

# Spotlight

ON COTTON R&D

**SPRING 2019**

Boyce Analysis:  
Growing better than ever

Bringing tech to  
the field

Verticillium  
breakthroughs





Ian Taylor

# In the Spotlight

Welcome to the spring edition of *Spotlight*.

Firstly, we would like to congratulate our former R&D Manager Allan Williams on his appointment as CRDC's General Manager R&D Investment. In this role, he will oversee CRDC investments in RD&E, and as such will draw on his extensive experience and knowledge of RD&E, policy and advocacy. Allan will also seek to guide CRDC as we move more fully into the era of innovation and agtech which has required us to rethink our modes of investment and research to help our growers become more sustainable, profitable and future-ready.

CRDC has supported several key events focused on innovation and technology, which we feature in this issue, including evokeAG and the Australian Agriculture Immersive Technology Conference where the future of ag was on show. We also welcome new partnerships to take agtech to the field, with the commercialisation of canopy temperature sensors, in which CRDC has been a long-term investor.

While the climatic outlook for coming months in terms of rain is not ideal for many growers, we are still working hard behind the scenes, through RD&E, to bring efficiencies to the field. Crop nutrition is an area where we are seeing avenues for greater efficiency, particularly in terms of nitrogen. Through national programs such as More Profit from Nitrogen, led by CRDC under the Department of Agriculture's Rural R&D for Profit program, we have gained a greater understanding of how we can reduce inputs and increase efficacy.

Likewise, research is making in-roads into understanding Verticillium wilt. CRDC is supporting several projects to better understand the pathogen, how to predict inoculum levels in the soil and how to manage it. Growers can ill afford yield loss from disease, especially in dry times when plantings are significantly reduced. Choosing the best field and rotation crops are crucial to reducing the impact. Dr Linda Smith, the well-deserved recipient of the 2019 CSD Researcher of the Year, has undertaken a significant body of work in this area, and is to be congratulated for her award.

Breakthrough research has also identified that Noogoora burr is a host of Verticillium, and in good news, has also identified a bioherbicide solution to this pathogen-carry problem weed.

As growers try to preserve soil moisture, and many fields sitting fallow, attention also turns to weed control and management of herbicide resistance. The Crop Consultants Australia have some sage advice for us all in their regular column, which is fully backed by our research and industry initiatives to bring this issue to the fore. CRDC has invested heavily in resistance research and we will continue to report on these results as they come to hand. In this issue we feature windmill grass and the evolution of resistance, which will lead us to better management through understanding.

Despite the challenges presently facing the industry, the annual Boyce Comparative Analysis provides good news, and advice, for the industry. The top 20 percent of growers are in this bracket because they do all the little things thoroughly and on time. No single farming technique, method of operation or management decision is going to have a significant impact in isolation. We encourage all growers to take advantage of the research available to help them achieve this, which can be found in publications such as the Australian Cotton Production Manual and Cotton Pest Management Guide – a copy of which is enclosed with this edition of *Spotlight* – as well as attending the great seminars, updates and workshops of offer through CottonInfo and our partners.

Ian Taylor  
CRDC Executive Director





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**ON THE COVER:**  
2019 CSD Researcher of the Year  
Dr Linda Smith of QDAF.

## 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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# Spring 2019



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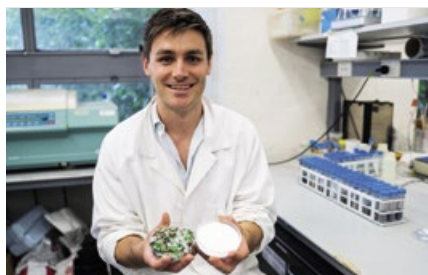
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Rhys Pirie – using waste glass to create a silicon-based additive to increase fertiliser efficiency.

## Calling young innovators

CRDC is once again inviting young agricultural innovators, scientists and researchers wanting to make a difference in agriculture to apply for the Australian Government's Science and Innovation Awards.

Minister for Agriculture, Bridget McKenzie, has encouraged 18 to 35-year-old innovators to undertake new and creative research to help agricultural industries to overcome industry challenges and to realise its potential.

Each winner receives a grant of up to \$22,000 to assist them in their quest.

"Many agricultural innovations come from young people working or studying in the industry, and the Science and Innovation Award grants aim to support early career researchers, scientists and other innovators to develop new approaches to industry issues," she said.

"On top of that, one grant recipient receives the Minister's Award for an extended research project which will have real and practical benefits to the agriculture sector."

Several past CRDC-supported awardees have also won the Minister's Award, including Rhys Pirie and Dr Alison McCarthy.

The Award recipients will be publicly presented as part of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) Outlook 2020 conference in Canberra.

Applications close October 4 2019.

### For more

[www.agriculture.gov.au/scienceawards](http://www.agriculture.gov.au/scienceawards)



Emma Ayliffe (at back right) releasing beneficial insects from drones at the IREC field site at Whitton in the Riverina prior to the CRDC board meeting in Griffith earlier this year.

## Release the... wasps!

**BENEFICIAL** insects play a key role in pest management, and what better way to get them into your field than with targeted releases from the air using drones!

CRDC has been supporting consultant Emma Ayliffe from SummitAg at Griffith to investigate the impact of alternative silverleaf whitefly (SLW) management techniques and area-wide management.

Commercial test releases of predatory mites and the parasitoid *Eretmocerus hayati* using drones have shown considerable promise for reducing the rate of SLW build-up and negating the need to spray on a cost comparative basis to conventional insecticide-based management. Emma tested biological control agents to inoculate fields with key predators and parasitoids early in the season to reduce the likelihood of pests building up and requiring insecticide treatment.

There have been commercial scale releases in several valleys last season (2018-19) following positive results observed from Emma's releases targeting SLW during the 2017-18 season.

"It can be tricky as we need growers to commit to using these beneficials at the start of the season (September)," Emma said.

"We did some controlled application of oils and beneficial releases of farms within a two-kilometre radius in an area-wide-management approach this past season.

"We then sampled farms well outside the test range to check SLW numbers.

"From what we can see in the data so far it looks like farms where oils and beneficials were applied had lower numbers."

Emma says it is not inconceivable that as these technologies develop, the use of inoculative releases of key natural enemies (as opposed to a mid-season bio-insecticide mass-release approach requiring enormous numbers) will evolve to become an effective tactic for the longer term sustainable management of pests such as SLW or mealybugs.



Moree grower Mick Humphries used the drone technology to release *Eretmocerus hayati* into his crop in February this year.

# Natural fit for industry leader

Allan Williams has been appointed to the position of CRDC General Manager, R&D Investment.

Allan has been an R&D manager with CRDC for seven years, and takes over the general manager role from Dr Ian Taylor, who in March 2019 was appointed CRDC's Executive Director. He has experienced the industry from the coal face to the international level, literally having spent his life surrounded by cotton. Growing up on a cotton farm near Wee Waa, Allan has spent the past 25 years working in Australian and international cotton industries.

With a passion for improving practice

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*“Improving and demonstrating the sustainability of cotton farming will remain a key area of focus for CRDC.”*

and sustainability in the industry, during his time with ACGRA in the 1990s Allan's responsibilities included development of the industry's BMP Program, the predecessor to *myBMP*. Since 2006, Allan has held the position of Chair of the International Cotton Advisory Committee's (ICAC's) Expert Panel on the Social, Economic and Environmental Performance of Cotton, and was the senior agronomic advisor for the global Better Cotton Initiative from 2006 to 2012.

Allan brought an extensive amount of experience in R&D to CRDC when he joined in 2012, as the former executive officer for the (then) Australian Cotton Growers Research Association, and Cotton Consultants Australia (now Crop Consultants Australia). The industry stalwart also holds Bachelor of Science and Bachelor of Law (Hons) degrees from the University of Sydney, and is a graduate of the Australian Rural Leadership Program.

“The industry has changed for the better considerably over the years, and I'm thankful to have been able to play a role

in that through the development of BMP. It is very pleasing to see it underpinning the industry's sustainability credentials both domestically and internationally more than 20 years later!

“Improving and demonstrating the sustainability of cotton farming will remain a key area of focus for CRDC,” Allan said.

“The textile supply chain's desire for greater transparency of production methods and impacts is here to stay.

“As well as our traditional areas of research such as soil, water and natural resources management, the advent of ‘digital’ agriculture presents the industry with an opportunity to further improve its stewardship, and provide information to the supply chain in a timely and efficient way,” Allan said.

“On behalf of CRDC, we congratulate Allan on his appointment to the General Manager, R&D Investment position,” CRDC chair Richard Haire said.

“He brings a wealth of knowledge, experience and passion to this role across so many facets, which is an enviable trifecta.”

## Spreading the better cotton message

**CRDC'S** new General Manager R&D Investment, Allan Williams, spoke at the world's largest international textile and garment technology exhibition in Barcelona, Spain in July.

The ITMA Textile and Garment Technology Exhibition provides a platform where the industry converges every four years to explore fresh ideas, effective solutions and collaborative partnerships for business growth. Allan presented as part of the Better Cotton Initiative (BCI) Seminar. Given Allan's role in the initial development of the Better Cotton System before he joined CRDC, the Better Cotton team invited him to share some of his experiences of the early days of BCI. It was also an opportunity to highlight the advantages and benefits of growing cotton and to dispel some of the myths around cotton's water use, he says.

“Global BCI production sits at around



an impressive 20 percent of the crop, and uptake by the supply chain exceeds one million metric tonnes,” Allan said.

“Nonetheless BCI has ambitious plans to reach 30 percent of global production by the end of 2020.”

To achieve this target BCI runs forums at industry events such as ITMA to explain to the supply chain – retailers, brands, suppliers and manufacturers – how the Better Cotton System works and to encourage membership and participation in the initiative.

BCI is the largest cotton sustainability standard in the world. Australia is a member of BCI via Cotton Australia, and under CRDC's Strategic RD&E Plan 2018-23, CRDC actively collaborates in global leadership for sustainability initiatives.

### For more

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# Research supports new industry

**COTTON** research has been conducted in Northern Australia since the mid-90s, initially in the Ord River Irrigation Area region of Western Australia.

Past projects assisting cotton industry understanding of potential and management in coastal North Queensland and tropical Australia have provided expert knowledge to assist cotton investment decisions, validate the Burdekin production package (NORpak) for new wet season growing areas, extend past research to dry season cotton growing areas and support implementation of sustainable and economic production practices for those regions.

The information contained in NORpak-Burdekin was a distillation of results from research, conducted over the last decade, building on an earlier version - NORpak - which investigated dry season cotton production in the Ord River Irrigation Area.

“Past research has particularly focused on understanding the dynamics of pest and beneficial insects associated with cotton grown in the region, and to devise an integrated pest management (IPM) based approach to insect control which avoids the major pests,” CRDC R&D Manager Susan Maas said.

From 2015-18 CRDC and CSD

supported CSIRO’s Steve Yeates in the role of Northern Cotton Development and Coordination Leader. Steve was involved in irrigated cotton experiments established with partners at the Ord River and Gilbert River region of Queensland. Working with QDAF’s Dr Paul Grundy, Steve’s research focused on the biophysical challenges to cotton production in the tropics such as sustainable pest management, preventing nitrogen losses during the wet season and management options to minimise the impact of extreme climatic events that occur in the tropics (monsoonal cloud, supra and suboptimal temperatures).

Crop protection is a serious consideration for any northern development.

CRDC supported additional trial work at the Ord River with Paul working with Bayer to confirm the efficacy of Bollgard 3 to *Spodoptera litura*, a major pest to early attempts to grow cotton in the tropics. The project has also considered the risk that pink bollworm, present in the north, poses to crops in Central Queensland and further south. CRDC has also been actively assessing biosecurity threats through Dr Murray Sharman’s research into cotton blue disease, which he previously detected in East Timor. Murray’s work



CSIRO’s Steve Yeates took this image in the Ord, one of the regions in Northern Australia where he has been working with growers, potential growers, industry and farmer groups.

with the Northern Australia Quarantine Strategy (NAQS) links the industry into surveillance and raise awareness of the risks associated with exotic threats.

“CRDC is providing ongoing support to build on this past research focused on addressing knowledge gaps in cotton development in tropical regions with a particular focus on new areas,” Susan said.

This project supports CRDC’s goal to ensure new farming systems are sustainable and productive.

“We are looking to work closely with growers and potential growers,” Susan said.

## For more

Steve Yeates

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## Considering heading north?

**NORTHERN** cotton faces some very different challenges when compared to traditional growing regions in the south. Higher temperatures and rainfall, soils with lower water holding capacity that are prone to crusting, and the need to allow for compensatory growth after fruit shedding when climatic stresses occur (cloud, temperature extremes) need to be factored into management plans.

The main thing, according to researches working in the north, is to remember to be realistic about initial yield potential.

“While cotton is a hardy and resilient plant well suited to tropical production, inexperience and the unexpected can quickly result in lost yield potential,” CSIRO’s Steve Yeates says.

“During the last 10 years, irrigated crop

yields in Northern Australia have varied from 5.5 to 12 bales/ha, with about 10 percent of irrigated crops abandoned due to unforeseen events.

“Therefore, if considering tropical cotton, do not assume that you will achieve industry-reported average yields from Southern Australia during your first attempts.”

To assist growers and potential growers ‘looking to the north’ the *Tropical cotton production: consideration for Northern growers guide* is now

available. This document came from a collaboration between CA, CRDC, CSD and Bayer and draws on the experience and research of CSIRO’s Steve Yeates and QDAF counterpart Dr Paul Grundy, who both have extensive experience in northern/tropical cotton growing.

Traditional crop production in



Northern Australia usually occurs during the dry season, but cotton is more likely to succeed as a wet season sown (summer) crop. No two wet seasons are the same – what worked last year may not be suitable this year. Flexibility and lateral problem-solving are essential in a wet season environment. Wet season cropping can throw up significant challenges for both experienced and new growers, including reduced availability of products and people for a start. Recommended rates of nitrogen, growth regulators and irrigation are all different. Taking the crop through cut out, picking and the distance to ginning facilities are critical drivers.

## For more

Tropical cotton production

[www.cottoninfo.com.au/publications/tropical-cotton-production](http://www.cottoninfo.com.au/publications/tropical-cotton-production)



# NT growers make a start

It literally is a long way to Tipperary from traditional cotton growing regions, yet this isn't daunting the enthusiasm of some Northern Territory farmers.

'Tipperary Station' in the Douglas/Daly region has recently received the results of their first crop of cotton, and the only one grown in the Territory in the last 15 years.

The Tipperary Group's Bruce and David Connolly recently harvested the first commercial cotton trial at Tipperary of 50 hectares of semi-irrigated and 10 hectares of dryland, with good results.

"We are really pleased, yield and turnout were high – seven bales per hectare in the 50 hectares which we didn't fully irrigate, it only got 80mm more water than the dryland which yielded four bales," Bruce said.

The dryland was planted in early January, and the semi-irrigated late January.

Modules were transported to St George in South-West Queensland for ginning, which is where Bruce spent time contract farming in the cotton industry. Even though familiar with growing cotton, Bruce said the north poses unique and ever-changing issues which require taking a slightly different approach.

The region has a 60-inch rainfall, with defined wet and dry seasons with high humidity. Managing intense crop growth is a major factor, with potential fungal infections and boll rot in particularly wet seasons. This year the station only received half its average rainfall with around 30 inches, hence deciding to opt for semi-irrigated rather than fully irrigated crop.

"With developments and new technology in cotton with Bollgard 3, we thought we could have a go at it," Bruce said.

"We knew an agronomist – Greg Nicol from Total Ag Services in Dirranbandi – who had experience growing cotton in a tropical climate so we got him on board, along with local agronomist Matt Dennis from E E Muir and Sons in Katherine.

"We have one season under our belt and this first year we have



**Cotton has made a successful comeback in the NT at Tipperary Station after a 15-year absence.**

learned a great deal.

"What we have seen this season is very encouraging.

"Each region is unique, and within regions there can be different conditions.

"It is a case of monitoring your crop closely and being ready to deal with unforeseen circumstances as they arise."

There are plans to grow another, potentially larger crop, next year. Bruce says their interest in growing cotton is because the region and farmers "need another crop up here to form an industry".

"The added benefit of growing cotton is that when we can build a gin we can keep the cotton seed in the north.

