Australian Government
Cotton Research and Development Corporation

Cotton Catchment Communities CRC

FINAL REPORT 2006

Part 1 - Summary Details

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

CRDC Project Number: **DAN174C**
OR Cotton CRC Project Number:

Project Title: Expanding WEEDpak: developing integrated weed management packages for the cotton farming system

Project Commencement Date: 1 Jul 2003 **Project Completion Date:** 30 Jun 2006

CRDC Program: 3 – Crop Protection
OR CRC Program: - Please Select One -

Part 2 – Contact Details

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Part 3 – Final Report Guide (due 31 October 2006)

Background

1. Outline the background to the project.

The project DAN 174C was negotiated with CRDC and its focus was the result of discussions with growers, ACGRA and CRDC. It built on work established in earlier CRDC projects, and concentrated on providing support for **WEEDpak**, the Integrated Weed Management guide for cotton. Work commenced in Project DAN 171C in October 2002. This project ran for 9 months and was effectively wrapped into the new (current) project. It was agreed that the final report for project DAN 174C (this report) should cover the results from both projects. There were a number of components to the projects, supporting varying areas of WEEDpak. The background to these components follows.

WEEDpak: The first edition of **WEEDpak** was released at the 2002 ACGRA Australian Cotton Conference. This package was compiled by weed's researchers at ACRI with the support of extension and industry, and contains specific units on weed identification and an array of material on weed management, including information on the management of the problem weeds nutgrass, polymeria take-all and cowvine (peachvine). It was deemed essential that this package was supported and promoted to the cotton industry with extension and technical input. **WEEDpak** was not complete and needed additional weed identification units and material on a range of additional topics. Maintaining and upgrading **WEEDpak** was central to this funding application.

Problem weeds: A change in the weed spectrum has occurred in the cotton system over the last decade, as shown by surveys by Charles, Roberts and Taylor. A number of weeds that were of minor importance in the 80s are becoming comparatively more difficult to control as the cotton industry moves from a heavy cultivation and residual herbicide based system, to combinations of light cultivation (no soil inversion), permanent beds, stubble retention and Roundup Ready (Flex) cotton. Examples of weeds that are becoming more problematic are cowvine (peachvine), bladder ketmia, sowthistle, fleabane, dwarf amaranth and red pigweed. Primarily the changes in the weed spectrum have resulted from reduced use of heavy cultivation and greater reliance on glyphosate in all stages of the farming system. Increasing problems with cowvine and bladder ketmia are largely due to their tolerance to herbicides and particularly glyphosate. Sowthistle, fleabane, dwarf amaranth and red pigweed also have small seeds that are readily controlled by burial from cultivation, but are favoured by minimum tillage systems and tyned implements that do not invert the soil.

The development of management packages for these problem weeds was a major component of this project. The management of fleabane, bladder ketmia and sowthistle were covered by other projects.

Roundup Ready cotton: Observations and research had indicated that there were potential problems with the Roundup Ready product that could impact on its value in the cotton system. RR cotton volunteers were an increasing problem, RR cotton appeared to be more susceptible to damage from other herbicides than was conventional cotton, and there appeared to be a problem with RR cotton and nitrogen (being covered in Dr. Ian Taylor's project). Work was undertaken to asses the extent or otherwise of these problems.

Weed surveys: Surveys continued on the Warra farming systems experiment and growers' fields. This data provides information on seasonal and long-term changes in the weed spectrum in the cotton system and has greatly enhanced the value of the general weed surveys of Graham Charles, Grant Roberts and Ian Taylor.

Herbicide damage: This component was introduced into the final year of the project in response to large problems encountered by growers in previous seasons, and a dearth of reliable and relevant information.

Herbicide damage has been an ongoing issue for the Australian cotton industry for as long as herbicides have been used. Crop damage has been reported every season from herbicides applied to the crop, or to a preceding crop, and increasingly, to drift from a herbicide no directly applied to the crop, but applied to an adjacent field, or to a field that may be some kilometres away. This

damage is most commonly from 2,4-D and increasingly, from glyphosate, applied to a fallow, or to a glyphosate tolerant cotton crop. Damage has also occurred from glyphosate applied to the wrong field, or from poor application, especially with shielded sprayers.

