



Australian Government

**Cotton Research and
Development Corporation**

FINAL REPORT 2018

Choose an item.

Part 1 - Summary Details

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

CRDC Project Number: SC1601

Project Title: National Cotton Extension Development & Delivery - stewardship of
biotechnologies and crop protection

Project Commencement Date: 1/07/2015 **Project Completion Date:** 30/06/2018

CRDC Research Program: 2 Industry

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Date Submitted: _____

Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Transgenic cotton was introduced to Australia in 1996 with Ingard® which was replaced by Bollgard II® in 2004/05. Transgenic cotton is now grown by over 95% of Australian cotton growers so is an integral part of the Australian cotton industry, helping enable the industry to dramatically reduce insecticide use. In 2015/16 the industry introduced 3rd generation Bt cotton (Bollgard 3). This has been a critical time for stewardship of Bt cotton during the transition phase to Bollgard 3, to ensure the industry is aware of the importance of continued stewardship in the future.

Historically, the cotton industry has been able to work closely with the commercial companies involved and regulatory bodies in developing Bt resistance management plans and monitoring the performance of the technology primarily through the TIMS committee and research organisations. However, the stewardship of the technologies at a grower level has been largely the responsibility of the commercial companies. An industry need was identified for the delivery and promotion of independent industry research focussed on resistance to Bt cotton and the effectiveness of commercial stewardship programs to ensure the protection of the technology for future industry use. The current project SC1601 has been filling the industry gap identified by promoting independent industry research in the areas of stewardship. The project has also provided for an independent facilitator to act between grower and research representative bodies (CRDC, TIMS Committee and Tech Panels) and relevant commercial companies in amending and developing resistance management plans for both biotechnologies and insecticides. This project continued to build on the work of previous project SC1301 during a critical time for the industry in promoting and improving stewardship of Bt and insecticides.

Objectives

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

Objective 1. Lead the continuous improvement of the industry's best practice recommendations for Bt and Insecticide stewardship

Milestone 1.1. Facilitate the exchange of research results annually in areas related to the current and future deployment of Bt cotton.

Achieved. REFCOM is the industry's forum for the annual facilitation of research results in areas related to Bt cotton. REFCOM was held in Narrabri in 2015, Gold Coast in 2016 and Griffith in 2017.

Milestone 1.2. Facilitation of TIMS Bt Technical Panel

Achieved. Facilitation of the TIMS Bt Technical Panel has resulted in:

- Development of the Bollgard 3 Annual Review Charter
- Approval of the Bollgard 3 Northern RMP
- Reviewed and provided feedback to TIMS on a number of research permits, planting window variations, research discussion papers, regional RRMPs
- Formally met on a number of occasions for the BG3 Annual Review, REFCOM and to review the Bayer CropSciences Bt Technology Product, prior to this being pulled from the commercialisation path.

Milestone 1.3. Facilitation of TIMS Insecticide Technical Panel

Achieved. The TIMS Insecticide Technical Panel has met annually to review the industry IRMS and review resistance research results to inform any changes required to the IRMS.

The IRMS has been updated annually prior to the publication of the Cotton Pest Management Guide. As required, the Insecticide Technical Panel has been consulted on emerging issues.

Milestone 1.4. Prepare industry for Bt resistance management in the future

Achieved. The Bollgard 3 Annual Review Charter was ratified by TIMS in 2016. The charter was developed in conjunction with representatives from Monsanto, Cotton Australia and CRDC. The aim of this document is to:

- To provide a forum in which regulatory requirements of the APVMA Conditions of Product Registration for Bollgard 3 cotton can be fulfilled.
- To formally review the adequacy of tactics implemented as part of the Resistance Management Plan (RMP) to manage the development of resistance in target pests.
- To discuss any proposed changes to the RMP in response to changes in resistance allele frequencies and also to support continuous improvement in resistance management techniques.

Overall, the annual review allows a process where any potential resistance threats can be managed, with the onus on industry (represented by the TIMS Committee) to make the necessary management decisions. It also provides a clear process that can be replicated if other Bt products from other suppliers enter the Australian market.

Milestone 1.5. Provide a clear communication path for key industry bodies with CRDC and the CottonInfo Team such as CropLife Australia, Crop Consultants Australia, Cotton Australia TIMS Committee and commercial trait companies in areas related to stewardship.

