COTTON RESEARCH & DEVELOPMENT CORPORATION

Spotlight on Cotton R&D

SPRING 2013

DELAYING Bt RESISTANCE

COTTON IN THE CLASSROOM

INNOVATIVE IRRIGATING

Best Practice

CONTENTS SPRING 2013

IMAGE ROSE BRODRICK, CSIRO.

Dr Onoriode Coast has recently joined the cotton industry in irrigation research.

IN THE SPOTLIGHT

As the cotton season begins in earnest once again we are reminded of how busy the industry is, not just in the cotton field, but in the fields of research as we continually strive to improve our product and the way we produce it.

This edition of *Spotlight* outlines many of the great achievements of individuals and groups, like Cotton Grower Associations who are making the most of CRDC Grassroots funding to improve education and participation in the industry. It is rewarding to see grower associations making the most of these grants to proactively address issues that are important firstly to them but which also serve the greater good of the industry.

There are also new beginnings for CRDC and the broader industry, as we farewell Mike Logan as CRDC Chair and welcome Mary Corbett, who will lead the Board as CRDC implements a new Strategic Plan. The new Plan sets bold aims that we are sure growers, researchers and the broader industry will embrace.

Getting down to the business of farming, this edition of *Spotlight* addresses pertinent crop management issues of growing resistance to herbicides in weeds, integrated pest management and stewardship. I'm sure growers will be concerned by the warnings on herbicide resistance from international expert Jason Norsworthy, who we interviewed to learn from the experiences of growers in the United States. In particular, the threat of wide spread glyphosate resistance is real and needs to managed through integrated weed management and targeted research. Weeds and insects don't recognise farm boundaries, so it is important to remember that 'we are in this together' and good management benefits neighbours, the region and the entire industry.

Integrated pest management is as crucial today as it has ever been in sustaining the pest control efficacy of Bt technologies. Realising the potential benefits of Bollgard III in coming years will rely heavily on sustaining the efficacy of the current Bt technology. This is well explained in our IPM feature and resistance management articles. The research fraternity must be commended for their exemplary work which combined with the commitment to stewardship from growers is ensuring the industry protects its production technologies and its biosecurity.

We have also highlighted new research that is seeking to further help growers improve the way they manage natural assets. From aquifer monitoring in the Condamine region to monitoring riparian vegetation and the refinement of irrigation scheduling and techniques, the quest to find better ways of doing things through research and its application by growers is ongoing. The recent appointment of Jon Welsh as the Carbon Technical Specialist within the CottonInfo Team is another step forward in supporting growers with this commitment.

In this edition we also look to the future for blue sky farming innovations and profile how drone technology is helping agronomists and consultants provide even greater services to growers.

We hope you enjoy this edition of *Spotlight* and wish you great success for the season.

Bruce Finney

Australian Government
Cotton Research and Development Corporation

Spotlight is brought to you by Australia's cotton producers and the Australian Government through the publisher Cotton Research & Development Corporation (CRDC).
CRDC is a research and development partnership between the Australian cotton industry and the Australian Government.
Cotton Research and Development Corporation
ABN: 71 054 238 316
Our vision: A globally competitive and responsible cotton industry
Our mission: Invest and provide leadership in research, innovation, knowledge creation and transfer.
Our outcome: Adoption of innovation that leads to increased productivity, competitiveness and environmental sustainability through investment in research and development that benefits the Australian cotton industry and the wider community.
Corporate background: CRDC was established in 1990 under the Primary Industries and Energy Research and Development Act 1989 (PIERD Act.) which outlines its accountability to the Australian Government and to the cotton industry through the Cotton Australia. CRDC is responsible to the Australian Government through the Minister for Agriculture, Barnaby Joyce. CRDC is committed to fulfil its legislated charter to: Invest in and manage an extensive portfolio of research, development and extension projects to enhance the ecological, social and economic values associated with cotton production systems and to benefit cotton industry participants, regional communities and the Australian community.