The 2004/5 season saw a large number of problems with herbicide drift. The main questions asked by growers with herbicide damage were:

1. Which herbicide(s) caused the damage, and at what approximate rate(s)?
2. What damage will the herbicide(s) cause? Should the crop be terminated, or could it still achieve an acceptable yield?
3. What management inputs can be employed to best assist the crop to recover from the damage?

Components of this project addressed aspects of these issues.

Objectives

2. List the project objectives and the extent to which these have been achieved.

Objective	Achievement
Provide continuing extension and technical support to WEEDpak. Include additional weeds in the identification section and undertake targeted experiments to address strategic areas not adequately covered in WEEDpak. Continue to promote WEEDpak at grower meetings, field days etc.	**Fully achieved**
Examine the management of problem weeds of cotton to develop or improve management guidelines for these weeds. Weeds being assessed include peachvine, bellvine, David's spurge, dwarf amaranth and red pigweed. Work continues on nutgrass, lippia and polymeria takeall. Aspects to be studied include the susceptibility of the weeds to a range of herbicides and herbicide combinations, and the management of the weeds in cotton and the cotton farming system.	**Most components fully achieved**
Explore aspects of weed management in the Roundup Ready production system. Examine negative interactions between Roundup applications and residual herbicides.	**Fully achieved**
Continue monitoring the weed density and diversity on the CRC farming systems experiment at Warra and on farmers' fields throughout the industry, giving important data on changes in the weed spectrum over time.	**Fully achieved**
Develop and present herbicide damage information so as to assist growers to identify and manage herbicide damaged cotton crops.	**Fully achieved**

Methods

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

WEEDpak weed identification: Identification material was obtained using a combination of field collection and photographs, and pot grown seedlings. This combination ensured that early growth stages of weeds were correctly matched to the adult stages. Identification employed a range of published material, with herbarium assistance as required.

Research: The research components of this project were achieved using a combination of experiments conducted in field, glasshouse and controlled environment cabinets. All experiments were fully replicated, designed as either complete factorials or randomised complete blocks, with a minimum of 4 replicates.

Most field experiments on problem weeds were undertaken in commercial cotton crops on fields where the specific weeds were present in high numbers, with major experiments in commercial fields at Dirranbandi (cowvine) and Emerald, Theodore and Murgon (bellvine). Field plots were

generally 10-20 m long and 4 m wide. Soil cores were taken to assess the weed seed density in the soil seedbank. Herbicide treatments were applied using a 4 m wide hand-held boom, and incorporated by the grower as required. The effectiveness of the treatments was normally assessed by counting the number of surviving weeds on each treatment and comparing this with the weed population on untreated plots. Cotton yields were assessed on experiments conducted at the Australian Cotton Research Institure, Narrabri.

These experiments allowed a wide range of herbicide management systems to be assessed on weeds growing in commercial crops, giving a good understanding of how these treatments might perform in the real world. The weakness of this work is that it assumes that a uniform population of weeds is present on the trial area, and that no uncontrolled factors, such as the environment, have an influence on the results. Glasshouse studies were used to complement the field work to ensure the robustness of the results.

Glasshouse studies were able to be conducted during all seasons, allowing promising treatments from one season to be explored before the next season. These studies have the advantage that herbicide was applied to a known number of weed seeds or weeds of known age, in the absence of adverse environmental conditions, using a factorial experimental design where practical. This allows the robustness of herbicide treatments to be determined over a known range of weed size and age. These assessments have on occasions, been able to show that treatments which looked promising in the field were not as effective as they appeared.

Weed surveys: Surveys were conducted using fixed transects across the Warra CRC farming systems site and grower's commercial fields. The survey at the Warra CRC site was conducted by counting the numbers of each weed species present on each of five 50 m^2 survey areas, on three occasions throughout the year (approximately November, March and August). Growers fields were surveyed using two transects, each of ten 50 m^2 observation points across each field, with approximately four fields surveyed per farm. The transects were established from GPS points.