Achieved. The role of Bt and Insecticide Technical Lead within the CottonInfo Team provides a clear communication path in the cotton industry evidenced by:

- Close relationship with Cotton Australia TIMS Committee in developing and managing resistance management plans in the cotton industry
- Regular consultation with CropLife Australia and Crop Consultants Australia on insecticide resistance management plans
- Cross industry collaboration for resistance management plans with grains and pulse industry through the GRDC NIRM group
- Representative of CottonInfo team asked to present at Australian and International resistance management meetings and workshops, including Crop Consultants Australia, GRDC and CSIRO.

Milestone 1.6. Facilitate the annual review of practices in the myBMP Biotech module

Achieved. The myBMP modules have been updated annually. This ensures content remains current and reflects the latest best management practices. Importantly the transition from Bollgard II to Bollgard 3 and the changing resistance management plans have been incorporated into myBMP. Resources that are available as part of modules has also been updated, such as stewardship fact sheets and the latest Resistance Management plans.

Objective 2. Develop and implement a communication plan for the delivery of Bt and Insecticide stewardship best practice through the CottonInfo ‘In It Together’ campaign designed to support the relevant R&D objectives

Milestone 2.1. Materials promoting Bt and insecticide stewardship are developed and integrated consistently into all forms of industry communication.

Achieved. Materials developed that promote Bt and insecticide stewardship include a range of media articles, publications, presentations and updates that are distributed via the CottonInfo network of Enews, industry publications, regional newsletters and other regional updates as required.

Milestone 2.2. Work closely with the CottonInfo RDO's to deliver communication of Bt and Insecticide stewardship best practice, and collect seasonal and regional feedback.

Achieved. Regular communication with the CottonInfo Team through achieved through fortnightly teleconferences and biannual CottonInfo Team meetings. Communication is also informal through phone calls, emails and other industry meetings. These are all opportunities to deliver communications on emerging stewardship issues and collect seasonal and regional feedback from the team.

Milestone 2.3. Support the CottonInfo team, as required, in developing and communicating IPM messages, particularly in areas that relate to stewardship.

Achieved. The Technical Lead role works closely with the CottonInfo Team to develop and communicate IPM messages. As described above, regular communication is upheld to be aware of any emerging issues in stewardship.

Objective 3. Monitor and evaluate the success of the stewardship communication plan.

Milestone 3.1. Participate in the development of attitudinal questions for the industry's annual CCA and grower surveys. Analyse relevant data as part of the process for communicating the stewardship campaign.

Achieved. Data is collected from both the CCA and CRDC grower surveys that assesses attitudes toward stewardship in the cotton industry. Data from Monsanto compliance reports is also used to assess grower attitudes toward Bt stewardship.

Objective 4. Provide technical training and support to the CottonInfo Team in the areas of Bt and insecticide stewardship.

Milestone 4.1. Work closely with the CottonInfo Team to increase their technical knowledge and awareness of Bt and insecticide stewardship issues to improve their ability to communicate stewardship messages directly to industry.

Achieved. Summaries of resistance monitoring reports are provided to the CottonInfo team when these are distributed, along with summaries and explanation of the content. Other relevant content on emerging stewardship issues is distributed as required. Specific stewardship issues are discussed on CottonInfo teleconferences and CottonInfo meetings, with follow up information provided as required.

Methods

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

The methodologies for this project have been in the area of communication and extension.

Methodologies used:

1. **Print media.** This project has produced 12 articles for Spotlight Magazine and The Australian Cottongrower. The use of print media in industry publications has been a key way for the project to communicate stewardship research to the industry. This methodology has been particularly useful for complex stewardship topics such as the global rise of resistance to Bt crops.
2. **E news.** The project has used both the CottonInfo Enews and the CCA e-newsletter to communicate messages to the industry. This has been used for short messages such as the release of the new IRMS each season, or for emerging issues that require immediate information, such as the management of *Helicoverpa* spp. survivors in Bt crops.
3. **Presentations.** The project has been involved in 4 key presentations to industry (details in publications section) including presenting at CCA Forums and the 18th Australian Cotton Conference. Topics have covered the importance of the Bollgard 3 RMP, resistance management in Bt cotton and insecticide resistance. Presentations

are also given at TIMS meetings and CottonInfo Team Meetings to provide updates on the latest resistance management results and key issues.