"This will provide an essential protein alternative for feed supplements in the grazing industry, thus allowing a vertical integration for producers who have cotton and cattle or a second income stream for the cotton grower.

"The added benefit to the livestock industry is that this protein will be produced locally thus reducing the ever-increasing freight costs.

"There are a lot of smart farmers up here looking for opportunity; we now need the scientists and researchers with experience to help us develop our management style and government support to help develop the industry."

Tipperary Group are one of just two

farms who grew cotton in the NT this year. NT Farmers' Andrew Philip led a study tour of potential NT cotton growers 'down south' earlier this year, through support from a CRDC Grassroots Grant. He expects another 10 growers to trial cotton next season.

"Cotton looks to be the crop that can be a cornerstone of an NT cropping system and with the development of ginning in the north, cotton and the crop rotations that will come with a sustainable cropping system will lead to greater intensification of the NT beef industry," Andrew says.

"There has been major interest in significant expansion of cotton in the NT, especially to grow dryland (rain fed) to make the most of the considerable and consistent wet season conditions, with guaranteed dry harvest period to produce high quality cotton.

"Other landholders are looking at what the Connollys are doing and can see it's not out of their reach either, especially with the inclusive and sharing nature of the cotton industry."

## For more

**Andrew Philip**

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Griffiths Ag and UNE Cotton Course convenor Brendan Griffiths will be there!

## Be a part of the conference

**THE** biennial Australian Cotton Research Conference is getting closer, with researchers preparing the latest in cotton research to present, discuss concepts, key issues and findings in research relevant to the industry and research community.

The conference is a fantastic avenue for networking and collaborations. CRDC is a founding sponsor of the event, with the theme this year *Taking cotton research to new heights*. It will run from October 28 to 30 at The University of New England, Armidale.

Association of Australian Cotton Scientists (AACS) organisers are encouraging researchers to take the opportunity to share project results with the industry and cotton research community.

### How to become a presenter

1. Figure out from all the exciting projects and work you are currently doing, what you would like to share.
2. Write your abstract(s).
3. Decide on a presentation type: 15 or three minutes, thesis or poster.
4. Submit abstract by September 20 via [www.australiancottonscientists.org/submit-abstract/](http://www.australiancottonscientists.org/submit-abstract/)
5. Encourage colleagues or students (cotton-relevant research) to submit.

Remember with the Conference primarily focused on the sharing of research findings, abstract topics should address a research question or focus and report on research results/output or methodology.

Registration is \$350 and \$250 for students and is inclusive of all catering and events including the conference dinner on the Tuesday evening.

### For more

[www.australiancottonscientists.org](http://www.australiancottonscientists.org)

## Consultants' seminar attracts record numbers

**MORE** than 175 delegates descended on Narrabri in June for the Crop Consultants Australia Inc (CCA) annual seminar event breaking all previous attendance records. The two-day event saw consultants, researchers, students and broader industry members come together to discuss all things agronomic.

Organisers say the CCA event is growing rapidly due to the relevancy of the agenda. It has become a 'must-attend' event for consultants across all growing regions.

CCA seminars have their agenda completely developed via feedback and input from its membership. The topics covered are considered by the CCA board to be relevant and timely, and they are delivered specifically with consultants in mind.

AgriFuture's 2018 South Australia Rural Women's Award winner Alex Thomas challenged the audience to take a different view on Work Health and Safety in their businesses and on farm. Alex is the driving force behind the #Plantaseedforsafety campaign which brings a fresh and uncomplicated approach to daily safety routines – an alternative to the traditional 'mountains of paperwork'.

In contrast, Hall of Fame keynote speaker Amanda Gore had the audience 'in stitches' with her high energy dose of reality in life and reinforcing that agronomists needed to look after each other.

On the agronomy front, of interest to CCA members were a series of presentations from researchers who are utilising data which has been collected by CCA. Since 1982, CCA has been

coordinating the collection of survey data with its members across the key cotton growing regions of Australia.

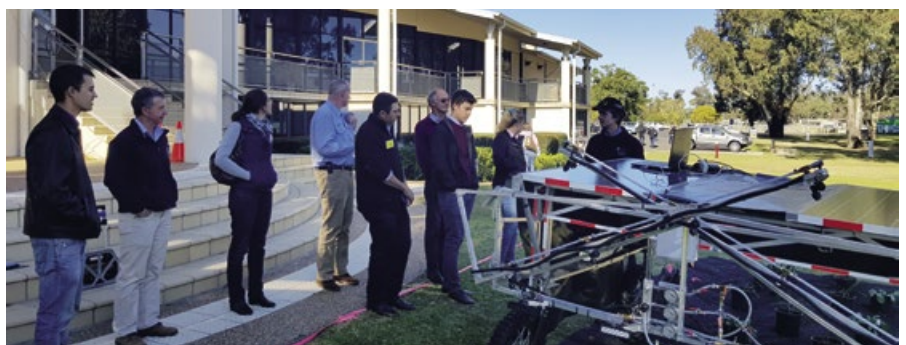
While many CCA members would be aware of and have contributed to the CRDC-supported *Cotton Market Audit* and *Cotton Consultants Survey*, the Seminar provided an opportunity to see this data in action. Using the data, Mick Rose from NSW DPI showed great improvements in cotton's environmental performance while CottonInfo Fibre Quality Technical Lead Rene van der Sluijs teased the data to reveal key trends in defoliation practices which complement his ongoing research on fibre quality.

Dinner at the CCA Seminar is becoming a feature of the events. Now in its 33rd year of incorporation, with just over 200 members, the organisation took the opportunity to honour one of its founding members, Queensland based consultant Graham Boulton, with life membership. Graham joins an elite group of life members including Geoff Brown, Steve Warden, Iain Macpherson and the late Chris Lehmann. Also, in recognition of services to the cotton research sector, long time attendee and presenter at CCA events, Dr Grant Herron was awarded Honorary Membership.

CCA Seminars have grown exponentially over recent years, and this year will be backed up at a regional level with smaller regional workshops in August.

### For more

[www.cropconsultants.com.au](http://www.cropconsultants.com.au)



Seeing what's new in agricultural robotics was on the agenda at the CCA's Narrabri seminar.





## Collectively speaking: good turnout in Griffith

**CLIMATE** change, water and Australian cotton on the world stage were all on the agenda at this year's Cotton Collective in Griffith.

The event brought more than 600 people from the industry together for a series of well-received speaker sessions, panel forums and trade show. This year included new product demonstrations and talks from growers on technology and automation. It was also a chance to hear more about Cotton Australia's Cotton to Market program and the Better Cotton Initiative.

The trade show attracted around 170 exhibitors who packed the exhibition area, while a comprehensive line up of speakers for the forum on water and irrigation attracted around 400 people on day one.

There were a number of pre-collective events, including the joint CRDC and Cotton Australia board meeting and a local district tour organised by the Southern Valleys CGA and CottonInfo. The Riverina is a hotbed of agricultural diversity, with the tour visiting local farming enterprises that have state-of-the-art irrigation systems and produce a variety of commodities, including almonds, fish, forestry, olives and prunes.

The line-up of speakers included the CRDC-supported Dr Katie Broughton from CSIRO, who provided an overview of the glasshouse and field experiments that are underway looking at how the physiology of cotton plants is affected by different environmental conditions. Dr Dio Antille, CSIRO then presented on research around nitrogen use efficiency under the CRDC-led More Profit from Nitrogen project.

Talking climate were CottonInfo Energy and Climate Technical Lead Jon Welsh who shared his knowledge on what's new in energy technologies and how cheap solar power can help in a future cotton system. Professor Mark Howden from the ANU Climate Change Institute presented on climate change research and provided an outlook on the effects of global warming.

## Innovative industry highlighted through people

**THE** excellence, achievements and resilience of the Australian cotton industry over the past year was recognised at the 2019 Australian Cotton Industry Awards held in Griffith.

The awards were run in conjunction with the Cotton Collective, from July 23-24, with a strong turnout of southern growers.

The awards night was its usual festive self while highlighting industry achievers such as Tom and Charm Arnott from Boggabilla in NSW, who received the Bayer Grower of the Year award, recognising their efficient and effective farm management practices at their properties.

Australian Food and Fibre's Moree farm manager, Murray Connor, was recognised for his commitment to innovation and passion for the cotton industry by receiving the ADAMA Chris Lehmann Trust Young Cotton Achiever of the Year award.

One Tree Agriculture farm managers Jamie Traill and Ashley Tunks, of Warra in Queensland, were awarded the AgriRisk High Achiever of the Year award.

The Cotton Seed Distributors Ltd Researcher of the Year award was presented to Dr Linda Smith from the QDAF for cotton pathology research.

The IPF Service to Industry award was presented to one of the industry's longest serving regionally-based cotton extension officers, Kieran O'Keeffe who is based in Griffith and represents the southern region.

"Firstly, I congratulate all the finalists, for their contributions to Australian cotton and being outstanding role models and advocates for our world-leading industry," Cotton Australia CEO Adam Kay said.

"Particular congratulations must go to the award recipients: our industry is incredibly proud of your achievements, and we applaud you for the work you do in keeping Australian cotton at the cutting-edge of agriculture.

"Despite this terrible drought, the Australian cotton industry has made significant gains across all areas, particularly around our sustainability targets and efficiency measures.

"Our growers continue to produce the best and highest-yielding cotton in the world, supported by leading scientists and researchers right across the supply chain."

**For more**

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

# Boyce Analysis: explore low cost options with biggest impact

According to the Australian Cotton Comparative Analysis, 2018 has been the most profitable year in the history of this analysis, on the back of very profitable years in 2015 through to 2017.

The Comparative Analysis is a joint initiative of CRDC and Boyce Chartered Accountants to produce the industry benchmark for the economics of cotton growing in Australia.

The 2018 analysis shows an unprecedented season for both the 'Average Farmers' and the 'Top 20% Farmers' in the study. The Top 20% had a profit of \$3821 per hectare. This was well above 2017 (\$2592/ha) and the five-year average of \$2901/ha. The fact that the Top 20% Farmers grew more cotton per hectare at a lower cost per hectare highlights the opportunity for many growers.

For the 'Average Farmers', similar to the previous three years, 2018 was another great season, with net profit per hectare of \$2234 – higher than last years' \$1557 and higher than the five-year average of \$1621. Based on these figures, a yield of 7.77 bales/ha was required to cover total expenses, a figure well below the five-year average of 8.59 bales.

The report says that historically, and again confirmed in 2018, that being in the Top 20% Farmers is predominately driven by yield.

"Asking 'How can I improve yield as cheaply as possible?' should be a

well-considered question, and one which has been raised before," Boyce's Hamish Cullenward said.

"In our view, the main focus for growers has to be the low-cost options that have the biggest impact on the bottom line. While this may be self-evident, it deserves some serious structured and documented thought by the industry."

## High yields

The report shows that best farmers consistently achieve yields in excess of 11 bales/ha year after year (assuming adequate water availability and no disasters such as hail or floods). Total farm averages of greater than 11.0 bales/ha have been achieved and are now a realistic goal.

"High yields are the reward for getting all aspects of a farming operation right," Hamish says.

"No single farming technique, method of operation or management decision is going to have a significant impact.

"Top performers do all the little things thoroughly and on time and as a consequence reap the rewards."

The analysis found that the cotton industry continues to reinvest in Best Management Practices, sustainability



programs and in the communities in which it operates, citing an example of this is the *2018 Australian Cotton Comparative Analysis*.

The sample of participants this year again captures a representation from the different cotton-growing valleys.

“If you are a grower and find this report instructive but do not currently participate in the analysis, we would welcome your involvement,” CRDC Executive Director Ian Taylor said.

“We believe that this effort leads to a greater understanding of the numbers that drive your business with respect to other growers and trends within the industry.”

This year is the third year per bale figures have been analysed. As the industry continues to evolve, and as other studies on industry practices are finalised the analysis will continue to compare the results from those studies and these figures with a view to providing better information for the industry.

Two aspects that are relatively unchanged are price per bale and increasing costs of per unit inputs. The increased profits for the industry are coming from efficiency (less quantity of inputs) and increased yield.

To read the full analysis go to CRDC's website. To become involved in the study, contact Hamish Cullenward.

#### For more

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

[australian-cotton-comparative-analysis](http://australian-cotton-comparative-analysis)

### Average Farmers

- ◆ Yield (11.82 bales/ha) increased an average of 1.23 bales from 10.59 bales/ha in 2017. This is 0.18 bales/ha more than the five-year average of 11.64.
- ◆ Price per bale was \$542 which is \$15 higher than last year and \$29 above the five-year average of \$513.
- ◆ Operating costs were higher but still below the five-year average. 2018 costs per hectare were \$3896 compared to \$3722 for 2017 and \$4080 for the five-year average.
- ◆ Water, fuel, wages, fertiliser and general overheads were key cost items to increase while chemicals and application were notably down in 2018.
- ◆ Total income was \$6409 per hectare for 2018. This was up \$834 per hectare from 2017 and up \$413 on the five-year average.

### Top 20% Farmers

- ◆ Yield (13.33 bales/ha), was an increase of 2.98 bales/ha from the previous year (2017 was 11.35 bales/ha) and slightly above the five-year average of 12.85 bales/ha.
- ◆ Price per bale was \$550, which is \$1 up from 2017 and \$22 above the five-year average.
- ◆ Interestingly, operating costs for this group fell, from 2017 to 2018, by \$69 to \$3378, which is \$337 below the five-year average. The main contributors to the 2018 result being \$337 below

the five-year average were repairs and maintenance, depreciation and wages.

- ◆ This group grew more cotton (1.51 bales/ha) than the Average Farmers and did it more cheaply (by \$518 per hectare).
- ◆ The main contributors to the \$518 variance per hectare were: repairs and maintenance (\$176); water charges and purchases (\$155); (\$131); depreciation (\$93); fuels (\$77). Out of interest, to compensate for these savings, the Top 20% Farmers spent more than the Average Farmers on a per hectare basis, on chemicals (all), consultants, fertiliser and insurance.
- ◆ Yield per hectare continues to trend upward but are not at the same levels seen in the 2015 and 2016 seasons. The term ‘statistical yield’ indicates a fixed ceiling beyond which yield cannot exceed. Without further plant development, this would be a worrying prospect, especially in light of cost increases. Continuing development means that statistical yield is a moving target, but it's important to note that we are tending towards a maximum yield, whereas there do not seem to be similar cost constraints.
- ◆ Operating profit continues to trend positively for both Average Farmers and Top 20% Farmers with unprecedented profit highs for the 2018 crop. However, the industry must be realistic that profits will vary based on seasonal conditions.



# Imagining the future at evokeAG

evokeAG is an immersive technological experience delivering diverse topics and cutting-edge innovation. It's the only event of its type where people come together to connect, collaborate and evolve all things ag.

CRDC supported the inaugural AgriFutures Australia international event evokeAG held in Melbourne in February, which attracted the brightest agricultural and technological minds from around the world. The event was a platform for the food and agriculture sector to exchange information and share best practices on how technology can shape the future. CRDC's Jane Trindall, Ruth Redfern and Susan Maas attended the event.

Jane said the event was a fantastic showcase of innovative thinking, and agtech opportunities. From an R&D provider perspective, she said the event challenged the traditional models of R&D funding and gave a glimpse into the future of the evolving agricultural innovation sector.

"Venture capitalists were the theme and we were introduced to a host of venture capital funds who want to solve real problems, scale globally and make

## Attend evokeAG

CRDC is giving 15 growers – one from every cotton grower association – the chance to attend evokeAG 2020.

"This is such a fantastic event, it is so interesting, so thought provoking, so focused on the future of farming and ag, yet the majority of people in the room weren't producers," CRDC's Executive Director Ian Taylor said.

"Next year, AgriFutures and CRDC are keen to build up the producer numbers, and we want to do what we can to encourage that to happen.

"Growers can obtain enormous benefits from attending evokeAG. To see the rapid change that is already happening and start them thinking about how they can adapt to, capitalise on and drive it."

Contact your local CGA to register your interest.

big money," Jane said.

"In a domestic environment of declining and short-term funds and public sentiment to support research, new capital could really drive Australia's aspirations to be a hot bed of agricultural innovations."