Postal: PO Box 282, Narrabri NSW 2390
Offices: 2 Lloyd Street, Narrabri NSW 2390
Tel: 02 6792 4088; Fax: 02 6792 4400
Email: spotlight@crdc.com.au
Web: www.crdc.com.au
Technical Editor: Tracey Leven
Editorial co-ordinator: Melanie Jenson
Editorial Contributors: Melanie Jenson, Susan Maas, Sally Ceeney, Sarah Cox, Chrissy Brown
Layout, composition: Deacon Design

NURTURING EDUCATORS HAS BECOME A HIGH PRIORITY FOR THE AUSTRALIAN COTTON INDUSTRY IN ITS DRIVE TO COMMUNICATE COTTON TO THE WORLD.

COTTON CREATES EXCITEMENT IN QLD SCHOOLS

It is well recognised that schools are the ideal platform to improve community perception and awareness of the significant steps taken by the industry in environmental and production management, best practice and technology adoption over the past 15 years.

That recognition has transpired into the development of a comprehensive education program targeting all levels of the learning environment from principals to teaching staff and students.

From field walks to Cotton Conference attendance and participation in the nationally acclaimed Field to Fabric course, the industry is helping `teachers teach cotton'.

Around 50 teachers and students attended the Australian Cotton Conference in 2012 through a joint effort between Cotton Australia, WinCott and CGAs from the Darling Downs, Upper Namoi and Macintyre along with the CRDC and Future Cotton Leader Kate Groves and Georgie Carrigan.

Attendance at the conference was a pre-cursor to teachers at Goondiwindi, Dalby, Pittsworth and Emerald State High Schools integrating a pilot term-long science unit into the schools' curriculums looking at the structure and physiology of cotton plants as well as the processing and end use of the fibre.

The inclusion of cotton into the teaching modules has been well received by students and teachers alike and is helping generate awareness about the industry, the crop and its importance to local economies according to Dalby State High School (DSHS) teacher Jodie Maher.

Jodie is a classroom teacher in maths, science and agricultural science and after attending last year's cotton conference, has introduced additional cotton-focused programs and activities into her curriculum with the support of local Cotton Australia representatives and agronomists.

"The conference was able to give me some basic knowledge of the cotton plant itself, some great contacts in the industry which I have gone on to use and the means to find out what programs are running in other schools and states which helped me focus our course at Dalby State High School," she said.

Year 12 students Hayley Cuzens, Rachel Doyle and Colin Blinco from Dalby State High School showing off their cotton crop grown last season.

"It also gave me 'take home' perspectives on the importance of the industry to Australia and especially the Downs region, current issues occurring in the industry and what is being done to combat them as well as a general excitement about the crop itself.

"I found the cotton conference extremely fulfilling and came back to school very excited and ready to implement new programs and activities."

Since then her enthusiasm for the cotton industry has not only motivated her students to learn more about cotton and consider it as an attractive career option, it was also a key driver in her enrolment in the Cotton 300 course through UNE.

"I chose to do the course to gain a better understanding of the growth and management of the crop – the cotton conference really sparked my interest in this area."

Agricultural science is a relatively new subject at Dalby State High School and was strengthened by Education Queensland's acquisition of the former Australian Agricultural College Corporation (AACC) site and facilities in 2011.

Integrating cotton into the agri-

cultural science program at DSHS was a leading priority given the industry's relevance and importance to the local region and economy.

"For our Year 11 and12 students we run an experiment which looks at the different genetically modified varieties of cotton and the effect of pests on them," Jodie said.

"Industry contacts have been invaluable in implementing this program - Cotton Australia's Maree-Louise Offner helped us work with Monsanto and local agronomist John Ash helped us prepare the ground, plant and monitor the crop.

"Our Year 10s study a unit called Plants and Animals for Fibre where we look at cotton and other fibres and compare them while the Year 9s do a unit on cotton production looking at the growth and processing of the plant.

"The integration of cotton into our learning program is having an impact on students, particularly those who had no prior knowledge of the industry or involvement in it – they are excited and keen as well."

The cotton industry is keen to communicate its many recent advances in technology and practices and has identified school-based programs as one of the most effective ways to grow and improve the industry's perception within local communities.