This system provides a practical method to follow in-field weed densities over a long period, providing valuable information on long-term changes in weed densities and changes in the weed spectrum.

Herbicide damage: This was assessed in the final year of the project using a large field experiment on the Research Station where Roundup Ready Herbicide, Baton (2,4-D amine) and a combination of the two herbicides were applied at known rates over the top of 6, 8, 12 and 16 node cotton. Herbicides were applied in 100 L water/ha using a 4-metre wide, hand-held boom. One metre of cotton plants was taken from each treatment at exposure and every 2 weeks following till harvest to assess the impact of the herbicides on crop growth and development. Plant height, dry weight, node number, leaf number, leaf area, square, flower and boll number and boll size was assessed on each occasion. Crop maturity and lint yield were also assessed at the end of the season. This in-crop assessment system was based on the technique successfully used by Dr. Mike Bange and others.

The experiment had 4 replicates and produced very detailed information on the crop response to each treatment. This information is now available on the CRC web site and will be on the next **COTTONpaks CD**.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

Objective 1. Provide continuing extension and technical support to WEEDpak. Include additional weeds in the identification section and undertake targeted experiments to address strategic areas not adequately covered in WEEDpak. Continue to promote WEEDpak at grower meetings, field days etc.

With the assistance of the extension team, and David Larsen in particular, **WEEDpak** has been promoted at the Australian Cotton Conferences, Cotton Trade Show, and many valley grower field days and meetings. Updates to **WEEDpak** have also been promoted in 3 articles in the Australian Cottongrower magazine and in Cotton Tales.

The **Weed Identification and Information Guide** has been expanded and updated. 53 new weed identification sets and 73 new information pages have been added, and the original sets have been improved and updated. The indexes have also been updated and additional weed seed identification indexes have been included. These updates are available on the CRC web site and in **COTTONpaks CD** v2.1.

Additional targeted experiments are covered under Objective 2.

Objective 2. Examine the management of problem weeds of cotton to develop or improve management guidelines for these weeds. Weeds being assessed include peachvine, bellvine, David's spurge, dwarf amaranth and red pigweed. Work continues on nutgrass, lippia and polymeria takeall. Aspects to be studied include the susceptibility of the weeds to a range of herbicides and herbicide combinations, and the management of the weeds in cotton and the cotton farming system.

Feedback from **WEEDpak** identified the need for additional experimental work particularly on bellvine, cowvine, nutgrass, polymeria takeall and vetch crops. Consequently, in line with Objective 1, work on these weeds was given priority over planned work on David's spurge, dwarf amaranth and red pigweed.

The priority of Objective 2 was further reduced following discussion with CRDC mid-way through the project's life. In response to major problems with herbicide drift experienced by the cotton industry, it was agreed that herbicide damage should become the focus of the final year of this project.

Results:

Bellvine: Seven replicated field experiments were conducted over the project's life, on growers' fields at Emerald, Theodore and Byee. These were supported by 19 glasshouse experiments, 4 of which are yet to be completed. The available results were compiled and published in "Ringing the bell on bellvine" in The Australian Cottongrower and in a new **WEEDpak** document "Managing bellvine in cotton", available on the CRC web site, **COTTONpaks CD** v2.1, and from the TRC and extension staff. Additional results from this work will be complied and published after the conclusion of the last experiment. The **WEEDpak** document and Cottongrower articles are attached in the appendix.

Cowvine: Three replicated field experiments were conducted over the project's life, on growers' fields at Moree and Dirranbandi. These were supported by 16 additional glasshouse experiments, 5 of which are yet to be completed. The results to date were compiled and published in an updated version of the **WEEDpak** document "Managing cowvine in cotton", available on the CRC web site, **COTTONpaks CD** v2.1, and from the TRC and extension staff. Additional results from this work will be compiled and published after the conclusion of the last experiment. The **WEEDpak** document is included in the appendix.

