

# Spotlight.

ON COTTON R&D

Winter 2015

Weapons of crop destruction:  
Why they're so important

Managing verticillium

N losses through irrigation



Australian Government  
Cotton Research and  
Development Corporation



Bruce Finney

# In the Spotlight

Welcome to the new-look CRDC *Spotlight on Cotton R&D* magazine.

In this edition of *Spotlight*, we look at how an integrated approach to farming provides benefits at both a farm and industry level. Our articles covering post-harvest crop management, insect, weed disease management have a shared message – integration is key to the best control.

The time for actions that keep next season's crop safe from pests and disease starts now with an integrated approach post-harvest and continues through winter by keeping rogue cotton and weeds under control. In this issue, industry specialists have identified 10 reasons to keep in front of mind when carrying out post-harvest crop destruction, and in our articles around volunteer cotton, we find that recent surveys show an integrated approach is the most effective management strategy. One mode of control is not enough.

We must also ensure our weed control strategies are integrated so that we don't add to the issue of glyphosate (and other herbicide) resistance. This edition's article on glyphosate-resistance in sowthistle, and the biology of this weed, provides further understanding of the need for an integrated approach to weed control. CRDC is supporting ongoing research into glyphosate resistance and management. Under CRDC, cotton is the first agricultural industry in Australia to produce a weed resistance management strategy, which I urge all growers and consultants to reference when making weed control decisions.

This season saw the widespread emergence of verticillium wilt and the detection of another strain which has the potential to adversely affect yield. This edition's article with Dr Karen Kirkby outlines how this too will require an integrated approach to manage, both within industry and in the field. This includes careful post-harvest management, choice of rotation crop, farm hygiene and variety selection.

The industry has moved quickly to manage new threats in an integrated fashion, and reniform nematodes in Central Queensland are a case in point. CRDC is continuing support of research into management, with rotation crops looking the likely saviour. But like most issues, it's an integrated approach that will prevail, requiring good farm hygiene – Come Clean Go Clean – weed control and rotation crop choices.

Researchers and scientists all advise referencing the tools CRDC, CottonInfo and others produce. These include the new *Australian Cotton Production Manual*, out with this edition, and the *Cotton Pest Management Guide*, out in September.

We trust that you find this edition of *Spotlight* informative, and look forward to seeing you at the combined industry Cotton Collective, Cotton Trade Show and Cotton Industry Awards in August.

A handwritten signature in black ink that reads "Bruce Finney". The signature is fluid and cursive, with a large, stylized initial 'B'.

Bruce Finney  
CRDC Executive Director





MELANIE JENSON

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**Cotton Research and Development Corporation**

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**Postal:**

PO Box 282, Narrabri NSW 2390

**Offices:** 2 Lloyd Street,

Narrabri NSW 2390

**Tel:** 02 6792 4088

**Fax:** 02 6792 4400

**Email:** [spotlight@crdc.com.au](mailto:spotlight@crdc.com.au)

**Web:** [www.crdc.com.au](http://www.crdc.com.au)

**Communications Manager:**

Ruth Redfern

**Editorial co-ordinator:**

Melanie Jenson

**Editorial Contributors:**

Melanie Jenson, Ruth Redfern,

Sally Ceeney, Meg Strang,

Chrissy Brown.

**Design:** Deacon Design

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## Want to see more of Spotlight?

This edition can be viewed online at: [www.crdc.com.au](http://www.crdc.com.au)



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# Winter 2015



MELANIE JENSON

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# Fast Facts

## 3500

Years ago – the world's first cotton gin – the “churka,” (pictured centre) was invented in India. While effective for ginning long staple cotton, it was ineffective on short staple varieties.



## 200,000,000

Dollars – invested in cotton R&D over the past 24 years by cotton growers and Australian government.

## 7

Dollars – the estimated return on investment for growers for every \$1 invested in R&D.

## 2.3 million

Bales - the forecast Australian cotton production total for the 2014-15 cotton season.

## 35

The average number of kilograms of nitrogen lost per hectare from the field into the irrigation network in recent trials (see story page 22).



## Researcher of the Year says award is for the team effort

CSIRO senior principal research scientist Dr Greg Constable has been selected as the International Cotton Advisory Committee (ICAC) Cotton Researcher of the Year.

Greg, who has been based at the Australian Cotton Research Institute over his research career, was surprised and humbled by the award, and says he is accepting it on behalf his colleagues.

“This award was a surprise and I know it is an honour, but all of my research has been long-term and has relied heavily on the excellent research teams I have been part of, so it is impossible for me to take sole credit for my work,” he said.

“I was humbled as I know there are many good cotton scientists across the world and I would never consider myself the best by any means.”

With a long list of achievements and innovations, Greg says a highlight of his career is being part of a research team which has developed superior germplasm and varieties, and adding genetically modified traits of interest to Australian conditions.

“That type of work is long term, requires many thousands of plots and careful attention to the detailed results. Our team has in excess of 20 dedicated staff to make all that happen – which is how we work at CSIRO,” Greg said.

CRDC with the support of CSIRO nominated Greg for the award, and Executive Director Bruce Finney said it's a fitting tribute for his outstanding contribution to cotton research.

“Greg's experience in cotton research is spread over four decades. His achievements are well recognised across agronomy, breeding and physiology, and scientific leadership,” Bruce said.

“Greg has led one of the most successful cotton breeding programs in the world, to the benefit of cotton growers both at home and abroad.

“Average cotton yields in Australia are not only the highest in the world, but are almost three times the global average for 2014-15 and Greg has made a significant contribution to this outstanding performance with his innovative research into farming systems and the development and application of new transgenic traits.

“He is well recognised internationally for his research, and we are very pleased Greg's efforts have been acknowledged by ICAC with the title of Researcher of the Year.”





Emerald-based consultant Jamie Iker has been working with researchers in Central Queensland investigating alternative early planting dates for cotton.



## Launch into a leadership experience not to be missed

**THE** cotton industry has again come together to support its leaders, with the announcement of consultant Jamie Iker and farm manager Sean Boland as the latest participants in the Australian Rural Leadership Program.

Jamie is an agronomist with Spackman Iker based in Emerald, Central Queensland and sponsored by CRDC and Auscott Ltd. CRDC and Cotton Australia have sponsored Sean, who is the General Manager at Auscott "Midkin" near Moree in North West NSW.

Don't miss the opportunity to apply for one of the most dynamic and acclaimed leadership development experiences open to established leaders working in and for rural, regional and remote Australia.

Applications to join the 23rd Australian Rural Leadership Program (ARLP) are now open, and as in past years, CRDC, Cotton Australia and Auscott Ltd will sponsor cotton industry participants.

Course 23 will take place during sessions over 50 days, from August 2016 to October 2017. Applications are open until August 31 2015. This is a national, competitive selection process, and candidates will be notified of the outcome of their applications in October 2015.

### For more

**t** 02 6281 0680  
**e** info@rural-leaders.com.au  
**w** [www.rural-leaders.com.au](http://www.rural-leaders.com.au)

## Secure a future in the industry now

**THE** Australian cotton industry is proactively working to address the skills and labour shortage in agriculture by placing university students into internships with cotton-focused agribusiness.

In a move to help connect employers with potential future employees, the Cotton Professional Program links students seeking work experience with agribusinesses seeking skilled staff.

The CRDC-funded program is offering placements for students studying an agriculture-related degree with an interest in working in the cotton industry. Students in their first, second or third year of study may apply for a PICSE Cotton Internship, while students in their fourth/final year are invited to apply for the Professional Program, for placement into an organisation that focuses on agricultural engineering, agribusiness, crop agronomy, crop research, NRM or similar.

Applications close October 30 2015, with placements able to be arranged during university holidays.

### For more

**Trudy Staines**  
**t** 02 6799 1500  
**e** [trudy.staines@csiro.au](mailto:trudy.staines@csiro.au)

## Down to grassroots: promoting grower ideas

**CRDC's** Grassroots Grants can assist farmers keen to set up their own local project – be it a weather station, supporting growers to undertake tactical research to solve a particular on farm issue or other initiatives that build capacity within the industry.

Running since 2011, the Grassroots Grant program encourages Cotton Grower Associations (CGAs) to apply for funds to support capacity building projects in their region.

Up to \$10,000 is available to CGAs to help fund a project that will increase the engagement of growers in the industry, solve specific regional issues and improve their skills, knowledge base and networks.

The last round of grants again yielded varied and interesting projects including:

- Dryland cotton planter equipment assessments
- Weather stations in the Central Highlands, the Darling Downs and the Namoi (see *Spotlight* Spring 2015)
- Tools to manage soil compaction in the Gwydir Valley
- Development of a grower friendly booklet outlining trial results in the Macquarie Valley
- Cotton nutrition workshops in the southern valleys
- Supporting Tandou's school-based traineeships and education days for

school students and the community.

Grassroots Grants applications open July 1 2015 and close November 20 2015, with applications reviewed on a first-come first-served basis. The program's guidelines and application form are available from CRDC – [www.crdc.com.au](http://www.crdc.com.au) – log on to the 'For Growers' section then click on the 'Community and Grower Support' tab.

### For more

**Ian Taylor**  
**t** 02 6792 4088  
**e** [ian.taylor@crdc.com.au](mailto:ian.taylor@crdc.com.au)

# Collectively speaking: have your say

**THE** Cotton Collective is an opportunity for those involved in all sectors of the industry to hear and be heard.

The industry gathering at Narrabri's Crossing Theatre will start on Wednesday August 5 and be followed by the Australian Cotton Industry Awards cocktail evening. For the first time, the Collective will run in conjunction with the two-day Australian Cotton Trade Show.

The Collective is designed to address policy updates, research outcomes and the work underway around the most important issues facing cotton growers. Experts from across the industry will share their views and answer important questions, giving growers, consultants, researchers and policy makers the opportunity to stay informed and contribute to the discussion.

"This is an important event to bring the cotton industry together in the off-Conference year. It ensures that key developments over the course of the year are addressed, new issues identified and key research outcomes distributed," CRDC Executive Director Bruce Finney said.

"Cotton Australia coordinates the Collective on behalf of the industry, and we are working closely with them to ensure that important research information supports the agenda. It's a valuable forum for us to share information with the industry and also to receive feedback on our research – how it's being extended and implemented in the field, and what future

research needs are across the supply chain. "We encourage all within the industry - from growers to merchants - to attend and have their say."

Morning sessions include updates on key industry issues and identify learnings from other industries through a varied line-up of speakers. Afternoon sessions will inform on research/policy areas associated with Cotton Australia's advisory panels, which in line with CRDC's Strategic Plan are: farmers, industry, customers, and people.

Cotton Australia CEO Adam Kay says the Collective is a wonderful opportunity for the industry to gather, exchange ideas, catch up on the latest research and technology, and hear the latest about issues of importance.

"The event is also critically important for Cotton Australia, as it provides a platform to directly receive feedback from cotton growers and others in the industry," Adam said.

"We're very excited the Cotton Collective will this year be held in conjunction with both the Cotton Industry Awards and Cotton Trade Show - having all three together makes it a compelling, must-attend event."

## For more

Full program available soon –  
[www.cottonaustralia.com.au](http://www.cottonaustralia.com.au)

To register: Entry is free, for catering purposes  
RSVP to [talktous@cotton.org.au](mailto:talktous@cotton.org.au)

## Finalists announced

**THE** Australian Cotton Industry Awards and cocktail party will be held Wednesday evening, August 5 at the Crossing Theatre.

The awards celebrate excellence, innovation and leadership across the whole supply chain and recognise the valuable contribution to Australia's cotton industry of growers and ginners to product suppliers, consultants, agronomists, researchers and extension teams.

The 2015 awards saw nominations roll in from Emerald to Carathool, Canberra to Ayr in North Queensland.

### The finalists are:

#### Monsanto Grower of the Year and AgriRisk High Achiever of the Year

- Daisy Lodge, Carathool NSW – Peter & Caroline Tuohy
- Bengerang, Condamine QLD – Jason Sinclair
- Jedburgh Farming, Gunnedah NSW – Scott & Jo McCalman
- Turkey Lagoon, Boggabilla NSW – Graham & Kylie Cook
- Reardon Farms, Talwood QLD – Tristram Hertslet and Robert Reardon
- Korolea Farming, Boggabilla NSW – Andrew & Rob Newell

#### CSD Researcher of the Year

- Steve Yeates, CSIRO, Ayr QLD
- Sandra Williams, CSIRO, Narrabri NSW
- Geoff Baker & Colin Tann, CSIRO, ACT/ NSW

#### Chris Lehmann Trust Young Achiever of the Year Sponsored by Bayer CropScience

- Ross Burnett, Emerald QLD
- Ryan Pratten, Narromine NSW
- Ben Dawson, Moree NSW

The finalists will feature in a Forum Q&A session at the Cotton Collective and in "finalist films", giving a unique opportunity to see what key innovators, leaders and enthusiasts are working on. The awards cocktail evening will feature innovative entertainment and the anticipation of the awards. Tickets are \$75 per person (available at the Crossing Theatre).

### For more

**w** [www.australiancottonawards.com](http://www.australiancottonawards.com)

## All together now

**TO** be held in the riverside grounds of the Crossing Theatre, the Australian Cotton Trade Show opens Wednesday August 5 at 9am and runs through to Thursday August 6, including the Trade Show Industry Seminars throughout the afternoon.

"We have a new time, a new venue and a new site plan but the focus remains the same - we will be doing all we can to ensure that the Trade Show is your gateway to the Australian cotton industry," says organiser Brian O'Connell.

"Growers, consultants, researchers and suppliers from all growing districts will be in there making this the biggest cotton industry gathering of 2015. In step with modern cotton farmers' needs, the trade show this year will incorporate the Modern Cropping Systems Expo featuring irrigated and dryland summer and winter rotation crops."

Full program at: [www.cottontradeshow.com.au](http://www.cottontradeshow.com.au)  
Brian O'Connell 02 6778 3255/ 0413 130 777

# Joining forces to increase grower profit

*Smarter irrigation for profit* is a large scale, ambitious project to improve the profit of 3000 cotton, dairy, rice and sugar irrigators by \$20,000 to \$40,000 per year.