Many CGAs have identified this as a key objective including the Dawson Valley CGA (DVCGA) which recently facilitated three teachers from Theodore State School, Moura State High School and Biloela State High school to attend the Field to Fabric course under the CRDC's Grassroots Grants program.

Cotton Australia Dawson Valley regional manager Bronwyn Christensen, Jessica Gibson (Biloela State High School), Carlie Atkins (Theodore State School) and Fiona Zimmerlie-Clarke (Moura State High School) at the Field to Fabric course in Geelong.

"THE INTEGRATION OF COTTON INTO OUR LEARNING PROGRAM IS HAVING AN IMPACT ON STUDENTS…"

Presented by CSIRO Textile and Fibre Technology laboratory at Geelong, the three-day course gives participants an insight into the operation and integration of the different industry sectors through a series of 10 modules.

It addresses every aspect of the cotton industry from global perspectives, environmental issues, variety selection, agronomy, fibre properties, harvesting, ginning, classing and marketing to yarn manufacture, fabric formation, dyeing, finishing and printing.

Cotton Australia's Dawson Valley regional manager Bronwyn Christensen accompanied the teachers to Geelong and said the course proved an invaluable source of knowledge and information on every aspect of the cotton industry which the teachers could then integrate into their curriculum delivery.

"The course was a one-stop shop on the cotton industry, covering every aspect from seeds being planted to the production of jeans," she said.

"One of the main focus of the DVCGA is to improve the perception of the cotton industry in our region through education and community involvement.

"Being an older cotton growing area, we want to raise awareness of some of the fantastic work that has been undertaken by the cotton industry over the past decade or so in areas like environmental management, soil, water, pest and disease management and the implementation of best management practice programs.

"Identifying and nurturing industry champions within the teaching profession of our schools is extremely important as they are an invaluable link to the younger generations.

"Each of the teachers who attended to Field to Fabric course took away information and experience that was relevant to them and their students – one was a high and lower primary school teacher, another was an ag-science teacher while the other was a home economics teacher."

Boggabri cotton grower and Wincott member Georgie Carrigan and Future Cotton Leader Kate Groves mentored students from Calrossy Anglican School at last year's Australian Cotton Conference, which, with the help of Grassroots Grants has been a launching pad for generating interest in cotton in the classroom.

Dalby State High School Science teacher Jodi Maher has introduced additional cotton-focussed programs and activities into her curriculum. Jodi is pictured with Year 12 students Rachel Doyle and Eryn Jackson.

INDUSTRY IMPROVED BY GETTING BACK TO GRASS ROOTS

INDUSTRY PARTICIPATION AND PROMOTION HAS BEEN BOLSTERED THROUGH GRASSROOTS GRANTS, AS SARAH COX REPORTS.

The Darling Downs cotton industry is well aware that being proactive is being progressive.

That premise was the driving incentive behind the Darling Downs Cotton Growers Inc's (DDCGI) decision to apply for a $10,000 grant through the CRDC's Grassroots Grants Program to improve spray application management, boost the uptake of the *my*BMP program and foster a greater relationship between the cotton industry and local schools.

CRDC's Grassroots Grants Program is an innovative program designed to stimulate grower-led projects to build capacity of growers and other industry people at the 'grass roots' level, and improve the communities in which they operate.

Conducted throughout 2012, the DDCGI's projects were a resounding success resulting in improved spray management and reporting, several growers attaining ACDC License Accreditation, engaging a wider cross-section of growers in the online *my*BMP program and the establishment of an information-sharing network between cotton industry personnel, teachers and students from a number of schools across the region.

Bridging the information gap

Project administrator and Cotton Australia regional manager for the Darling Downs Marie-Louise Offner said the Grassroots Grants concept allowed regional grower groups to identify their individual issues or priorities and begin implementing projects to help bridge the information and extension gaps.

"The grants concept is certainly a positive for industry development and progression. Successful implementation of projects though relies heavily on having clearly defined guidelines, manageable projects with achievable targets and someone to oversee their facilitation," Marie-Louise said.

The Darling Downs grant application incorporated three key initiatives – engaging growers in best management practices, up skilling growers in safe chemical use and nurturing the engagement of youth in the cotton industry.