Jane says the event provided a glimpse into the future.

"I think we have to remember that venture capitalists invest long term – say 10 years, so events like this give us a glimpse of what may be to come for agriculture.

"We've got to remember it is not the present we are envisioning but the future.

"This event gave innovators, producers and research providers a chance to reimagine the future – what we will be producing and what our customer is looking for."

Startup entities who governments and industry have invested in such as Flurosar and the Digital Agriculture Service were highly visible as examples of how innovation can be supported.

"Research and Development Corporations (RDCs) have an exciting potential future role as technology transfer organisations connecting global capital," Jane said.

"Australian Pork Limited's Board have approved a new strategy separating their funding into two streams – one traditional and one 'strategic ideas' with the aim of attracting new teams and new capital to solve the industry's problems.

"The question is 'what way can the cotton industry partner with venture capitalists to help them understand opportunities and/or problems and co-invest?'"

"High value horticulture is attracting much of the innovation and investment, particularly from organisations entering the market, whereas it seems broadacre is being left to the big corporates.



Agtech startup Flurosar developer Anastasia Volkova.

"Companies like Yamaha and Bosch both (at the event) indicated this, however there could be a role for us to broker innovators to look at cotton."

## Connecting with global capital

Large industry players including Visy's Anthony Pratt and Elders Chief Executive Mark Allison challenged the sector to look at how much money is invested in agtech in comparison to other economies. In Australia only \$0.12 per person per year is invested in agtech in comparison to \$5.80 in the US – 50 times more.

"How do RDCs and agricultural scientists bring their IP/knowhow to partner with venture capital funds and how can RDCs collaborate to engage?" was a common theme at evokeAG.

Jane said in terms of opportunities for innovative growers, venture capitalists are taking risks on innovative ideas in agriculture and investment companies are keen to work with growers directly.

"The innovation has to be scaleable, but Australian farmers by design are risk takers and creators, so this is a good space for them to be both early adopters and innovators.

"If they have invented something or have an idea, there is capital and support around.

"If you are a grower wanting to find out what's next in the agtech space, CRDC is providing bursaries for 15 growers – one from each Cotton Grower Association – to attend next year's event, which I'd highly recommend applying for."

evokeAG 2020 will be held in Melbourne from February 18-19, 2020.

For more  
evokeAG

[www.evokeag.com](http://www.evokeag.com)



# Partnerships bring agtech to growers

After many years of investment, research and development by CSIRO and CRDC, the commercialisation of canopy temperature sensor technology has come about through a partnership with agtech entity Goanna Ag, making it available for the 2019-20 season.

The interest in using canopy temperature systems to assist in detecting crop stress in irrigated cotton started with industry scientist Dr Warren Conaty's PhD thesis in 2010, supported by Cotton Catchment Communities CRC and Irrigation Futures CRC. Warren (now a cotton breeder with CSIRO) was instrumental in demonstrating the utility of canopy temperature to quantify water stress in deficit irrigation systems. CRDC and CSIRO invested in research to begin to apply the knowledge in irrigation management, to further establish the opportunity and ensure it would deliver value to growers.

"Being a plant-based approach, using canopy temperature offered different but complementary information to soil and



Tom Dowling holding the Goanna Ag's new canopy temperature sensor next to CSIRO's sensor, with CSIRO's Michael Bange, Victoria Smith, and Hiz Jamali.

weather-based approaches," CSIRO's Mike Bange said.

"The infrared sensors are affordable, easy to use and maintain.

"Continuous sensing offers more accurate irrigation scheduling, as decisions are based on the crop's response to immediate soil water status rather than relying on a fixed soil-water deficit."

To give growers the opportunity

to schedule irrigations further out, the CSIRO scientists developed a model to predict canopy temperature a few days in advance, using forecasted weather conditions, allowing for more flexibility in the irrigation system.

With the technology now ready to take into the field, CRDC and CSIRO teamed up with Goanna Ag in a commercial partnership to make this happen. The team at Goanna Ag, based at Goondiwindi in regional Queensland, is currently working with CSIRO researchers to integrate the canopy temperature algorithms into Goanna's existing platforms growers are already using.

"Improving water use efficiency is forefront in our minds," Goanna Ag's Tom Dowling said.

"This partnership will allow us to offer the tools to do this more accurately than ever."

The wireless canopy temperature sensor will be released with LoRaWAN connectivity and a deploy-anywhere satellite option.

This technology will fill the gap in their GoField product by monitoring plant health.

"Along with our soil moisture probes monitoring below the soil surface and GoSat analytics monitoring what is

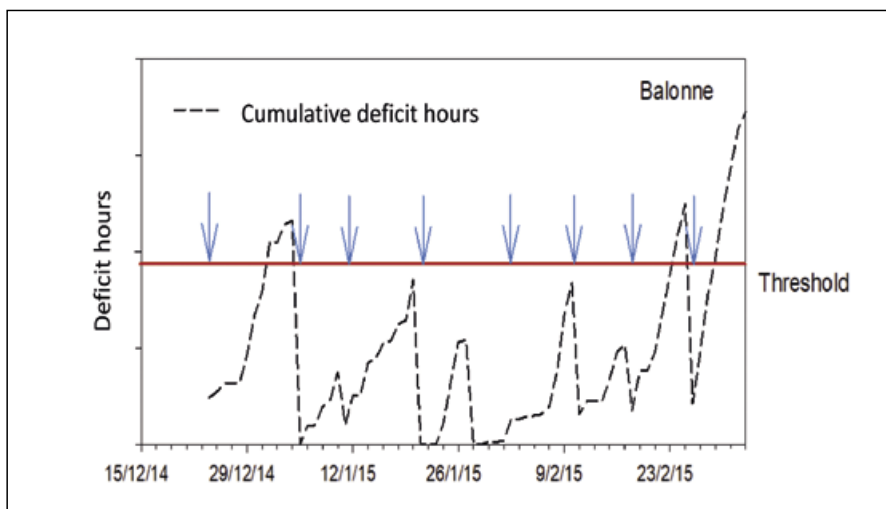


Figure 1 shows a farm where irrigations were mostly applied earlier, and in some cases, later than the sensor's recommended threshold. These observations highlight significant opportunities to increase water productivity through optimising irrigation scheduling. Blue arrows show irrigations; irrigations applied when deficit hours are below the red line (threshold) are considered early and vice versa.

happening spatially at the field level, a more complete tool kit to water scheduling is now available to the industry this coming season,” Tom said.

Goanna Ag was invited by the USDA to trial the GoField product in the US in August.

Cotton industry researchers are now looking to optimise the canopy temperature approach for use in limited water situations. They also aim to

determine the optimum number of sensors required to capture spatial variability on larger farms.

**For more**

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Cotton’s optimum temperature for physiological functioning is 28°C. The time the cotton canopy temperature stays above 28°C – and meeting some other criteria – are called “deficit hours”. The crop needs irrigation once the cumulative deficit hours since last irrigation reach a certain threshold, as determined by previous CSIRO research supported by CRDC.

Trials with some growers of high yielding crops were encouraging, as yields comparing the canopy temperature approach with their existing scheduling matched closely even though in some instances one less irrigation was applied using the canopy temperature treatment. In deploying the sensors across other systems, the

analytics have shown considerable opportunity to be more precise with timing to prevent overwatering or impacts on yield.

In other trials growers have integrated canopy temperature into their existing decision-making processes using soil moisture probes and their experience. The grower feedback provided important insights into how the technology might fit into their whole farming system and how it can be improved. Glen Price was one of the growers who used this technology for two cotton seasons at his farm in St George, south-west Queensland.

“You have to integrate different types of information,” Glen said. “You can’t ask the plant.”

## New ways to market

Tom Dowling founded Goanna Telemetry 17 years ago and the business soon became well known in the cotton industry for its agricultural sensing technology. Tom is an agronomist with extensive experience in plant and soil nutrition, crop health and irrigation scheduling. Goanna Telemetry was acquired by Discovery Ag in 2018 to become Goanna Ag.

The business has grown to what it is today by using Tom’s knowhow and the latest science and technology to bring products to the field which improve sustainability and streamline crop management, especially irrigation management.

Tom has formed relationships with research organisations, researchers, universities and industry bodies such as CRDC over the years and says the way he interacts with science and technology providers is changing as his business grows and the drive to commercialisation from research providers gathers momentum.

The advantage of working with organisations such as CRDC and CSIRO is the quality of the science and thoroughness of the research.

“Australian research organisations in agriculture are very well respected,” Tom says.

“Working with CRDC and CSIRO in commercialisation ventures brings with it a high level of confidence in the science, both for me and the end user.

“It comes with a level of confidence and validation.”

While he says he’s been in the game too long to be considered a ‘start-up’, he says with the advent of start-ups and venture capitalists, the landscape is now changing as start-ups look to these organisations for products, research data and knowledge to build or use in their platforms or products.

“In the past I mainly approached the researcher to learn more about the science and technology and whether we could collaborate. Now, since Goanna has grown and we have exposure across the industry we are being invited more for collaborations.

“Innovators are seeing the potential of working with research organisations to bring products to market.

“Our cotton industry is still a standout for how efficient and forward thinking they are, and there is always a role for CRDC and others to play in linking business with research to put this knowledge to work in the field.”



Glen Price (left) trialled the sensors on his St George farm.





The MLA's ThinkDigital VR bus has already had 100,000 people through its doors.

# Facing new realities

Augmented and virtual reality technologies are predicted to be as common as smartphones in five to 10 years. Harnessing this technology will be the key to improving profitability in agricultural sectors.

A group of Rural Development Corporations (RDCs) including CRDC are committed to making sure agriculture is ready and willing to take up the changes and capitalise with an exciting new event held recently in Melbourne.

The Australian Agriculture Immersive Technology Conference was a two-day augmented and virtual reality conference and trade show. The program was designed for solution providers to demonstrate what is possible today and what might be possible in the future.

A recent study by the RDCs through the Precision to Decision Agriculture project (led by CRDC) found that the ag sector lacks digital maturity and has been slow to harness the benefits it may offer agriculture.

CRDC Innovation Broker Jane Trindall attended the conference and says events like this help agriculture to understand the potential of virtual and augmented reality (VR and AR) systems to Australia's agriculture supply chains. It also assisted VR and AR software and hardware providers to understand the role of the technology to add value to agriculture.

Using the retail sector as an example, Jane says that an incredible 72 percent of shoppers purchased items they had not planned to because of AR.

"Would AR have the same power for extension in the cotton industry?"

"Can we imagine 72 percent of farmers adopting best practice or technology they hadn't planned to due to an AR experience?"

"Along with the presentations, attendees immersed themselves in available technology and we were able to discuss the application of VR and AR for our sectors.

"Initially, VR and AR are likely to add value to the sector in areas of marketing, education and training.

"VR could help in situations such as chemical training and situations where having skills before undertaking an operation would be preferable – in the same way flight simulators work for fighter pilots.

"The Meat and Livestock Australia (MLA) ThinkDigital VR bus has already had 100,000 people through its doors, demonstrating how engaging this technology can be."

Led by MLA, RDCs will invest in developing the value proposition of real time information systems specific to their industries, surveying industry stakeholders and performing detailed economic and ROI analyses to identify

## What are these realities?

**AUGMENTED REALITY (AR)** is an interactive experience of a real-world environment where the objects that reside in the real-world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities. Examples may be labelling that features people, and when you hold your smartphone over them (using apps) they speak to you!

**VIRTUAL REALITY (VR)** is a simulated experience that can be similar to or completely different from the real world.

the best opportunities to implement this technology. Based on the results of this analysis, off the shelf technology will be deployed or prototypes developed and adoption activities undertaken by RDCs.

The conference was presented by Meat and Livestock Australia, with support from CRDC, AgriFutures Australia, Australian Eggs, Australian Pork, Australian Wool Innovation, Dairy Australia, Forest & Wood Products Australia, Grains Research and Development Corporation, Hort Innovation, Sugar Research Australia and Wine Australia.

**For more**  
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# Focus on fish stewardship

In response to industry and public concerns around the recent fish deaths across the Murray-Darling Basin, CRDC convened a workshop to identify research priorities associated with fish stewardship in the Northern Basin.

Led by scientists Dr Sam Capon and Dr Stephen Balcombe from Griffith University, participants explored potential approaches to fish stewardship in riverine systems including riparian management strategies and the alignment of land and water management approaches.

Held in Brisbane earlier this year, the workshop represented a cross-sectoral collaboration with government and university fish and riparian researchers,

## River mapping underway

UNE PhD student Marita Pearson is mapping the location of deep waterholes in the Barwon-Darling river system and looking at how they respond to changes in flow. She has found that there appears to be a shallowing of waterholes since the 1800s in the system by as much as 1.5m. The consequence of shallowing in deep waterholes is that they dry quicker, are more fragmented and in event of reduced water quality, such as algal blooms, the potential for fish to move to more favourable locations is reduced. Marita is investigating the contribution of sediment from gully erosion as a potential cause of this shallowing.

the Murray-Darling Basin Authority, cotton industry bodies and growers to identify knowledge gaps and research priorities associated with fish stewardship.

“The mix of people at this workshop gave a very broad and detailed picture of fish management in the Northern Basin,” CRDC’s R&D Manager Natural Resource Management (NRM) Stacey Vogel said.

“We now have a better understanding of terrestrial and riparian influences on the condition and resilience of fish populations, especially the Northern Basin.

“Managing for resilient fish populations in hydrologically variable catchments depends on robust riparian and catchment management as well as good water management.”

Sam Capon’s previous research, that looked at the drivers of riparian recruitment in the Northern Basin, found that local land management practices (grazing, thinning, clearing etc) can disrupt local environmental factors that play an important role in shaping patterns of riparian vegetation regeneration such as canopy cover and surface leaf litter. In turn riparian vegetation plays a particularly important role in river ecosystem function, especially in arid landscapes, shading watercourses, reducing in-stream temperatures and limiting light available to algae.

The workshop focused on non-flow factors determining fish resilience and strategies that aligned land and water

management approaches, providing a more holistic approach to fish stewardship.

“We’ve assessed where the knowledge gaps are and how CRDC can work with partners to fill them,” Stacey said.

Some of the knowledge gaps and research priorities include the environmental and economic impacts of fish entrainment diversion technologies such as fish screens; spatial and temporal factors affecting the quality and value of river refuges such as deep pools; restoration establishment techniques for macrophytes (water plants); how vegetation structure determines riparian function; and how can we improve technology or capitalise on existing farm technology to monitor and evaluate riverine condition over time.

CRDC is leading applications for funding to investigate the impact of different types of river systems (natural and regulated) and the location and type of irrigation infrastructure on fish entrainment; and the environmental and economic impact of different types of diversion technologies such as fish screens.

CRDC is committed to supporting research on environmental stewardship and sustainability and over the past five years has invested \$1.1m in NRM projects which focus on riverine health

“Future research investments will identify key terrestrial and riparian management strategies to protect, restore and enhance the condition and resilience of fish populations in our riverine systems,” Stacey said.

**For more**  
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# Elevated CO<sub>2</sub>: friend or foe?

Research conducted within the cotton industry has repeatedly found that elevated CO<sub>2</sub> increases cotton growth and yield. However, a recent study suggests that the positive effect of elevated CO<sub>2</sub> could be short-lived, or even reversed in the long-term.

The study, supported by CRDC and led by Western Sydney University and CSIRO, examined what would happen if cotton plants were grown consecutively at elevated CO<sub>2</sub> and temperature in the same soil.

Crop productivity is influenced by soil conditions which often reflect what happened in the previous seasons; things such as crops were planted and how the residues were managed.

“We know from the scientific literature that elevated CO<sub>2</sub> decreases nitrogen (N) concentration of plant biomass,” says Dr Yui Osanai who conducted the experiment.

“This can lead to slower decomposition of non-harvestable biomass returned to the soil and reduce N mineralisation in the soil.

“Cotton plants rely on mineralised N to supplement a third of their N requirement, so we were interested to see how such changes in decomposition may impact soil N availability for the subsequent crops grown at elevated CO<sub>2</sub>.

“Would yield response remain the same, or would it be different in the second season?”

