this project as the HVI data was not available until 2013), with additional work also undertaken on the effects of residual 2,4-D after areas of residual damage were noted on a number of properties in the 2012/3 season. These herbicides were:

<table>
<thead>
<tr>
<th>J3. Herbicide Damage Information</th>
<th>Appendix</th>
</tr>
</thead>
<tbody>
<tr>
<td>J3.2. Iodosulfuron plus mefenpyr diethyl (Hussar)</td>
<td>Group B 2.1a</td>
</tr>
<tr>
<td>J3.6. Imazamox &amp; imazapyr (Intervix)</td>
<td>Group B 2.1a</td>
</tr>
<tr>
<td>J3.8. Imazethapyr (Spinnaker)</td>
<td>Group B 2.1b</td>
</tr>
<tr>
<td>J3.25. Clopyralid (Lontrel)</td>
<td>Group I 2.1b</td>
</tr>
<tr>
<td>J3.31. Aminopyralid plus fluroxypyr (Hotshot)</td>
<td>Group I 2.1c</td>
</tr>
<tr>
<td>J3.42. Amitrole &amp; ammonium thiocynate (Amitrol T)</td>
<td>Group Q 2.1c</td>
</tr>
<tr>
<td>J3.3. Imazamox (Raptor)</td>
<td>Group B 2.1d</td>
</tr>
<tr>
<td>J3.37. Pyroxsulfone (Sakura)</td>
<td>Group K 2.1d</td>
</tr>
<tr>
<td>J3.11. Tribenuron-methyl (Express)</td>
<td>Group B 2.1e</td>
</tr>
<tr>
<td>J3.21. Flumioxazin (Valor)</td>
<td>Group G 2.1f</td>
</tr>
<tr>
<td>J3.33. Picloram</td>
<td>Group I 2.1g</td>
</tr>
<tr>
<td>J3.24. 2,4-D (residues)</td>
<td>Group I 2.1g</td>
</tr>
<tr>
<td>J3.5. Imazapyr (Arsenal)</td>
<td>Group B 2.1h</td>
</tr>
<tr>
<td>J3.7. Imazapic &amp; imazapyr (Midas)</td>
<td>Group B 2.1h</td>
</tr>
<tr>
<td>J3.10. Pyroxsulam (Crusader)</td>
<td>Group B 2.1h</td>
</tr>
<tr>
<td>J3.18. Bromoxynil &amp; pyrasulfotole (Velocity)</td>
<td>Groups C &amp; H 2.1h</td>
</tr>
<tr>
<td>J3.22. Saflufenacil (Sharpen)</td>
<td>Group G 2.1h</td>
</tr>
<tr>
<td>J3.39. Amitrole &amp; paraquat (Alliance)</td>
<td>Groups L &amp; Q 2.1h</td>
</tr>
</tbody>
</table>
The material for this section is available on the internet and presented in full in Appendix 2.1a – 2.1h. (Sorry, but I was forced to split these documents this way as the combined WORD versions of these combined documents are too large for my computer). Also, please note that the information in Appendix 2.1h has not been added to the web site as it was completed after David Larsen finished up. This information will need to be uploaded by the CRDC team, thanks.

Photo 1. Cotton plants severely damaged from a 50% rate of Arsenal herbicide applied at 8 nodes of crop growth.

**Obj. 2.1: Conclusion**

While still a handful of intended herbicides remains unscreened, this document now contains nearly all the priority herbicides, although the results are only for one site/one season. A valuable compromise for the future may be to screen all of these herbicides and rates a second time, but only recording the yield data for those herbicides where no issues were observed, reducing the work load for these herbicides by 90%. This approach would allow a large number of herbicides to be compared over a single season, bring much greater confidence where the season’s results are consistent, and indicate where further work should be focused when the 2nd season’s results are not consistent.

**Obj. 3.1: Analyse data sets for the weed control threshold**

**Obj. 3.1: Background**

The development of a weed control threshold for cotton was the brain-child of Dr. Ian Taylor, who initiated the work in 2002, undertaking field experiments to collect data for the application of an approach known as the Critical Period for Weed Control.