Facilitation of several group and individual *my*BMP workshops across the Darling Downs was the first step in improving awareness and encouraging uptake of the online program and was the impetus for a number of growers to achieve their Level 1 status according Marie-Louise.

Women involved in cotton growing enterprises were also active participants, attending a workshop in Brookstead.

"The women were particularly impressed with the Human Resources module and the range of resources that are available," Marie-Louise said.

"The project certainly delivered

an improved awareness of *my*BMP and with additional resources now available in terms of *my*BMP staff and advisors and on-going improvements to the on-line program, the Cotton Growers Association has no doubt that participation will grow."

Awareness and information increased

Local grower and co-organiser of the Brookstead workshop Georgie Krieg said it had been extremely valuable in generating awareness of the wide range of tools and information available to business as well as facilitating networking opportunities for those involved in cotton growing operations.

"One of the aims of the workshop was to show people how much information is available, where to go to access that information and knowing that they are getting the right information," Georgie said.

"Importantly though, it also provided an opportunity for the women involved in cotton enterprises to meet each other and share information."

Workshops in chemical and spray application management were also conducted across the region as part of the grant project.

Conducted by well-known and respected industry consultant Bill Gordon, the workshops attracted more than 150 participants who learnt about the latest in spray equipment technology and application management.

"Although only a small number of these completed the ACDC licensing, they are now eligible having completed

"THE GRANTS CONCEPT IS CERTAINLY A POSITIVE FOR INDUSTRY DEVELOPMENT AND PROGRESSION."

Cotton Australia's Darling Downs Regional Manager Marie-Louise Offner

the one day workshop to complete the course within 12 months," Marie-Louise says.

"The feedback from the growers was extremely positive and also has created an increase in spray drift reportings and grower feedback which is vital for accurate industry monitoring."

Taking the classroom to cotton

The third project under the DDCGI grant was aimed at introducing school students to the cotton industry and showcasing what it has to offer, particularly in terms of production and employment.

This coincided with the appointment of a Cotton Australia representative on the Darling Downs and the establishment of three Gateway to Agriculture Schools - Dalby State High School, Pittsworth State High School and Downlands College – which culminated in the incorporation of a 'cotton specific' curriculum and planting of cotton plots during the 2012/2013 season.

The grant enabled two students from each school, their teachers and department representative to attend the 2012 Cotton Conference on the Gold Coast and participate in specially tailored programs to boost industry awareness and encourage information sharing and networking between the cotton and education sectors.

"The DDCGA now has developed a very firm relationship with the teachers from these schools which is fundamental in ensuring the industry continues to showcase the opportunities available within the cotton industry," Marie-Louise said.

"The feedback from the students who attended the Conference was enormously positive and was able to be showcased on the Cotton Australia YouTube site."

Grant projects varied and successful

A number of programs have already been successfully rolled out across Queensland and NSW under the Grassroots Grants program.

This has helped place cotton growers, industry stakeholders and regional communities on the front foot in terms of awareness, testing and uptake of research and development (R&D) initiatives, adoption of Best Management Practices through *my*BMP, and growing the skills base, networking opportunities and collaboration of growers, industry personnel and regional communities.

Criteria for the grant program are deliberately broad in a bid to encourage applications for a range of projects across all cotton-growing regions of Australia.

Grants of up to $10,000 are available to all cotton grower associations and other informal grower groups for projects that improve ground truthing and testing of R&D findings, adoption of R&D outcomes, the adoption of *my*BMP; grow the skills and knowledge base of cotton growers and their communities; increase networking between growers, consultants and researchers; encourage new growers to the cotton industry and strengthen collaboration across communities, industries and regions.