4. **Industry publications.** Annual updates to the Cotton Production Manual and the Cotton Production Guide have been provided.
5. **Web Resources: myBMP/Fact Sheets/Case Studies.** The content of the myBMP biotechnologies module was updated annually. Key updates were required for myBMP to ensure it reflected the transition to Bollgard 3 technology and the Bollgard 3 RMP. Updates were provided to the stewardship fact sheets available on the CottonInfo website (crop destruction and pupae busting, refuge management and guidelines for *Helicoverpa* management in Bt cotton) to ensure consistency with messaging with the transition to Bollgard 3.
6. **Facilitation:** Facilitation of the TIMS Bt Technical Panel and Insecticide Technical Panel was an important component of this project. Effective facilitation included coordination of meeting times and agendas, facilitation of meetings/teleconferences, distribution of background information, minute taking and distribution of minutes. Facilitation was used to ensure the panels worked towards specific outcomes and was also used to develop communication pieces (articles etc.) for wider distribution.

Results

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

Objective 1. Lead the continuous improvement of the industry's best practice recommendations for Bt and Insecticide stewardship

Milestone 1.1. Facilitate the exchange of research results annually in areas related to the current and future deployment of Bt cotton.

REFCOM is the industry's forum for the annual facilitation of research results in areas related to Bt cotton. REFCOM was held in Narrabri in 2015, Gold Coast in 2016 and Griffith in 2017.

In 2016, following the development of the Bollgard 3 Annual Review Charter, it was decided that REFCOM no longer needed to serve the purpose of reviewing resistance management data for the previous season as this was now the role of the BG3 Annual Review. Also, there were concerns that some of the information presented was commercially sensitive, such as RMP compliance data, so was not appropriate to be shared in a public forum such as REFCOM.

This provided the opportunity for REFCOM to become a more targeted forum, dealing with current and emerging issues in Bt resistance management. The decision was also made that it would occur once every 2 years, unless there were emerging issues that required a forum more urgently.

REFCOM 2016 focus was on refuge management, the outcome of this meeting was to identify some major knowledge gaps in using refuges as a resistance management tactic. These are:

- What is the role of unstructured refuge in resistance management in the Australian landscape, and how does this differ regionally and seasonally.
- What is the role of refuges at the end of the cotton growing season? Are refuges potentially harbouring resistant alleles and therefore should be destroyed at the end of the season to prevent any resistant genes surviving? Or are refuges a source of susceptible individual's at the end of the season, in which case refuges should be left undisturbed so that individual's can emerge the following spring and dilute the population?

There were ~ 35 attendees at REFCOM 2016, primarily from the research community.

REFCOM 2017 was held in Griffith, the focus of the event was identifying the major constraints to implementing the BG3 RMP in a southern farming system. The meeting was well attended, with ~ 45 attendees, and around half of these growers or consultants from the region.

The main outcome from this meeting were:

- Need for more flexibility in the BG3 RMP for southern areas, particularly in end of season tactics such as pupae busting as climatic constraints makes it difficult for these tactics to be effectively implemented.
- Need for a better understanding of the climatic conditions in southern regions, and how these may impact the growing season and resistance management overall
- Need for better communication within the region, as the region encompasses a large area geographically, a range of climatic factors, and a range of growers and consultants with differing levels of experience and management priorities.

As a result of this meeting, the RRMP for Bollgard 3 cotton was revised in 2017 to include moth busting as an alternative approach to spring trap crops for quarantining Bt resistance alleles between cotton crop. The use of moth busting as an alternative to pupae busting in the BG3 RMP continues to be investigated.