Funding for the project was announced in May by Federal Minister for Agriculture Barnaby Joyce as part of the government's Rural R&D for Profit program.

CRDC will lead the initiative in partnership with Dairy Australia, the Rural Industries Research and Development Corporation (RIRDC) and Sugar Research Australia to increase on-farm profitability by integrating new irrigation scheduling and delivery technologies into good irrigation practice. It will build on previous research to drive additional improvements in the four sectors, draw on the support of 16 R&D partners and develop farmer-managed learning sites.

CRDC R&D Manager Jane Trindall oversaw the submission on behalf of CRDC and says the combined research effort with these major irrigated agricultural industries will increase sharing of research and innovation between the sectors. She believes the combined capacity will enable all industries to accelerate irrigation research and its adoption at a scale not achievable without this funding.

"The major aim is improving water productivity; increasing the dollar return on a per megalitre basis for irrigators," Jane said.

"CRDC has a lot to bring to the table in terms of our irrigation research – we have one of the most innovative industries and a leading group of researchers in this field who are working in areas such as automation, precision and predictive control.

"On behalf of Australian cotton growers and the government, CRDC alone has invested around \$1.5 million per year in recent years in irrigation research."

Jane says the development of farmer-managed learning sites on working farms is integral to this project, as places where technology can be tested on a commercial scale and shared with others. The industry has previously seen the success of such



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New irrigation scheduling and delivery technologies will help irrigators' profits under the *Smarter irrigation for profit* project which successfully gained funding under the federal Rural R&D for Profit scheme.

sites, where irrigators have opportunities to interact with optimised irrigation research and technology to see how it could 'fit' on their farm in a practical and cost effective way.

CRDC Executive Director Bruce Finney welcomed the announcement which will see up to \$4 million directed from the Rural R&D for Profit program to this project.

"Irrigated agriculture is responsible for 30 percent of all agricultural production in Australia, and half the profit," Bruce said.

"This project is designed to achieve a 10 to 20 percent improvement in water productivity, efficiency and farmer profitability, while also improving cross-sector industry research collaboration."

CRDC is a partner in a further four projects selected under the Rural R&D for Profit scheme:

- *Stimulating private sector extension in Australian agriculture to increase returns from R&D*, led by Dairy Australia;
- *Improved use of seasonal forecasting to increase farmer profitability*, led by RIRDC;

- *A profitable future for Australian agriculture: Biorefineries for higher-value animal feeds, chemicals, and fuels*, led by Sugar Research Australia; and
- *Consolidating targeted and practical extension services for Australian Farmers and Fishers*, led by RIRDC.

"We are very pleased to partner with our fellow RDCs on these projects, which, while representing the very diverse fields of extension, climate and biorefinery, all share the same aim of improving farmer profitability," Bruce said.

"CRDC is really looking forward to the innovation that is going to be created with our partners and delivering these five projects to the benefit of cotton growers and the broader agricultural industry."

## For more

**Jane Trindall**

t 02 6792 4088

e jane.trindall@crdc.com.au



## What's your motivation?

AS rewarding as farming can be, it is a complex, often risky and stressful occupation where survival is often at the mercy of elements out of a farmer's control. So what motivates farmers – in particular cotton growers – to be in the business? This question is currently the focus of a CRDC project.

Through a national on-line survey (see below to take part) University of Southern Queensland Doctoral candidate Geraldine Wunsch hopes to better understand why people enter and/or remain in the cotton growing game.

Geraldine – herself a cotton grower for 20 years – is researching the psychological and characteristic adaptations among growers that may affect their motivation and work/life satisfaction.

"Each season brings with it a new set of variables including environmental, economic, and human resource factors, so the goal posts keep changing," Geraldine says.

"Growers' views on how they handle these seasonal variables which influence their decision-making will give insight into factors around the retention of growers in the industry."

**HAVE YOUR SAY:** To be part of the national on-line, 15-minute survey, follow the link: <http://usqsurvey.usq.edu.au/~Cotton~Growers-2015>

There is an opportunity for growers to be involved in a follow up study (grower identity will not be published).

### For more

**Geraldine Wunsch**

**t** 0427 001 265

**e** geraldine.wunsch@usq.edu.au



## Settle back for a good yarn

**EVERYONE** likes a good yarn and to get the 'good oil' and there's no better way to hear it than straight from the horse's mouth.

With this in mind, CottonInfo Darling Downs Regional Development Officer John Smith is recording a series of audio podcasts with personalities who've got an interesting story or innovation to share with the cotton community.

Cotton Conversations ([www.cottoninfo.com.au/audio-podcasts](http://www.cottoninfo.com.au/audio-podcasts)) are a great way for listeners to meet cotton growers and others from inside and outside the industry, hear their stories, how they operate and what they've achieved.

"The podcasts are informal chats with fascinating people which I've timed to be about as long as a smoko break, for easy, convenient listening in a way that people feel like they are right there with us," John says.

"The conversations are opportunity to 'look over the fence' at what these people are doing regardless of where you are."

For the first instalment, John interviewed John 'Cowboy' Cameron, who has achieved outstanding dryland yields through refined farm management. Cowboy and Ros's dryland farming property is on Queensland's Darling Downs, and say they started farming 25 years

ago with "very little financial backing and not much experience!"

However since their first crop, the Camerons have become well-regarded growers and innovators, and were awarded the Australian Cotton Industry Grower of the Year award in 2013. In this podcast, Cowboy talks about his journey and 'that' 10 bale/ha dryland crop in 2012-13.

The second podcast is a conversation with farmer and agronomist Andrew Bate, whose vision is using robotics to revolutionise the way we farm. While not a cotton grower, his work has huge potential for the industry. Andrew has developed robotic technology for agriculture and is passionate about how these systems will change its future.

Stay tuned for the next conversation with Goondiwindi cotton grower and Nuffield Scholar Nigel Corish.

### For more

**John Smith**

**t** 0408 258 786

**e** john.smith@cottoninfo.net.au

**w** [www.cottoninfo.com.au/audio-podcasts](http://www.cottoninfo.com.au/audio-podcasts)

## Verticillium meeting outlines priorities

IN response to concern about verticillium wilt in crops this season, CottonInfo and CRDC held a meeting in Narrabri during April. The meeting brought together more than 30 cotton industry participants including growers, consultants, and researchers to listen to concerns about verticillium wilt, review the current research and identify research and extension gaps and opportunities.

"It is clear from the strong participation this is a concerning issue, with growers in a few regions having to drop cotton out of their rotation due to the devastating yield

impacts," says CRDC's Susan Maas.

"The intention is to form a small working committee with some growers and consultants as well as CRDC, CA and CSD to ensure a focussed effort and to ensure the list of priorities developed at this meeting is addressed. These priorities will also inform the current CRDC procurement process."

For more on managing verticillium post-harvest, see our story on Page 15.



# CRDC R&D manager heads up global sustainability report

A global report to empower cotton communities around the world to measure, benchmark, and continuously improve their performance has been co-authored by CRDC's Allan Williams.

Allan co-authored the report on sustainability through his role as Chair of the International Cotton Advisory Committee (ICAC) Expert Panel on Social, Environmental and Economic Performance of Cotton Production (SEEP).

The *Measuring Sustainability in Cotton Farming Systems: Towards a Guidance Framework* global report was produced by the ICAC and the Food and Agricultural Organisation of the United Nations (FAO) and provides an overview of critical sustainability issues for cotton growing. It also recommends a set of indicators to assess and measure progress against these issues, based on a global review of current research findings.

The indicators in the report cover environmental issues affecting cotton growing countries the world over including pest and pesticide management, water and soil management; land use and biodiversity, and climate change. Economic factors included economic viability, poverty reduction and food security, economic risk management; and social issues such as labour rights and standards, occupational health and safety, equity and gender and farmer organisations.

"The supply chain is becoming increasingly interested in having good metrics available regarding the impacts of growing cotton, so it is important for the industry to be in a position to provide them; and probably more importantly, the cotton industry



CRDC's Allan Williams speaking at last November's ICAC meeting held in Thessaloniki, Greece.

needs to be involved in discussions about what those metrics should be," Allan said.

"This is particularly so given sustainability metrics are one of the key fronts in cotton's competition with man-made fibres.

"It is very much hoped that this report can provide the stimulus for those discussions.

"Good quality data collection is resource intensive, so the practicalities and costs of collecting data need to be an issue on the table as well."

The report references sustainability programs run by cotton growing countries around the world, including Australia's myBMP program and the Better Cotton Initiative, of which Australia is a member.

Allan co-authored the report with SEEP Vice-Chair and FAO's Francesca Mancini and he says it is designed to identify critical sustainability issues and their metrics on a global cotton industry scale, while recognising the diversity that exists between cotton growing countries.

"This report looks at the sustainability of our industry and the improvement to livelihoods of growers internationally, and aims to identify a broad list of indicators that reflect the challenges of growing cotton regardless of location," he said.

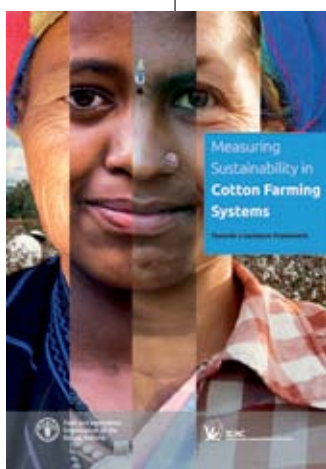
"The report recognises that there are too many differences for a blueprint, or a one-size-fits-all approach.

"Instead, the report provides a framework for how cotton communities in individual countries can measure, benchmark, and continuously improve their performance – and we hope that through this report, they will be empowered to do so.

"The (SEEP) Expert Panel very much sees the report as a starting point for on-going discussion in the global industry, and plans are already underway to test the framework, to see how it can work in practice and what improvements can be made."

The release internationally of the ICAC/FAO report follows the CRDC and Cotton Australia launch of the *Australian Grown Cotton Sustainability Report in November last year*, which tracks the social, economic and environmental footprint of the Australian industry.

The ICAC/FAO *Measuring Sustainability in Cotton Farming Systems: Towards a Guidance Framework* report and the *Australian Grown Cotton Sustainability Report* are available to download at [www.crdc.com.au](http://www.crdc.com.au)



## For more

**Allan Williams**

**t** 02 6792 4088

**e** [allan.williams@crdc.com.au](mailto:allan.williams@crdc.com.au)





## Crop destruction BMP

- Where possible, undertake all operations (including tillage and picking) when soil is dry to reduce compaction risk
- Pupae destruction must be performed by July 31 in Bollgard II and prior to August 30 in conventional cotton. Tillage is required to a depth of 10cm across the whole bed and furrow.
- The destruction of plants and incorporation of crop residues should generally be performed by a mulch and root cut operation, followed by tillage.
- Remove cotton volunteers and ratoon plants from all cropping and non-cropping areas to reduce carryover of pests and diseases (also as a component of the Bollgard II RMP to reduce resistance risk).



# Post-harvest management: for all the right reasons

There are many benefits to effective crop destruction and pupae busting.

Destruction of Bollgard II cotton after harvest and pupae busting are important mandatory components of the Bollgard II resistance management plan (RMP). Implementing an effective farm plan to remove all Bollgard II volunteers and ratoon plants, as well as pupae busting, can have a huge positive impact on your overall farming system, not just in resistance management.

Controlling volunteers and ratoon cotton is an integral part of the cotton cropping system, as it has impacts on Bt resistance, insecticide resistance, integrated pest, weed and disease management; biosecurity and impacts your bottom line. Winter is the perfect time to get started.

*Spotlight* spoke to CottonInfo's Sally Ceeney and Ngaire Roughley who

highlighted the following Top 10 reasons why ratoon and volunteer cotton must go:

**Helps beat verticillium.** Destruction and incorporation of plant residues into the soils is an important tool to prevent build up of disease inoculum from year to year, not just for verticillium wilt but also black root rot, boll rots, seedling disease and *Alternaria*.

**Reduces pest carryover.** A number of pests can survive overwinter on volunteer and ratoon cotton, including silverleaf whitefly, mealybug, aphids and pale cotton strainers.

**Helps beat bunchy top.** Aphids that survive overwinter on volunteer and ratoon plants may be vectors for cotton bunchy top disease. Removing the plant hosts will reduce the risk of the disease the following season.

**Reduces resistance.** Pests that survive overwinter on volunteers and ratoons are potentially carrying resistance genes to insecticides or to the toxins in Bt cotton. Allowing them to survive increases the risk of those resistance genes being carried through to the next season.

**Nematodes nemesis.** Crop residues can

carry over the reinform nematode from one season to the next. Effective incorporation can help reduce the risk.

**Reduces BGII resistance.** Ratoon and volunteer cotton present outside of the typical cotton season place pressure on Bt resistance, by lengthening the growing season and increasing the amount of time *Helicoverpa* is exposed to the toxins in BGII.

**Pupae busting reduces number of volunteers.** Following crop destruction, an effective pupae busting job can help incorporate lint on the soil surface, reducing the number of volunteers next season.

**Pupae busting doesn't discriminate.** It is effective at killing potentially resistant individuals in diapause, regardless of whether they carry resistance to the toxins in Bollgard II, or resistance to insecticides.

**Saves you dollars.** Established ratoon and volunteer cotton can be difficult and expensive to control, reducing the numbers and controlling them early will save dollars in the long run.

**Watch out for new nasties.** Volunteer and ratoon cotton are a biosecurity risk, they are a potential point of establishment for exotic pests.

IMAGE: MELANIE JENSON



# Survey tells volunteer story

A recent industry survey showed volunteer cotton was most prolific in back to back cotton fields and that an integrated, consistent approach is the key to effective control.

CottonInfo’s Volunteer and Ratoon Technical Specialist Ngaire Roughley surveyed volunteer cotton presence on farms across Queensland and Northern NSW in an effort to assess the distribution and abundance of early season volunteers.

“The aim of the survey was to collect a data set which quantitatively represents the in-field volunteer population over the 2014-15 season,” Ngaire said.