To apply for the Grassroots Grants program or for more information on grant funding opportunities, contact Sally Hunter on 0459 944 778 or sally@fundbase.com.au

email us

GRANTS HELP GROWERS

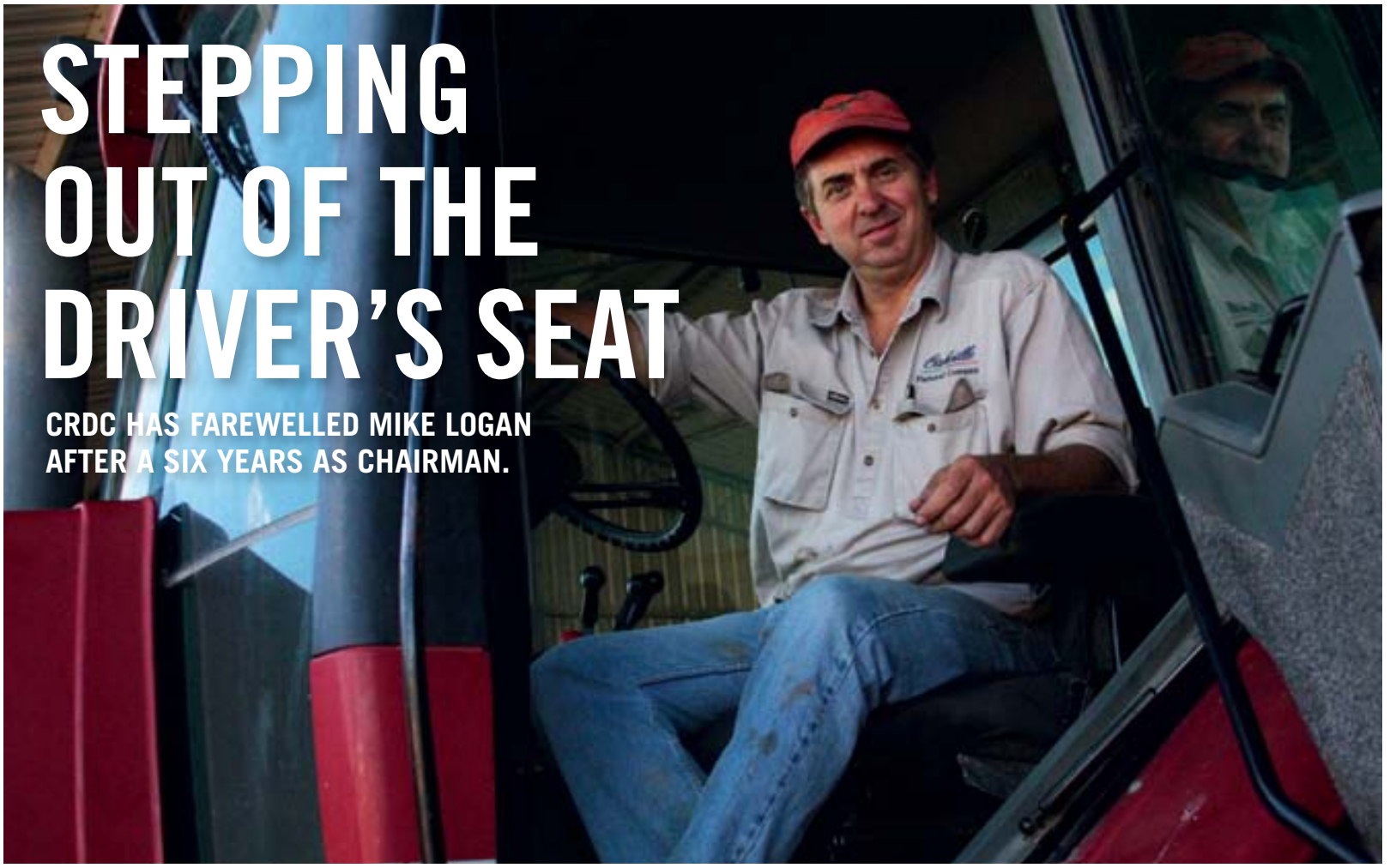
THE CRDC'S GRASSROOTS GRANTS PROGRAM HAS SUPPORTED 16 PROJECTS ACROSS THE COTTON GROWING REGIONS OF AUSTRALIA OVER THE LAST TWO YEARS.

Now in its third year, the Grassroots Grants Program continues to encourage groups of cotton growers and CGAs to apply for funding to support capacity building projects.