Milestone 1.2. Facilitation of TIMS Bt Technical Panel

Facilitation of the TIMS Bt Technical Panel has resulted in:

- Development of the Bollgard 3 Annual Review Charter, in conjunction with Monsanto and Cotton Australia. This provides an annual forum for the resistance monitoring and compliance data for BG3 to be presented and any emerging issues with BG3 resistance management to be discussed.
- Development of an updated Northern RMP in 2017 in conjunction with Monsanto, which now encompasses all of northern Australia and allows for more flexible planting dates across this climatically diverse area while still maintaining a robust RMP.
- Facilitating the communication between TIMS and Monsanto to ensure commitments made in the BG3 submission (which were not enforced by the APVMA) toward maintaining refuge quality were incorporated into the BG3 annual review process. This commitment has been delivered on through:
 - Availability of an improved pigeon pea variety ‘Sunrise’
 - New refuge ranking system that uses a matrix system. The resulting rank is determined independently of the auditor, reducing the amount of subjectivity in refuge ranking for compliance.
 - Joint effort through both CottonInfo and Monsanto in extension material outlining the importance of effective refuge management in resistance management.
- Review of Bayer CropSciences submission for introducing another Bt product to the Australian cotton industry. This was done through a number of face to face meetings and teleconferences prior to the commercialisation plan being cancelled in September 2016.
- Review of research papers pertinent to Bt resistance management:
 - Webinar discussing the result of Nancy Schelhorn and Tony Ives modelling that indicated pupae busting may be having a relatively small impact on resistance management. This information is being used to inform current discussion on the potential introduction on moth busting as an alternative to pupae busting.
 - Teleconference discussing a paper by Mary Whitehouse investigating whether refuges are acting as genetic diluters or seasonal quarantine. This paper

informs the tech panel discussions around the role of refuges at the end of season.

- Advice to TIMS on proposed variations to the BG3 RMP including planting window variations and the inclusion of Victoria
- Advice to TIMS on a number of research permit requests, including Monsanto sucking pest trait trial in northern Australia, a winter cropping trial in St George, Magnet research trials in southern valleys and planting date trials in northern Australia. These research permits allow the industry to continue to learn about resistance management with the intent to make improvements to both practically and effectiveness.
- Development of RRMPs, such as the regional RRMP issued for southern regions in 2016. A wet winter meant the majority of the region was unable to complete pupae busting within the required time frame and moth busting was introduced as an alternative to spring trap cropping.

Milestone 1.3. Facilitation of TIMS Insecticide Technical Panel

The TIMS Insecticide Technical Panel meets annually to review the latest insecticide resistance monitoring results and draft the Insecticide Resistance Management Strategy (IRMS) for the following season. This has been achieved annually with the reviewed IRMS being available by deadline each year, to be printed in the Cotton Pest Management Guide following an industry consultation period.

Key areas for discussion at each annual meeting are:

- Latest resistance results in key insect pests: Helicoverpa, Silverleaf Whitefly, Green mirid, Cotton Aphid, Mites and Thrips
- Updates on changes to pest complexes
- Updates to resistance monitoring techniques
- New products, including the risk of resistance and impact on beneficials
- Other emerging issues

Apart from the annual review of the IRMS, key outcomes of these meetings is to identify any emerging resistance issues that require industry communication. These have included:

- Increase in abamectin resistance in Two Spotted Mite
- Increase in indoxacarb resistance in Helicoverpa
- High risk of resistance in Helicoverpa in Altacor
- Increase in imadicloprid resistance in thrips
- Changing mite complex from Two Spotted Mite to Strawberry Mite
- Increase in pyriproxyfen resistance in Silverleaf Whitefly

The increase in resistance to pyriproxyfen was highlighted as key issue for the industry prior to the 2017/18 season, as it is a key product for SLW control. The TIMS Insecticide Technical Panel recommended a change in use pattern, reflected in the IRMS, of a 30 day regional window, aimed to fall between peak flowering and open bolls, with a maximum of 1 application. A whole of industry response was initiated involving the CottonInfo Team and Cotton Australia to communicate this message. Full details of resistance monitoring results were not available at the time of this report, however early implications are that resistance levels have not continued to increase in 2017/18.

Milestone 1.4. Prepare industry for Bt resistance management in the future

The Bollgard 3 annual review allows a process where any potential resistance threats can be managed and necessary future management decisions can be made. It also provides a framework that can be replicated if other Bt products enter the Australian market. The charter was ratified by TIMS in 2016 and the Bollgard 3 annual review has now been held twice, in

2017 and 2018 and the members of the review are the TIMS Bt Technical Panel, Cotton Australia TIMS representatives and Monsanto representatives

. The main topics for discussion have been:

- Resistance monitoring results from both CSIRO and Monsanto
- RMP compliance report from Monsanto
- Emerging issues including: refuge management, Northern RMP, research trial permits and compliance management.