“This season, there were high numbers of volunteers across all of the areas I surveyed (see Figure 1).

“From Emerald to Gunnedah, volunteers are not exclusive to one region – it’s an industry-wide issue which requires an integrated yet targeted approach to management.”

Ngaire surveyed fields with a variety of rotation systems and found that crop history played a major factor in the presence of volunteer cotton in-field. In fields with volunteers, 93 percent were in back to back cotton, with the remainder following a summer fallow or grain rotation.

“The total number of back to back fields was lower in some regions than others, most likely a result of restricted water and smaller plantings this season,” Ngaire said.

“These conditions also meant the number of back to back cotton fields varied within regions – many larger farms were only growing cotton in fields that were previously rotated or fallow.

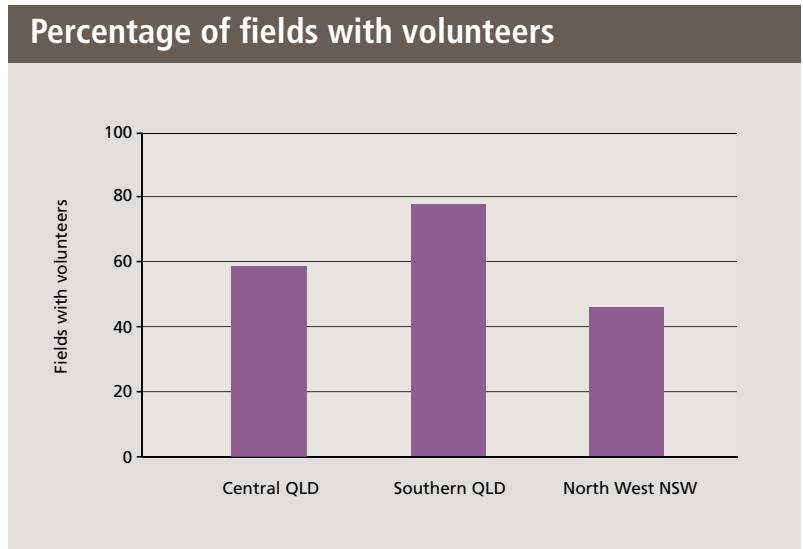


Figure 1: Distribution of fields with volunteers

“However, the consistent message is that wherever back to back cotton was growing – so too were volunteers.”

## Grower control strategies

The survey also evaluated the success of various control strategies (see Figure 2).

“Back to back fields with no volunteers were shown to be the result of where growers had combined control tactics – that is a pre-planting herbicide application and multiple inter-row cultivations,” Ngaire said.

“Back to back fields found to have low to moderate volunteer populations had generally been only subject to a single control tactic – either a one pass inter-row cultivation or shielded spray application.

“Fields with a high volunteer population were the result of either a single control tactic or where the grower had no specific management.

“My take home message is simple – to achieve effective control, you need to implement multiple control tactics and keep at it during the season.

“There is no silver bullet to controlling volunteers. It requires timeliness and persistence.”

FIGURE 2: Effect of control strategies on volunteer incidence







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# Keep the rogues under control

Good farm hygiene is the linchpin of the cotton industry's integrated pest and disease management strategies and biosecurity plans.

Removing weed hosts over winter is essential in breaking the green bridge needed for pests and diseases to survive through to the next season, and is a stewardship requirement for growers of Bollgard II cotton, as CottonInfo's technical specialist for volunteer and ratoon cotton, Ngaire Roughley explains.

"The presence of volunteer and ratoon cotton is also a risk factor for the development of resistance in *Helicoverpa* moth populations to the insecticidal proteins in Bollgard II cotton.

"A key part of the Resistance Management Plan (RMP) for growers of Bollgard II cotton is the control of volunteer and ratoon cotton"

## Controlling volunteers

Steps can be taken to control volunteer plants throughout the year, not just during the growing season or once they appear.

"Successful volunteer control begins when picking the crop, by removing as much of the lint and seed from the paddock, effective crop destruction

to ensure ratoons are eliminated and seed cotton has ample opportunity to degrade during the winter fallow," Ngaire says.

"Effective cultivation helps incorporate any remaining seeds into the soil where it has the best chance of breaking down, resulting in less volunteers the following season.

"Volunteer seedlings which emerge over winter are likely to be killed by frosts, but seedlings emerging later in the year will likely establish and grow in all areas of a farm.

"Volunteer are most problematic following dry winters, with potentially very large numbers of seedlings emerging following spring rains or irrigation."

## Herbicide control

Control is about timing, as there are no chemicals with registrations for seedlings beyond nine nodes of growth. There are a number of herbicides registered for controlling volunteer cotton seedlings, as listed in the *Cotton Pest Management Guide 2014-15*, with most chemicals effective in controlling four to six node seedlings. These registrations give growers a range of options for effective control of seedlings in a range of situations.

"Even within the label window, it is highly recommended that growers target smaller seedlings wherever possible, as 100 percent control is unlikely on larger seedlings under less than ideal conditions,

A picture of farm cleanliness: There is no silver bullet to controlling volunteers. It requires timeliness and persistence.

Where ratoons occur, it is a sure sign there is a problem in the system and is best addressed by using heavy cultivation.

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such as moisture stress or cold stress,” Ngaire said.

“For all these herbicides, best results will occur from using a double knock strategy, such as using a registered herbicide to control volunteer seedlings prior to crop emergence followed up by an early inter-row cultivation to remove any survivors.

“When volunteer plants get beyond this growth window, there are no registered herbicides for controlling these weeds and cultivation, either by machine or through chipping is the most cost effective and efficient option.”

*“In practical terms, it is rarely possible to get ratoon plants to take up enough chemical through their leaves to kill the roots.”*

### Controlling ratoons

Ratoon cotton is a plant surviving over winter and regrowing from the old root stock. This is not unexpected if plants are not disturbed, as cotton is a perennial plant, and has the potential to grow over many years, becoming progressively larger and more difficult to manage over time. Hence, cotton has to be managed post-harvest to prevent the problem.

“It is almost impossible to control a ratoon plant with herbicides in spring/summer, because of the relatively small leaf area on a ratoon plant compared to its very large root system,” Ngaire said.

“In practical terms, it is rarely possible to get ratoon plants to take up enough chemical through their leaves to kill the roots. Even above-label rates of herbicide are very unlikely to be effective on ratoon cotton.

“When applied at high rates, a herbicide is more likely to kill the leaf material before much is translocated to the roots, so given the small amount of leaf material and large root system on ratoon plants, it is a given that a rate sufficiently high to kill the roots will almost certainly kill the leaves before it gets translocated, and so will not be effective at doing anything more than defoliating the plants.

“The simplest and most cost effective way of controlling ratoon cotton is to prevent it occurring by carrying out effective root cutting or root pulling after picking, in conjunction with an effective pupae-busting cultivation.”

### Cultivation

“Where ratoons occur, it is a sure sign there is a problem in the system and is best addressed by using a heavy cultivation to remove the plants,” Ngaire says.

“Dryland growers may be reluctant to use heavy cultivation to manage ratoon cotton, but it is the only cost-effective option, and the moisture lost through a cultivation pass will be less than the moisture lost through the ratoon plants that can easily dry down the profile to a metre or more.

“A precisely placed tyne, according to the row configuration can eliminate this problem with minimal soil disturbance and loss of moisture.”

For control rates for volunteer and ratoon cotton, see the *2014-15 Cotton Pest Management Guide* available at [www.cottoninfo.com.au/publications/2014-15-cotton-pest-management-guide](http://www.cottoninfo.com.au/publications/2014-15-cotton-pest-management-guide)

### For more

**Ngaire Roughley**

**t** 0477 394 116

**e** [ngaire.Roughley@daf.qld.gov.au](mailto:ngaire.Roughley@daf.qld.gov.au)



# Managing verticillium after harvest

Dr Karen Kirkby says she can't stress enough the need for farm hygiene protocol to be adhered to in the fight against verticillium wilt.

The NSW DPI pathologist says farm hygiene must be in front of people's mind. With harvest completed, growers should also incorporate residue as quickly as possible.

"If you know you have verticillium, incorporate cotton stubble as quickly as possible, but make sure when moving between fields that machines are very well cleaned down," Karen warns.

"If you are using contractors, make sure they have cleaned down before entering your property, between fields and when leaving.

"If possible, leave infected fields until last to harvest, mulch, root cut and pupae bust."

Farm hygiene, following the industry's Come Clean Go Clean policy, also extends to controlling alternative weed hosts over winter, of which there are many, so the best option is to keep farms free of all weeds.

"There are many reasons we keep harping on the need for farm hygiene in terms of controlling winter weeds – which includes rogue (volunteer and ratoon) cotton," says Karen.

"The presence of verticillium is a case in point and it's not just diseases weeds harbour, it's pests as well.

Verticillium wilt of cotton is caused by *Verticillium dahliae*, a soil-borne fungus that enters the roots and grows into the vascular system of the plant. Non-defoliating strains of Verticillium have been present in Australia for many years and as knowledge of this pathogen and the technology to isolate and identify it improves, new discoveries are being made. Just last year the non-defoliating, 2A Verticillium strain was identified in cotton for the first time by DAF Pathologist Dr Linda Smith. This discovery prompted further laboratory testing in late 2014 to compare historic cultures taken from cotton crops in the 80s which indicated a defoliating strain had been present. This was also recently confirmed by an independent diagnostic laboratory in Spain.

A collaborative effort between NSW DPI Pathology and NSW DPI molecular specialists at Elizabeth Macarthur Agricultural Institute and



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Plant Health Diagnostic Service, investigated the Verticillium pathogen at a molecular level. This led to the defoliating strain being positively identified in samples previously taken and those from this season.

Added to the management challenge is that pathologists from QLD and NSW have confirmed cases of the presence of both verticillium and fusarium in the same field.

"It's a case of knowing which is more prolific and managing fields to suit the pathogen." Karen says.

"Furthermore, growers may consider rotations with non-host crops such as cereals and sorghum and if choosing to grow cotton in these fields next season, choosing the variety with the highest relevant F or V rank."

Growers who have not harvested infected fields are urged to take and send samples for testing.

"This not only allows them to make correct management decisions, it helps the industry form a picture of what the situation is so we can also work to better manage the spread of this disease," Karen said.

The Verticillium control options include incorporating cotton stubble as quickly as possible after harvest and planting cereals as a winter rotation.

## For more

For more information on verticillium symptoms and control visit [www.cottoninfo.com.au/publications/verticillium](http://www.cottoninfo.com.au/publications/verticillium)

To speak to your state pathologist, contact

### NSW: Dr Karen Kirkby

**t** 02 6799 2454 or 0428 944 500

**e** karen.kirkby@dpi.nsw.gov.au

### QLD: Dr Linda Smith

**t** 07 32554356 or 0457 547 617

**e** linda.smith@daf.qld.gov.au

# Sowthistle:

## diligent approach required

Unlike glyphosate-resistant summer grasses, the evolution of resistance in sowthistle is more complicated and usually slower: but the paradox is it's also ultimately going to be harder to avoid in the mid-term which calls for extremely diligent management now.

A big message for growers this winter is not to treat sowthistle patches in fallows with glyphosate only – and to be cautious about glyphosate plus 2,4-D combinations.

This warning comes as the agricultural industry deals with the recent classification of glyphosate resistant populations of sowthistle (*Sonchus oleraceus*) in five populations at Quirindi, Boggabri, Curlewis and Malleale in Northern NSW.

“With one half of the typical mixture now potentially out of action, we're going to see a lot of pressure on the other partner – and 2,4-D + glyphosate resistant sowthistle will be particularly difficult to manage,” says weeds researcher Dr David Thornby.

“Certainly a biotype that's resistant to both would be a disaster, so growers will need to think very carefully about widening their options in winter. Thankfully tillage is a good option, especially as the seeds are so fragile.”

These warnings are based on recent modelling by David which suggests that the evolution of resistance in sowthistle is more complicated than in summer grasses, in that it is usually slower and ultimately harder to avoid. David has been undertaking the research with Queensland Department of Agriculture and Fisheries (DAF) Weeds Researcher Dr Jeff Werth, who led the recent CRDC-supported project *Improved integrated weed management in transgenic farming landscapes*.

So what makes this weed's evolution more complicated and harder to avoid?

“The answer to both questions is as much to do with farming systems where resistance is present or likely to develop, as it is with sowthistle biology,” David said.

“We have only seen resistance in dryland, broadacre cropping systems, and as these systems switch between winter and summer cropping, and because sowthistle has the ability to germinate throughout the year, there are potential times in any rotation where sowthistle will be growing in fallows and thus has no crop competition; and also times when it's growing in-crop with competition, and under whatever herbicide regime suits the crop.

“This rotation system also means that sometimes it'll be controlled only with glyphosate (especially in cotton) and sometimes with something else.

“In particular, I included one spray of glyphosate plus 2,4-D in every winter fallow in the modelling I did, because the consensus was that that is a very common practice – while summer grasses were more likely only to be hit with glyphosate-only in fallows.”

### Diversity's effect on evolution

This greater diversity both in competition and in herbicide use slows down the rate of evolution. “However, it also means that there are always parts of any rotation where glyphosate alone is used, and

because sowthistle can germinate all year round, there are always cohorts that are only controlled with glyphosate – at least in my simulations,” David says.

“So we found fewer rotations that could prevent resistance occurring in sowthistle than there were for summer grasses, which have a more predictable germination pattern and therefore can be controlled with more diversity in robust summer-focused systems.

“It's harder (and perhaps more expensive) to develop a system that is diverse all the time, rather than just in summer (or in winter, for example in Western Australia) – though it's not impossible.”

### Ease of seed movement

Due to the ease of movement throughout the landscape through wind-blown (but fragile) seeds, there's likely to be a lot of mixing between sub-populations, from different paddocks and farms and roadsides. David says this leads to both the rapid selection in a glyphosate-dominated location being diluted by imported seeds from areas where control of the population is either lower (ie less selection by any herbicide); or more diverse, so the population doesn't move towards being dominated by resistant individuals so quickly, despite local pressure for resistance being high.