Nutgrass: One field experiment was completed at Narrabri, supported by 2 additional glasshouse and 2 controlled environment experiments, which are yet to be completed. These experiments examine the response of nutgrass to temperature and humidity and should target the optimal temperature and humidity conditions for glyphosate applications. Once completed, the results will be compiled and published in a scientific paper, the Australian Cottongrower, and an updated version of the **WEEDpak** document "Managing nutgrass in cotton".

Polymeria takeall: Additional replicated field experiments at Walgett and Collarenebri were supported by 4 new glasshouse experiments. These experiments clarified the value of 2,4-D for controlling polymeria in autumn and confirmed the results already published in **WEEDpak**. An updated version of the **WEEDpak** document "Managing polymeria (take-all) in cotton" containing this additional information will be published in the next few months.

Vetch: Four replicated field experiments were conducted at ACRI Narrabri to assess weed control and crop management for this rotation crop, for which no management information was available. The results were compiled and published in "Managing vetch in rotation crops" in The Australian Cottongrower, and in a new **WEEDpak** document "Managing weeds in vetch rotation crops", available on the CRC web site, **COTTONpaks CD** v2.1, and from the TRC

and extension staff. The **WEEDpak** document and Cottongrower articles are included in the appendix.

Dwarf amaranth: Three replicated field experiments and 2 glasshouse experiments were conducted on this weed, with 1 glasshouse experiment yet to be completed. The results showed that dwarf amaranth was most easily controlled using glyphosate, and consequently this weed should not be more problematic under a Roundup Ready system. The observed problems with this weed do not indicate a tolerance to glyphosate, but that dwarf amaranth is favoured by a reduced tillage system with reduced inputs of residual herbicides. These results will be complied and published after the conclusion of the last experiment.

Red pigweed: Four replicated field experiments and 2 glasshouse experiments were conducted on this weed, with 1 glasshouse experiment yet to be completed. The results showed that pigweed was easily controlled by most of the standard residual herbicides, but was very tolerant of glyphosate and the other post-emergence herbicides currently available (tolerance to Liberty was not tested). Consequently this weed is likely to become increasingly problematic under Roundup Ready and reduced residual herbicide systems. Where pigweed does become problematic it may become necessary to re-introduce some residual herbicides into the system. An additional experiment examining the efficacy of Liberty herbicide is planned and will commence in the next few weeks. The results from this work will be complied and published after the conclusion of the last experiment.

David's spurge: This weed proved very difficult to grow in the glasshouse. Little seed was initially available, and the seed has a very high level of dormancy, which has been difficult to break. Only 1 glasshouse and 1 field experiment were run on David's spurge, confirming the poor efficacy most herbicides have on this weed.

While some further work will be undertaken on David's spurge control, the management of this weed received lower priority than initially envisaged, as it was found to be reasonably manageable using glyphosate in Roundup Ready cotton, and should be well controlled in Roundup Ready Flex cotton crops.

Lippia: The results from earlier work were compiled and published in "Managing lippia in the cotton farming system" in the Australian Cottongrower, and in a new **WEEDpak** document "Managing lippia in the cotton farming system", available on the CRC web site, **COTTONpaks CD** v2.1, and from the TRC and extension staff. The **WEEDpak** document and Cottongrower articles are included in the appendix.

Caustic weed: The results from earlier work were compiled and published in a new **WEEDpak** document "Managing caustic weed in cotton", available on the CRC web site, **COTTONpaks CD** v2.1, and from the TRC and extension staff. This **WEEDpak** document is included in the appendix.

Mint weed: The results from earlier work were compiled and published in a new **WEEDpak** document "Managing mint weed in cotton", available on the CRC web site, **COTTONpaks CD** v2.1, and from the TRC and extension staff. This **WEEDpak** document is included in the appendix.

Umbrella sedge: A replicated field experiment and 2 glasshouse experiments were conducted on this weed which is becoming more problematic on irrigation channels. The results are being complied and will be published when the experiments are completed.