Discussions at these meetings have included future threats to resistance management and management implications. These include:

- Expansion of the industry in northern areas. How will resistance monitoring be done in these regions? Should the industry be looking at lepidoptera and pink bollworm monitoring also?
- Resistance monitoring frequency requirement into the future
- How to incorporate molecular techniques in the future
- The inclusion of moth busting to the RMP as an alternative to pupae busting

Milestone 1.5. Provide a clear communication path for key industry bodies with CRDC and the CottonInfo Team such as CropLife Australia, Crop Consultants Australia, Cotton Australia TIMS Committee and commercial trait companies in areas related to stewardship.

The Bt and Insecticide Stewardship Lead is established a key contact for industry collaboration and consultation evidenced through:

- Close working relationship with the Cotton Australia TIMS Committee through both the Bt and Insecticide Tech Panel. Attendance to TIMS meetings as the panel's representative.
- Regular communication with Monsanto through the Bt Technical Panel in organising the BG3 annual review and addressing RMP variations and research permit requests as they arise.
- Annual consultation with Crop Consultants Australia in reviewing the IRMS.
- Annual consultation with CropLife Australia in reviewing the IRMS.
- Invitation to present at the 3rd Australian Agrichemical Resistance Meeting run by the GRDC Grains Pest Advisory Council November 2016
- Invitations to participate at the Grains Pest Advisory Council resistance workshop November 2016
- Consultation in developing a cross industry resistance management plan for Group 28 insecticides through the GRDC National Insecticide Resistance Management (NIRM) Group
- Consultation in the development of a grains Helicoverpa resistance management strategy by NIRM and a Red Legged Earth Mite resistance management strategy
- Presentations at CCA forums on insecticide resistance management
- Presentation at the 18th Australian Cotton Conference in 2016 on The Importance of Resistance Management
- Invitation to present at and participate in a Consultative Workshop on Technology Commercialization and Product Stewardship Outreach Program for Cotton Stakeholders in Ethiopia October 2017

Milestone 1.6. Facilitate the annual review of practices in the myBMP Biotech module

The myBMP biotech module has now been incorporated into the myBMP IPM module.

Updates have been provided annually to ensure:

- myBMP module represents current best practice in resistance management
- module is consistent with Bollgard 3 RMP requirements
- module has been updated during the transition from Bollgard II to Bollgard 3
- relevant resources are available through myBMP and are up to date

Objective 2. Develop and implement a communication plan for the delivery of Bt and Insecticide stewardship best practice through the CottonInfo ‘In It Together’ campaign designed to support the relevant R&D objectives

Milestone 2.1. Materials promoting Bt and insecticide stewardship are developed and integrated consistently into all forms of industry communication.

The communication plan is incorporated into the CottonInfo Annual Operating Plan (AOP) where applicable. The following materials promoting Bt insecticide stewardship have been developed:

- Annual updates to the Cotton Pest Management Guide (CPMG) and Cotton Production Manual
- IRMS updated annually. This is communicated through the CPMG but also sent as a separate article to the CottonInfo Team and CCA to be distributed through newsletters, including highlights to any resistance concerns and changes to the IRMS. This has included concerns with abamectin resistance in mites and indoxacarb resistance in Helicoverpa.
- Annual resistance reports completed by researchers, including Helicoverpa (Bt and insecticides), Silverleaf Whitefly, Mites, Aphids and Mirids are distributed to the CottonInfo Team, along with a summary page used to inform the CottonInfo Team and that can be distributed through newsletters
- Number of articles produced for Spotlight Magazine and The Australian Cotton Grower (details in publications section)
- Number of articles produced for CottonInfo Enews (details in publications section)
- Updates to the CottonInfo website on stewardship information, including updating fact sheets to ensure the information remains relevant to the BG3 RMP.
- Development of a process to implement the pyriproxyfen 30-day regional window. The process was as follows:
 - A teleconference was held with the CottonInfo Team to discuss the window.
 - A presentation with explanatory notes was produced for the CottonInfo Team to present at each of the regional CSD meetings to inform growers and consultants of the window.
 - A letter to be sent to each of the CGAs requesting them to nominate a 30-day window was produced
 - The CottonInfo was involved in ensuring each of the CGAs provided a window to Cotton Australia
 - Communications material was developed and sent out via Enews and CottonInfo regional newsletters.
- In 2018 a set of guidelines for CRDC and the CottonInfo Team was developed and distributed on the use of the terms ‘Bt Cotton’ and ‘Bollgard 3’ in industry communications.