“Of course the flip side is that populations that are being controlled by diverse methods are 'polluted' by imported seeds from glyphosate-dominated parts of the landscape. So again, resistance evolution is both slowed, yet made more difficult to avoid in the long-term,” he warns.

These “transport” factors also apply to summer grasses like barnyard grass, but sowthistle really specialises in moving around the landscape like that – as it has small, short-lived, mobile seeds, and can

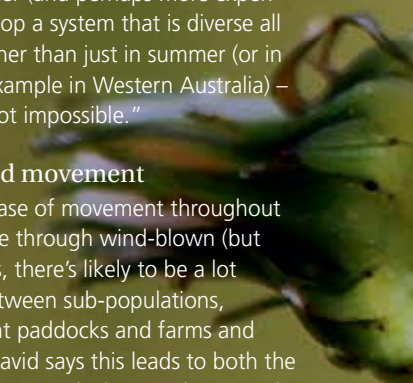



IMAGE: MELANIE JENSON





germinate in a wide variety of conditions.

"In a sense, it's always looking for a new unexploited piece of land to grow and reproduce in, and when competition comes, or conditions change, it just moves on," David said.

"Fleabane has the same strategy, although sowthistle populations anecdotally are more transitory and mobile."

Grasses have largely evolved to find, colonise and dominate a stable, suitable landscape, with (somewhat) longer-lived and less-mobile seeds that only germinate when conditions are good.

"So, again unlike sowthistle, what happens distantly from a particular paddock has a much smaller influence on grass's evolution towards resistance."

DAF's Dr Jeff Werth said sowthistle has been a growing concern for a number of years, as mature plants are often seen surviving in both summer and winter fallows.

"The recent finding of glyphosate-resistant populations makes it all the more important to manage sowthistle with a range of chemical and non-chemical options and ensure no survivors are allowed to set seed."

**For more**

**Jeff Werth**

**t** 07 4639 8851

**e** jeff.werth@daf.qld.gov.au

## Glyphosate resistance in sowthistle has serious implications such as:

- A serious threat to glyphosate-tolerant crops, particularly in cotton systems sensitive to the alternative Group I chemistry that can often be used to control this weed.
- Increasing use of Group B or I modes of action to control these populations. Both Group B and Group I resistance are already present in Australia, so populations with multiple resistance will inevitably occur.
- Spread of glyphosate resistant sowthistle will be rapid due to wind-borne dispersal of seed and frequency of glyphosate applications in fallows, crops and non-agricultural areas.
- Resistant sowthistle is likely to co-exist with other glyphosate resistance species in paddocks. Options to control resistant grasses may not be suitable for resistant broadleaf species such as this.

# Rotations to reduce nematode numbers

Cereal rotation crops may be key for growers managing reniform nematode in Central Queensland.

Growers around Theodore have been working with cotton industry pathologists to investigate nematode control methods.

It was initially thought that this pathogen was confined to more tropical environments; however a nematologist visiting from the US last year warned it has the ability to spread south into cooler climes, as experienced in the US.

As part of a CRDC-funded research project Queensland's Department of Agriculture and Fisheries (DAF) pathologists led by Dr Linda Smith are looking into the use of alternative crops as a control method, as other controls are costly and lack efficacy. Where practical, crop rotation is an excellent practice for managing nematode soil population densities.

## Crop rotation

If planting a winter crop, winter cereals are currently the most suitable for managing reniform nematodes as they are non-hosts.

"As a general practice, two years rotation with a non-host crop is usually sufficient to reduce nematode populations to below damaging levels," Linda says.

"Sorghum and corn are good non-host choices, however, depending on pre-determined soil population densities of the reniform nematode, taking cotton out of production for two or more years may be necessary to bring reniform nematode soil population densities below economic thresholds.

"In the US, growers with reniform nematode always rotate cotton with a non-host routinely before going back into cotton as this is the only way they can get a profitable cotton crop."



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Sorghum and corn are good non-host choices.

## New non-host varieties

A replicated strip trial is being conducted over two seasons on Peter French's farm "Nandina" in Theodore to investigate the effect of non-host crops on reniform populations in the soil. Being investigated are a sorghum plant with specialised biocidal production capabilities, grain sorghum, and two corn varieties. These four non-hosts significantly reduced nematode populations in the trials, with reductions of 98 percent compared with cotton. The trial will be over-sown with cotton next season and each plot will be assessed for yield and population to assess the effect of on the following cotton crop. Subsequent trials will look at rotations out of cotton for two or more years.

## Stubble management

The roots of the cotton plant can survive in the soil for long periods after harvest. If there is a delay in the onset of cool soil temperatures (less than 15°C), nematodes can feed and reproduce on these and associated weed roots which will increase nematode soil population densities that survive through to the next planting season. Therefore it is imperative that cotton stalks are slashed/mulched and soil in the stubble zone tilled immediately after harvest (or as

soon as is feasibly possible) to destroy these breeding sites. It is also important to ensure that root-cutting is successful and that there is no re-growth.

## Winter crops vs bare fallow

Nematodes need live roots on which to feed, so bare fallows are a very good management option. However success depends on having a host-free fallow (cotton or weedy hosts) - and the length of the fallow - as the longer the better.

Linda says research conducted overseas has shown that in the absence of hosts, a clean fallow led to a natural decline of reniform nematode during winter.

"However in plots where forage sorghum was grown, a decrease in nematode populations during winter was significantly greater than under a clean fallow, but this needs investigating under Australian conditions, which future trial research will address," she said.

## For more

Linda Smith

t 07 3255 4356 or 0457 547 617

e linda.smith@daf.qld.gov.au





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# Meeting highlights need for ongoing adherence to an integrated approach

The cotton industry needs to be mindful of the use of synthetic pyrethroids.

ABOVE: One consideration in an IPM system is any use of SPs must be carefully weighed against the potential costs that result from removing beneficial insects.

Monitoring resistance in key cotton pests to insecticides forms the cornerstone of Australia's successful Insecticide Resistance Management Strategy (IRMS) and the continued efficacy of products in the fight against resistance.

The Transgenic and Insecticide Management Strategies (TIMS) Insecticide Technical Panel met in late April for the annual review of the 2014-15 IRMS in preparation for next season. The aim of this review is to:

- identify any potential resistance issues to insecticides used in cotton;
- look at any new insecticides coming on to the market and identify where the product may fit in the IRMS; and
- identify any other key changes required.

CRDC supports research and resistance monitoring programs for the key pests in cotton: Helicoverpa, mites, aphids, green

mirids and silverleaf whitefly.

"The results from these resistance monitoring programs are used to inform the industry of any potential resistance issues," says CottonInfo Technical Specialist (Bt and Insecticide Stewardship) Sally Ceeney.

"This provides the industry with an early warning system to potential threats and informs changes to the IRMS with the intention of managing emerging resistance issues before they result in large economic damage through widespread field failures.

"Based on the results of the 2014-15 resistance monitoring, there are still resistance issues with synthetic pyrethroids (SP) in a number of pests.

"This confirms the decision by the panel to reduce the recommended number of SP sprays per season to just one in the 2014-15 IRMS.

"In an integrated pest management (IPM) system, any use of SPs must be carefully weighed against the potential costs that result from removing beneficial insects, and the likelihood of a spray failure occurring given such high levels of SP resistance are present."

### SP use a cross-industry issue

Helicoverpa insecticide resistance monitoring by NSW DPI's Lisa Bird and team at the Australian Cotton Research Institute (ACRI) shows continuing high resistance to SPs.

"This is despite use of SPs in cotton being low, and therefore it is thought that high usage of SP in other crops, particularly summer pulses, is the main driver for high levels of (SP) resistance," Sally said.

"This shows that resistance in pests to insecticides is a cross-industry issue.

"That's why this year the TIMS Insecticide Technical Panel invited a representative from the grains National Insecticide Resistance Management group to be a part of the meeting, so we could better engage the grains industry on resistance issues.

"The two groups are now looking for ways to collaborate in the future to manage resistance to insecticides from a cross-industry perspective."

The Helicoverpa monitoring also found moderate to high resistance to carbamates (methomyl) and low resistance to organophosphates. There was very low/no resistance to Group 28s (eg Altacor) and emamectin benzoate (Affirm). Low resistance to indoxacarb (Steward) was detected and work is being conducted to characterise this resistance in indoxacarb, however results so far show resistance is partially dominant.



Two-spotted mite.

### Mites and aphids

Resistance monitoring in aphids, mites and mirids is conducted by NSW DPI's Grant Herron and team, based at EMAI (Elizabeth Macarthur Agricultural Institute, Camden).

Grant found that among mites, the pest complex is changing. Historically the dominant species has been two-spotted mite (TSM). However in recent seasons more strawberry mite is being detected. Thankfully, strawberry mite does not generally cause economic damage to cotton.

Resistance testing of TSM showed SP resistance remains high. Abamectin resistance is moderate to high and proparagite (eg Comite) resistance is low.

In aphids, neonicotinoid resistance has dropped dramatically from a high of 96 percent (in 2010-11) to around 10 percent.

"It is likely that this is due to a reduction in the use of neonicotinoid sprays for other pests which was inadvertently selecting for resistance in aphids," Sally said.

"This result demonstrates the importance of practicing sound IPM strategies in the fight against resistance and being aware the flow-on effect of insecticides on resistance levels in off-target species."

Pirimicarb and dimethoate/omethoate resistance (which are all cross-resistant) is low as was sulfoxaflor in aphids.

"All in all, the meeting demonstrated that there are still a range of insecticides available for control of the major pest species in cotton and that resistance levels for selective chemistry remains low," Sally said.

"By continuing to follow the IRMS and IPM guidelines, the industry is in an excellent position to protect these 'soft option' insecticides and ensure that efficacy of these products is maintained."

The TIMS panel will now prepare the draft IRMS for 2015-16. There will be a period of industry consultation following this, which allows feedback on the draft to be provided prior to finalising the IRMS before planting begins in 2015.

### For more

Sally Ceeney

t 0459 189 771

e sally@ceenag.com.au

# Maintaining

Annual testing for insecticide resistance in silverleaf whitefly has found resistance to pyriproxyfen, reiterating the need for an integrated pest management approach to controlling resistance in cotton pests.

Annual testing for the incidence of insecticide resistance in silverleaf whitefly (SLW) is conducted at Queensland Department of Agriculture and Fisheries' (DAF) entomology laboratory in Toowoomba as part of CRDC's ongoing support for stewardship and resistance management.

DAF entomologist Jamie Hopkinson says toward the end of the cotton season the research team travel to cotton growing regions, and in collaboration with local agronomists, collect SLW from farms, most often where they have been treated with insecticides such as pyriproxyfen (eg Admiral) or diafenthiuron (eg Pegasus).

"These whitefly populations are then tested against a suite of products to determine any changes in resistance levels to insecticides used to control or suppress SLW. This data underpins the integrity of the Insecticide Resistance Management Strategy (IRMS) provided to industry each season," Jamie says.

In results from testing during 2014, for the first time evidence was found of resistance to pyriproxyfen developing, being detected in two out of 13 field populations.

"This indicates that SLW may become harder to kill in the future with pyriproxyfen, but we expect that current field efficacy at this stage should still be robust," Jamie said.

*"Importantly, SLW management starts early in the season..."*



# control of resistance in SLW

"Testing of diafenthiuron showed no evidence of resistance developing, yet consultant feedback suggested that there were some fields where it did not provide the expected level of control.

"Our data suggests that resistance was not a factor and therefore other field factors are likely to be at play where control has been found wanting.

"Similarly, recent testing shows no significant changes for spirotetramat (Movento) and the newly registered product cyantraniliprole (Exirel).

"However we found that widespread, low levels of resistance exist across the industry to bifenthrin, with resistance factors up to 11 times higher than the baseline lab susceptible SLW population.

"This means that while resistance has been detected, bifenthrin is still likely to provide adequate control initially, but from an Integrated Pest Management (IPM) perspective its use should be avoided, due to its extremely disruptive effect on natural enemies/beneficials, increasing the likelihood for follow up control of not only SLW, but other pests such as mites."

Two other insecticides being tested are the neo-nicotinoid (group 4A), clothianidin (Shield) and the group 4C sulfoximine.

"Testing of clothianidin showed that field populations are elevated but this may be due to vigour tolerance rather than resistance," Jamie says.

"We are currently working on refining our discriminating dose for this insecticide which will help us more clearly define populations as being either susceptible or resistant.

"Our testing of the recently registered sulfoximine has not shown any evidence of resistance in field populations to date."

## Slowing the development of resistance

There are management options based on IPM and best practice to lower the risk of resistance developing in SLW and other cotton pests.

These include controlling on-farm volunteers and ratoon plants to reduce overwintering of pests near subsequent crops; using control thresholds; and adhering to the IRMS



Stephanie Kramer inspects silverleaf whitefly bioassays for resistance to different chemistries at DAF's entomology unit in Toowoomba.

when making control decisions.

"Insecticide choice is especially relevant, evidenced by the recent changes observed for pyriproxyfen which suggest greater caution should be exercised when using this product," Jamie says.

"The Resistance Management Plan (RMP) and SLW threshold matrix are both found in the *Cotton Pest Management Guide* and have excellent advice regarding the timing and guidelines for the usage of pyriproxyfen.

"Importantly, and we often say, SLW management starts early in the season when pest management for insects such as mirids should focus on the use of softer options and the defined pest thresholds.

"The temptation to apply low rates of insecticide such as fipronil prophylactically as a combination with field passes of glyphosate to sub-threshold mirid numbers should be avoided as such practices reduce the activity of natural predators (beneficials) and increase the likelihood of SLW reaching treatment thresholds requiring control with pyriproxyfen later in the season.

"Pyriproxyfen remains the most

effective cornerstone product for IPM of SLW, and being that applications are already strictly limited to one application per season, reducing the number of seasons where the use of this product occurs through better IPM will go a long way to preserving the product's effectiveness.

"I really urge farm managers to make use of the information and tools the industry makes available, in particular the *Cotton Pest Management Guide*, and CottonInfo brochures and the web-based Cottassist SLW Matrix tool."