I took over this work when Dr. Taylor left ACRI and have now generated a vast bulk of data relating cotton yield loss to competition from a known range of weeds and weed pressure, culminating in the release of a threshold to the industry in 2008.
**Obj. 3.1: Outcome**

Approximately 6 months of this project has been spent on integrating much of the data from this work. Again, this has proven to be a much bigger challenge than was anticipated. Nevertheless, the work has led to Mr. Charles enrolling in a PhD through UNE, and this PhD is the focus of his current (2015 – 2018) project supported by CRDC.

The PhD supervisors are Ass. Prof. Brian Sindel from UNE and Dr. Annette Cowie, a Principle Research Scientist with NSW DPI, based at UNE.

The PhD will be by publications, with the aim to publish 4 papers from this work and compile these into a PhD. The detailed results from this work will be presented to CRDC over the life of the 2015-2018 project.

![Photo 2. Weed competition plots using natural weed populations for GreenSeeker assessment on 30 Dec 2014.](image)

**Obj. 4.1: Undertake glasshouse and field studies on desert cowvine, scurvy weed, pigeon peas and volunteer cotton**

**Obj. 4.1c: Background – desert cowvine**

Desert cowvine first came to my attention when I noticed plants in a field at Dirranbandi adjacent to a field I was using for an cowvine and bellvine experiment. The plants were present in a well managed cotton field and appeared unaffected by the herbicides used in the field. After pointing this out, plants were noticed in a number of other fields.

I had also observed this weed growing prolifically at a pump site at Emerald.

More recently, I was shown a field nearer Moree where desert cowvine was growing in a steadily increasing patch and again appeared to be reasonably tolerant of the herbicides used.

Very little is known about this Australian native, so I undertook to do some basic glasshouse work on this weed using the standard herbicides normally used in cotton.
Obj. 4.1c: Outcome – desert cowvine

This experiment proved to be quite challenging as the seed collected in the field had low viability, desert cowvine has little or no apparent hard-seededness, but also is finicky to germinate, and the plant is very susceptible to the mites and white fly that are often so problematic in a glasshouse. Nevertheless, some good results were obtained, and parts of the experiment were repeated when apparently anomalous results were observed.

Desert cowvine proved to be reasonably difficult to kill, especially at the cotyledon stage. Full rates of prometryn and prometryn+fluometuron gave the best results. A full rate of diuron or Envoke also gave very good results, with only 1 of 20 or more plants surviving in these treatments.

Disappointingly, both glyphosate and dicamba gave very poor control of this weed, with a full rate of glufosinate also giving poor control.

The treatments and results for this work are presented in Appendix 4.1c.

Obj. 4.1c: Output

This work will be written up in WEEDpak and a CottonGrower article in the next few weeks.

Obj. 4.1s: Background – scurvy weed

Scurvy weed has been another native weed that has become problematic for some cotton growers and for which no successful control treatments have been identified.

Obj. 4.1s: Outcome – scurvy weed

Scurvy weed proved to be extremely difficult to propagate under glasshouse conditions in sufficient quantity to allow a replicated experiment with herbicides to be applied.

Given the difficulties encountered, this objective was replaced by adding a 2nd season to each of the pigeon pea and volunteer cotton experiments.
Obj. 4.1p: Background – pigeon peas

Over the years there have been an increasing number of growers expressing frustration regarding difficulties in controlling weeds in pigeon pea refuges. Consequently, two experiments were conducted in 2012/13 to examine the potential of some alternative herbicides to control weeds in pigeon peas.

Obj. 4.1p: Outcome – pigeon peas – 2012/3

The treatments, design and results for this work are presented in Appendix 4.1p – 12-3.

1st experiment

The 1st experiment was laid down on a very weedy site and the first planting of pigeon peas failed to emerge satisfactorily. The second planting, on 29th November 2012 resulted in a good stand of pigeon peas, but was under strong weed pressure, especially from bellvine and awnless barnyard grass.