Milestone 2.2. Work closely with the CottonInfo RDO’s to deliver communication of Bt and Insecticide stewardship best practice, and collect seasonal and regional feedback.

Regular communication with the CottonInfo Team through achieved through fortnightly teleconferences and biannual CottonInfo Team meetings. Communication is also informal through phone calls, emails and other industry meetings. These are all opportunities to deliver communications on emerging stewardship issues and collect seasonal and regional feedback from the team. This has resulted in:

- Feedback on the practicality of implementing the regional 30 day pyriproxyfen window
- Feedback on industry insecticide use patterns, including off label practices, and practices outside the IRMS that may impact resistance management

- Feedback on the use of industry thresholds for pest management
 - Feedback on pest pressure in season, and spraying practices
- The ability to gain regional feedback allows for the identification of emerging issues and development of timely extension material.

Milestone 2.3. Support the CottonInfo team, as required, in developing and communicating IPM messages, particularly in areas that relate to stewardship.

The Technical Lead role works closely with the CottonInfo Team to develop and communicate IPM messages in areas that relate to stewardship. This has resulted in:

- The development of an early season IPM workshop in Southern NSW in 2016 in conjunction with CottonInfo RDO Kieran O’Keefe.
- Development of an IPM workshop with the CottonInfo team aimed at identifying constraints to IPM in southern regions, conducted prior to REFCOM in Griffith in 2017
- Presenting at the Macquarie and Southern NSW IPM workshops on resistance management in 2017
- Assistance with coordinating a NRM ‘Birds, Bats and Bugs’ event in the Macquarie with Stacey Vogel and Amanda Thomas in 2017 and presenting on resistance management at the event
- Assistance in a range of articles for distribution including pyriproxyfen resistance with Jamie Hopkinson, pigeon pea management with Paul Grundy, ratoon management with Sharna Holman and Paul Grundy
- Assistance with facilitating a mirid workshop run by Richard Sequeira in 2018
- Assist regional CottonInfo team members in organising SLW meetings in the Macquarie and the Gwydir in 2017, and facilitating the Macquarie meeting
- Assistance with developing a trial protocol for the CottonInfo Team in investigating the impact of early season mirid damage, and participating in the trial in the Macquarie
- Assistance to Jon Welsh and Janine Powell in developing CottonInfo Gross Margins, in the area of insecticide choice and number of sprays per season

Objective 3. Monitor and evaluate the success of the stewardship communication plan.

Milestone 3.1. Participate in the development of attitudinal questions for the industry’s annual CCA and grower surveys. Analyse relevant data as part of the process for communicating the stewardship campaign.

Attitudinal questions have been included, where possible, into the CRDC grower surveys and CCA annual surveys.

In the 2017 CRDC Grower Survey, 14% of respondents thought that growing resistance to current pest and disease control measures was a main challenge. This indicates stewardship is still a key priority for growers, among other more immediate challenges that directly influence profitability such as water availability, off target herbicide drift and input costs.

Other responses were:

- 90% growers use the recommended industry thresholds
- 91% aim to conserve beneficials when making spray decisions
- 83% follow the IRMS

Reasons for not following the IRMS included:

- timing with other operations 45%
- presence of other pests 35%
- industry thresholds are either too high or too low 47%

The results from the CCA Survey following the 2016/17 season were:

- 88% aim to conserve beneficials when making spray decisions
- 75% follow the IRMS

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.

The outcomes identified in the project application are as follows:

1. Growers are using RMPs that contain best available science, and are also practically achievable. Uptake of best practice of stewardship is increased.
2. Industry is better prepared to manage new technologies and potential future resistance issues to ensure the impact on productivity and sustainability of the industry is reduced.
3. Grower awareness and knowledge of the importance of effective stewardship is increased. Uptake of best practice of stewardship is increased.

Growers are using RMPs that contain best available science, and are also practically achievable. Uptake of best practice of stewardship is increased.