### For more

**Jamie Hopkinson**

**t** 0475 825340

**e** jamie.hopkinson@daf.qld.gov.au

**Paul Grundy**

**t** 0427 929172

**e** paul.grundy@daf.qld.gov.au



# Measuring nitrogen loss and indirect emissions



As the cotton industry works towards continually reducing its carbon footprint, new research shows nitrogen fertiliser losses from run-off in irrigated cotton systems can be significant.

The study is the first of its kind for the cotton industry and found an average 35 kilograms of nitrogen (N) per hectare can be lost from the field into the irrigation network (Figure 1).

This average was determined in a furrow-irrigated field with 260kg N/ha surface applied urea.

CSIRO researcher Dr Ben Macdonald (pictured) has led the Australian Department of Agriculture Filling the Research Gap – funded study, and says there is a pressing need to monitor N levels in tailwater and quantify losses. From a grower's perspective N lost means lost dollars and decreased N use efficiency (NUE). From an industry perspective, reducing the conversion of N to nitrous emissions is important to lower the industry's greenhouse gas emissions, reduce its carbon footprint, and work towards the objective of improved sustainability and environmental outcomes.

Once nitrate and other forms of nitrogen enter the tail water it is lost from the field and may undergo denitrification to become nitrous oxide ( $N_2O$ ). This process is defined as an indirect  $N_2O$  emission. This is significant because as well as meaning that N is being lost to the crop,  $N_2O$  emissions account for up to a third of all greenhouse gas emissions from agriculture globally.

## Quantifying loss

To quantify the potential to improve NUE and reduce indirect emissions in cotton systems, Ben and a team of researchers, including Guna Nachimuthu from NSW DPI have been measuring the transport of nitrate, ammonium, dissolved organic nitrogen (DON) and urea in irrigation water in supply channels and tail water returns in cotton fields. The figure shows the composition and amount of N source directly from the field and the total loss including the N supplied by the head ditch.

Ben says the initial results in the figure were surprising because it is expected that nitrate would be the biggest loss pathway.

"We were quite surprised by initial results which show a significant proportion of the nitrogen that is leaving the field is from the DON pool because it was expected that nitrate would be



the biggest loss pathway," he says.

"The export of the dissolved nitrogen pool from the soil has the potential to affect soil DON is a component of the N-pool that is typically overlooked in N management.

"The transfer occurred mainly during the first the irrigations, and while urea losses occurred during the growing season, the biggest loss was primarily also during the first irrigation.

This was likely due to the fact the urea was surface applied and watered into the field."

### International standards

The Intergovernmental Panel on Climate Change suggests that between 0.5 to 25g nitrous oxide-N is produced for every kilogram of nitrate-N lost. Potentially, up to 1.5kg nitrous oxide-N could be produced from the tail water surface alone, when the DON is included in the calculation.

Ben says further work still needs to be undertaken to determine the N<sub>2</sub>O production rate and the indirect emissions per unit area.

"What the research does show is that while nitrate losses can be small in the irrigation tail water, losses of DON and urea can be large," he said.

"The amount of time various forms of nitrogen remain in a useable form in the cotton tail water and storages has not been determined, but other studies indicate that it is short: one or two days.

"However with this in mind there are still ways growers can mitigate losses, reuse this valuable resource and improve NUE."

### Improving efficiency equals reducing costs

Improving overall water use efficiency (WUE) is a key to improving NUE. Managing irrigations to reduce run-off will help keep the nitrogen where it is needed – in the field.

Furthermore, potential may exist in some irrigation set-ups to reuse the N in tailwater on specific fields.

"As N is quickly consumed and denitrified in the tailwater, rapid reuse could be the key to mitigating these losses," Ben said.

"If possible, by setting aside a field/s where fertiliser application has been reduced (up front and in crop) and then in-season tailwater is applied exclusively to these fields to top them up.

"Furthermore, if residual N levels are known by using commercially available test strips, subsequent rates of N in fertigation and side-dressing in all fields can be adjusted accordingly."

Ben has also encouraged farm managers to undertake their own 'experiments' with fertiliser N rates.

"Taking soil tests and varying rates and timing across fields and looking into rotations which have proven to increase soil N levels, growers can get a clearer whole farm picture to make future decisions," he suggests.

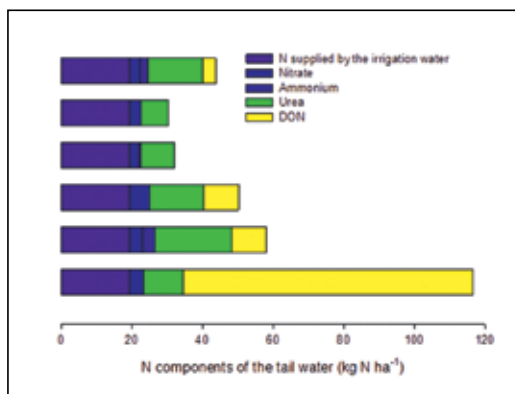
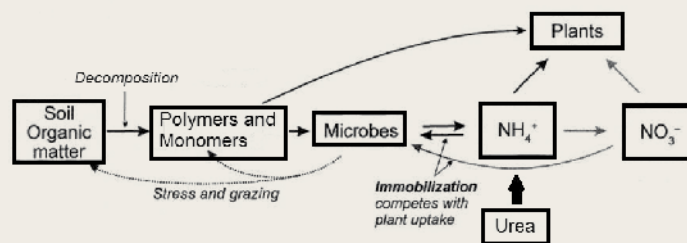


FIGURE 1. The composition and cumulative total of the nitrogen components in the irrigation tail water, and the contribution of N supplied by the head ditch, for a tillage rotation trial undertaken at ACRI, Narrabri. (DON = dissolved organic nitrogen) (MC= maize-cotton, WC= wheat-cotton, CC= cotton-cotton).

## The soil nitrogen cycle



The two main N inputs into the agricultural system are from the decomposition of soil organic matter and fertiliser inputs such as urea. Plants can access nitrogen from the soil nitrate, ammonium and organic nitrogen pool (polymers and monomers). Soil testing generally measures the mineral nitrogen pool (nitrate and ammonium) and sometimes the dissolved organic nitrogen (DON) pool. DON, which is produced from organic matter decomposition, urea and nitrate can be transported and leached from the soil by water. Excess soil nitrogen can also be transformed and lost as nitrogen, nitrous oxide and ammonia.

Ben's findings are also valuable to aid in extension messages, particularly those of the Australian Government funded 'Carbon farming in the Australian cotton industry' extension project.

"Identifying loss pathways and emissions at a field scale can help refine current BMPs for nitrogen use as this information comes to hand," says CottonInfo Carbon, Climate and Energy Technical Specialist Jon Welsh.

"Recent survey results from nutrition workshops conducted by CottonInfo and Dr Chris Dowling show growers are really keen to know how to drive their fertiliser costs down, while reducing greenhouse gas emissions.

"With some bumper yields recorded in the current picking season, nitrogen management will be a key focus of planning and decision making again for the 2015-16 season's crop as yields and removal rates increase from high yielding varieties."

### For more

**Dr Ben Macdonald**

**t** 02 6246 5947

**e** ben.macdonald@csiro.au

**w** [www.cottoninfo.net.au](http://www.cottoninfo.net.au)

## Digging deeper into nitrogen research

A new CRDC project aims to significantly reduce the uncertainty cotton growers experience in terms of the magnitude of nitrogen (N) losses and the role of soil organic matter in supplying mineral N for cotton production.

“The goal through this research is to help reduce N fertiliser inputs across the industry without any negative impacts on productivity,” says CRDC R&D Manager Allan Williams, who oversees the project.

“Industry surveys suggest we are currently over-fertilising crops to reduce risk – but is this increasing the cost of production and reducing profit?

“Data also shows we are not taking advantage of mineral N supply from soil organic matter, so this project will determine the N supplying power of soil organic matter as well as total gaseous nitrogen losses on application of fertilisers, which are both areas of major uncertainty in the cotton production system.”

The project will also assess the impact of alternative placement, timing of split applications and N fertiliser type including enhanced efficiency/slow release formulations on gaseous N losses and N use efficiency.

The joint project is being undertaken by Dr Dio Antille and Professor Bernard Schroeder at University of Queensland/National Centre for Engineering in Agriculture and (NCEA) and led by Queensland University of Technology’s Professor Peter Grace and Dr Clemens Scheer.

The trial work will be undertaken on cotton farms throughout the Darling Downs.

“Overall, this research will better enable the industry to construct accurate N budgets which quantify the contributions of N from fertiliser and soil organic matter to crop N uptake and develop best management practice for optimising the uptake of applied N and reducing the cost of N management,” Dio says.

“This data will be used to update N budgeting tools to improve nitrogen use efficiency, reduce N losses and increased profitability as well as inform extension.

“Furthermore, the data will also be made available to further refine decision support tools such as Nutrilogic, Back Paddock, Cotton Carbon Management Tool, and popular simulation models which will greatly enhance the profitability and sustainability of the industry.”

## Regional research into optimal rates

Nitrogen fertiliser is an integral application in cotton growing, and its ultimate effect on yield is being quantified through industry-wide trials to help growers make more informed decisions about rates and timing of application.

Nitrogen trials undertaken by CottonInfo Regional Development Officers in crops across cotton growing regions showed that increasing rates of nitrogen (N) fertiliser didn’t always correlate to higher yields. Further data from CSD variety trials and the Crop Consultants Australia annual survey show that percentage yield increases are not in line with rising N fertiliser application rates.

While much research has been undertaken around nitrogen use in cotton growing, there is still a lot of uncertainty regarding optimal rates, with most growers more likely to apply “more than is needed” than “not enough” at the risk of compromising yield.

This approach can lead to an overall reduction in Nitrogen Fertiliser Use Efficiency (NFUE), which is the ratio of lint yield removed for each kilogram of N applied. But what is needed by the crop to achieve maximum yield and what denotes “not enough”? How much influence does the rate and timing of the application have on yield?

### Aiming for optimal returns

Yield and nitrogen data from CSD variety trials conducted between 2008 and 2012 showed there has been a 22 percent increase in the amount of N fertiliser applied to crops – from 202kg N/ha to 245 over the period; while yield increased roughly six percent – from 2451kg lint/ha to 2594.

Meanwhile the RDO trials showed that NFUE could be improved through lower up-front N application rates with subsequent in-season N application without a risk to yield.

Soil scientist Dr Oliver Knox is working with the cotton industry in soil-related research and says given these trials are based on grower practices, they actually signify a reduction in lint production in relation to the amount of N being applied.

“As the returns of lint from the excess kilograms of nitrogen applied start to decrease, your production costs for that extra lint get higher so you are no longer getting optimal returns,” Oliver said.

“While cotton responds well to N fertiliser application, it is a ‘hit and miss’ way to increase yield, as many other management and environmental variables have an influence over final yield and both the CSD and RDO trials certainly highlighted this.

“Analysis of the CSD trials data showed that the greatest influence on NFUE between 2008 and 2013 were the season in which the crop was grown and whether the field had been under fallow or cotton in the preceding season.

“Region and variety choice had some influence on the outcome, but to a much smaller extent.”

### RDO N trials

During the 2013-14 cotton season the CottonInfo RDOs started further investigations into the influence of N on irrigated cotton production.





ABOVE: Noticeable difference in N treatments in the Darling Downs trials undertaken by RDO John Smith.



IMAGE: UNIVERSITY OF SOUTHERN QUEENSLAND

LEFT: One of the RDO nitrogen (N) response trials (through the middle of the field) where N had an impact on plant development and lint yield. This photo also shows the impact that in-field variability can have highlighting the importance of considerations around where to sample to determine and monitor crop nutrient requirements.

Of the 10 trials and field demonstrations, four appeared to show N as the most influential factor on yield, while the remaining six sites were clearly identified as being influenced by factors other than N.

In Southern NSW, increasing the rate applied up-front from 254 to 300kg N/ha provided an additional 0.04 bales/ha (10kg lint/ha). The Macquarie Valley trial applied in split applications: 230, 260, 290 and 320kg N/ha (140kg N/ha was water run in-crop) with the highest rate of 320kg N/ha yielding 81kg of lint more than the lowest. Yields varied from 9.46 bales/ha to 9.82 bales/ha at the highest rate.

In Central Queensland trials, there was a small increase in yield by increasing N rates from 120 (upfront) to 360kg N/ha (applied as a split with 120kg N/ha in-crop) from 10.8 bales/ha at the lowest rate to 11.5 bales/ha at the highest rate.

The field scale demonstration in Goondiwindi had one rate up front (184kg N/ha) and four rates applied in crop to give total N applied rates of 250, 303, 356, 461kg N/ha. The rates applied in-crop were applied in one application for the 250 total N treatment and two applications for the other three

treatments. Increasing the N from 250 to 303kg/ha provided an extra 1.5 bales/ha; increasing from 303 to 356kg N/ha provided an extra 0.8 bales/ha; the highest rate which had another 105kg N/ha provided an extra 0.5 bales/ha.

Although in this individual trial applying more N produced more lint, the NFUE fell from 18.2 to 6.1. Similarly, in the 303kg N and above treatments, for each extra \$1 of N applied the extra lint value was also roughly \$1. This was opposed to \$14 and \$10 lint returns on each dollar of N applied in the lower treatments and does not factor in other production costs such as application.

The remaining six sites were clearly identified as being influenced by factors other than N, which resulted in greater yield variability than that of the N treatments, although it was possible that the N treatments may have exacerbated some of these other issues.

For example, in the Gwydir Valley there was yield difference between the 250 and 300kg N/ha treatments at 11.68 and 11.65 bales/ha, respectively. However, hail and disease resulted in a 2.82 bale/

ha decrease in the highest rate of 400kg N/ha. Other sites on the Darling Downs and two at Walgett in NSW were influenced by water shortages and disease (respectively) where no differences in yield or yield penalties occurred within the range of N application rates used.

### Post-harvest N levels

Soil tests were undertaken after harvest to ascertain residual soil N levels. These test showed variable levels of nitrate-N to the increased rates of applied N. The Macquarie and Gwydir sites in particular showed increases in the levels of soil nitrate with increased N application rates.