Terbyne, Spinnaker and Sencor at 1/2X, 1X and 2X rates were applied over-the-top of the pigeon peas 25 days after emergence, but only Spinnaker at the highest rate achieved an acceptable level of weed control (Photo 1), with the worst treatments swamped by weeds (Photo 2). Terbyne was noticeably ineffective in controlling awnless barnyard grass and the Terbyne plots were dominated by this weed.

![Photo 1. Spinnaker at 280 g/ha 33 days after treatment.](image-url)
2nd experiment

Although the results of the 1st experiment were disappointing, a 2nd experiment was established at the site to compare a couple of additional herbicides, prometryn and Envoke. The 1/2X rates were dropped from the design as the weeds had gained in size by this stage.

Sencor at 940 g/ha, Prometryn at 5 kg/ha and Envoke at 30 g/ha all gave surprisingly good control of these large weeds and caused minimal damage to the pigeon peas. Envoke had not been used on pigeon peas previously and caused some yellowing, but also gave good post-emergent weed control. Prometryn had been used in previous experiments, but at this very high rate gave surprisingly good control of large, established weeds. Sencor gave poor results in previous experiments, but excellent control in this experiment, with no obvious reason for this discrepancy.
Obj. 4.1p: 2012/13 - Conclusion

These experiments demonstrate that large weeds can be controlled with herbicides in pigeon peas without causing unacceptable damage to the crop. Further work needs to explore the potential for using a directed spray to control weeds with minimal crop damage.

Obj. 4.1p: Outcome – pigeon peas – 2013/4

The treatments, design and results for this work are presented in Appendix 4.1p – 13-4. The experiment was laid down in Field A1 at ACRI, a long-term cotton field, with bladder ketmia the only weed present at moderate to high density. The pigeon peas were planted into moisture on 15\textsuperscript{th} October 2013, resulted in a reasonable, but patchy stand, and the post-emergent sprays were applied on 30\textsuperscript{th} November and 18\textsuperscript{th} January.

Of the herbicides applied prior to planting, only Terbyne at 2 kg/ha caused observable damage to the pigeon pea seedlings and significantly reduced the plant stand (Table 1). The heavy rates of Terbyne, Envoke and Roundup Ready Herbicide also caused some damage to seedlings and seedling mortality when applied over-the-top 5 weeks post-emergence (Table 2). The heavy rate of Staple and the lighter rates of Prometryn and Envoke caused significant damage but didn’t reduce the plant stand.

The herbicides were applied both as an over-the-top and directed sprays 12 weeks after emergence, and all treatments were assessed for crop damage, flowering and weed control (Table 3).

By 104 days post-emergence, significant visual symptoms of damage were only apparent on the heavy rate of Envoke applied at 5 weeks and the over-the-top application of Envoke at 12 weeks. No damage was apparent where the Envoke was applied as a directed spray.
Photo 5. Envoke at 30 kg/ha 12 days after spraying and 47 days after crop emergence. The spray caused significant damage to the pigeon peas, but didn’t cause mortality. No damage remained evident 104 days after emergence.

Most plants had around 80% flowering by this time, with the flowering% only lower on the heavy rates of Envoke and Roundup Ready Herbicide applied at 5 weeks.

Treatments varied greatly in their ability to control the bladder ketmia present in this experiment, with the treatments applied to large weeds 12 weeks after emergence generally far less effective than the treatments applied to the smaller weeds earlier in the season (no surprise there).

Of the treatments applied prior to planting, Terbyne at 2 kg/ha and Staple at 120 g/ha gave the best control. Terbyne and Staple also gave the best level of control when applied 5 weeks post-emergence.

None of the herbicides gave good control when applied to these large weeds 12 weeks post-emergence, but the levels of crop safety recorded suggest that a number of these options could be used to control smaller weeds at this advanced stage of crop growth without adversely affecting the crop.