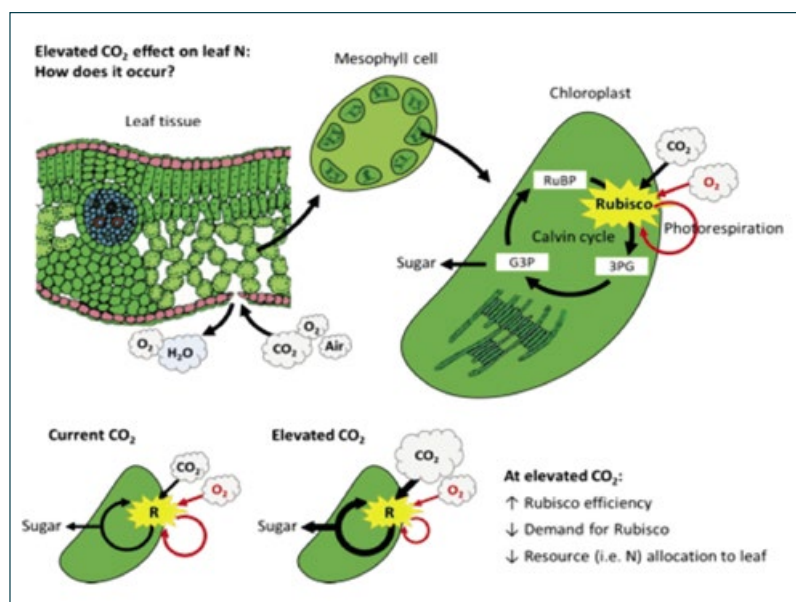
In order to test this, cotton plants were grown at elevated CO<sub>2</sub> and temperature first, and after the harvest, non-harvestable biomass was mulched and incorporated back into the soil to simulate the residue management in the field. After the seven-month fallow, cotton was re-sown to the soil ‘conditioned’ by the previous season. The results were certainly unexpected for Yui.

“The results were very surprising to be honest,” she said.

“The positive effect of CO<sub>2</sub> on yield observed in the first season was no longer there: in fact, elevated CO<sub>2</sub> significantly reduced yield in the second season.”

## The mechanism

Plant and soil nutrient analyses revealed that this response was indeed caused by N limitation of plants, caused by N-poor litter produced at elevated CO<sub>2</sub> during the first season. Furthermore,



N limitation during the second season caused plants to allocate more carbon (C) below ground (ie root biomass and root exudates), triggering microbial population growth and immobilisation of N.

“It was hypothesised that plants at elevated CO<sub>2</sub> would allocate more C below ground under N limitation, in an effort to increase N capturing capacity by extending roots, and to enhance microbial decomposition,” Yui said.

“But, this has rarely demonstrated experimentally, so to see this in our study was amazing.

“In our study, however, increased microbial biomass and activity was not in favour of plants, as it caused N immobilisation when plants needed it the most.

“The timing is pretty important, especially for N – it’s all about synchronising crop’s demand with supply.

“So, the combination of reduced N mineralisation and increased N immobilisation proved to be detrimental to cotton’s reproductive output.

“Interestingly, total biomass production was largely unaffected, suggesting that N limitation shifted biomass allocation within the plants (Figure 1).”

## Can we avoid N limitation by optimising fertiliser management?

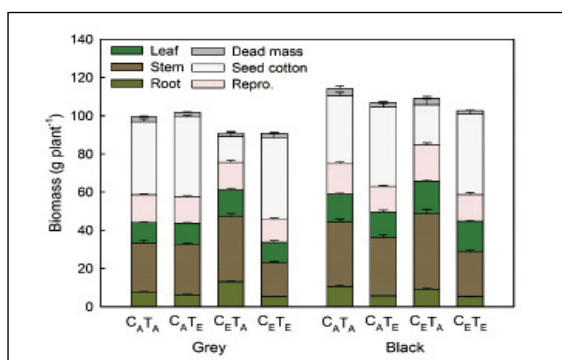
Yui says this may be possible, but it’s not that simple.

“Studies on wheat found that elevated CO<sub>2</sub> also reduced crops’ ability to utilise N, meaning that simple changes in fertiliser management may not be enough,” Yui explained.

“We haven’t tested on cotton yet so the next step would be to repeat this study in the field, and see the

**Fig. 1: Elevated CO<sub>2</sub> increases the efficiency of Rubisco, an enzyme responsible for capturing CO<sub>2</sub> during photosynthesis. Rubisco is inefficient in capturing CO<sub>2</sub>, as it has a higher affinity to fix O<sub>2</sub> (a process called photorespiration). When the concentration of CO<sub>2</sub> is increased (relative to O<sub>2</sub>), the efficiency of Rubisco is also increased. This reduces the need for plants to invest resources to produce Rubisco at elevated CO<sub>2</sub>. Since the major constituent of Rubisco is N (up to 40% of leaf N in C3 plants is contained within Rubisco), this leads to reduced leaf N concentrations at elevated CO<sub>2</sub>.**

**Fig. 2** Biomass allocation of cotton plants grown on grey and black vertosol under the four climate change treatments in the second season. CATA: ambient CO<sub>2</sub>, ambient temperature; CATE: ambient CO<sub>2</sub>, elevated temperature; CETA: elevated CO<sub>2</sub>, ambient temperature; CETE: elevated CO<sub>2</sub>, elevated temperature.



strength of the legacy effect in the real world.

“We can then manipulate fertiliser N rates to see if that helps with the N limitation in the second season.”

ACRI has four field chambers that allow manipulation of CO<sub>2</sub> and temperature in the field. They have been operational since 2014, and CRDC-supported researcher Dr Katie Broughton from CSIRO has been championing the field experiments, providing valuable insights into field-level response to elevated CO<sub>2</sub> and temperature.

“What was interesting in our study is that this negative effect of CO<sub>2</sub> on yield was only observed at ambient temperature,” Yui said.

“Elevated temperature counterbalanced the negative effect of elevated CO<sub>2</sub> on yield, but this is where the results from glasshouse experiments may differ from field experiments as there are more extreme temperature fluctuations in the field.”

Yui says they know that elevated temperature increases the rate of plant growth and N mineralisation in the soil, but exactly how it counterbalances the negative effect of CO<sub>2</sub> is a mystery. Improving N mineralisation and synchronising it with crop N demand is probably the key.

“We suspect it would involve complex interactions between plant, soil and microbes that are constantly changing and responding to the environment and to each other. It is a highly dynamic system spatially and temporally,” Yui said, “And it’s definitely challenging to study!”

### Plant response to elevated CO<sub>2</sub> is dynamic

Yui says the most important take-home message from this study is that plant response to elevated CO<sub>2</sub> is highly dynamic. She said judging from the response of the second season crops, the response of the third season crops (if there were) to elevated CO<sub>2</sub> is likely to be different again.

“However what we know and what our study was able to show is that crop productivity is influenced by the past conditions. So, we must account for the legacy effect when predicting future productivity,” she said.

“We definitely shouldn’t assume that elevated CO<sub>2</sub> will always increase yield.”

### For more

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# Calculating for ammon

Cotton scientists have collated research to help understand the role of ammonia volatilisation as a significant N loss pathway in irrigated systems.

Nitrogen (N) fertilisers improve crop nutrition and yield, however losses in reactive forms from the soil-plant system can have negative impacts upon the environment, land assets and in some forms, human health. By optimising N use efficiency (NUE) there are win-win gains for both the environment and business profit.

CRDC is leading the cross-sector More Profit from Nitrogen (MPfN) program on behalf of the cotton, sugar, dairy and horticulture industries, funded through the Department of Agriculture’s Rural R&D for Profit Program. Collaboratively, these intensive N use sectors are striving to enhance NUE to improve profitable and sustainable use by better understanding the influence of contributing factors which effect optimisation.

Researchers from NSW DPI and CSIRO Agriculture and Food are delivering one of 10 sub-research projects, *Enhancing nitrogen use efficiency in cotton*, involving Drs Graeme Schwenke, Guna Nachimuthu and Jon Baird (NSW DPI), Dr Ben Macdonald (CSIRO) and Drs Helen Suter and Mei Bai (University of Melbourne).

This project has led the team to examine previous research into ammonia gas losses through fertiliser application. Ammonia is one form of reactive N that can be lost from the soil either directly – following fertilisation with anhydrous ammonia; or indirectly via volatilisation of ammonia after the application of anhydrous ammonia or urea. The review has resulted in some interesting considerations for cotton.

The proportion of anhydrous NH<sub>3</sub> directly lost during application into soil is usually low when it is directly injected into fine-textured (clay) soils. While a 1977 study at Narrabri found ammonia losses were one percent of applied N during injection of anhydrous ammonia (107 kg ha) into the soil, the effect of different rates, rig speed and soil moisture conditions on direct anhydrous NH<sub>3</sub> losses have not been quantified in Australia. Ben Macdonald says indirect NH<sub>3</sub> loss via volatilisation varies from ‘negligible’ to more than 40 percent of the applied N, depending on amount and placement of fertiliser, soil type, crop growth stage, follow-up rainfall/



# pathways ia loss

irrigation, temperature and wind speed.

"In 2002, a global review of ammonia volatilisation research estimated an average of 14 percent of all fertiliser N applied was lost by  $\text{NH}_3$  volatilisation across all scenarios," he said.

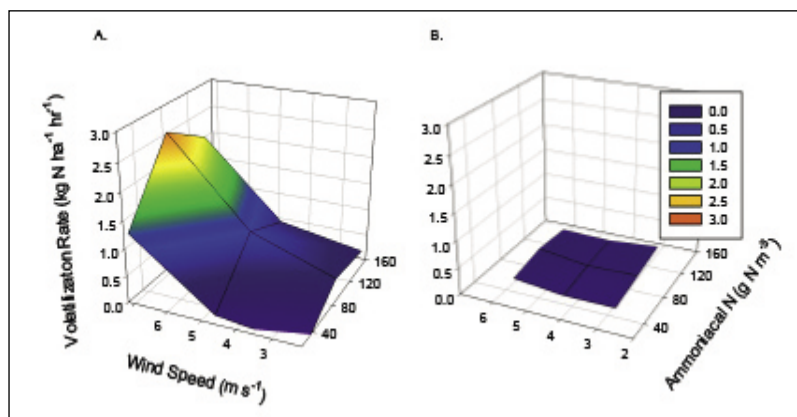
"Most of the non-rice irrigated crop research included in the review was conducted not in cotton but other crops with intermittent irrigation such as maize and sunflowers."

In irrigated cropping systems, N is either applied into the soil (pre-plant or side-dress), broadcast then irrigated, or water-run. Ammonia volatilisation from incorporated N fertilisers is minimal as the injected or produced gaseous  $\text{NH}_3$  is adsorbed on the soil particle surfaces and on the cation exchange sites of clays. However,  $\text{NH}_3$  produced at, or above, the soil surface is at greater risk of loss unless broadcast urea is immediately followed with irrigation (or rainfall) that dissolves the urea and transports the applied N into the soil, before the conversion of urea into ammonia occurs.

In contrast to ammonia, urea is only weakly adsorbed by soil particles and so moves through the soil with the percolating water. Broadcasting urea onto a wet soil will dissolve the urea at the surface but not transport it lower into the soil, potentially causing ammonia volatilisation losses to be significantly higher.

The situation with water-run N should be similar to broadcasting urea followed by irrigation. Several studies in the 1980s at Narrabri and Griffith found  $\text{NH}_3$  volatilisation losses from water-run urea applications of 84 and 120 kg urea N/ha were negligible (less than two percent of the N applied). While water-run urea will reduce ammonia loss, some N loss will still occur. The loss rate will be greater at warmer water temperatures and at longer flooding durations which will allow conversion of some urea into the ammonia form before it is safely into the soil.

Ammonia volatilisation losses when injecting anhydrous ammonia into irrigation water can be large, as  $\text{NH}_3$  is adsorbed by soil particles and more is retained more at the soil surface, particularly in soils at the source end of the paddock. A 1982 study in maize fields near Griffith found  $\text{NH}_3$  losses to the atmosphere of up to 30 percent per hour of the N applied. Losses in that study were found to be exacerbated by wind speed over the soil surface, as less  $\text{NH}_3$  was lost from a taller crop with greater plant canopy cover than from a shorter crop (Fig. 1). There was a significant interaction between wind speed and



**Fig. 1 Ammonia flux rate as a function of wind speed and the initial ammoniacal N concentration in the irrigation water. A. Short maize crop (height 0.9 m and leaf area index 1.0) B. Tall crop (height 1.5 m and leaf area index 1.9). The wind speed was measured 3.3 m above the zero-plane displacement. The actual heights were 4 m above the ground in the short crop and 4.75 m in the tall crop (Denmead et al., 1998).**

ammoniacal N concentration and ammonia loss.

That study also found that the delivery of N from water-run anhydrous was uneven across the field, which led to crop nutrition problems. The implications for management are that if water-running anhydrous ammonia, the product needs to be applied into the water as close as possible to the field, applied to shorter paddocks, applied to more mature crops than early season crops, applied preferably at night (cooler temperatures, less windy, thermal inversion suppresses turbulent transfer), and applied at concentrations less than 50 kg N ha<sup>-1</sup>. This advice is applicable for water-run urea.

## For more

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## Key points

- Direct  $\text{NH}_3$  loss during anhydrous ammonia injection into soil should be minimal, unless soil is very dry or very wet and the slots remain open.
- Ammonia volatilisation is a process that occurs at the soil surface and is driven by wind speed and temperature.
- Ammonia volatilisation from N fertiliser can result in significant losses of N from the soil-plant system into the atmosphere. The key to prevention of  $\text{NH}_3$  volatilisation is to get applied N into the soil and away from the surface.
- Urea must first be hydrolysed into ammonia before it is at risk of volatilisation. Getting in-crop urea into the soil takes irrigation (or rainfall) after broadcasting or water-run urea application.
- If water-running anhydrous N
  - ◆ Do it during cool and non-windy days (or at night)
  - ◆ Do it after the crop is well established
  - ◆ Do not apply excess amounts of N
  - ◆ Apply the N to the water near to the target field and wash the N into the profile.

# Deciding on deficits for better nitrogen efficiency

Australian cotton growers have overcome many constraints in their efforts to become the most productive and sustainable growers in the world.

Water is the key constraint in agricultural systems, however well-managed irrigation can overcome this and increase yield. Pest and diseases are also a major influence and have been a major constraint in some regions in the past. However today they can largely be managed through integrated systems.

According to NSW DPI cotton scientist Jon Baird, the soil's ability to supply both macro and micronutrients is also a major constraint faced by cotton growers.

"Soil nitrogen (N) supply is important and is augmented by N fertiliser applications," Jon says.

"Fertiliser use efficiency in the Australian cotton industry has shown that only 30 to 60 percent of the inorganic N applied prior to sowing is taken up by the plant, highlighting the importance of N mineralised from the soil for crop nutrition.

"The rate of soil N mineralisation is influenced by soil temperature, water content, porosity and soil organic matter content."

In the Australian cotton industry, different soil-water deficit thresholds are used by growers to schedule irrigations. However, does this variation impact upon the availability of mineralised N from soil sources?

Under the More Profit from Nitrogen (MPfN) project as part of the Department of Agriculture's Rural R&D for Profit Program, and with support from CRDC, the NSW DPI MPfN team, including Jon, ran field experiments over the 2017-18 summer cropping season at ACRI to assess the effects of differing deficits on soil N mineralisation.

In-field N mineralisation was quantified in nil-N plots of both 50mm and 70mm deficits. Overall, during the season the 50mm deficit treatment lint yield was

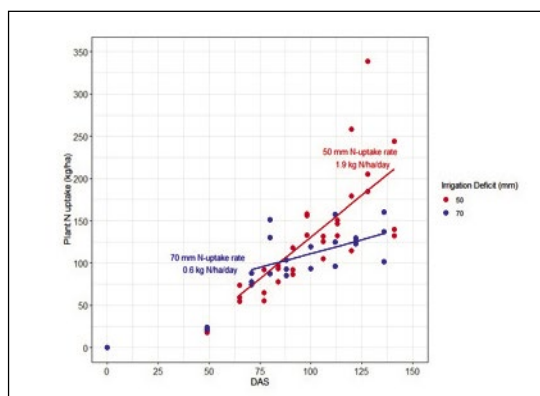


Figure 1. Plant N uptake as a function of irrigation deficit.