The Darling Downs did not have increasing amounts of soil nitrate corresponding to increased N application rates, suggesting larger amounts of fertiliser N were unaccounted for or potentially lost from the system during that crop.

“There is an often held thought that N applied to cotton that is not used by the crop will be there for the next crop which, while loosely true, is an extremely risky way to manage N requirements in a subsequent crop.

“This form of N is at a high risk of loss from the system due to a number of means, most commonly denitrification resulting from any type of waterlogging event.

“So increasing N application with the thought that what is not used by the cotton will be used by the next crop becomes an extremely high risk way of managing its N requirements, and (as evident on the Darling Downs) there may be no N remaining at all after harvest.”

Oliver said there are a number of things that are apparent from the trial data.

“Firstly, it is possible to grow a 12 to 14 bale/ha crop and to achieve NFUE outcomes of 13 to 18kg of lint/kg of N applied, however, most cotton growers currently aren’t in this range.

“As we know, yield is not solely determined by N: there are many factors that affect the way the plant develops, sets fruit and yields lint and we’ve no control over the weather, which is the biggest of these external factors.

“However, the data from CSD and the growers surveys do appear to indicate that across the cotton growing regions there is some difference in the amounts of N applied (Table 1).

“Hopefully this is because of yield expectations within

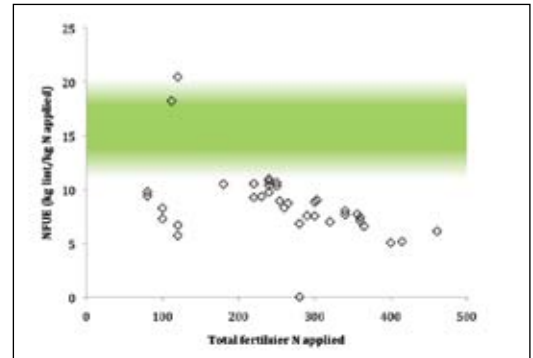


Figure 1. NFUE outcomes from the 2013 RDO trials plotted against the fertiliser N applied (kg/ha) in the trials. The optimal range is 13 to 18kg lint/kg N applied (roughly indicated in green).

the region and local knowledge of field constraints.

“If this is the case then for many reaching an NFUE of 13 to 18 might be a dream, but it does not mean that it is not worthwhile to attempt to improve NFUE.

“Improving your NFUE can be done in one of two ways: either reducing your N inputs or by improving yield to match the levels of N used – and that’s where we think the opportunities exist, because it involves getting a better handle on the whole system.”

### Better managing N

So what action can be taken to achieve optimum efficiency without risking yield?

Firstly, calculate current NFUE across fields to determine if there are some that rate better than others. It may be possible to identify an aspect of management that could be adapted elsewhere to improve NFUE across other fields on the farm. It is also good practice to take soil and in-season tissue tests and apply N accordingly.

The RDO trials showed that NFUE could be improved through lower up front N application rates with subsequent in-season N application without a risk to yield.

“Finally, either run your own N rate trials to see what rates and methods of application work best for your situation or talk to your local RDO about trials in the region.

“In the face of relatively static global prices for cotton and ever rising fuel and fertiliser costs, being on top of your NFUE and improving your N management is one way to improve profit margins while reducing potential N losses to the environment.”

	kg N/ha			lint yield			NFUE		
	CSD	CSD12/13	Grower	CSD	CSD12/13	Grower	CSD	CSD12/13	Grower
Central Queensland	229	260	216	1924	2149	1654	8.6	8.3	7.7
Darling downs	186	185	189	2123	2147	1951	12.2	11.6	10.9
Macquarie	221	290	285	2671	3160	2727	13.0	10.9	9.8
Northern NSW	212	216	244	2447	2650	2469	12.0	12.5	10.6
Southern NSW	221	237	227	2492	2560	2418	11.6	10.9	11.1
Southern Queensland	245	270	276	2582	2655	2278	11.1	10.3	8.3

Table 1 Regional average N applied, lint yield and NFUE calculated from CSD trials from 2008 to 2013, from the CSD trials conducted in 2012-13 and the 2012-13 Growers Survey.



## MEET THE RESEARCHER

# It's a long way from Santa Fe

Dr Dio Antille has recently joined the Australian cotton industry research community, and it's a long way from Santa Fe in Central-East Argentina...



Dr Diogenes Antille, or "Dio" as he is known, is a researcher with CRDC's project *Increasing profitability through improved nitrogen use efficiency and reducing losses of nitrogen* from his base at the National Centre for Engineering in Agriculture (NCEA) at University of Southern Queensland (USQ) in Toowoomba, Queensland.

Dio grew up in the city of Santa Fe in Central-East Argentina, the commercial and transportation centre for a rich agricultural area producing grain, oilseeds and livestock. However Dio's main love was spending time whenever possible on the family farm – a 750Ha cattle and grain growing operation about an hour and a half out of Santa Fe adjacent to the impressive Parana River, the second longest (only to the Amazon) in South America.

The Parana River stretches along the Santa Fe Province from north to south, encompassing the "Llanura Chaco-Pampeana" (flat pampas), an iconic region, which, apart from a few sierras in the northwest and south, appears perfectly flat. The region has been transformed since the mid-19th century when it was only home to cattle and horses, rounded up by gauchos, who were celebrated for their horsemanship, hardiness, and lawlessness.

"I would spend as much time as I could there when I was not at school," Dio says.

"As had been in the past, horses (and later polo) and cattle were a part of our lives. I was also into rugby, which I played from an early age until I retired in 2011.

"Our farm was about 10 kilometres

from the Parana River, with cotton and rice grown to the north, grain and beef to the west, and grains and dairy to the south/south-west."

So how does a boy from the flat lands of Santa Fe come to follow a life of study and research around the world?

"I love farming and I have always had a special interest in soil and water conservation since early days," Dio says.

"Perhaps I inherited this from Dad. He was a research and extension officer at the ministry of agriculture in Santa Fe and led many projects on soil conservation in the 80s and early 90s and I used to go along in his field campaigns.

"Later while at the Universidad Nacional del Litoral in Santa Fe studying agricultural engineering I was involved in projects as a research assistant in the soils department – a time I enjoyed very much as the people there were former colleagues of Dad at the ministry – so were well known to me.

"After university I went to work in our capital Buenos Aires as a consultant in soil and water management and irrigation until 2002, when the economic crisis hit Argentina.

"Our main projects were with overseas clients who were unwilling to continue to invest in our unstable economy, so the offer to go to England was welcomed and my time in the UK was very rewarding.

In 2005, still in England and motivated by his continued interest in soil science, Dio enrolled in a Master of Science (MSc) in Soil Management, investigating the effect of

combine harvester tyres and rubber tracks on soil compaction at the UK National Soil Resources Institute (formerly at Cranfield University Silsoe).

"When I finished, I was offered a scholarship by the Engineering and Physical Science Research Council to undertake my Engineering Doctorate studies at Cranfield," he says, "This research led to the development of a urea-coated organomineral fertiliser made with biosolids granules.

"From there I went to work in Ireland with Teagasc, the national Agriculture and Food Development Authority."

Dio's migration to Australia came toward the end of his contract with Teagasc and he saw an ad for a position with the NCEA/USQ in Toowoomba.

"The position had many elements at the heart of my interests, and there was also a logic career progression in the decision to apply," he says.

"The NCEA is developing fast and consolidating an excellent group of scientists and engineers with multidisciplinary backgrounds, so for me it's a good place to be."

The rest is history as they say, and in May 2013 Dio made the move to Toowoomba where he is currently a Research Fellow (Irrigated Soils) with the NCEA at USQ, working toward helping Australian cotton growers improve fertiliser nitrogen use efficiency. This project is jointly conducted with QUT and led by Professor Peter Grace.

# Understanding what drives the weather at Walgett

Farmers Toby and Susie Moore understand the importance of interpreting information to manage climate risk on their Walgett property “Walma” – particularly at key decision-making times.

The Moore’s operate an extensive enterprise including grazing, dryland and irrigated farming on the Lower Namoi floodplain in North-West NSW. Understanding the local climate in terms of rainfall drivers and temperature has been a critical survival skill Toby has embraced as a farmer. After studying biochemistry and biology at university, Toby made a career in the pharmaceutical industry before returning to the family business. He has adapted skills in analysis, due diligence and sourcing information to aid his decision-making in agriculture.

## Know key climate drivers

The Moore’s preparation for growing a cotton crop starts at least two seasons ahead, with planning for row spacing, nitrogen fertiliser rates for an estimated cropping area, and most importantly, available irrigation water.

“With early stage analysis of available irrigation water, together with stored soil moisture and seasonal forecasts, we can plan for a range of likely scenarios when procuring inputs such as seed, fertiliser and diesel,” Toby says.

“Knowing historically where indicators such as Niño 3.4 sea surface temperature and the Southern Oscillation Index (SOI) need to be for the rainfall outlook to be more favourable, and in which months

there is a stronger correlation, (or no correlation) helps me to understand how to interpret seasonal forecasting models in conjunction with the computer-generated guidance maps that tend to dominate our decision making.

“Looking at the CottonInfo climatic rainfall analysis for the Walgett area, the SOI is a key driver of rainfall from May right through until spring planting.

“In summer months there is very little connection with the El-Niño SOI, but if we know rainfall processes are completely random in these months, at least we don’t need to take too much notice of the media’s commentary around SOI.”

## Two basic functions

In terms of understanding basic climatic processes, Toby believes it’s best to break them into two basic functions: moisture supply (sea surface temperature indices); and moisture delivery and activation (atmospheric indicators).

“Rain-making processes work pretty much the same as my irrigation system. We have a moisture supply component - ocean temperatures, and a delivery component - a series of pumps and channels representing the atmosphere,” he said.

“When the ocean indices are in the wrong place, the available moisture for rain events is reduced, just like a storage



Analysing and interpreting climate information is a key part of Toby Moore’s decision-making on his farm “Walma” at Walgett.

dam being low, so it is a lot harder for the atmosphere to deliver a decent rain event.

“Similarly when moisture supply is average or good (warm sea surface temperatures in the Indian and Pacific oceans), we really need a favourable SOI and the Southern Annular Mode to transport and activate the moisture to make it rain, a bit like starting our irrigation pumps and filling the channels.”

## Value in workshops

Through attending CottonInfo webinars and workshops with Carbon, Climate and Energy Technical Specialist Jon Welsh, Toby understands how the atmosphere and ocean temperatures work together and what to watch for in the winter and spring seasons when the connection with these indicators is strongest.

“Watching the smooth line of sea surface indicators can at least give some guidance as to what the atmospheric moisture supply will be like on a long lead time. This year (2015), unfortunately all the models seem to say we are heading for El Niño for the remainder of the year,” Toby said.

“But out here the SOI really is a key driver of rainfall so I’ll be keeping an eye on that throughout winter and spring.”

“The fortnightly summary in the CottonInfo e-news Moisture Manager also saves me time searching for the modelling results. What I’m looking for is a clear trend from a range of sources to give me confidence that something is going to change.

“At least then I can try and run some scenarios in our business and manage my farm inputs in advance.”

Information Source/Indicator	Season			
	Winter	Spring	Summer	Autumn
Seasonal (3 monthly) rainfall outlooks	X	X		
Seasonal temperature outlooks	X	X	X	X
Multi-week rain/temp models	X	X	X	X
Southern Annular Mode		X		
Southern Oscillation Index	X	X		
Sea surface temperature indicators	X	X		
Madden-Julian Oscillation			X	

Suggested seasonal risk management plan for farming in the Walgett region. The ‘X’ indicates seasons when a climate indicator is likely to provide relevant information.



# Climate risk management:

## making decisions and dealing with imperfect information

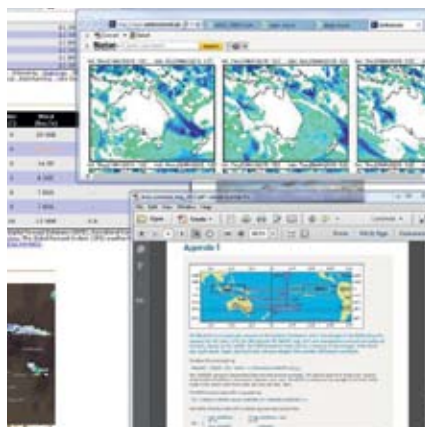
CottonInfo Climate, Energy and Carbon Technical Specialist Jon Welsh 'breaks down' how best to use available climate data to assess risk.

Evaluating and interpreting layers of climate information, weather acronyms and colour charts at key decision making times can be a daunting prospect.

Some growers have their favourite weather sites on which to base their decisions, while others prefer to watch for a flock of black cockatoos on the wing or a cactus flowering to see if rain is coming. Others only believe forecast rain when the gutters are running water. Those that have been burnt by a forecast in the planning stage have an inherent distrust in weather predictive systems.

Whatever the view as a user, relying on modern forecasting tools in an environment with imperfect information is common in other sectors; particularly commodity markets, foreign exchange and share markets. Fundamental principles on risk management can help navigate a way through the maze.

Here are five suggestions on dealing with climate information and climate risk in your business.



1

### Survey information sources widely

Relying on one particular model or information source is risky. Computer guidance can be very good at certain times of the year and have strengths or weaknesses with climatic influences that are not always known to the user. When it comes to seasonal (three-month) forecasts and strategic planning it is prudent to look at the output from other leading climate research agencies. The Australian Bureau of Meteorology releases monthly seasonal temperature and rainfall forecasts. The results of this forecast should be considered in the context of other models such as government meteorological agencies in the US, Europe and Asia.

The Bureau of Meteorology is only one of around 12 operational seasonal General Circulation Models (GCM's). Identifying consensus from these models can give extra confidence in decision making. Variable results can also signal a more conservative approach is required.



2

### Using seasonal temperature forecasts

As a farmer, it is human nature to go on-line and seek out rainfall forecasts, as naturally, a decent rain event drives production and operational decisions.

As managers of moisture we also need to consider another side of the ledger on our moisture balance sheet – evaporation from high temperatures. Too often concentrating on rainfall output can be misleading. From a purely scientific perspective, modelling and simulating rainfall convective processes in various layers of the atmosphere is very challenging. The accuracy of rainfall seasonal predictions also varies throughout each season.