**Obj. 4.1p: Output**

These experiments demonstrate that there are a number of potential options available to control weeds with herbicides pre-and post-emergence in pigeon peas without causing unacceptable damage to the crop. This work will be written up in WEEDpak and a CottonGrower article in the next few weeks.

**Obj. 4.1v: Background – volunteer cotton**

Managing volunteer cotton plants has always been an issue for the cotton industry, but has become more problematic over time with the introduction of cotton varieties that are tolerant to herbicides and heliothys, and are increasingly well adapted to the environment.

Volunteer cotton emerges everywhere that cotton seed and cotton trash end up, with problems most commonly in fields and tail drains, on roads and road sides and in
irrigation channels. These plants are problematic for a range of reasons, including that that can harbour pests and diseases and contaminate following crops.

There is a limited range of herbicides registered for controlling volunteer cotton, with most herbicides only applicable to plants up to the 5-node stage of growth. A selection of the more likely candidates from this group were used in this experiment.

This work is intended to look at what options (if any) may be available to control larger volunteer plants. Permits or registration will be needed to allow the use of any of the options presented in this work.

**Obj. 4.1v: Outcome – volunteer cotton – 2012/3**

The experiment was designed to use a double-knock at 7 and 21 days. However, on each occasion the later part of the double-knock was delayed by irrigation and/or rainfall and didn’t occur until 28 – 36 days after the initial application. This issue of timing is an inherent difficulty with the double-knock strategy.

The treatments, design and results for this work are presented in **Appendix 4.1v – 12-3.**

**8-nodes**

Good control of the 8-node plants was achieved with the Spray.Seed combinations, with up to 93% of the plants killed (Table 1). Inferior levels of control were achieved with the alternative herbicides, even when these were followed by a double-knock with Spray.Seed.

The reason for the poor levels of control with the double-knock is inherent in this approach where desiccating herbicides are used. The initial application was made to vigorously growing plants with relatively large leaf areas for herbicide contact. However, the follow-up applications occurred to plants that had lost much or all of their leaf area, though they may have had a small amount of regrowth. Nevertheless the plants were stressed and had very little leaf area to take up the 2nd herbicide. Hence, the 2nd application was largely ineffective, except in the case where the 1st application was ineffective, and in this situation, the 2nd application is being made to a plant that is now larger (and more difficult to kill) than was initially the case.

However, although some treatments were relatively ineffective in killing cotton, they did defoliate the plants, delaying their regrowth and greatly reducing their size later in the season compared to the undamaged plants. There may be situations (such as crop stubbles) where it is not essential that the volunteer cotton plants be killed (as they will be removed by cultivation later in the season), but that they need to be defoliated (eliminating them as a refuge for insects) and prevented from setting seed (removing this issue in the next crop). Consequently, some of the treatments which did not give a high level of kill, may still be of value if they sufficiently delayed plant growth. To test this, the better treatments from the experiment were retained through to picking and subsequent yields recorded 147 and 227 days after the initial treatment, with the 2nd pick giving an indication of the delay in boll maturity on these treatments.

Lint yield was reduced by around 90% on the best treatments, in line with the percentage kill on these treatments (Table 2). Disappointingly, the treatments that gave a poorer level of control, also failed to reduce boll production (as indicated by lint yield) sufficiently to be of value.
Photo 5. Spray.Seed double-knock 9 days apart, 23 days after the initial spray.

Photo 6. Spray.Seed double-knock 28 days apart, 91 days after the initial spray.

**16-nodes**

Good control of the 16-node plants was again achieved with the Spray.Seed combination of the double-knock at 29 days, with up to 91% of the plants killed (Table 3). Inferior levels of control were achieved with the all other alternative herbicides and combination applied to these larger plants.

Lint yield was reduced by around 99% on the best treatment, showing that the few plants that did survive this treatment were severely damaged and unable to compensate (Table 4).

The poor result with the Spray.Seed double-knock 9 days apart was not surprising, as the plants were almost completely desiccated at this time, with no green leaves present to
take up the 2nd application. However, these plants were also severely damaged, with no open bolls at picking, and 93% less lint in July at the 2nd pick.