"Some of these projects have increased the engagement of growers in the industry as well as improving their skills, knowledge base and networks," Grassroots co-ordinator Sally Hunter said. "Recently the Upper Namoi CGA has run some soil nutrition workshops, the Lower Namoi and Walgett took a group of young growers and staff members on a tour of CSD, ACRI and CRDC and the growers of the Macquarie Valley took a tour of the Riverina cotton growing region."
Changes to the program this financial year include an opening period of July to December 2013, meaning applications can only be submitted prior to December 31 2013. Growers and CGAs are encouraged to discuss their project ideas with Sally in this period to allow for submission prior to the closing date. Feel free to contact Sally on 0459 944 778.

STEPPING OUT OF THE DRIVER'S SEAT

CRDC HAS FAREWELLED MIKE LOGAN AFTER A SIX YEARS AS CHAIRMAN.



In mid-August Mike Logan stepped down as former Minister for Agriculture, Fisheries and Forestry Joel Fitzgibbon appointed Mary Corbett to the position. Mary has been a non-executive Director of CRDC since 2008 and the Board's Vice-Chair since 2011.

As Mike embarks on his new role as Dairy Connect NSW CEO, he has nothing but praise for the people who make up Australia's enviable cotton industry. As a cotton grower, Mike has a deep appreciation for what it means to be part of this innovative group.

"Our 'industry' is really a collection of like-minded people who all want to grow good cotton well," Mike said.

"That is what I see when I stand back, a group of really committed people who want to do what they do, grow, research, gin, support and deliver cotton at a standard that is better than anyone in the world. It is just people working together.

"Each of our farms is open to everyone else to see our experiments, our successes and our failures. We have a scientific and research community that should be the envy of other primary industry.

"All of the researchers and research managers are known to us personally and available on the phone or to come to a field day or farm walk.

"The advisors offer advice to their own clients and anyone else as part of their day to day businesses.

"The shippers come to meetings, write daily and weekly reports and answer the phone to everyone.

"I can't think of a better one to be a part of."

When questioned as to his proudest achievements as Chair, Mike cites an industry turn-around in environmental aims and outcomes.

"Our environmental performance has gone from being our biggest risk to our most significant achievement," Mike said.

"Now we are now finding ways to convert those environmental values, along with the remarkable qualities of our fibre, into real value."

CRDC Executive Director Bruce Finney said CRDC owes much to Mike Logan for his six years of service, working to guide the corporation and industry through some difficult times.

"When Mike assumed the position in 2007, the cotton industry was still mired in drought," Bruce said.

"This meant a reduced income for our research activities and great challenges in preserving the core research effort and retaining the people who carried out the research.

"His experience on the boards of (the former) Land & Water Australia, CRC for Irrigation Futures and Cotton Australia, combined with his long record of exemplary environmental management in his own cotton farming, brought specific expertise and knowledge that aided in addressing these issues."

Mike's term as Chair saw the development of a more strategic organisation and industry. For the Australian cotton industry, this included the development of Vision 2029 and recognition of new opportunities for marketing the sustainability and qualities of Australian cotton.

"For CRDC it meant ensuring a successful transition in cotton RD&E with the cessation of the Cotton Catchment Communities CRC, development of a new, ambitious five-year Strategic R&D Plan and ensuring effective governance," Bruce says.

"Mike has steered our organisation successfully through these difficult challenges and new opportunities with skill and aplomb.

"The Board and staff—as well as the wider cotton industry—thank him for his support and guidance and wish him well for the future."

New Chair Dr Mary Corbett has more than 17 years' experience as a company director, particularly in the fields of education, training, and rural, food and medical research. She also has a wealth of experience in agriculture, ranging from sugar to rural education and has a strong background in agricultural science. These roles have given Mary the experience to lead CRDC toward its goals to enhance the performance of the Australian cotton industry, through investment in research, development and extension initiatives.

More information on CRDC is available at www.crdc.com.au

see our website

Mike Logan: proud to have been part of an industry he describes as "a group of like-minded people who all want to grow good cotton well".

CRDC READY FOR THE

THERE ARE SOME BOLD CLAIMS IN CRDC'S NEW 2013-2018 STRATEGIC PLAN.