All results were analysed using the GENSTAT statistical package, with data analysed using Analysis of Variance, REML or regression routines as appropriate. Analyses were undertaken with the assistance of the departmental statisticians where required.

Objective 3. Explore aspects of weed management in the Roundup Ready production system. Examine negative interactions between Roundup applications and residual herbicides.

Replicated field experiments were established at ACRI in 2003/4 and 2004/5 examining possible interactions between glyphosate, other residual herbicides and water logging on Roundup

Ready Cotton. Neither experiment found any evidence of a problem with this technology. The experiments of Dr. Ian Taylor were also negative, and so this work was dropped.

Objective 4. Continue monitoring the weed density and diversity on the CRC farming systems experiment at Warra and on farmers' fields throughout the industry, giving important data on changes in the weed spectrum over time.

Surveys were undertaken as planned and produced valuable information which was presented and published in articles in the proceedings of the 3rd World Cotton Research Conference, the 14th Australian Weeds Conference and the 12th Australian Cotton Conference.

The results for the farming systems experiments have been compiled and were presented to the farming systems coordinator last year, but have not seen the light of day. The results will be revised with the inclusion of additional data and published in the next year.

Objective 5. Develop and present herbicide damage information so as to assist growers to identify and manage herbicide damaged cotton crops.

A large pilot experiment on herbicide damage was conducted at ACRI in the final season of this project. The experiment used detailed in-crop measurements to explore the effects of glyphosate, 2,4-D and a glyphosate/2,4-D combination on crop growth and development. The herbicides were applied at 2 rates to 6, 8, 12 & 16 node cotton.

The results of this experiment have shown the value of this approach. Preliminary results have been compiled and were presented in a "hands-on-research" session at the 13th Australian Cotton Conference, and in the **Herbicide Damage Guide** now in **WEEDpak** on the CRC web site. This information will also be available through the next **COTTONpaks CD** when it is released. The **WEEDpak** and hands-on-research documents are included in the appendix

This information has also been promoted by the CRC in the Australian Cottongrower, and is to be featured by CRDC in the near future.

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.

WEEDpak has been one of the most heavily used of the Cotton CRC web sites, as well as being accessed in hardcopy and via the **COTTONpaks CD**. It has been an important pivot point for encouraging the cotton industry to continue to embrace an integrated approach to weed management.

The biggest threat to **WEEDpak** is that it becomes 'old' and out-of-date. Regular updates are important not only for providing new information, but also for encouraging growers to continually re-visit the information already available in **WEEDpak**.

This project has been highly successful in its support of **WEEDpak**, greatly increasing the value of the **Weed Identification and Information Guide** and **Management of Problem Weeds** sections through improvements in the original material as well as the addition of new material.

The project has also been highly successful in promoting **WEEDpak**, with material available in the original hardcopy, in specific hardcopy additions for each set of new material, via the internet and on the **COTTONpaks CD**. The emphasis on the internet and CD methods of presentation has ensured that the latest version of **WEEDpak** is freely available to all.

The recent inclusion of the **Herbicide Damage Guide** is a major step forward for **WEEDpak**, adding a totally new area to the coverage of this document. Expansion of this information over the new few years will not only provide valuable information regarding herbicide damage, but will also ensure that **WEEDpak** continues to be a most valuable and regularly accessed document.

The inclusion of an extra 53 weeds to the weed identification section and new management information on 4 additional weeds have greatly improved these sections, with more weeds and more information to be included over the next few years.

6. Please describe any:-

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

No outcomes of this type resulted from this project

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

No outcomes of this type resulted from this project

c) required changes to the Intellectual Property register.

No action required. **WEEDpak** is vested with the CCC CRC. Changes to this document are registered with the CCC CRC.