The current RMPs used in the industry for both Bt crops and insecticides are based on the best available science:

- Annual review of both RMPs occurs with the aim to assess the latest resistance monitoring results and any new research relating to resistance management. Industry researchers play a key role through the TIMS technical advisory panels in ensuring RMPs contain the best available science in collaboration with commercial research results
- Regular consultation through the TIMS technical advisory panels as required outside of the annual review process on any emerging issues in the resistance space
- REFCOM forum is used to discuss emerging and current issues in Bt resistance management. This collaborative forum brings together researchers, growers and consultants to share the best available on the issue and propose future management options
- The practicality of RMPs is achieved through regular industry consultation. This occurs through:
 - The technical panels work closely with the grower TIMS Committee in developing and managing RMPs
 - Each technical panel has a current grower or consultant representative, offering significant feedback on the practicality of any proposed RMP changes
 - The IRMS is sent out for industry consultation annually to the TIMS Committee, CCA, CropLife Australia and the Cotton Australia Cotton Grower Associations

Uptake of RMPs is increased if the RMP is not only scientifically robust, but practically achievable, and these processes ensure RMPs used in the cotton industry are both.

Industry is better prepared to manage new technologies and potential future resistance issues to ensure the impact on productivity and sustainability of the industry is reduced.

- There is a process in place that ensures resistance is managed from the time of introduction of any new Bt technologies or insecticides through the industry RMPs
- Resistance research and management plans are reviewed annually, and can be reviewed at other times in the event of an emerging issue, which ensures the industry can proactively manage any potential resistance threats.

*Grower awareness and knowledge of the importance of effective stewardship is increased.
Uptake of best practice of stewardship is increased.*

Through implementation of the project communication plan, grower awareness and knowledge of the importance of stewardship and uptake of stewardship practices is increased. This is evidenced by:

- Increased grower participation at REFCOM forum
- Good grower engagement in emerging issues such as the pyriproxyfen window for Silverleaf Whitefly control. An increase in grower communication through area wide management groups and other regional grower groups was seen following the implementation plan of the window and supporting communication plan.
- 83% of growers and 73% of consultants follow the IRMS when making spray decisions.
- Improvement in RMP compliance in Bt crops. The average number of RRMPs has reduced from 5 – 8% of TUAs with Bollgard II crops to 1.5 - 3% of TUAs following the introduction of Bollgard 3. This shows an increase in the uptake of best practice for resistance management and is also likely to be reflective of the improved practicality of the Bollgard 3 RMP, making it easier for growers to implement.

6. Please describe any:-

- a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);**
- b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and**
- c) required changes to the Intellectual Property register.**

N/A

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 overall aim of the project has been to increase grower awareness of stewardship not as a ‘must do’ but a ‘should do’ to protect the industry’s access to biotechnologies and insecticides in the future. Monsanto compliance data for Bollgard 3 shows that non-compliance cases are still heavily influenced by environmental factors outside of the control of the grower. There are very few cases of intentional non-compliance and the average annual number of RRMPs implemented have been reduced since the introduction of Bollgard 3. The industry has been growing Bt cotton for over 2 decades now. Despite this long history, resistance monitoring data from both CSIRO and Monsanto in 2016/17 show that resistance to Cry1Ac remains relatively rare for both *H. punctigera* and *H. armigera*. Resistance to Cry2Ab is higher in both species, but there is no evidence for a significant increase in resistance frequencies since 2007/08. This indicates that our current resistance management strategy is working, especially when the evidence that Australia is one of the few countries in the world that grow Bt crops where resistance has not increased is considered.

The continued review of the industry IRMS each season ensures that it remains relevant and useful in a Bt dominant industry. The management of pests other than *Helicoverpa* has become an important part of crop management, and the IRMS is a key tool for an effective IPM strategy. Continuing the industry high adherence to the IRMS and IPM principles has been an important focus of the project. However, it must be acknowledged that most cotton growers also grow a number of other crops. Resistance management in pests is not something that can be managed solely within an industry as many key pests are found in a number of crops, and insecticide chemistry is also used in a range of crops. Collaboration between the cotton industry, grains and pulse industries has begun to look at resistance management above individual crop types, which has the potential to benefit insecticide resistance management on a much wider scale.

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

As this project is an extension project, a further extension plan is not required.