24-nodes

At the time of the 24-node application, a large number of relatively undamaged plots remained from the 8-node applications, allowing the experiment to be expanded at this point to take a closer look at the Spray.Seed double-knock options. Also, a change was made in the application approach, in the hope that the value of the Spray.Seed application could be improved on these much larger plants.

Both paraquat and diquat, the active ingredients in Spray.Seed require sunlight to activate, and when applied in full daylight, activate almost instantly, immediately desiccating exposed leaves but preventing any translocation of the herbicides in the plant, as the plant material is killed before the herbicide can be translocated. When Spray.Seed is applied at night, there is little herbicidal activity until the following day. This means that the herbicide can be translocated throughout the plant, but also allows dilution of the herbicide and some break-down to occur.

Night applications of Spray.Seed improve the level of control with some plants and it was decided to attempt this use pattern for these large cotton plants. Night application also allows for the possibility of tank mixing Spray.Seed with another product, where the 2nd product can translocate and be effective before the Spray.Seed activates. Normally a tank-mix with Spray.Seed is pointless, as the Spray.Seed desiccates the leaves before the 2nd herbicide can have any effect. Tank mixes were not added in this experiment, but were included in the following experiment in 2014/15 where all applications were made at night.

The potential for night applications of paraquat is discussed in the following article, for example: http://paraquat.com/news-and-features/archives/paraquats-evening-performance

The Spray.Seed applications were expanded to include double-knocks at 3, 5 and 7 days, but unfortunately again the 21 day spray was challenged by rain and delayed till 37 days following a storm and major deluge.

The double knock options used improved control from only 31% from a single application of Spray.Seed to 93% control with a double knock at 7 days (Table 5), a surprisingly good result considering the size of the target plants. Interestingly, a triple knock at 1, 3 and 5 days didn’t improve control, giving 90% kill, suggesting the interval needs to be 7 days or more, but an alternative strategy where both knocks occurred together (doubling the rate) gave the best result of 95% control.

The remaining herbicides and combinations gave much lower levels of control, although nearly all damaged the cotton plants, reducing lint yield (Table 6). The single application of Spray.Seed, for example, only killed 31% of plants, but reduced the lint yield (at the 1st pick) by 87%.
Obj. 4.1v: 2012/13 - Conclusion

With the exception of Spray.Seed, the herbicides used in the experiment did not give acceptable levels of control of large cotton plants, even when followed with Spray.Seed as a double-knock.

Some of the Spray.Seed combinations gave very good control of large cotton plants, especially when applied at night, showing that there is potential to manage these plants with herbicides.

Further work should concentrate on these larger plants, night applications and potential tank-mixes with a larger range of herbicides, to ensure that valuable herbicides have not been missed.

Obj. 4.1v: Outcome – volunteer cotton – 2013/4

A wider range of candidate herbicides for controlling volunteer cotton were applied to 12 node and 24 node irrigated cotton plants. These herbicides were:

- **Alliance**: 4 L/ha
- **Baton (2,4-D amine)**: 1.25 kg/ha
- **Basta**: 3.75 L/ha
- **Bromicide 200**: 1.5 L/ha
- **Garlon**: 160 ml/ha
- **Hammer**: 100 ml/ha
- **Sharpen**: 26 g/ha
- **Spray.Seed 250**: 3.2 L/ha
- **Starane**: 1 L/ha
- **Tordon 75D**: 1 L/ha
- **Valor**: 45 g/h
- **Valor (high rate)**: 300 g/ha

The herbicides were applied alone and in combination, generally with Spray.Seed in a tank-mix or as a double-knock, with the double-knock 11 and 13 days after the initial application (12- and 24-node applications respectively). All applications were made after
sundown in the evening to allow the maximum opportunity for the Spray.Seed to translocate, but due to the size and complexity of the experiment, some treatments occurred hours before others, giving some much longer opportunity for translocation.