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 introduction of Roundup Ready cotton varieties has allowed a quantum step forward for weed management in the Australian cotton industry. This technology provides a powerful tool for managing many of the problem weeds of cotton and allows the development of weed management systems that are much less reliant on residual herbicides. It is estimated that approximately 30% of cotton fields are adversely impacted by problem weeds. However, this technology also has the potential to allow the development of weed management systems that are cost effective in the short term, but are not sustainable in the longer term due to species shift and possibly herbicide resistance.

A primary aim of **WEEDpak** has been to provide cotton growers with the information to allow them to develop low impact, sustainable, integrated weed management systems for cotton. The components of **WEEDpak** facilitate this through encouraging accurate weed identification, emphasising the need to consider all the available components of weed management and providing detailed information for the management of problem weeds.

The results achieved in this project will support **WEEDpak** and will have a large impact on individual cotton growers and individual fields where weed problems are occurring. The information will allow cotton growers to develop low impact, sustainable weed management systems, reducing weed seedbanks and weed pressure over time, and reducing the cost of weed management, while optimising crop yields.

The take-home messages of this project are:

- Weed problems can't be solved by simply using a single management tool (such as glyphosate) time after time.
- Maintaining an integrated approach to weed management is important for maintaining the systems sustainability.
- Integrated weed management systems can be developed that manage problem weeds, reduce weed pressure, reduce costs and optimise crop yields.

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.

Extension has been a focus and a strength of this research project. Continued support and expansion of **WEEDpak** is essential to maintaining the value of this document and will require the continuing support of the cotton extension network.

The project primarily focussed on delivering its information via the internet and **COTTONpaks CD.** The next step in this process is to develop an updated hardcopy version of this information which can be slotted into the existing **WEEDpak** folder. This has been done for the problem weed management units which are available through the TRC, but still needs to be done for the Weed identification and Herbicide Damage modules.

Some of the core **WEEDpak** documents are becoming outdated with the rapid uptake of Roundup Ready, Roundup Ready Flex and Liberty Link cottons. These documents focus on

the residual herbicide system and need to be updated to the transgenic era. Documents in this category include the:

Integrated weed management guidelines

Managing weeds in cotton, and

Managing Roundup Ready cotton

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

The results of this project will be disseminated in scientific papers over the next couple of years as time becomes available for this process.

(c) for future research.

Continuing support of **WEEDpak** is essential. To facilitate this, it is important that all future work be developed to fit into the **WEEDpak** framework. Regular additions to the weed identification and herbicide damage modules will be essential.

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

A list of publications follows. Copies of most papers are included as an appendix.

WEEDpak updates:

Weed Identification & Information Guide

- Originally 38 image sets, 18 with description text
- Now 91 image sets, all with description text, plus
- New seed identification index and all other indexes updated
- Many original images and all text updated

New Herbicide Damage Guide

- Totally new guide with 5 sets of herbicide damage images, and
- 24 sets of herbicide damage information, covering damage from glyphosate, 2,4-D, and the combination of glyphosate & 2,4-D.

Managing Problem Weeds: WEEDpak Section H

- Managing bellvine in cotton, Charles G. 2006 (new)
- Managing caustic weed in cotton, Charles G. 2006 (new)
- Managing mintweed in cotton, Charles G. & Roberts G. 2006 (new)
- Managing lippia in the cotton farming system, Charles G. 2006 (new)
- Managing cowvine in cotton, Charles G. 2006 (revised & updated)

Rotation Crops: WEEDpak Section I

- Managing weeds in vetch rotation crops, Charles G. 2006 (new)
- Managing lucerne strips in cotton, Charles G. & Mensah R. 2006 (new)
- Herbicides for use with pigeon pea trap crops, Charles G. 2006 (revised & updated)

Papers & Articles

Charles G. W. and Taylor I. N. (2006). Positioning the second generation of herbicide tolerant cotton varieties – Roundup Ready Flex® and Liberty Link® cottons – into Australian cotton farming systems: opportunities and threats. 15th Australian Weeds Conference, Adelaide, p. 359-362.