- 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)

“IRMS a must for decision making.” Spotlight Magazine Spring 2015.
“In a variable farming landscape, good refuges are vital” Spotlight Magazine Spring 2016
“Refuge health vital” Spotlight Magazine Spring 2016
“World’s Best Science: the basis of the BG3 RMP” Spotlight Magazine Spring 2016
“Think long-term early for SLW later: when we kill natural enemies we inherit their work”
Spotlight magazine Spring 2017
“Spraying Helicoverpa in Bollgard crops” CottonInfo E news, September 2017.
“Are your ratoons rampaging”? CottonInfo E news, August 2017.
“Is your refuge effective? New variety of pigeon pea: Sunrise” CottonInfo E news, August 2017.
“How much damage can ratoon cotton do? Effective crop destruction is an important part of the management of a Bollgard 3 system” CottonInfo E news, May 2018
“Bt resistance on the rise globally” Spotlight magazine Winter 2018
“Effective crop destruction crucial in a Bollgard 3 system” Spotlight Magazine Winter 2018
“Ethiopian interest in Bt cropping highlights the global threat of rising Bt resistance” The Australian Cottongrower February – March 2018

List of key presentations

“Insecticide Resistance Management in the Cotton Industry: reasons for success and future challenges” 3rd Australian Agrichemical Resistance Meeting, University of Melbourne, November 2015
“The Importance of Resistance Management” 18th Australian Cotton Conference, Gold Coast August 2016
“Bt Cotton Experience in Australia” Consultative Workshop on Technology Commercialization and Product Stewardship Outreach Program for Cotton Stakeholders in Ethiopia October 5 – 6, 2017, Addis Ababa, Ethiopia
“Outcomes of industry response to pyriproxyfen resistance and update on cotton pest resistance research” CCA Forum, Narrabri June 2018

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

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

The major outcomes identified of the project are as follows:

Growers are using RMPs that contain best available science, and are also practically achievable.

The current RMPs used in the industry for both Bt crops and insecticides are based on the best available science:

- Annual review of both the Bollgard 3 RMP and the IRMS occurs with the aim to assess the latest resistance monitoring results and any new research relating to resistance management. Industry researchers play a key role through the TIMS technical advisory panels in ensuring RMPs contain the best available science in collaboration with commercial research results
- REFCOM forum is used to discuss emerging and current issues in Bt resistance management. This collaborative forum brings together researchers, growers and consultants to share the best available on the issue and propose future management options
- The practicality of RMPs is achieved through regular industry consultation. This occurs through:
 - The technical panels work closely with the grower TIMS Committee in developing and managing RMPs
 - Each technical panel has a current grower or consultant representative, offering significant feedback on the practicality of any proposed RMP changes
 - The IRMS is sent out for industry consultation annually to the TIMS Committee, CCA, CropLife Australia and the Cotton Australia Cotton Grower Associations

Industry is better prepared to manage new technologies and potential future resistance issues to ensure the impact on productivity and sustainability of the industry is reduced.

- There is a process in place that ensures resistance is managed from the time of introduction of any new Bt technologies or insecticides through the industry RMPs
- Resistance research and management plans are reviewed annually, and can be reviewed at other times in the event of an emerging issue, which ensures the industry can proactively manage any potential resistance threats.

Grower awareness and knowledge of the importance of effective stewardship is increased. Uptake of best practice of stewardship is increased.

Through implementation of the project communication plan, grower awareness and knowledge of the importance of stewardship and uptake of stewardship practices is increased. This is evidenced by:

- Increased grower participation at REFCOM forum
- Good grower engagement in emerging issues such as the pyriproxyfen window for Silverleaf Whitefly control. An increase in grower communication through area wide management groups and other regional grower groups was seen following the implementation plan of the window and supporting communication plan.
- 83% of growers and 73% of consultants follow the IRMS when making spray decisions.
- Improvement in RMP compliance in Bt crops. The average number of RRMPs has reduced from 5 – 8% of TUAs with Bollgard II crops to 1.5 - 3% of TUAs following the introduction of Bollgard 3. This shows an increase in the uptake of best practice for resistance management and is also likely to be reflective of the improved practicality of the Bollgard 3 RMP, making it easier for growers to implement.

Uptake of RMPs is increased if the RMP is not only scientifically robust, but practically achievable, and these processes ensure RMPs used in the cotton industry are both.