Unfortunately the results were variable (leading to large LSD values), at least partly due to the issue of night spraying, although strong trends were obvious. Unfortunately, also, the 2nd application of Spray.Seed was not included as an alone treatment, reducing the comparisons that can be made.

Nevertheless, some valuable findings resulted.

12-nodes

Excellent levels of control were achieved with many of the herbicide combinations applied to 12-node cotton, although with all but one case, the high level of control was achieved in combinations that included Spray.Seed, the herbicides giving much poorer control when not in a double-knock with Spray.Seed.

It is clear that Spray.Seed is doing most of the work in all the treatments, with Tordon 75D the only alone treatment that achieved a high level of control. Bromoxynil, Basta, Baton, Garlon, Hammer, Sharpen and Valor achieved no appreciable control when not in combination with Spray.Seed. Interestingly, a double-knock with Spray.Seed didn’t in any case give superior results to applying the herbicide as a tank-mix with Spray.Seed, even in the case of Hammer, where the results suggest antagonism between Spray.Seed and Hammer in the tank-mix (the tank-mix gave significantly poorer control than Spray.Seed alone). Hammer as a tank-mix with Spray.Seed still gave better control than Hammer alone or Hammer followed by a double-knock of Spray.Seed.

Photo 8. Starane double-knocked with Spray.Seed 11 days apart, 22 days after the initial spray.
24-nodes

Some additional combinations were included in the 24-node application, with some herbicides double-knocked by themselves rather than using Spray.Seed as the double-knock partner, with surprising results.

The outstanding new treatments were Baton double-knocked with Baton, and Starane double-knocked with Starane, both giving 100% control of large cotton plants. Tordon 75D double-knocked with Tordon 75D was not included in the experiment, but bares future examination.

Excellent levels of control were achieved with Baton, Starane, Tordon 75D, Garlon, Sharpen and Spray.Seed combinations, but again the Spray.Seed appeared to be doing most of the work. Also again, a double-knock with Spray.Seed didn’t in any case give superior results to applying the herbicide as a tank-mix with Spray.Seed (when applied at night).

No combinations including Basta, Hammer or Valor at the high rate gave high levels of control of these large cotton plants, indicating some antagonism of these products with Spray.Seed.

Photo 9. Baton double-knocked with Baton 13 days apart, 35 days after the initial spray. This combination gave a much slower kill than some of the contact herbicides, but there were no surviving plants on this plot of 12 m by 8 rows 121 days after treatment.

Obj. 4.1v: Output – volunteer cotton – 2013/4

This additional work on volunteer cotton will be added to WEEDpak Section F4.1, and written up in a CottonGrower article in the next few weeks.

Obj. 4.1v: Conclusion

Control of large volunteer cotton plants is achievable with registered rates of a range of products and the option of registration or permits for this use should be explored. However, before this occurs, the current work needs to be repeated, hopefully reducing the variability of the results, with cotton in both irrigated and stressed situations to
determine the best combinations to pursue. The observation that double-knocking with Spray.Seed is not giving an advantage over a tank-mix with Spray.Seed also needs exploring, although this may only be the case with night spraying. However, the saving in time and application cost makes this option attractive when compared to the traditional double-knock approach.

**Obj. 5.1: Monitor weeds in cotton in the Burdekin and MIA areas**

**Obj. 5.1: Background**

The Roundup Ready crop management plan is a central component of the herbicide resistance management plan for cotton. The plan has been developed through the TIMS process with input from scientists and industry and has been supported with a series of independent weed surveys over time undertaken by the weed scientists. These surveys covered the traditional cotton area from Emerald to the Macquarie.

However, when cotton was to be commercially grown in the Burdekin, the Weeds Technical Panel of the TIMS committee was asked to judge the appropriateness or otherwise of the southern Roundup Ready Flex Crop Management Plan for this northern cotton with very little data on the expected weed pressure or weed spectrum of this area. Consequently, to assist the TIMS committee, Mr. Charles undertook a series of surveys of the Burdekin cotton commencing in 2008. The data from these annual surveys was considered by the Weeds Technical Panel as an on-going review of the Crop Management Plan for growing Roundup Ready Flex cotton varieties in Northern Queensland.