Charles G. W. and Taylor I. N. (2006). Opportunities and threats with Roundup Ready Flex® and Liberty Link® cottons, the next generation of herbicide tolerant cotton varieties. 13th Australian Cotton Conference, Gold Coast, Qld,

Charles, G. (2006). Hands-on-research: 2,4-D & glyphosate damage to cotton. 13th Australian Cotton Conference, Broadbeach, pp. 8.

Charles, G. (2006). WEEDpak has been updated (again!!). 13th Australian Cotton Conference, Broadbeach, pp. 2.

Charles, G. (2006). WEEDpak updated with new management tools. *The Australian Cottongrower* **27, (4):** 20.

Charles, G. (2006). Managing vetch in rotation crops. *The Australian Cottongrower* **27, (2):** 22, 24.

Charles, G. (2006). The 3 'whats' of managing herbicide damage. 2006 Lower Namoi Field Day Book, p. 65.

Charles G. W. (2005). Ringing the bell on bellvine. *The Australian Cottongrower* **26, (6):** 16-19.

Charles G. W. (2005). Managing lippia in the cotton farming system. *The Australian Cottongrower* **26, (4):** 14-17.

Charles G. W. (2005). WEEDpak on the web has been updated. *The Australian Cottongrower* **26, (1):** 56.

Charles G. W. (2005). WEEDpak on the web has been updated. Lower Namoi 2005 Field Day book. p. 44.

Charles G. W., Constable G. A., Llewellyn D. J. and Hickman M. (2005). Tolerance of cotton expressing a 2,4-D detoxification gene to 2,4-D applied in the field. *Weed Technology* Submitted.

Charles G., Taylor I. and Roberts G. (2004). Integrated weed management in the cotton farming systems: should the industry adopt this approach. Proceedings of the Twelfth Australian Cotton Conference, Gold Coast, Qld, pp. 313-317.

Charles G., Taylor I and Roberts, G. (2004). The impact of the cotton farming system on weed succession: implications for herbicide resistance and adoption of an integrated weed management approach. 14th Australian Weeds Conference, Wagga Wagga, p. 410-413.

Charles G. W. and Taylor I. N. (2003). Herbicide resistance and species shift in cotton using an integrated weed management (IWM) approach. 3rd World Cotton Research Conference, Cape Town, South Africa, p. 817-828.

Johnson S. B., Sindel B. M. and Charles G. W. (2004) Bladder ketmia (*Hibiscus tironum* L.) in Australia – a variable taxa. 14th Australian Weeds Conference, Wagga Wagga, p. 544-547.

Johnson S. B., Sindel B. M. and Charles G. W. (2004). Bladder ketmia (*Hibiscus trionum*) how variable is it? Proceedings of the Twelfth Australian Cotton Conference, Gold Coast, Qld, p. 307-312.

Johnson S., Sindel B. and Charles G. (2003). What bladder ketmia have you got. *The Australian Cottongrower* **24, (5):** 50-54.

Johnson S. B., Charles G. W., MacKinnon L., Roberts G. N. and Taylor I. N. (2003) 'Cutting-edge' weed science WEEDpak – A weed identification and management guide for the Australian cotton industry. 3rd World Cotton Research Conference, Cape Town, South Africa, p. 829-834.

Johnson S. B., Charles G. W., Christiansen I. H., Hazlewood S. M., Kerlin S. E., Kelly D. G., Roberts G. N., Spora A. C., Taylor I. N. and Watson J. (2002). Getting the message out. WEEDpak - A developing weed identification and management guide for the Australian Cotton Industry. Australian Weeds Conference, Perth, pp. 456.

Johnson S. B., Sindel B. M. and Charles G. W. (2002). The problem of Malvaceae weeds in cotton farming systems. Australian Weeds Conference, Perth.

Johnson S. B., Taylor I. N., Sindel B. M., Charles G. W. and MacKinnon L. (2002). The distribution, spread and management of bladder ketmia, anoda weed and velvetleaf in Australian cotton farming systems. Proceedings of the Eleventh Australian Cotton Conference, Brisbane, Qld, p. 169-176.