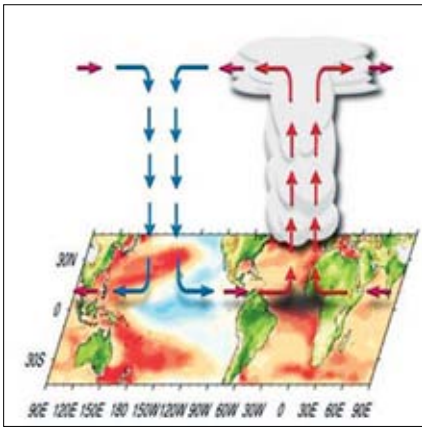
Temperature on the other hand can be a useful guide to how the air pressure patterns are behaving. We all know that a high pressure cell stabilised over south-eastern Australia can create day-after-day of clear, fine and warm weather. Air pressure patterns are the primary input into temperature predictions and these outputs generally come with a higher accuracy than rainfall predictions. Above average temperature forecasts can be a good guide to approaching months of heat waves and extreme weather. Models showing below average 3 monthly outlooks can also signal increasing cloud cover and lower evaporation, and hopefully rainfall.

#### For more

Jon Welsh

t 0458 215 335

e jon.welsh@cottoninfo.net.au



3

## Do you know how El Niño Southern Oscillation (ENSO) affects you?

Depending on your geographic location, leading indicators of ENSO such as the SOI or Niño 3.4 Sea Surface Temperature indices driving rainfall and temperature will be variable. Most technical information on climate will offer commentary on Pacific Ocean warming, trade winds and Southern Oscillation Index.

Generally, from January to May, temperature and rainfall in most summer cropping regions is poorly correlated with ENSO. However, in the winter cropping season and the onset of summer crop planting we need to assess what ENSO phase we are in (El Niño, Neutral, La Niña). Recent research by Professor Roger Stone found climate models had far greater accuracy during defined La Niña or El Niño events than they did in neutral years. Neutral years should not be confused with average years; variability will increase during ENSO neutral years and the longer term accuracy of seasonal models is reduced.



4

## Benchmarking computer guidance with indicators a must during planting

With such a large amount of information available on rainfall and temperature guidance and most short-term models changing every 12 hours, it is unlikely even the most optimistic user to be fully comfortable with a forecast when applying knowledge to a farm management decision. Each computer generated colour chart has its own individual algorithm with a different set of weighted ingredients, that is sea surface temperature and atmospheric data. Spring planting time is a classic example of watching the phase of the Southern Annular Mode (SAM) index; researchers have found that the SAM influences moisture circulation patterns in the eastern Australian cropping region. When looking to plant summer crop or top-dress winter crop in the spring keeping one eye on the SAM index can help validate rainfall model outputs to some extent, and increase user confidence.



5

## The big picture – is our business over-exposed to ENSO variability?

Many farmers and farm businesses become frustrated when forecast rain doesn't materialise or drought occurs without warning. Primary production is very exposed to the vagaries of extreme climate variability and Australia has the most variable climate on Earth.

In other sectors such as commodity trading or foreign exchange, firms protect themselves with hedging strategies to reduce their exposure to extreme variability. These are generally complex financial instruments which require constant monitoring to limit downside risk.

From a big picture perspective farm businesses owners are, in a general sense, also managers and purveyors of financial capital. Financial research shows the correlation between farm returns and those returns from residential real estate, global share markets and various sectors of the economy as counter-cyclical. This goes some way to explaining why large multi-national life insurance funds are investing in Australian agriculture; to reduce their exposure to financial markets. A good example of portfolio diversification and natural hedging in agriculture is a business supplying crop herbicides to farmers in wet years and also supplying livestock liquid supplements in dry years, to dampen fluctuations in income.

## Sign up for the CottonInfo Moisture Manager

To assist grower decision making, Jon puts together the CottonInfo Moisture Manager – an information-rich, user-friendly and timely weather and climate service, essential for farming businesses looking for an edge in climate risk management. Further climate information is available at [cottoninfo.net.au](http://cottoninfo.net.au)

To sign up for the fortnightly e-newsletter (and other CottonInfo communications) [www.cottoninfo.com.au/subscribe](http://www.cottoninfo.com.au/subscribe)

Twitter – @CottonInfo.com

This project is supported by funding from the Australian Government.



# CRDC's 2015 -16 projects

In 2015-16, CRDC will be investing \$20.6 million into more than 150 projects across the five program areas of the CRDC Strategic R&D Plan (farmers, industry, customers, people and performance) on behalf of Australia's cotton growers and the Australian Government. This table outlines the projects that CRDC will be investing in, along with the lead researcher, their research organisation, and the commencement and completion dates for the projects. Please note that this table is current as of 15 May 2015, and is subject to change.

Project title	Project code	Researcher	Organisation	Commenced in	To be completed in
<b>Program one: Farmers</b>					
Advancing integrated weed management in the Australian cotton and grains industries (CottonInfo technical specialist)	DAN1510		NSW DPI	Apr-15	Jun-18
Advancing VARlwise with autonomous irrigation (and a grower's guide)	NEC 1401	Alison McCarthy	NCEA	Jul-13	Jun-16
Agronomic management for better fibre and textile quality	CSP1308	Michael Bange	CSIRO	Jul-12	Jun-16
Agronomy for resilient future cotton systems		Michael Bange	CSIRO	Jul-15	Jun-18
Applying plant-based measurements for irrigation in water-limited environments.	CSP1104	Onoride Coast	CSIRO	Jul-12	Jun-16
Assessing the impacts of new harvesting technologies on cotton	NEC1301	John Bennett	NCEA	Jul-12	Dec-15
Assisting cotton industry diversification in coastal NQ & tropical Australia	CSP1302	Steve Yeates	CSIRO	Jul-12	Sep-15
Benchmarking water use efficiency and crop productivity in the Australian cotton industry (CottonInfo technical specialist)	DAN1505	Janelle Montgomery	NSW DPI	Jul-14	Jun-19
Carbon farming in the Australian cotton industry (CottonInfo technical specialist)	CFEO1401	Jon Welsh	CSD	Jul-13	Jun-17
Centre for Biopesticides & Semiochemicals: Development of new tools & strategies for IPM	DAN1404	Robert Mensah	NSW DPI	Jul-13	Jun-18
Centre for Biopesticides & Semiochemicals: Novel insecticides and synergists from endemic and exotic flora	UWS1401	Robert Spooner-Hart	UWS	Oct-13	Jun-18
Centre for Biopesticides & Semiochemicals: Semiochemical management for occasional pests of cotton and grains	UNE1404	Peter Gregg	UNE	Oct-13	Jun-18
Commercial development and evaluation of a machine vision-based weed spot sprayer	NEC 1402	Cheryl McCarthy	NCEA	Jul-13	Jun-16
Commercial grower-led irrigation system comparison in the Gwydir Valley		Louise Gall	G VIA	Jul-15	Dec-17
Crop protection development specialist (CottonInfo technical specialist)	DAQ1502	Ngaire Roughley	QDAF	Jul-14	Jun-17
Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems	AOTG1401	Steve Kimber	NSW DPI	Jul-13	Jun-17
Development of a pump efficiency monitor for use in the Australian cotton industry	NEC1501	Phillip Szabo	NCEA	Jul-14	Jun-16
Development of Revolutionary "Float Actuated, Fully Automatic, Flow Regulating Valves (Commissioned)	CRDC1514	Peter Cocciardi	Cocky Valves	Jul-14	Jun-16
Diseases of Cotton XI	DAN1403	Karen Kirkby	NSW DPI	Jul-13	Jun-16
Economic and risk analysis for carbon farming in the Australian cotton industry	CFEO1502	Janine Powell	NSW DPI	Jul-14	May-17
Enhancing IPM in cotton systems	CSP1401	Lewis Wilson	CSIRO	Jul-13	Jun-18
Establishing southern cotton IPM	DAN1501	Sandra McDougall	NSW DPI	Jul-14	Jun-17
Fusarium wilt management in cotton	DAQ1402	Linda Smith	QDAF	Jul-13	Jun-16
Future farm automation and robotics management			USQ	Apr-15	Jun-18
Identification of beneficials attacking silverleaf whitefly and green vegetable bug	CSP1303	Lewis Wilson	CSIRO	Jul-13	Jun-16
Improving cotton productivity with crop nutrition	CSP1403	Ian Rochester	CSIRO	Jul-13	Jun-16
Increasing profitability through improved nitrogen use efficiency and reducing gaseous losses of nitrogen		Peter Grace	QUT	Jul-15	Jun-18
Indirect emissions of nitrous oxide from broad acre irrigated agriculture	FTRG1401	Ben Macdonald	CSIRO	Jul-13	Jun-16
Integrated program to deliver automated, adaptive, precision irrigation system		Joseph Foley	USQ	Jul-15	Jun-18

Project title	Project code	Researcher	Organisation	Commenced in	To be completed in
Irrigation agronomy for tailored and responsive management with limited water		Rose Brodrick	CSIRO	Jul-15	Jun-18
Management of Solenopsis mealybug, mirids and apple dimpling bug in Bollgard® cotton	DAQ1501	Moazzem Khan	QDAF	Jul-14	Jun-17
Management options enhancing beneficial microbial functions in cotton soils	CSE1401	Gupta Vadakattu	CSIRO	Jul-13	Jun-16
Microbial solutions for sustainable cotton and soil health management	UNE1303	Lily Pereg	UNE	Jul-12	Oct-15
Monitoring greenhouse gas emissions from irrigated cropping systems	CLW1401	Ben Macdonald	CSIRO	Jul-13	Jun-16
Network Development Officer – Upper Namoi Valley (CottonInfo regional development officer)	CRDC1405	Katie Slade	UNCGA Agvance	Jul-13	Jun-16
Optimising management of manure in southern NSW cotton production		Wendy Quayle	CSIRO	Jul-15	Jun-18
Optimising water and energy use in the CQ irrigation sector (CottonInfo technical specialist)	DAQ1404	Lance Pendergast	QDAF	Jul-13	Jun-16
PhD: Enhancing resistance to salinity, drought and diseases in cotton using a single gene		Ben Schreiber	UNE	May-14	Apr-17
PhD: Host plant relationships of green mirids – is alternative control possible?	UQ1402	Justin Cappadonna	UQ	Nov-13	Nov-16
PhD: Microbial tools for advancing the management of soil and seedling health in cotton production systems	UNE1305	Sarah Cooper	UNE	Feb-13	Feb-16
PhD: Multiple host use and gene-flow in green vegetable bug relative to cotton crop	UQ1403	Dean Brookes	UQ	Mar-13	Jun-16
PhD: Quantifying and mapping the impacts of herbicide drift on cotton (non-target crop)	USQ1404	Luz Cadavid	USQ	Dec-13	Dec-16
PhD: Self-guided drones for tracking irrigation in a cotton field	USQ1402	Derek Long	USQ	Mar-14	Mar-17
PhD: Soil-specific strategic irrigation: identifying saline-sodic water as a resource	NEC1403	Aaditi Dang	NCEA	Mar-14	Jan-17
PhD: The impact of irrigation methods and management strategies on nitrogen fertiliser recovery in cotton	UQ1502	John Smith	UQ	Jul-14	Dec-18
PhD: The physiology of cotton crop nutrition, shade & waterlogging	US1301	Najeeb Ullah	USYD	Mar-12	Sep-15
Phosphorus availability in raingrown cotton	UNE1501	Brendan Griffiths	UNE	Jul-14	Feb-16
Post doc: Cotton production in a future climate	CSP1501	Katie Broughton	CSIRO	Jul-14	Jan-18
Post doc: Hard to control weeds in northern farming systems – understanding key processes to improve control methods	DAN1402	Sudheesh Manalil Velayudun	NSW DPI	Jul-13	Jun-17
Post doc: Professor of soil biology	UNE1403	Oliver Knox	UNE	Jan-14	Dec-18
Resilient cotton-farming systems in irrigated vertosols: soil quality, carbon & nutrient losses, cotton growth & yield in long-term studies	DAN1503	Guna Nachimuthu	NSW DPI	Jul-14	Jun-17
Soil system research – physical, chemical and biological processes for plant growth and nutrient cycling down the whole soil profile	UNE1601	Brian Wilson	UNE	Jul-15	Jun-18
Specialist agronomic, physiology and systems support for new and existing region		Steve Yeates	CSIRO	Jul-15	Jun-18
Staying ahead of weed evolution in changing cotton systems	UQ1501	Jeff Werth and Bhagirath Chauhan	QAAFI	Jul-14	Jun-19
Strengthening the Central Highlands cotton production system	DAQ1401	Paul Grundy	QDAF	Jul-13	Jun-16
The implications of 'big data' for Australian agriculture	CRDC1529	Mick Keogh	AFI	Apr-15	Mar-16
Viruses, vectors and endosymbionts: exploring interactions for control	UQ1305	Sharon van Brunschot	UQ	Apr-13	Jun-16

#### Program two: Industry

Baselining Lower Namoi groundwater and evaluating Pilliga CSG developments		Bryce Kelly	UNSW	Jul-15	Jun-18
Conventional insecticide resistance in Helicoverpa – monitoring, management and novel mitigation strategies in Bollgard 3	DAN1506	Lisa Bird	NSW DPI	Jul-14	Jun-19
Cotton industry adaptation to extreme weather and climate change	UWS1301	Brajesh Singh	UWS	Jul-12	Dec-15