With the increasing spread of cotton to the south, it was decided that a similar approach should be used in the south, with annual surveys established in the Griffith, Hay and Hillston areas.

**Obj. 5.1: Outcome**

No commercial cotton was grown in the Burdekin during the life of this project due to a range of factors including declining cotton prices and increasing sugar prices. Consequently, no weed surveys were undertaken in the Burdekin during this project.

Surveys were undertaken in the Griffith area in 2013, and the Griffith, Hillston and Hay areas in 2014 and 2015.

As was found with the Burdekin surveys, the weed spectrum and pressure in the southern cotton was not hugely different to the weed issues in the more traditional areas. However, there were a few notable differences, with many ‘winter weed’ species flourishing in mid-summer in the south. The levels of weed pressure observed in the surveys ranged from low to high, but were generally higher than was expected and a number of suspected glyphosate resistant plants were found in the Griffith and Hillston areas.

The presence of glyphosate resistant weeds in the southern cotton had not previously been reported (although this reporting is required under the Crop Management plan). A large number of glyphosate resistant annual ryegrass plants were observed in cotton on a property at Griffith in 2013 (also 2014 & 2015 on this property), and resistant windmill grass was noted in 2014 at Hillston (only a single plant in cotton). By 2015, resistant windmill grass was common in the tail drain of this Hillston property, as well as resistant fleabane, and several plants of what appeared to be resistant awnless barnyard grass. By 2015, a 2nd Hillston property appeared to have resistant sowthistle and a 2nd, unidentified grass.
While this proliferation of apparently resistant weeds is very concerning, it will be important to monitor these weeds over time and it is also essential that monitoring be undertaken in the more central cotton areas to provide context to these observations and determine if these observations are unusual (indicating a problem in the southern industry) or simply noting the rapid spread of glyphosate resistance in the farming system.

The results of these surveys were presented to CRDC and the Weeds Technical Panel of the TIMS committee and are presented in Appendix 5.1a – 5.1c.

Outcomes

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

Updating and expanding WEEDpak was the primary focus of this project and has been fully achieved. This has greatly increased the value and relevance of WEEDpak to the Australian cotton industry, making this information on weed management and herbicide damage readily available to the industry.

The need for this information has been increased by the increasing expansion of the industry into new (mostly southern) areas, and by the growing problem of glyphosate resistance, which is now starting to challenge components of the northern cropping system.

The outcomes from this project will assist Australian cotton growers by:

- Increasing the weed identification guide, enhancing grower’s and consultant’s ability to identify weeds at all growth stages, monitor species shift and emerging problems, and better make better informed decisions for weed management,
- Increasing the range of material on herbicide damage available to them to identify symptoms of herbicide damage, make appropriate post-damage decisions, and make appropriate management decisions to minimise future damage problems,
- Improving the science behind the current weed management threshold,
- Providing management information for desert cowvine,
- Increasing the options for managing weeds in pigeon peas,
- Increasing the options and knowledge for managing volunteer cotton, and

Assist the cotton industry by:

- Developing a benchmark set of data and knowledge of the weeds issues of the southern cotton industry.

6. Please describe any:-

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

none

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

none

c) required changes to the Intellectual Property register.

none

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?
The value of the update and expansion of WEEDpak is only limited by the willingness of individual cotton growers to take on this information and modify their systems before they encounter major problems.

Getting these messages out has been made easier by the increasing use of the internet, as the information from this project is readily found on the web.

Linking this information into MyBMP will be another important way to make the information easily available to cotton growers. However, the process to do this is beyond the scope of this project. Any assistance in ensuring this information is linked in MyBMP would be very valuable for this project.