## Key Messages

- A well-managed soil can provide significant amounts of nitrogen (N) to the crop
- Zero-N plots within fields are a way of assessing apparent soil N supply
- Soil and plant measurements of N mineralisation show that irrigation management is an important factor soil N availability
- The hill contributed the bulk of mineralised N
- The late Dr Ian "Rocky" Rochester's work shows that rotations and cover crops, residue management and an appropriate fertiliser plan is the key to maintaining a healthy soil

3500kg lint/ha with a plant N uptake of 220kg/ha from the soil. This was different from the 70mm deficit as the yield was 2950kg lint/ha with a plant N uptake of 140kg/ha from the soil. Therefore, the production of lint per unit of N was better in the 70mm deficit, as shown in Figure 1 below. There was cumulative change in mineral N (nitrate + ammonium) in the zero to 30cm depth of the soil at the various sampled positions.

"It was apparent that most N mineralisation activity occurred in the middle of the plant bed, followed by the non-irrigated hillside position, while least N was available in the soil under the furrows," Jon said.

"It was also apparent that while the mineralised N in the 50mm deficit was retained in the soil between irrigations, there was a period during January in the 70mm deficit treatment where N losses through denitrification/leaching/runoff outweighed the gains from organic matter mineralisation.

"This was potentially caused by soil moisture differences and N losses between the treatments as more water was applied per irrigation when the irrigations were further apart."

Ben Macdonald said the late CSIRO soil scientist Ian Rochester's work at ACRI provides further insights to the ability of a soil profile to supply nitrogen to the crop. Over a 20-year period Rocky investigated nutrient management as a function of crop rotation, within these trials there were zero-N plots. The work showed that the soil could supply upwards of 1.51kg N/ha in the cotton-wheat-vetch rotation down to 0.83kg N/ha in back to back cotton.

## For more

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## Are we getting the drift?

CRDC is conducting a survey with GRDC and UNE to better understand the spray application practices, drivers and barriers to mitigating spray drift.

CRDC R&D Manager Rachel Holloway said despite both the grains and cotton industries investing substantial funding toward spraying workshops, extension, research and communications about how to manage spray drift on farms, it is still occurring.

"We are using UNE's School of

Psychology to investigate how we can understand people's behaviour, and develop evidence-based strategies to change how we deliver extension and communicate spray drift," Rachel said.

"Throughout August and early September our researchers are providing a survey for grain and cotton growers along with ground rig operators to discuss their current spray practices and views on spray drift.

"These discussions will be used to

understand the motivational factors for improved spray application on farms so we can reduce the drift incidences from happening."

If you would like to be a part of the survey, or know an operator, supplier or grower who may be interested, contact Lynette McLeod ([lmcleod7@une.edu.au](mailto:lmcleod7@une.edu.au)) or Rachel Holloway ([Rachel.Holloway@crdc.com.au](mailto:Rachel.Holloway@crdc.com.au)).

## Growers go for free

Australian cotton growers have the opportunity to attend, free of charge, the biggest international cotton event to come to Australia in years.

Australia is hosting the 78th International Cotton Advisory Committee (ICAC) Plenary meeting in Brisbane in December, with support from the Australian Government Department of Agriculture, CRDC, Cotton Australia and Australian Cotton Shippers Association. The theme of the conference is *Global leadership: pushing cotton's boundaries*.

ICAC members from up to 30 countries will converge on Brisbane to meet with Australian cotton growers, ginners, shippers, marketers, analysts, policy makers, textile manufacturers, agricultural suppliers and investment bankers.

The meeting will provide a forum for Australia to lead and inform discussions on the challenges facing the global cotton industry. These include the need

to encourage sustainable production systems, supply chain transparency and traceability, and the reporting of production metrics; an increasing push for a circular textile economy; cotton's declining share of the global fibre market; and distortions to production and trade. The challenge for the global industry is to continue adapting to these changes, while remaining profitable, sustainable and competitive.

To support the local industry, Australian cotton growers are invited to participate in the Conference free of charge, while all other Australian industry representatives are invited to attend at a greatly reduced cost of US\$250 (approximately A\$360; for overseas delegates it's US\$750 or around A\$1100). To take up the offer, email [comms@crdc.com.au](mailto:comms@crdc.com.au) to obtain the password required in the registration form, then head to the website [www.icacaustralia2019.com](http://www.icacaustralia2019.com).

Conference manager Jann George says attendees can expect sessions led by outstanding industry speakers and panellists, to be informed, share expertise and ideas in interactive sessions.

The World Café offers the perfect place to collaborate with colleagues in a relaxed setting.

An informative and exciting technical tour will take place after on the conference on Queensland's Darling Downs.

The Plenary will take place from December 2-5 at Brisbane Sofitel Hotel, followed by the field trip to the Darling Downs on December 6-7. Special conference rates are available at the Sofitel.

### For more

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# All the dirt on Vert

The irrigated cotton system is a perfect environment for the survival and persistence of *Verticillium* inoculum in the soil.

With optimum soil temperature, moist soil, plenty of nutrition and a susceptible host, researchers say this suitability makes controlling the disease difficult but not impossible.

NSW DPI pathologist Dr Karen Kirkby has worked extensively in *Verticillium* research. She says currently in Australia, recommended management strategies include planting tolerant varieties, planting into high firm beds, avoiding over irrigating and optimising nutrition throughout the growing season.

“Following harvest, stubble should be turned in as soon as possible to assist in the breakdown of plant material. Rotate cotton with non-hosts and control weeds, volunteer and ratoon cotton as they serve as alternate hosts for the *Verticillium* pathogen,” Karen said.

In the US, there is evidence that higher planting rates can reduce the incidence of

disease. Ideal rotation crops include but are not limited to sorghum, durum wheat and corn. Rotating with a non-host crop is more effective when inoculum levels are low.

The benefit of a rotation crop includes the wetting and drying of the soil which adds to the germination of microsclerotia, but as the host is not suitable for infection it helps drive down the inoculum. Alternate host crops include legumes, sunflower, safflower and some biofumigant crops.

Biofumigation crops have been effective for reducing inoculum for some diseases such as black root rot in cotton. Care must be taken in selecting suitable biofumigation crops as some are hosts for *Verticillium*.

“I have recently isolated *Verticillium dahliae* from Ethiopian cabbage, mustard, safflower and Noogoora burr,” Karen says. “Following molecular testing at EMAI, I can report these are hosts for the defoliating VCG 1A strain and are particularly virulent on cotton.

“I am currently conducting a pathogenicity trial in a controlled environment growth room to better understand what role alternate hosts play in the survival and transmission of inoculum.

Karen found the fungal isolates from infected Ethiopian cabbage and safflower are particularly virulent, killing cotton plants.

“Another interesting result is the non-virulent cotton fungal isolate was very virulent on Noogoora burr, which means the inoculum produced from a non-virulent strain in cotton can reproduce in weeds and alternate crops with the potential to produce a lot of inoculum.

“Weeds such as Noogoora burr for example, can produce up to 115,000 propagules per plant.”

### The role of nitrogen

Nitrogen can contribute to increased microsclerotia concentrations in the soil. Researchers in South Africa in 1971 reported nutrient deficiency and microbial substances may play a role in fungistasis (the inhibition of fungal growth). A more recent study in 2017 on olive mill composts in Spain found an increase in nitrogen contributed to an increase in microsclerotia concentration. The increase in nitrogen availability help microsclerotia overcome fungistasis which allows microsclerotia to thrive in the presence of the host plant, explaining an increase in concentration of microsclerotia.

## Predicting disease severity

In an effort to predict disease severity in a later crop, researchers are looking at pre-season levels of *Verticillium dahliae* inoculum.

Inoculum levels in cotton-growing soil naturally fluctuate throughout the growing season. Work published back as far as 1967 has reported the highest inoculum levels recorded are after picking in winter when decaying and dead tissue containing microsclerotia falls to the ground.

Recent results of field trials conducted in 2017-2018 by NSW DPI’s Dr Karen Kirkby found similar trends in inoculum (Figure 1). Karen found that inoculum levels naturally decline following planting

through the wetting and drying of the soil as well as the germination of microsclerotia in the soil. The research showed levels peaked in May (2018) following defoliation, harvest and the incorporation of infected plant tissue.

“Over the past two seasons, my technical staff Sharlene Roser and Peter Lonergan and I have been working to establish a correlation between pre-season inoculum levels and disease incidence,” Karen said.

“This has proven difficult, as one propagules per gram (ppg) of soil can

produce up to 60 percent disease incidence in cotton, however I have found a relationship between inoculum levels and minimum disease incidence.

“The minimum disease incidence increases as the inoculum levels increase.” (Figure 2).

The wetting of soil can stimulate microsclerotia to germinate repeatedly. Microsclerotia can persist in the soil for at least 14 years without a host. Microsclerotia germinate and sporulate after consecutive cycles of wetting and drying soil. However, the percent

Threshold (ppg)	Risk	Minimum incidence	Range incidence
1-10 ppg	Medium	30%	30-67%
11-22 ppg	High	42%	42-87%
23-36 ppg	Extreme	67%	60-96%

Table 1. Thresholds developed over two seasons for *Verticillium dahliae* inoculum in cotton soil.



## Microsclerotia

Microsclerotia are melanised multicellular structures which are the main survival and dormancy structures and serve as the primary inoculum on many plant hosts. Soil conditions: moisture; temperature; pH and nitrogen, can affect the germination of microsclerotia. Optimum soil temperature is five to 20°C with moisture levels at 50 to 75 percent field capacity, along with soil pH of eight. The optimum temperature for *Verticillium* conidia is 30°C when water availability is low, but this is reduced to 25°C when water is abundant.

germination of microsclerotia and the number of germinating hyphae decreases with successive wetting and drying cycles. The research done in the 1960s showed microsclerotia that ceased multiplying for several months when the soil was dried multiplied again when rewetted.

Germination of microsclerotia is the first step in microsclerotia returning to vegetative growth and initiating wilt disease. The range of disease potential from each level of inoculum observed in the plot trials may be explained by the fact each microsclerotia can germinate up to 13 times. Furthermore, each germinating microsclerotia can produce between 20 and 48 germinating hyphae depending on their size and the number of times the microsclerotia germinate.

From the plot data the average incidence of disease from each inoculum level up to 36 ppg was determined (Figure 3) and used to develop thresholds for the minimum disease (Table 1). This coming season, further work will be done to validate thresholds in commercial fields. Thresholds may vary under wet seasons, with different VCGs, variety planted and fields with different nutritional status.

*“Inoculum levels naturally decline following planting through the wetting and drying of the soil”*

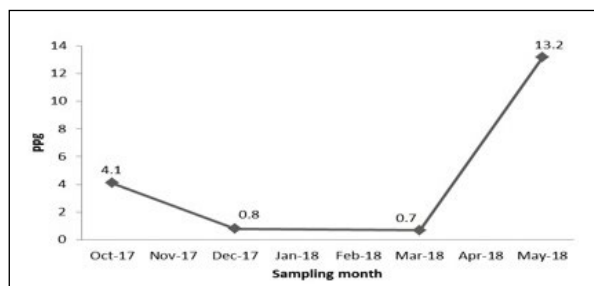


Figure 1. Natural fluctuations of inoculum levels measured as propagules per gram (ppg) of soil throughout the growing season. Soil sampling was in October 2017 before planting; December 2017; March 2018; and May 2018.

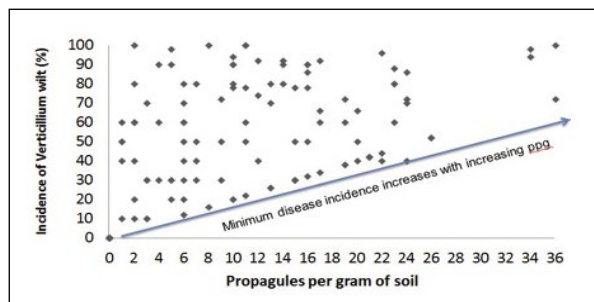


Figure 2. Relationship between inoculum levels and disease levels established in field trial plots.

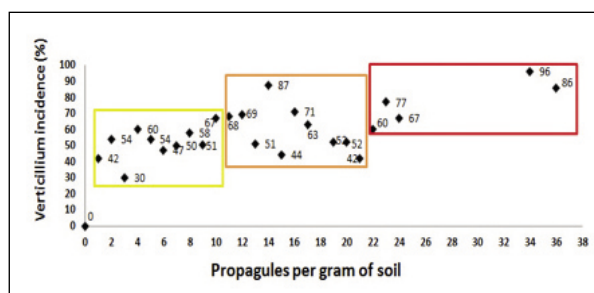


Figure 3. Average disease incidence from each plot with different inoculum levels. The coloured boxes show the range of disease incidence for individual inoculum levels (1-10, 11-22 and 23+ ppg).

Dr Karen Kirkby undertook long-term inoculum levels from six GPS sites in a field at the property ‘Mirrabooka’ near Narrabri from May 2013 to December 2018. Karen found that the benefit of rotating with non-host crops was a decline in the inoculum levels in the soil as seen in Figure 1. The graph shows results from May 2013 following a cotton crop, to July 2016, following durum wheat and sorghum rotations.

The inoculum levels continued to decline in December 2016. Following a cotton crop in the 2017-2018 season, the inoculum levels increased to an average of 2.3 propagules per gram (ppg) of soil. Even with higher inoculum levels, the field yielded 5.2 bales/ha as opposed to four bales/ha in 2011-12 prior to the trial.

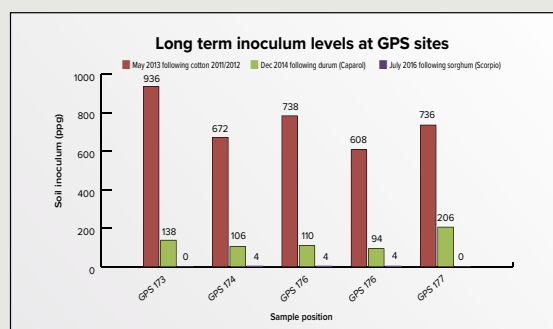
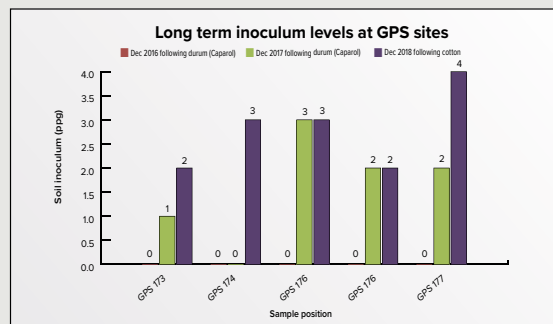


Figure 1. December 2016 to December 2018 – Inoculum levels increased following cotton planted in 2017-18 season.



Twenty random sites have been assessed from July 2016 to December 2018 – inoculum levels increased in 15 of the 20 random sampling sites following cotton planted in 2017-18 season.

# Rotations: making sure what comes around doesn't go around

Verticillium wilt has become increasingly problematic to the industry; however, research is making inroads into better understanding how to manage it using rotation crops.

Whether *Verticillium dahliae* is the defoliating or non-defoliating strain is irrelevant, because it is the virulence of the pathogen, and its ability to reduce productivity that is important.

The annual disease survey for the 2018-19 season detected the presence of Verticillium in the Darling Downs, Border Rivers, St George, Gwydir, Upper and Lower Namoi, Macquarie and Lachlan regions. Some fields recorded incidences as high as 71 percent of plants infected. The Murrumbidgee region continues its record with no confirmed cases, however without appropriate biosecurity measures by all members of the industry it is likely only a matter of time before the pathogen is detected south of the Lachlan.

## No silver bullet

Like most soil-borne pathogens, there is no silver bullet control option for *V. dahliae*. Its wide host range, resilient long-lasting spores and ability to colonise plants' vascular tissue effectively 'hides' it from fungicides, meaning that once present in a field, it is near impossible to eradicate.

"You won't ever truly eliminate a fungal pathogen from the soil, it will always be there in very low underlying levels," CottonInfo Technical Lead for Disease Tim Green said.

"The aim here is to either reduce it to a level where it will not cause disease, or suppress it with the growth of good microorganisms that will compete against it."

If *V. dahliae* is present, implementing practices that promote a healthy soil to naturally suppress and compete against the pathogen should be considered.