Llewellyn D., Constable G. and Charles G. (2005). Development of GM 2,4-D tolerant cotton. ACGRA workshop on 2,4-D tolerance, Narrabri.

Smith R. (Collator), Lucy M., Heuke L., Charles G., Hedger A., Addison S., Wark J., Wilson L. and Kochman J. (2005). Agronomic management of pigeon peas as a refuge or trap crop in the cotton farming system. CCC CRC Information Sheet, pp. 4.

Taylor I. N., Charles G. W. and Ichbold B. (2003) Reducing residual pre-emergent or pre-plant herbicide use in cotton through the development of weed thresholds. 3rd World Cotton Research Conference, Cape Town, South Africa, 835-846.

Taylor I. N., Charles G. W. and Ichbold B. (2003). Reducing residual pre-emergent or pre-plant herbicide use in cotton through the development of weed thresholds. Proceedings, Lower Namoi Valley Cotton Field Day, 16 pp.

Taylor I. and Charles G. (2002). Integrated weed management for Australian cotton production systems. Proceedings of the Eleventh Australian Cotton Conference, Brisbane, Qld, p. 133-145.

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

The outcomes from this project have added important new information to **WEEDpak**, available on the Cotton CRC website.

Expanding WEEDpak: developing integrated weed management packages for the cotton farming system

Background: WEEDpak, the Integrated Weed Management Guide for the Australian cotton industry was launched in 2002 in response to a rapidly changing weed management climate in the industry with the introduction of transgenic, Roundup Ready Cotton, and as a vehicle to facilitate the delivery of integrated weed management information to the cotton industry.

The WEEDpak internet site has been one of the most heavily used of the Cotton CRC web sites. WEEDpak is also available in hardcopy and via the COTTONpaks CD. It has been an important pivot point for encouraging the Australian cotton industry to continue to embrace an integrated approach to weed management.

The biggest threat to WEEDpak is that it becomes 'old' and out-of-date. Regular updates are important not only for providing new information, but also for encouraging growers to continually re-visit the information already available in WEEDpak.

Outcomes: The primary focus of this project has been the support and promotion of WEEDpak through focussed research and extension with the support of the Cotton TRC. The project has been highly successful in achieving these aims, greatly increasing the value of WEEDpak to the cotton industry, and maintaining this document as a regularly used resource.

Research focussed on monitoring weed problems in commercial cotton fields, developing management packages for problem weeds and developing herbicide damage information to assist cotton growers. The outcomes of this research have been delivered to the cotton industry primarily through WEEDpak, with promotion through a range of other mechanisms.

WEEDpak has been expanded in four areas.

1. Through additions and upgrades to the weed identification module, with the addition of 53 new weed sets and 73 weed information pages, as well as new indexes and upgrades to all the original material.
2. Through revision and expansion of the problem weed management module, with the addition of management guides for bellvine, mint weed, lippia and caustic weed, as well as updating the cowvine management guide.
3. Through revision and expansion of the rotation crop module, with the addition of management guides for lucerne strips and vetch crops, as well as updating the pigeon pea management guide.
4. With the inclusion of a totally new module, the Herbicide Damage Guide. This guide contains 24 sets of detailed herbicide damage information for drift rates of glyphosate, 2,4-D amine and a glyphosate/2,4-D amine combination. This information details the impact of known rates of herbicide on cotton exposed at different growth stages. Such information as the impact on node production, inter-node length, leaf number, leaf area, squaring and boll production and retention throughout the season are given.

   A second section, the herbicide damage images, shows examples of how the symptoms of damage develop over time.

This new material is available in hardcopy, via the internet and on the COTTONpaks CD. The emphasis on the internet and CD methods of presentation has ensured that the latest version of WEEDpak is freely available to all.

The recent inclusion of the Herbicide Damage Guide is a major step forward for WEEDpak, adding a totally new area to the coverage of this document. Expansion of this information over the new few years will not only provide valuable information regarding herbicide damage, but will also ensure that WEEDpak continues to be a most valuable and regularly accessed document.

For more information on this project, contact:

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