Project title	Project code	Researcher	Organisation	Commenced in	To be completed in
Critical thresholds for riparian vegetation regeneration in the northern Murray-Darling Basin	GU1401	Samantha Capon	Griffith University	Jul-13	Jun-16
Demonstration of novel evaporation mitigation technology in large scale trials	CRCP1401	David Solomon	CRC Polymers	Jul-13	Jun-16
Developing the groundwater health index (GHI) as an industry-wide monitoring tool	MQ1501	Grant Hose	Macquarie University	Jul-14	Jun-17
Economic risk assessment of resistance management strategies for Bt cotton	CSE1404	Stuart Whitten	CSIRO	May-14	Jun-16
Helicoverpa egg collecting in cotton regions to support Bt and insecticide resistance monitoring	CCA1401	Fiona Anderson	CCA	Jul-13	Jun-16
Helicoverpa punctigera in inland Australia – what has changed?	UNE1502	Peter Gregg	UNE	Jul-14	Jun-17
Investigating the on-farm risks of aflatoxin contamination of cottonseed	DAN1406	Kathy Schneebeli	NSW DPI	Jan-14	Dec-16
Keeping pest populations lower for longer: Connecting farms and natural systems	CSE1501	Nancy Schellhorn	CSIRO	Jul-14	Dec-17
Managing Bt resistance and induced tolerance in Bollgard 3 using refuge crops		Mary Whitehouse	CSIRO	Jul-15	Jun-18
Managing Bt resistance, H.punctigera movements & cotton planting windows	CSE1306	Geoff Baker	CSIRO	Jul-12	Jun-16
Managing climate variability program	GRDC1401	Beverley Henry	GRDC	Jul-13	Jun-16
Managing riparian corridors on cotton farms for multiple benefits		Rhiannon Smith	UNE	Jul-15	Jun-18
Measuring deep drainage from a cotton/wheat trial	CLW1301	Anthony Ringrose-Voase	CSIRO	Jul-12	Jun-16
Monitoring to manage resistance to Bt toxins	CSE1402	Sharon Downes	CSIRO	Jul-13	Jun-16
National cotton NRM technical specialist (CottonInfo technical specialist)	CRDC1501	Stacey Vogel	Consultant	Jul-14	Jun-17
National facility for cotton climate change research	CSP1402	Michael Bange	CSIRO	Jul-13	Dec-16
NCEDD – Stewardship of biotechnologies and crop protection (CottonInfo technical specialist)		Sally Ceeney	Consultant	Jul-15	Jun-18
PhD: Effects of climatic fluctuation and landuse change on soil condition in the lower Lachlan	US1403	Patrick Filippi	USYD	Mar-14	Mar-17
PhD: Evolution of viral diversity and virus ecology in the management of resistance to biopesticides	QUT1402	Chris Nouné	QUT	Jan-14	Jun-17
PhD: Spatial & temporal importance of diffuse & stream recharge in semiarid environments: Implications for integrated water mgt	UNSW1403	Calvin Li	UNSW	Mar-14	Feb-17
PhD: Sustainable water extractions: Low flow refugia and critical flow thresholds	UNE1406	Marita Pearson	UNE	Jan-14	Dec-19
Resilience assessment of the Australian cotton industry at multiple scales	CRDC1502	Francesca Andreoni	Bel Tempo	Jul-14	Jun-17
Silverleaf whitefly resistance monitoring 2013-2016	DAQ1403	Jamie Hopkinson	QDAF	Jul-13	Jun-16
Substitutes for pupae busting-commercial scale trials of moth busting	UNE1301	Peter Gregg	UNE	Jul-12	Dec-15
Surveillance and studies for endemic and exotic virus diseases of cotton		Murray Sharman	QDAF	Jul-15	Jun-19
Surveillance for exotic cotton viruses: multiple targets in and nearby Australia	DAQ1405	Cherie Gambley	QDAF	Jul-13	Jun-16
The impact of improved water use efficiency on paddock and catchment health	DNRM1401	Mark Silburn	DNRM	Jul-13	Jun-16
The sustainable chemical control and resistance management of aphids, mites and mirids in Australian cotton: 2014-2019	DAN1507	Grant Herron	NSW DPI	Jul-14	Jun-19

### Program three: Customers

A review of emission methodologies for the Australian cotton industry & development of a detailed study for NW NSW (Commissioned)	DAN1508	Pip Brock	NSW DPI	Jul-14	Dec-15
Breathable cotton for compression athletic wear		Maryam Naebe	DeakinU	Jul-15	Jun-17
Determining the shelf life of round modules and impact on cotton quality	CMSE1501	Menghe Miao	CSIRO	Jul-14	Jun-16
Developing renewable fine chemicals from cotton biomass		William Doherty	QUT	Jul-15	Jun-18

Project title	Project code	Researcher	Organisation	Commenced in	To be completed in
Enhancing and testing the Cotton Carbon Management Tool	UQ1503	Francois Visser	UQ	Jul-14	Jun-16
Ever-dry self-cooling cotton fabrics	DU1402	Tong Lin	DeakinU	Jan-14	Dec-15
Identifying the glass transition temperature behaviour of Australian cotton	CMSE1201	Chantal Denham	CSIRO	Jul-11	Dec-15
Measuring and managing fibre elongation for the Australian cotton industry	CMSE1504	Shouren Yang	CSIRO	Jul-14	Jun-16
Novel anti-wetting & self-sterilising cotton fabrics	DU1501	Xin Liu and Yun Zhou	DeakinU	Jul-14	Jun-17
Novel spinning technologies for fine and high quality Australian cotton yarns	DU1502	Xungai Wang	DeakinU	Jul-14	Jun-17
PhD: Effects of cotton cellulose structure & interactions on dye uptake	CMSE1308	Genevieve Crowle	CSIRO	Jul-12	Jun-16
PhD: High value bio-extractives and bioethanol from cotton gin trash	DAN1504	Mary Egbuta	NSW DPI	Jul-14	Aug-17
PhD: Improving length, strength and fineness of cotton fibre	DU1401	Rangam Rajkhowa	DeakinU	Jan-13	Jan-16
PhD: Low wax Australian cotton – reducing the scouring requirements of cotton fabric	CMSE1403	Katherine Birrer	CSIRO	Apr-14	Mar-17
Raising the quality of Australian cotton through post harvest initiatives	CMSE1503	Rene van der Sluijs	CSIRO	Jul-14	Jun-17
Smart cotton/carbon fabrics for electromagnetic interference shielding		Jin Zhang	DeakinU	Jul-15	Jun-18
The contribution of cotton cellulose crystallites to fibre strength	CMSE1502	Stuart Gordon	CSIRO	Jul-14	Jun-16

Program four: People					
AACS 2015 Australian Cotton Researcher Conference	CRDC1520	Paul Grundy	AACS	Jan-15	Oct-15
Australian cotton production and best practice documentaries	DAQ1302	Paul Grundy	QDAF	Jul-13	Jun-16
Australian Rural Leadership Program			ARLP	Jul-15	Jun-16
CCRSPI	CCR1201	Heather Hemphill	RIRDC	Jul-13	Jun-16
Co-investment in PIEF Membership for the cotton industry	CA1503	Adam Kay	CA/PIEF	Jul-13	Jun-16
Collaborative partnership – primary industries health and safety	RIRDC1301	Simon Winter	Joint Partnership RIRDC	Aug-12	Jun-17
Cotton Conference foundation sponsorship			CA	Jul-15	Sep-16
Cotton ginning training program	CMSE1302	Rene Van der Sluijs	CSIRO	Jul-12	Dec-15
Cotton industry leadership development strategy	RIR1401	Matt Linnegar	ARLF	Jul-13	Jun-16
Cotton industry young professionals program	USQ1501	Kay Lembo	USQ	Jan-15	Dec-15
CRDC Grassroots Grants			CGAs	Jul-15	Jun-16
CRDC Summer and Honours Scholarships				Jul-15	Jun-16
Developing education capacity for the Australian cotton industry (CottonInfo technical specialist)		Trudy Staines	CSIRO	Jul-15	Jun-18
Education and Development of the Cotton Industry	CGA1507	Emma Ayliffe	CGA	Dec-14	Dec-15
Horizon Scholarships 2013 – Alana Johnson	RIRDC1305	Alana Johnson	RIRDC	Apr-13	Dec-15
Horizon Scholarships 2013 – Charlie French	RIRDC1303	Charlie French	RIRDC	Apr-13	Dec-15
Horizon Scholarships 2013 – Emily Miller	RIRDC1306	Emily Miller	RIRDC	Apr-13	Dec-15
Horizon Scholarships 2013 – Jessica Kirkpatrick	RIRDC1302	Jessica Kirkpatrick	RIRDC	Apr-13	Dec-16
Horizon Scholarships 2013 – Paul Sanderson	RIRDC1304	Paul Sanderson	RIRDC	Apr-13	Dec-16
Horizon Scholarships 2014 – Alana Martin	RIRDC1404	Alana Martin	RIRDC	Mar-14	Dec-17
Horizon Scholarships 2014 – Felicity Taylor	RIRDC1401	Felicity Taylor	RIRDC	Mar-14	Dec-17
Horizon Scholarships 2014 – Grace Scott	RIRDC1402	Grace Scott	RIRDC	Mar-14	Dec-17
Horizon Scholarships 2014 – Michael Wellington	RIRDC1405	Michael Wellington	RIRDC	Mar-14	Dec-17
Horizon Scholarships 2014 – Sam Johnston	RIRDC1403	Sam Johnston	RIRDC	Mar-14	Dec-17
Horizon scholarships 2015 – Camilla a'Beckett	RIRDC1504	Camilla a'Beckett	RIRDC	Jul-15	Jun-17
Horizon scholarships 2015 – Scott Nevison	RIRDC1503	Scott Nevison	RIRDC	Jul-15	Jun-17
IREC field station upgrade (jointly funded with CSD)	IREC1501	Rob Houghton	IREC	Jul-14	Jun-17
Nuffield Farming Scholarship – Matthew McVeigh	CRDC1413	Matthew McVeigh	Nuffield	Oct-14	Sep-16
Nuffield Farming Scholarship – Nigel Corish	CRDC1412	Nigel Corish	Nuffield	Oct-13	Sep-15



Project title	Project code	Researcher	Organisation	Commenced in	To be completed in
Nuffield Farming Scholarship – Thomas Quigley	CRDC1516	Thomas Quigley	Nuffield	Oct-14	Jun-16
People in farming – employment starter kit	DA1502	Shane Hellwege	Dairy Australia	Jul-14	Jun-17
Peter Cullen Trust			Peter Cullen Trust	Jul-15	Jun-16
PhD: Career motivational factors of cotton growers' (attraction and retention)	USQ1401	Geraldine Wunsch	USQ	Jul-13	Dec-16
PhD: Human capacity needs and management on cotton farms	UNE1402	Will Winter	UNE	Jul-13	Jun-16
PhD: Investigating cotton farm workers' experiences of job satisfaction using social cognitive career theory	USQ1403	Nicole McDonald	USQ	Jan-14	Jan-17
Science innovation awards	ABA1501		ABARES	Jul-15	Jun-16
Smart technology for best practice work health and safety (WH&S) by cotton growers	US1501	Tony Lower	USYD	Jul-14	Aug-15
Soils cross-sectoral strategy	DAFF1401		Dept of Ag	Jun-14	Jun-17
Stimulating Private sector extension			UMelb	Apr-15	Jun-18
Summer/Honours Scholarship: Benefits of plastic clad cotton	US1504	Elizabeth Shakeshaft	USYD	Nov-14	Nov-15
Summer/Honours Scholarship: Investigation of soil properties that have changed root soil profile exploration in cotton	UNE1504	Fanny Tisseau Des Escotais	UNE	Jan-15	Nov-15
Summer/Honours Scholarship: Using the Green & Ampt infiltration model on cracking clay soils with CP&LM sprinklers	NEC1502	Simon Kelderman	NCEA	May-15	Jul-15
The impact of farm workforce turnover in the cotton sector	UM1501	Geoff Kuehne/ Ruth Nettle	UMelb	Jul-14	Dec-15
UNE Cotton Production Course		Brendan Griffiths	UNE	Jul-15	Jun-18
Water cross-sectoral strategy				Jul-15	Jun-16
Workforce Development Strategy	CRDC1530	Ross Ord	AFSS	May-15	Jul-15
World Cotton Conference				Jul-15	Jun-16

#### Program five: Performance

'Science into best practice,' linking research with CottonInfo (CottonInfo technical specialist)	CSP1504	Sandra Williams	CSIRO	Jul-14	Jun-17
Annual Cotton Grower Practices Surveys: 2014, 2015 & 2016	RRR1501	Ingrid Roth	Roth Rural	Jul-14	May-17
Annual qualitative and quantitative surveys for the Australian cotton industry		Liz Todd	CCA	Jul-15	Jun-18
Boyce Cotton Comparative Analysis			BCA	Jul-15	Jun-16
Integrated economic environmental & social performance reporting of cotton industry	RRR1403	Guy Roth	Roth Rural	Jul-13	Jun-16

#### Key:

AACS	Australian Association Cotton Scientists	DNRM	Queensland Department of Natural Resources and Mines
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences	GRDC	Grains Research and Development Corporation
AFI	Australian Farm Institute	G VIA	Gwydir Valley Irrigators Association
AFSS	AgriFood Skill Solutions	IREC	Irrigation Research and Extension Committee
ARLF	Australian Rural Leadership Foundation	NCEA	National Centre for Engineering in Agriculture
ARLP	Australian Rural Leadership Program	NSW DPI	NSW Department of Primary Industries
BCA	Boyce Chartered Accountants	QAAFI	Queensland Alliance for Agricultural and Food Innovation
CA	Cotton Australia	QDAF	Queensland Department of Agriculture and Fisheries
CA/PIEF	Cotton Australia/Primary Industries Education Foundation	QUT	Queensland University of Technology
CCA	Crop Consultants Australia	RIRDC	Rural Industries Research and Development Corporation
CGAs	Cotton Grower Associations	UMelb	University of Melbourne
CRC Polymers	Polymers Cooperative Research Centre	UNCGA AgVance	Upper Namoi Cotton Growers Association and AgVance
CRDC	Cotton Research and Development Corporation	UNE	University of New England
CSD	Cotton Seed Distributors Ltd	UNSW	University of New South Wales
CSIRO	Commonwealth Scientific and Industrial Research Organisation	UQ	University of Queensland
DeakinU	Deakin University	USQ	University of Southern Queensland
Dept of Ag	Federal Department of Agriculture	USYD	University of Sydney
		UWS	University of Western Sydney

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