So how do we do this? Research with on-farm trials is showing that the answer is through rotation crops, and new evidence may suggest an ideal rotation crop is corn.

Tim says potato crops also suffer from Verticillium wilt. It will reduce total yield by



Dr Linda Smith has worked with growers in rotation experiments to assess the impact of rotations on Verticillium levels.

colonising and damaging feeding roots, promoting early senescence.

"A recent US study on the effect of corn as a green manure crop in rotation with potato, had no direct effect on *V. dahliae* inoculum in the soil. However, less roots were infected by *V. dahliae*, potato yields increased by 50 percent, and total number of tubers by 127 percent."

"The more biomass of corn that was incorporated into the soil the better the yield effect and the less disease observed. This raises questions for research in cotton."

## Corn as a rotation

Australian researchers have been hard at work investigating the benefits of corn as a rotation for cotton, through a rotation trial outside of North Star in North West NSW to investigate how many years of rotation it takes to reduce *V. dahliae* levels in the soil. They have observed significantly lower levels of inoculum and corresponding disease following two-year rotations with either corn, sorghum or bare fallow, compared to three years of continuous cotton.

"So what we've learnt is that while corn may not be an immediate fix for eliminating all *V. dahliae* from the soil, it will reduce the level of disease seen in the following cotton crop – but this raises the question: 'how is it doing this if it isn't directly killing off the pathogen?'" Tim says.

The answer lies with the rest of the soil microbiota.

Within the soil environment there are a multitude of fungal species all competing against each other for nutrients, water, and oxygen. Typically they exist in a balance, with no one species dominating the others. However when we interfere and sow monocultures such as cotton, this allows some fungi to rapidly reproduce as conditions are most favourable to them, in this case *V. dahliae*.

A rotation crop such as corn increases microbial diversity and quantity of beneficial microorganisms that compete with *V. dahliae*. A fallow field on the other hand is detrimental to all fungi due to a reduction in the amount of carbon present, and as such all microflora will suffer.

The reduced level of beneficial fungi with a cotton crop will immediately benefit *V. dahliae*; it will rapidly reproduce and leave its competitors behind, very quickly re-establishing the previous problem. Therefore it is important that the actual quantity of *V. dahliae* inoculum present in the soil be considered in the context of the amount of beneficial or competing species.

"The best way to manage Verticillium wilt is to manage your soil health," Tim says.

"A fertile soil promoting the growth of all soil microorganisms will outperform a barren (following fallow) or worse, a soil promoting the growth of only one fungus (cotton on cotton), every day of the week."

## For more

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# Burr breakthrough: insights into Noogoora

Australian scientists have developed a new biological control method for Noogoora burr, a troublesome weed with the ability to spread *Verticillium*.

While a range of herbicides are available to control Noogoora burr, all can cause off-target damage and are inappropriate for use in sensitive situations such as the riverine areas where the burr is often found. It is a serious threat to riverine ecosystems, habitats and native species, impacting 36 vegetation communities, including 11 Endangered Ecological Communities in NSW alone.

The burr is also a known host of the pathogen that causes *Verticillium* wilt, and through this project its presence was confirmed in all Noogoora species.

The Australian Government in collaboration NSW DPI, Murrumbidgee Irrigation, University of Queensland and CRDC supported the project *Biological control and taxonomic advancements for management in the Noogoora burr complex*. It was jointly led by NSW DPI's Graham Charles and Dr Stephen Johnson, with NSW DPI cotton pathologist Dr Karen Kirkby.

## Bio breakthrough

Bioherbicides contain naturally occurring fungal pathogens specific to the target weed. Among their many benefits they are safe for use in sensitive environmental and production areas and are highly cost effective to develop and use when compared

to traditional herbicides. However the pathogens typically in bioherbicides require free water from dew or rain for the fungi to develop and cause plant death. In dry areas this presents obvious limitations. "We have overcome this limitation, which we see globally, through the use of a complex emulsion," Graham said.

"Sourced through scientists from the University of Melbourne, and combining it with our pathogen, *Alternaria zinniae*, we were able to kill all Noogoora burr species and hybrid plants in our trials."

To get the technology into the field, the researchers will now partner with land managers in testing the product as it moves toward commercial viability. Future research could also extend the use of the emulsions to other pathogen/weed combinations to achieve bioherbicide control of other established weeds in primary production and environmental ecosystems, both in Australia and globally.

## Clearer identification

Prior to this project, there were four species in the Noogoora burr complex recognised in Australia, but only a single species in the US where the burr came from, which raised questions for the researchers.

"Clearly the identification of this weed was confused, and we were concerned this might have had implications for the control and disease-host status of the weed," Graham said.

"Initially, our research sought to better understand the taxonomy within the species complex since such uncertainty can constrain biological control efficacy.

"DNA barcoding and next-generation sequencing actually revealed that here the

**CottonInfo Gwydir REO**  
Janelle Montgomery  
collecting Noogoora  
burr samples for the  
breakthrough research.



Noogoora burr complex consists of two distinct genetic groups and a wide range of hybrids, not the four morphologically distinct species (morpho-types) originally described.”

Importantly, the researchers found the bioherbicide to be equally effective across all the groups. The use of the complex emulsions now has the potential to be extended to other pathogen/weed combinations to achieve the safe control of other established weeds in primary production and environmental ecosystems.

“The central strength of this project was the assembly of a multidisciplinary team which demonstrated strong collaboration and the ability to undertake a comprehensive research and development program for bioherbicides and control,” Graham says.

“The team included agronomists, an ecologist, pathologists, geneticists and support staff, with the assistance of biochemists and molecular engineers, working together to achieve an outstanding success.

“The use of a multidisciplinary team should be considered for future projects where rapid outcomes are required for complex problems, as we were supported by NSW DPI cotton pathologist Dr Karen Kirkby, who undertook the *Verticillium* testing component of the project.”

#### For more

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## Verticillium presence confirmed

Noogoora burr is a particularly important weed to the cotton industry as it is a host of *Verticillium dahliae*, a problem pathogen with the potential to cause significant plant death and yield loss.

With support from the Australian Government in collaboration NSW DPI, Murrumbidgee Irrigation, University of Queensland and CRDC, under the project *Biological control and taxonomic advancements for management in the Noogoora burr complex*, testing by Dr Karen Kirkby and her collaborative team from EMAI found a range of *Verticillium* strains across all Noogoora species and hybrids, included the defoliating VCG1A (vegetative compatibility group) and non-defoliating VCG2A strains.

“This raised further questions around the potential for some of these additional strains to be present in other weeds and cotton and is relevant to other industry researchers looking into the spread of *Verticillium* throughout cotton growing regions,” Karen said.

“These weeds harbour the pathogen that causes *Verticillium* wilt in cotton and consequently should be controlled in order to minimise the spread of the disease and increase of *V. dahliae* inoculum in soil.”

Some species were host to more than one VCG.

“Our study suggests the existence of main VCG clonal lineages that contain the isolates of VCGs 1A and 1B, VCGs 2A and 4B, and VCG 4A, and the existence of other VCGs or VCG subgroups that have been found rarely and seem to be genetically different,” Karen said.

“This is suggestive of a population structure consisting of some recombination events (maybe extant, rare, or past), with a clonal expansion of certain successful individuals possibly associated with agriculture.

“It is possible that these latter groups have emerged through the evolutionary mechanisms described above, but the one question arising is: ‘where are these variants originating from?’

“We believe that there are aspects of the *V. dahliae* biology that have not yet been explored appropriately, and it is possible that there is a more complex diversity in *V. dahliae* that has not been targeted.”

The techniques developed in this project to screen for the presence of *Verticillium* wilt, using PCR analysis to detect the pathogen, and then DNA analysis to identify the pathogen, will enable the presence of this and other pathogens to be explored in future projects.

#### For more

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Seedlings of *Xanthium* spp. and hybrids growing in the glasshouse during the experiments.





# Southern weeds trials show no residual damage

CRDC has been supporting a herbicide demonstration trial at the IREC field site in the Riverina.

The demonstration was designed to highlight to growers and consultants that a diverse approach to weed control with less reliance on glyphosate will protect and prolong its usefulness.

Research agronomist and CottonInfo Integrated Weed Management Technical Lead Eric Koetz of NSW DPI says the trial had to take into account issues raised by growers of the effect on crop establishment and plant stands when using pre-emergent and residual herbicides, especially early in the season under cooler conditions.

"Using residual herbicides is being promoted through cotton industry guidelines and Weedsmart as a part of its Summer Big 6," Eric said.

## Treatments

1. Glyphosate (Weedmaster DST) (1.5L/ha) only system; pre-plant and post emergent over the top (OTT) as required, +/- mimic weeds to show "resistant" scenario
2. Glyphosate (1.5L/ha) pre plus gly (1.5L/ha) + Bouncer (1L/ha) OTT post @ 4 nodes
3. Glyphosate (1.5L/ha) pre plus directed gly (1.5L/ha) + pendimethalin (2L/ha) (Rifle) @ 4 nodes
4. Pendimethalin (1.9L/ha) (Rifle) pre-plant (PSI) plus gly (1.5L/ha) + Bouncer (1L/ha) OTT @ 4 nodes
5. Diuron (1.5kg/ha) pre-plant (PSI) and glyphosate (1.5L/ha)
6. Conventional; pendimethalin (Rifle) (1.9L/ha) (PSI) + glyphosate (1.5L/ha) + Gesagard 2.5L/ha (applied as layby)

## Effect of residuals

"The importance of early weed control on crop establishment and growth and subsequent lint yield is clearly evident from this trial.

"Applying a pre-emergent herbicide reduces weed germination, therefore the first in crop glyphosate spray is only targeting a small number of weeds. Not only does this increase the chance of control, it also reduces the risk of resistance developing."

In this trial researchers took into account conditions growers face in the south when using these modes of action, due to a different climate than northern growers, and find a fit for them.

Glyphosate-tolerant cotton has been rapidly adopted by the Australian cotton industry since its introduction 13 years ago and currently accounts for nearly all of the crop grown.

"This has led to a change in weed management practices with growers moving from applying residual herbicides in anticipation of a weed problem to dealing with weed issues using predominantly glyphosate," Eric says.

"The use of other chemical or cultural methods to control problem weeds has reduced significantly during this period."

These changes have resulted in a shift in the weed species found across cotton growing regions. Increasingly the broadleaf weeds such as flaxleaf fleabane and sowthistle dominate weed spectrums in cotton crops with increasing weed burdens in the non-cotton component of the rotation. Populations of these weeds have been found to be glyphosate resistant. The glyphosate resistance level of weeds such as awnless barnyard grass, windmill grass and feather top Rhodes grass is also rising.

"Even though recent CCA survey results show an increase in the use of residual herbicides, this is masking a reduction in glyphosate efficacy on these problem weeds," Eric warns.

"That is, glyphosate is not providing the weed control that it used to.



Research at IREC took into account conditions growers face in the south.

## Results

- ◆ In comparison to the commercial crop (11.5 plants/metre) there was no significant reduction in plant establishment averaged across all treatments (11 p/m). Minor reductions in plant numbers between treatments did not carry over to boll numbers per metre.
- ◆ Yields from handpicked plots showed a significant reduction in lint yield from weedy control & T1 (9.6b/ha), compared to the highest yield from T 6 (13.2b/ha).
- ◆ The importance of early weed control on crop establishment and growth and subsequent lint yield is clearly evident from this trial.
- ◆ Hand gin results had turnouts between 42 and 43 percent independent of herbicide treatment.

"Resistance is slowly increasing and perhaps we are heading toward a tipping point."

A range of treatments were applied throughout the 2018-19 growing season (see table).

## For more

**Eric Koetz**

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# Weeds evolving to increase resistance

Research supported by CRDC has shown that resistance in windmill grass (*Chloris truncata*) has evolved at least twice – so what does this mean for management going forward?

Windmill grass is becoming an increasing issue for cotton growers as it makes its way into fields and channels, roads and waterways. The discovery of resistant individuals and populations by growers and through annual weeds surveys is of great concern for the cotton industry and CRDC.

The increasing rate at which glyphosate resistance is reported in weeds generally, and the significant challenge to food production presented by glyphosate resistance means that we need to understand how glyphosate resistance evolves and spreads geographically.

The results of a recently concluded CRDC-supported thesis study contribute to understanding these processes in windmill grass. The development of knowledge of glyphosate resistance is critical for the development of management strategies against weeds. If resistance evolution is a rare event then there is a possibility to focus resources on new cases of resistance and eradicate all weeds in affected populations. If resistance evolves readily, it could be a waste of resources to attempt early eradication like this.

As a summer weed, windmill grass has become a threat to zero-till farming because it can reduce the production of winter crops by competing for nutrients and soil moisture. Windmill grass is a common host for wheat streak mosaic virus (WSMV) and barley yellow dwarf virus (BYDV), so it causes indirect problems as well.

Because managing glyphosate resistance requires knowledge of the number of times that resistance has evolved, the way that it has evolved, and the way that it spreads across agricultural

and natural environments, CRDC's broad ranging project *Staying ahead of glyphosate resistance evolution* has multiple projects aimed at answering these questions in relation to the industry's most important weeds.

As part of this project, and under the supervision of Dr James Hereward and Professor Gimme Walter, The University of Queensland's Yu Shen's Masters' thesis addressed three major questions: is *C. truncata* one species or are there multiple cryptic species that resemble one another morphologically?; is there connectivity among windmill grass populations geographically?; and how many times has resistance evolved in windmill grass?

Yu says the results obtained prove that this highly self-pollinating (selfing) species has lower levels of genetic diversity and many populations were identical clones of each other genetically. The rate of selfing vs outcrossing is important for the evolution of herbicide resistance – if a weed outcrosses then it is easier for resistance to multiple herbicide modes of action to be 'stacked' in the weed. If the weed species only self's (or outcrosses very rarely) then it is much harder for that species to develop resistance to multiple modes of action. This is why ryegrass became resistant to so many modes of action so quickly. The high rate of selfing in windmill grass is therefore good news for the evolution of multiple herbicide resistance in this weed, however, once glyphosate resistance is widespread there is still risk of developing multiple resistance, so it is still critical to control glyphosate resistant populations.



## Species status: *Chloris truncata* and *Chloris divaricata*

The results of the research contribute to our understanding of the ecology of the two *Chloris* species investigated, the geographical connectivity of windmill grass populations, and the evolution of glyphosate resistance in these weeds.

"We confirmed, with genetic data, that the two morphologically similar described species, *C. truncata* and *C. divaricata*, are indeed two distinct species that are closely related," Yu says.

"This creates implications for understanding and dealing with glyphosate resistance."

Windmill grass is an Australian native grass, but there are many species that look very similar to it.

"There is also some variation within what is defined as *Chloris truncata*," Yu says.

"The species status of *C. truncata* must therefore be verified using population genetics approaches, otherwise, we cannot be sure that it is windmill grass alone that is resistant to glyphosate, or if other morphologically indistinguishable or similar species are also resistant to glyphosate."

Correct plant identification has proved to be crucial to understanding the resistance status and ecology of windmill grasses *C. truncata* and *C. divaricata* (slender chloris). Grass species identification can be difficult and challenging and correct identification is important. Incorrect identification can mean that we underestimate how many species have glyphosate resistance. Understanding glyphosate resistance and its evolution therefore requires accurate species identification.

"I had to make sure that it was windmill grass alone showing resistance to glyphosate rather than other similar-looking species which may or may not have been resistant to glyphosate," Yu said.

Several grass species in Australia look very similar to *C. truncata* and the genetic analysis showed that some of these were present in samples, including *C. divaricata* (slender chloris) and *Enteropogon ramosus* (curly windmill grass).

This highlights how incorrect species identification could also affect weed ecology studies.

Although *C. divaricata* and *C. truncata* have been shown to be two distinct species through the data presented, a number of individuals may be the result of hybridisation. This is important because if hybridisation does occur then glyphosate resistance could be passed from one species to the other.

"My data shows that *C. divaricata* and *C. truncata* have different distributions, so if hybridisation allowed glyphosate resistance to spread from *C. truncata* to *C. divaricata* then a much larger agricultural area could be affected," Yu said.