**Extension Opportunities**

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

   The value of the update and expansion of WEEDpak is only limited by willingness of individual cotton growers to take on this information and modify their systems before they encounter major problems. It is very important that this project is supported by the cotton extension team and MyBMP team to ensure that:
   
   - The 2014/15 herbicide damage information is uploaded to the web,
   - The updated and expanded information in WEEDpak is linked in to MyBMP, and
   - The cotton extension team continues to promote the cotton paks, including WEEDpak. It is always surprising to come across growers who are unaware of the vast bulk of information available to them, but it seems to be becoming increasingly common as generations change and properties change hand.

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

   Further articles and updates to WEEDpak have been identified in this report. This outputs will occur in the next few weeks and be passed on to CRDC to ensure they can be included in WEEDpak on the web.

   (c) **for future research.**

   Further developing the weed competition work into a series of scientific papers and grower information has become a priority and is the focus of my 2015-2018 CRDC funded project.

   Beyond that, the work identified as Objective 1.3 in this project to update and expand the Weed Growth & Development Guide remains a high priority, especially to ensure that sound data is available for the glyphosate resistant and glyphosate tolerant weeds that are becoming increasingly problematic in the Australian cotton industry.

9. **A. List the publications arising from the research project and/or a publication plan.**

   (NB: Where possible, please provide a copy of any publication/s)


Note: all the documents for WEEDpak have been included in the Appendix sections 1 – 2.


Yet to be published


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

All the online information developed from this project in in WEEDpak on the web.
Part 4 – Final Report Executive Summary

Updating and expanding WEEDpak in support of the cotton industry and myBMP

This project builds on many years of weeds work supported by CRDC and adds value to the earlier work, providing strategic information to growers in support of MyBMP, based around updating WEEDpak.

WEEDpak, the guide to integrated weed management in cotton, was first released in 2002. It covers a wide range of weed issues, weed identification material, guidelines for developing an Integrated Weed Management (IWM) approach for cotton, and extensive research findings on the management of specific, hard to control weeds. WEEDpak has been progressively expanded and updated since 2002, but the work in the current project represents an incremental step in further expanding and updating WEEDpak.

The main outcomes and outputs from the project were:

- doubling the weed identification section of WEEDpak from 100 to 200 weeds, with emphasis on the grasses, increasing this subset from 8 to 43 grasses, and also adding some water weeds. All weeds include multiple images and information on weed ecology and biology,
- updating all the remaining original material in WEEDpak, bringing the document into the world of Roundup Ready Flex cotton, adding material to many sections, and removing two out-dated sections,
- adding a further 17 herbicides to the original 18 herbicides in the Herbicide Damage Information Guide in WEEDpak (one of the newer sections in WEEDpak), more than doubling the amount of herbicide damage information available to growers and including residual information for most new herbicides. Also, importantly, adding information on the issue of residues to the existing section on 2,4-D,
- adding management information for feathertop Rhodes grass,
- adding management information for desert cowvine,
- expanding options for weed control in pigeon peas,
- expanding options for controlling volunteer cotton, and
- developing a benchmark set of weed data and knowledge of the weeds issues of the southern cotton industry.

Adding this information to WEEDpak on the web makes the information widely available to cotton growers and others, and easily available (via the web). Uptake by the industry is expected to be rapid, with articles in the Australian CottonGrower highlighting the changes, and the new information only a click away.

All of the information from this project is available through WEEDpak on the web, with linkages through MyBMP and via COTTONpaks, though the cottoninfo team. Alternatively, this information is available from the author, at graham.charles@dpi.nsw.gov.au

The information developed in this project is especially important in the newly developing weed landscape, where both glyphosate resistant weeds and glyphosate tolerant weeds are challenging the farming system, especially in fallows in the northern farming system.

Correct weed identification, weed monitoring and maintaining an integrated approach to weed management will be essential to maintain the efficiency and competitiveness of the Australian cotton industry into the future. However, this must be achieved within a system that does not suffer from herbicide damage. The information from the current project is vital for achieving this long-term goal of managing weeds without suffering crop damage from either the weeds or the tools used to manage these weeds.