These tests are preliminary and to fully test the number of times that resistance has evolved, the population genetic data Yu developed must be combined with herbicide screening to test for resistance, and tests to estimate the levels of EPSPS expression.

Industry weeds researcher and CottonInfo's Eric Koetz says an integrated strategy is always preferred, and reliance on herbicidal weed control should be avoided. Non-herbicidal strategies like biological control, can also help to prevent the development of glyphosate resistant weeds.

"The results of Yu's work show that resistance has evolved at least twice in windmill grass," he said.

"This emphasises that managers should avoid reliance on glyphosate for this grass and should monitor for survivors to enable resistance testing as well as control.

"The research also reiterates how vital it is to correctly identify weeds, so we urge all crop managers to use the industry's Cotton Pest Management Guide and Weeds ID publications to make sure they know what they are controlling."

### For more

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# Our inconvenient truth

There is a new threat out there in the paddock. It is not soil borne, transmitted by insects nor harboured in trash. It cannot be foliar treated, spot sprayed nor eradicated by breeding of resistant varieties. Sadly though, it is prevalent in our industry. It is called complacency.

Sadly, despite the international warnings and ever growing on-shore issues with herbicide resistance, it would appear that in some quarters, the message is just not getting through. Perhaps we are all just getting tired of hearing about it, or perhaps believe that it is only a problem in other cropping industries and areas but not ours. The bottom line is that resistance development is a natural process in plants, and we are always going to be confronted with this issue in varying degrees.

As scientists – and that is what we are and are qualified in, we tend to put our hope in the next ‘silver bullet’. But what if the silver bullet is not out there? What if the silver bullet does not come in the form of a chemical application that will fit perfectly into our current farming practices?

We have had our silver bullet in our industry that revolutionised the way that we farm. It is called glyphosate. This product, developed originally as an industrial descaler, has enabled us to move away from continuous cultivation and in the age of Roundup Ready cotton, control weeds at various times of crop development. Now the future of this product from both an availability and efficacy perspective is in doubt.

The cloud that hangs over its commercial availability can be debated long and hard. The recent experiences of Australia’s live export trade have taught us that decisions in the name of the ‘greater good’ can and will be made at the stroke of a pen. Without setting off alarm bells, it is possible that our industry may need to put a Plan B in action – and quickly. This of course is all based on speculation, media attention and the outcomes of domestic court cases.

The efficacy discussion however is a different ballgame. Herbicide resistance in our major weeds including those found in northern growing regions is real. It is already with us, and is calling for the Plan B.

The Western Australian Herbicide Resistance Initiative (WAHRI) was launched in 1998 as part of a GRDC initiative

in response to the emergence of herbicide resistance in the state’s cropping systems. In 2009, following a recognition that herbicide resistance was not limited to one state and that a national approach was required, the organisation changed its name to the Australian Herbicide Resistance Initiative.

The group focuses upon “research, development and extension /communications (RDE) of herbicide resistance and its management for profitable and sustainable cropping systems in the Australian grains industry”. (Beckie, 2019) It is perhaps the nature of the development of the organisation, and its base in the grains industry, which has led to some apathy within the cotton fraternity that this is ‘not our problem’.

Much of the work and recommendations of AHRI and their industry partner WeedSmart (supported by CRDC) are highly transferable to our own industry and their website and publications are a valuable resource in terms of farming options. (They are also well worth following on social media.) CCA member and AHRI Northern Weeds and Crops Extension Agronomist Paul McIntosh said that the message though is really a simple one: ‘Whatever you do – stop the seed set’.

“If you stop an annual plant from going to seed you will never have herbicide resistance,” Paul says.

Weedsmart are currently promoting their ‘Big 6’ approach to wise crop weed management where they recommend additional measures such as rotation of crops and pastures and mixing and rotating (full rate) herbicides.

At our recent CCA Seminar in Narrabri, members were also shown first-hand the technical developments and research being undertaken by some of agriculture’s youngest and brightest stars. The work being done in many of our universities provides exciting opportunities for ‘high tech’ and targeted weed control options. It is highly likely, that it will be from this work that our new ‘silver bullet’ will develop.

Just as glyphosate has shaped our farming systems, so too will the next wave of mechanical and management options that we will need to incorporate in our future integrated weed management practices. For now, it is very much a ‘watch this space’ event, but upcoming developments such as instant resistance testing options, robotics and even new herbicides based on microbial action are already not far from commercial reality.

Our role as advisors and growers is to ensure that we play an active role in halting the spread of herbicide resistance.

This is everyone’s business and there is no longer any room for complacency.

## For more

[www.weedsmart.org.au](http://www.weedsmart.org.au)

[www.ahri.uwa.edu.au](http://www.ahri.uwa.edu.au)

[www.cropconsultants.com.au](http://www.cropconsultants.com.au)

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*“If you stop an annual plant from going to seed you will never have herbicide resistance...”*



# CRDC Investments 2019-2020

The 2019-20 year marks the second year under CRDC's five-year plan: the 2018-23 CRDC RD&E Strategic Plan. Under this Plan, during 2019-20, CRDC will invest \$20.2 million into RD&E projects across five key areas, in collaboration with around 100 researcher partners, and on behalf of Australia's cotton growers and the Australian Government. This table outlines the projects that CRDC will invest 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 28 June 2019, and may be subject to change.

Key focus area	Outcome	Project title	Project code	Researcher	Organisation	Commenced in:	To be completed in:
<b>Goal 1: Increased productivity and profitability on cotton farms</b>							
1.1 Optimised farming systems	1.1.1 Improved yield and quality	Precision management for improved cotton quality	CMSE1802	Robert Long	CSIRO	Jul-17	Jun-20
		Improving crop establishment, termination and weed control in dryland cotton farming systems	CRDC1937	Annabelle Guest	DCRA	Jan-19	Apr-20
		Increased yield through improved management of soil constraints in cotton farm	USQ1903	John Bennett	USQ	Jun-19	Jun-22
		Managing cotton quality to maintain Australia's premium status (includes CottonInfo technical lead and myBMP module lead)	CRDC1924	Rene van der Sluijs	Textile Technical Services	Oct-18	Sep-20
	1.1.2 Improved input efficiencies	A biological alternative to nitrogen fertiliser in cotton	UN1901	Grace Scott	U Nottingham & Azotic	Sep-18	Sep-19
		Improving the nitrogen use efficiency of cotton crops through better understanding the role of dissolved organic N	CSP1904	Bennett Macdonald	CSIRO	Jul-18	Jun-21
		Improving water use efficiency in a changing climate	CSP1804	Katrina Broughton	CSIRO	Jul-17	Jun-20
		More Profit from Nitrogen – Enhancing nutrient use efficiency in cotton	RRDP1712	Graeme Schwenke	NSW DPI	Jul-16	Jun-21
		More Profit from Nitrogen – Improved nitrogen use efficiency through accounting for deep soil and mineralisable N supply, and deployment of Enhanced Efficiency Fertilisers to better match crop N demand	RRDP1717	Lukas Van Zwieten	NSW DPI	Jul-16	May-20
		More Profit from Nitrogen – Improving dairy farm nitrogen efficiency using advanced technologies	RRDP1715	Helen Suter	UM	Jul-16	Nov-19
		More Profit from Nitrogen – Increasing nitrogen use efficiency in dairy pastures	RRDP1714	David Rowlings	QUT	Jul-16	Nov-19
		More Profit from Nitrogen – New technologies and managements: transforming nitrogen use efficiency in cane production	RRDP1719	Matt Redding	QDAF	Sep-16	Jun-21
		More Profit from Nitrogen – Nitrogen use efficiency indicators for the Australian cotton, sugar, dairy & horticulture industries	RRDP1901	Dio Antille	CSIRO	Mar-19	Jul-19
		More Profit from Nitrogen – Optimising nutrient management for improved productivity and fruit quality in cherries	RRDP1721	Nigel Swarts	UTAS	Aug-16	Jun-21
		More Profit from Nitrogen – Optimising nutrient management for improved productivity and fruit quality in mangoes	RRDP1720	Mila Bristow	NTDPIR	Aug-16	Jun-21
		More Profit from Nitrogen – PMA Meetings	RRDP1722	Allan Williams	CRDC	Jul-16	Jun-20
		More Profit from Nitrogen – Project Communications	RRDP1735	Allan Williams	CRDC	Jul-16	Apr-20
		More Profit from Nitrogen – Quantifying the whole farm systems impact of nitrogen best practice on dairy farms	RRDP1716	Richard Eckard	UM	Jul-16	Apr-20
		More Profit from Nitrogen – Science leadership and project coordination	RRDP1711	Marguerite White	Consultant	Nov-16	Jun-20
		More Profit from Nitrogen – Smart blended use of enhanced efficiency fertilisers to maximise sugarcane profitability	RRDP1718	Weijin Wang	DSITI	Jul-16	Apr-20
		More Profit from Nitrogen – YourData platform	RRDP1727	Jeff Coutts	Coutts J&R	Feb-17	Jun-21
		Optimising the management of manures in southern NSW cotton production II	DU1903	Wendy Quayle	DU	Jul-18	Jun-21
		PhD: Electrophysiological and molecular identification of novel biopesticides	UWS1601	Michelle Mak	UWS	Jul-15	Jun-20
		PhD: Monitoring soil water dynamics for improving water use efficiency	UNSW1801	Ehsan Zare	UNSW	Jul-17	Jun-20
		PhD: Next-generation fertilisers for nutrient stewardship in cotton production	UQ1702	Rhys Pirie	UQ	Jan-17	Jan-20
		PhD: The impact of irrigation methods and management strategies on nitrogen fertiliser recovery in cotton in southern QLD	UQ1502	John Smith	UQ	Jul-14	Dec-20
		Professor of Soil Biology (includes CottonInfo technical lead and myBMP module lead)	1920FRP040	Oliver Knox	UNE	Jul-19	Jun-22
		Water use efficiency for irrigated and dry land cotton benchmarked (includes Ben Crawley – CottonInfo technical lead)	1920FRP006	David Perovic	NSW DPI	Jul-19	Jun-22
		Where does water go? Visualising irrigation efficiency by time-lapse water monitoring	UNSW1802	John Triantafyllis	UNSW	Jul-17	Jun-20

Key focus area	Outcome	Project title	Project code	Researcher	Organisation	Commenced in:	To be completed in:
	1.1.3 On-farm sustainable development is supported	Science leadership for cotton development in Northern Australia	CSP1903	Steve Yeates	CSIRO	Oct-18	Sep-21
	1.1.4 Improved reliability of cotton production	Minimising yield variability to maximise yield	DAN1801	Guna Nachimuthu	NSW DPI	Jul-17	Jun-21
		PhD: Utilising novel plant growth regulators to develop resilient future cotton systems	CSP1604	Claire Welsh	CSIRO	Apr-16	Sep-19
		Quantifying the effectiveness of cover crops as a means of increased water infiltration and reduced evaporation in the northern region	GRDC1801	David Lawrence	QDAF/ GRDC	May-17	Apr-20
		Supporting southern cotton production systems: Cotton Research Officer	EOI – 0271	Hayden Petty	NSW DPI	Jul-19	Jun-22
1.2 Transformative technologies are adapted for use in cotton	1.2.1 New technologies are adapted for use in cotton	Agri-innovation: Driving productivity for Australian cotton growers through partnerships and digital technologies	JT1901	Jane Trindall	Jane Trindall Consulting	May-19	Jun-22
		Application of genomic tools to monitoring for resistance alleles in <i>Helicoverpa</i> spp.	CSE1801	Tom Walsh	CSIRO	Jul-17	Jun-20
		Evaporation mitigating solution for Australian cotton water storages		Greg Qiao	UM	Jul-19	May-22
		Future Farm (phase 2): Technology solutions for improved nitrogen application	QUT1902	Peter Grace	QUT	Jul-18	Jun-22
		Gwydir Valley demonstration of the application of the latest digital technologies for precise automated irrigation		Louise Gall	GVIA	Jul-19	May-22
		Identifying sensors for better Integrated Pest Management (IPM) in cotton	NEC1901	Alison McCarthy	USQ NCEA	Jul-18	Jun-21
		Major Capital Item: ACRI cotton picker and precision-variable rate fertiliser technology to support cotton R&D in northern and southern NSW	DAN1905	Rod Jackson	NSW DPI	Apr-18	Dec-19
		PhD: Characterisation of brassinosteroid effects and brassinosteroid – responsive genes in cotton for growth and stress tolerance enhancement	UNE1605	Anahid A Essa Al-Amery	UNE	May-14	Nov-19
		Plant-based sensing for cotton irrigation		Hizbullah Jamali	CSIRO	Jul-19	May-22
		Precise real-time automated cotton irrigation for improved water productivity		Joseph Foley	USQ NCEA	Jul-19	May-22
		Precise real-time automated cotton irrigation for improved water productivity		James Brinkhoff	DU	Jul-19	May-22
	1.2.2 Cotton farms are digitally enabled	Australian Agriculture: Growing a digital future – Communications	GDF1908	Jane Trindall	CRDC	Jun-19	Sep-19
		Australian Agriculture: Growing a digital future – Digital capability framework for Australian agriculture sector	GDF1906	Georgie Aley	KPMG	May-19	Sep-19
		Australian Agriculture: Growing a digital future – Inception meeting assistance	GDF1904	Julia Skinner	Consultant	Mar-19	Sep-19
		Australian Agriculture: Growing a digital future – National Forum	GDF1907	Jane Trindall	CRDC	Jun-19	Sep-19
		Capital: Sundown Smart Farm Development	CRDC1928	Nick Gillingham	Sundown Pastoral	Nov-18	Oct-20
		Developing digital agriculture maturity index and assessing digital maturity levels across all agricultural sectors	GDF1901	Airong Zhang	CSIRO	Jan-19	Sep-19
		Developing transparency and trust for producers through Australian agricultural data governance: framework and action plan	GDF1902	Leanne Wiseman	GU	Jan-19	Sep-19
		Developing transparency and trust for producers through Australian agricultural data governance: principles	GDF1903	Jay Sanderson	USC	Jan-19	Sep-19
1.3 Protection from biotic threats and environmental stresses	1.3.1 Increased understanding of the impact of pests, diseases and weeds, and environmental stresses	Additional support – Fulbright scholarship to study Verticillium Wilt	CGA1911	Shelby Young	Lower Namoi CGA	Jun-19	May-20
		Biology of <i>Amaranthus hybridus</i> , <i>A. mitchelli</i> , and <i>A. powellii</i> : emerging weeds of cotton systems	UQ1703	Asad Khan	UQ	Jan-17	Dec-19
		Integrated weed management options for weed control in cotton farming systems (including CottonInfo technical lead and myBMP module lead)	DAN1901	Eric Koetz	NSW DPI	Jul-18	Sep-19
		IPM to support the management of emerging pests	CSP1905	Simone Heimoana	CSIRO	Jul-18	Jun-21
		Transformation of <i>Verticillium dahliae</i> , causal agent of Verticillium wilt of cotton, with the GFP gene	DAN1809	Aphrika Gregson	NSW DPI / UQ	Dec-17	Jun-20



Key focus area	Outcome	Project title	Project code	Researcher	Organisation	Commenced in:	To be completed in:
	1.3.2 Improved identification, surveillance and management systems for pests, diseases and weeds and environmental stresses	Biological based products for improved cotton production	UWS1901	Brajesh K Singh	UWS	Jul-18	Mar-22
		Characteristics of disease suppressive cotton farming systems and soils	1920FRP010	Linda Smith	QDAF	Sep-19	Jun-22
		CottonInfo IPM Technical Lead and pest management for high yield research (including myBMP module lead)	DAQ1902	Paul Grundy	QDAF	Jul-18	Jun-21
		Development of a spray drift hazard prediction system	MRES1701	Graeme Tepper	MRES	Jul-16	Sep-19
		iMapPESTS: Sentinel Surveillance for Agriculture	HIA1802	Wee tek Tay Dean Brooks	HIA	Feb-18	May-22
		Improved management of silverleaf whitefly on cotton farms	DAQ1903	Richard Sequeira	QDAF	Jul-18	Jun-21
		Improving the management of cotton diseases in Australian cotton farming systems	RRDP1724	Linda Smith	QDAF	Jul-16	Dec-19
		Innovative solutions to cotton diseases	DAN1703	Duy Le	NSW DPI	Jul-16	Dec-20
		Managing Climate Variability Program – Phase 5	MLA1701	Doug McNicholl	MLA	Jul-16	Jun-21
		Managing verticillium risk for cotton	RRDP1723	Karen Kirkby	NSW DPI	Jul-16	Dec-19
		Mirid and mealybug best practice management	DAQ1802	Richard Sequeira	QDAF	Jul-17	Jun-20
		Novel approaches for improved management of plant stressors	1920FRP039		CSIRO	Jan-20	Jun-22
		Novel topical vegetable & cotton virus protection: BIOCLAY	HIA1803	Neena Mitter	HIA/UQ	May-17	May-20
		PhD: Building climate change resilience in cotton through translational physiology	ANU1704	Demi Gamble	ANU	Feb-17	Mar-20
		Ready to use soil test to manage black root rot risks	MLAB1901	Maria Manjarrez	Microbiology Labs Aust	Jul-18	Jun-20
		Reducing the impact of weather, insects and microbes on cotton colour	CSP1901	Simone Heimoana	CSIRO	Jul-18	Jun-21
		Southern Cotton Crop Protection (including CottonInfo Disease Technical Lead and myBMP module lead)	DAN1903	Tim Green	NSW DPI	Jul-18	Oct-21
		Sustainable insect management through improved insect resistance monitoring	1920FRP014	Jamie Hopkinson	QDAF	Jul-19	Jun-22
		Sustainable insect management through improved insect resistance monitoring	1920FRP019	Lisa Bird	NSW DPI	Jul-19	Jun-22
	1.3.3 Industry is prepared for a biosecurity incursion	Khapra Beetle response	CA1708	Sally Ceeney	Cotton Australia	Jan-17	Dec-19
		Large scale biosecurity scenario to support cotton industry preparedness	PHA1902	Stephen Dibley	PHA	Jul-18	Dec-19
		Plant Biosecurity Research Initiative (PBRI)	HIA1801	Jo Luck	HIA	Jun-17	Jun-20

Goal 2: Improve cotton farming sustainability and value chain competitiveness							
2.1 Sustainability of cotton farming	2.1.1 Improved environmental footprint for cotton farms	Cotton Landcare Tech Innovations: Communications Support	NLP1903	Bernadette Pilling	HOC	Nov-18	Mar-22
		Cotton Landcare Tech Innovations: Improved natural capital (biodiversity) on Australian cotton farms	NLP1901	Erin Peterson	QUT	Jan-19	Nov-21
		Cotton Landcare Tech Innovations: Improved natural capital (biodiversity) on Australian cotton farms.	NLP1902	Rhiannon Smith	UNE	Jul-18	Nov-21
		Feasibility study of managed aquifer recharge for improved water productivity	ANU1901	Anthony Jakeman	ANU	Aug-18	Aug-21
		Improving the ability of the Australian cotton industry to report its sustainability performance	QUT1705	Erin Peterson	QUT	Oct-16	Oct-19
		PhD: Alternative energy technologies and policy solutions for the Australian cotton	UTS1901	Yunfeng (Forrest) Lin	UTS	Aug-18	Jun-21
		PhD: Sustainable water extractions: Low flow regia and critical flow thresholds	UNE1406	Marita Pearson	UNE	Jan-14	Aug-20
		Quantifying the nitrogen cycle: from farm gate to catchments, groundwater and atmosphere	ANSTO1801	Dioni Cendon	ANSTO	Jul-17	Jun-20
		Quantifying the potential environmental impacts of pesticides used on cotton farms	DAN1803	Mick Rose	NSW DPI	Jul-17	Jun-20
		Review of international water footprints and their assessment of Australian agriculture	CRDC1923	Tim Grant	Life Cycles Strategies Pty Ltd	Oct-18	Jul-19
		Synthesis of natural resource assets in the cotton growing region of eastern Australia	FWPA1801	Julian Wall	Eco Logical Aust P/L	Jul-17	Jun-20
		Understanding environmental impacts and resource impacts with changing demand for Australian cotton, assessed using a change modelling life cycle assessment approach	CRDC1911	Stephen Wiedemann	Integrity Ag and Environment	Aug-18	Feb-20

Key focus area	Outcome	Project title	Project code	Researcher	Organisation	Commenced in:	To be completed in:
2.2 Create higher value uses for cotton	2.2.1 Increased value for Australian cotton	Breathable cotton for compression fabrics phase 2: performance testing	DU1905	Maryam Naebe	DU	Jan-19	Dec-19
		Developing renewable fine chemicals from cotton biomass (Biorefineries for higher-value animal feeds, chemicals and fuels phase 2)		William Doherty	QUT	Jul-19	Jun-20
		High sound absorbing composites from recycled cotton	DU1901	Christopher Hurren	DU	Oct-18	Sep-19
		PhD: Exploring nanofibrous coating on cotton fabric with versatile protection and dynamic comfort	RMIT1702	Olga Gavrilenko	RMIT	Feb-17	Jan-20
	2.2.2 Increased understanding of market requirements and opportunities throughout the value chain	Bio-degradation of dyed cotton fabrics	NCSU1701	Nelson Vinueza	NCSU	Jan-16	Dec-19
		Joint RDC community trust project	RIRDC1903	Jennifer Medway	AgriFutures	Jun-19	May-21
		Micro particles generated from laundering of cotton and other fabrics	NCSU1702	Richard Venditti	NCSU	Jan-17	Dec-19
		Strategies for improving labour conditions within the Australian cotton value	QUT1903	Alice Payne	QUT	Jun-19	Jun-22
2.3 Measurement and reporting throughout the value chain	2.3.1 CRDC collaborates in global leadership for sustainability initiatives	Cotton industry report on social capital wellbeing sustainability indicators	1920FRP037	Jacki Schirmer	University of Canberra	Jun-19	Jun-22
		Membership of the Sustainable Agriculture Initiative (SAI) – Australian chapter	CRDC1902	Selwyn Heilbron	SAI Platform (Aust) Inc	Jul-18	Jun-20
		PhD: Textile supply chain transparency and accountability	UL1901	Mark Sumner	UL	Oct-18	Sep-21
		Sustainable Apparel Coalition membership	CRDC1817	Glenn Robinson	SAC	Aug-17	Jun-21
		Supporting the Australian cotton industry's sustainability strategy	CRDC1944	Chris Cosgrove	Sustenance Asia	Jun-19	Jun-22
		The second Australian cotton industry sustainability report	1920FRP035	Chris Cosgrove	Sustenance Asia	Jul-19	Jun-20
	2.3.2 The value chain is transparent and understood by participants	Engagement for Australian cotton industry contribution and perception scan report		Robert Poole	KPMG	Jun-19	Jul-19
		PhD: Sustainable value chain analysis of the Australian cotton industry	QUT1901	Zoe Mellick	QUT	Jul-18	Jul-21

Goal 3: Build adaptive capacity of the cotton industry							
3.1 Science and innovation capability, and new knowledge	3.1.1 Science and innovation capacity is strengthened and strategically fit for a digital future	2016 Horizon Scholarship: Sam Knight	RIRDC1602	Sam Knight	AgriFutures	Jul-15	Dec-19
		2017 Horizon scholarship: Holly Chandler	RIRDC1702	Holly Chandler	AgriFutures	Jul-16	Dec-19
		2019 and 2020 Science and Innovation Awards for young people in Agriculture, Fisheries and Forestry	ABA1901	Dean Brookes	ABARES	Jul-18	Jun-20
		Australian cotton industry digital strategy		Jane Trindall	Jane Trindall Consulting	Jul-19	Jun-21
		Australian Rural Leadership Program Course 25	RIR1901	Fleur Anderson	ARLF	Jul-18	Oct-19
		Australian Rural Leadership Program Course 25	RIR1902	John Durham	ARLF	Jul-18	Oct-19
		Australian Rural Leadership Program Course 26, Course 27, Trail 2019, Trail 2020	RIR1903	Matilda Ferguson	ARLF	May-19	Dec-20
		Honours: Baseline river water nitrogen compounds in the Murrumbidgee irrigation district	UNSW1901	Jessica Watson	UNSW	Feb-19	Dec-19
		Honours: Evaluation of relative damage caused by two-spotted mite, bean spider mite and strawberry mite in cotton	DAN1808	Chris Shafto	UTAS	Jan-18	Dec-19
		Honours: Soil Coalacence & compaction in southern NSW	US1903	Jonathon Moore	USYD	Jan-19	Dec-19
		Improving grower decision in complex systems: A targeted tool to assist cotton growers in appropriate technology adoption	QUT2001	Geraldine Wunsch	QUT	Jul-19	Mar-22
		Nuffield Australia Farming Scholarship 2018: Luke McKay	CRDC1801	Luke McKay	Nuffield	Jul-17	Sep-19
		PhD: Irrigation data science research capacity for the Australian cotton industry	US1901	Guy Roth	USYD	Jul-18	Jun-21
	3.1.2 Increased understanding of the diverse human capital in regional communities	AACS 2019 Australian Cotton Research Conference	CRDC1939	Oliver Knox	AACS	Apr-19	Dec-19
		People in Agriculture	DA1502	Shane Hellwege	Dairy Australia	Jul-14	Mar-21
		Post Doc: Understanding and planning for the future cotton workforce	USQ1801	Nicole McDonald	USQ	Oct-17	Oct-20
		Rural Womens Award 2019	RIRDC1904	Allanards Williams	AgriFutures	Jul-18	Dec-19
		Sustainable Economic Growth for Regional Australia (SEGRA) Conference 2019	CRDC1942	Jennifer Moffatt	Jennifer Moffatt Consulting	May-19	Sep-19
	3.1.3 Increased opportunities for innovation skills development	AgFrontier: regional Agtech incubator	CRDC1943	Sonya Comiskey	CHDC	Jun-19	Dec-19



Key focus area	Outcome	Project title	Project code	Researcher	Organisation	Commenced in:	To be completed in:
3.2 Futures thinking	3.2.1 Australian cotton growers are able to adapt to change	Thresholds for resilience in regional communities	UM1902	Ruth Nettle	UM	Sep-18	Jul-20
		2018-2021 Joint-RDC Health and Safety Farming Alliance	RIRDC1901	Jennifer Medway	Agrifutures	Jul-18	Jun-21
		Grassroots Grant: 2019 grower development and extension programs and off target spray drift mitigation	CGA1903	John Durham	Southern Valleys CGA	Nov-18	Sep-19
		Grassroots Grant: Field Assessment of the impact of late season thrip infestations	CGA1902	Lou Gall	Gwydir Valley CGA	Oct-18	May-20
		Grassroots Grant: Improving drought resilience	CGA1907	Bernie Bierhoff	Walgett CGA	Jan-19	Jul-19
		Nuffield Australia Farming Scholarship 2019: Renee Anderson	CRDC1901	Renee Anderson	Nuffield	Apr-18	Sep-20

#### Goal 4 (Enabling Strategy 1): Strengthening partnerships and adoption

4.1. Partnerships and collaboration	4.1.2 CottonInfo partnership is maintained and practice change improved	Assessing black root rot treatments in the Lachlan and Murrumbidgee valleys	CGA1904	John Durham	Southern Valley CGA	Nov-18	Aug-19
		Climate and energy for cotton farming businesses (including CottonInfo technical lead and myBMP project lead)	AE1801	Jon Welsh	AgEcon	Jul-17	Jun-20
		Communicating cotton best production practices with video	DAQ1901	Tonia Grundy	QDAF	Jul-18	Jun-21
		Cotton industry database management	CRDC1804	Lee Armson	Making Data Easy P/L	Jul-17	Jun-20
		CottonInfo irrigation field days	CSD1901	Kieran O'Keeffe	CSD	Dec-18	May-20
		CottonInfo Technical Lead – Nutrition (includes myBMP module lead)	DAN1906	Jon Baird	NSW DPI	Jan-19	Jun-22
		Extension coaching and external review for CottonInfo	CRDC1946	Sean Kenny	Rural Consulting Group	Jun-19	Jun-20
		National biosecurity and disease extension and coordination and CQ regional extension (including CottonInfo technical lead and myBMP module lead)	DAQ1801	Sharna Holman	QDAF	Jul-17	Jun-20
		CottonInfo NRM Technical Lead and extension campaigns (including myBMP module lead)	CRDC1805	Stacey Vogel	Consultant	Jul-17	Jun-20
	4.1.3 Partnerships are strengthened to engage multi-disciplinary and multi-institutional resources	2019 ICAC Plenary Meeting – Conference venue	ICAC1903	Kate Nicols	Sofitel Brisbane	Oct-18	Dec-19
		2019 ICAC Plenary Meeting – Event management	ICAC1901	Jann George	By George Consulting Pty Ltd	Oct-18	Dec-19
		2019 ICAC Plenary Meeting – Supporting activities	ICAC1902	Jann George	By George Consulting Pty Ltd	Oct-18	Dec-19
		2019 ICAC Plenary Meeting – Welcome reception venue and catering	ICAC1904	Jann George	QAGOMA	May-19	Dec-19
		AgVet collaborative forum, plant industries phase 3	RIRDC1701	Jennifer Medway	AgriFutures	Jul-16	Dec-19
		Climate Research Strategy for Primary Industries (CRSPI) 2017-2020	CCR1801		CRSPI	Jul-17	Jun-20
		Sponsorship: APEN Conference 2019	CRDC1933	Graham Harris	APEN	Nov-18	Sep-19
		WeedSmart phase 4	UWA1801	Lisa Mayer	UWA	Jul-17	Jun-20
4.2 Best practice (myBMP)	4.2.1 Best practice is based on science and measured impact	Review of myBMP Database: Caspio set up	CA1807	Rick Kowitz	Cotton Australia	Jun-18	Mar-20
		Review of myBMP database: Phase 2	CRDC1830	Mel Ziarno	Consultant	Jun-18	Mar-20

#### Goal 5 (Enabling Strategy 2): Driving RD&E impact

5.1 Impact and effectiveness	5.1.2 CRDC monitors and evaluates RD&E impact	Annual consultant qualitative and quantitative surveys	CCA1901	Fiona Anderson	CCA	Mar-18	Dec-20
		CRDC Cotton Grower Survey	CRDC1733	Michael Sparks	Intuitive Solutions	Mar-17	Dec-19
		Summaries of CRDC Research	CRDC1945	Bernadette Pilling	HOC	Jun-19	Sep-19

#### Key

AACS	Association of Australian Cotton Scientists	DCRA	Dryland Cotton Research Association	QDAF	Queensland Department of Agriculture and Fisheries
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences	DSITI	Queensland Department of Science, Information Technology and Innovation	QUT	Queensland University of Technology
AgriFutures	AgriFutures Australia (formerly the Rural Industries Research & Development Corporation)	DU	Deakin University	RMIT	Royal Melbourne Institute of Technology
ANSTO	Australian Nuclear Science & Technology Organisation	GRDC	Grains Research and Development Corporation	SAC	Sustainable Apparel Coalition
ANU	Australian National University	GU	Griffith University	UL	University of Leeds
APEN	Australasia-Pacific Extension Network	GVA	Gwydir Valley Irrigators Association	UMELB	University of Melbourne
ARLF	Australian Rural Leadership Foundation	HIA	Hort Innovation	UNE	University of New England
CCA	Crop Consultants Australia	HOC	House of Communication	UNSW	University of New South Wales
CRSPI	Climate Research Strategy for Primary Industries	MLA	Meat and Livestock Australia	UQ	University of Queensland
CGA	Cotton Grower Association	MRES	Micro Meteorology Research & Education Services	USC	University of the Sunshine Coast
CHDC	Central Highlands Development Association	NCSU	North Carolina State University	USQ	University of Southern Queensland
CRDC	Cotton Research and Development Corporation	NSW DPI	NSW Department of Primary Industries	USQ NCEA	University of Southern Queensland National Centre for Engineering in Agriculture
CSD	Cotton Seed Distributors	NTDPIR	Northern Territory Department of Primary Industries and Resources	USYD	University of Sydney
CSIRO	Commonwealth Scientific and Industrial Research Organisation	PHA	Plant Health Australia	UTAS	University of Tasmania
		QAGOMA	Queensland Art Gallery of Modern Art	UWA	University of Western Australia
				UWS	University of Western Sydney



**CRDC**

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