Among these claims are goals of increasing growers' productivity by three percent per hectare per year; doubling the premium for Australian cotton; and ensuring the Australian cotton industry is the world leader in sustainable agriculture.

"The new plan comes at an opportune time. After the misery of droughts and floods, farmers and industry are bouncing back from record low levels to record high levels of production and renewed financial capacity," says CRDC Executive Director Bruce Finney.

"Like farmers and other industry organisations we can now move confidently to focusing on our goals. For CRDC this is about investing in R&D which will enable the industry achieve its vision for the future (Vision 2029). So just imagine its now 2029 and what research will you have wanted?

"What aspects of Australian cotton and its production will need to have been or could have been positively transformed? This is the ambitious tone of our new plan."

The *2013-2018 Strategic R&D Plan* is CRDC's key R&D investment planning document. The new plan structure describes how RD&E projects and programs will be managed and implemented for the life of the plan. The plan consists of three, newly developed main R&D programs – Farmers; Industry; and Customers.

"The R&D investment programs have been designed and named to reflect the way in which we at CRDC think about our R&D investments," Bruce said.

"The key questions we ask ourselves and the Cotton Australia advisory panels when we are considering any R&D investment are 'How will this investment make our farmers more profitable, our industry more sustainable and Australian cotton more competitive for our customers.

"This is an important way to think about things if we are to achieve our vision of being 'a globally competitive and responsible cotton industry."

It's not all just a matter of investing in R&D however there are two other key programs in which CRDC invests in order to 'oil the cogs' of R&D, those being both the People and Performance programs.

"These programs support our Farmers, Industry and Customer programs by ensuring we have capable and connected people driving the industry and that the industry is able to also demonstrate its performance," CRDC General Manager R&D Investment Paula Jones said.

"CRDC'S RD&E PROGRAMS ARE DEPICTED AS COGS THAT CONNECT AND MOVE THE COTTON SUPPLY CHAIN."

HUGE INTEREST IN COTTON RESEARCH

This year CRDC has received the largest number of preliminary research proposals in its history, with 120 proposals submitted.

General Manager R&D Investment Paula Jones said CRDC was delighted with the quantity and quality of the proposals.

"The number of applications is really positive for the cotton industry, as it shows the strength of ideas and commitment in cotton industry R&D," Paula said.

"Preliminary research proposals closed in July, and after careful consideration and consultation with Cotton Australia and the grower panels, CRDC has managed to streamline the prospective proposals to around 60."

Researchers were contacted by CRDC to submit full project applications in October 2013 for potential new research to commence in July 2014.

"This latter program is important as industry is increasingly asked to demonstrate its social, environmental and economic credentials and having sound science-based evidence is vital.

"A most exciting aspect of our new strategic plan are our three new 'Futures' themes. These are themes within the Farmers, Industry and Customers programs where we have the opportunity to look well beyond the life of this plan and to invest in R&D that will ensure the industry is profitable, sustainable and competitive in 20 years time.

"The history of the modern cotton industry is founded on people with

CHALLENGE

The history of the modern Australian cotton industry is founded on people with real innovation and vision.

AUSTRALIAN GOVERNMENT GRANTS SECURE PRIORITY RESEARCH

CRDC has recently collaborated in a number of applications to the Australian Government for R&D grants. The process of preparing grant applications with industry and research organisations is valuable in focusing attention on priority issues and gaps in current research, development and extension. CRDC has been successful with three grants totalling over $2.5m which focus on carbon farming and energy efficiency in cotton systems. These grants are important as they will assist growers improve their energy efficiency, develop industry specific best practice guidelines for reducing nitrous oxide emissions on farm and provide technical support and training for growers on carbon farming.

real innovation and vision. We want to make sure the industry continues to have this innovation and vision and R&D is an important aspect of this.

"The plan gives a sense of the long-term vision for the industry, what we are trying to achieve and how we aim to achieve it.

"I encourage people to come and talk to us if they have an idea or want to get involved in the industry's R&D."

Bruce.finney@crdc.com.au
Paula.jones@crdc.com.au

email us

Information on all these programs can be found on the CRDC website www.crdc.com.au

see our website

IN REVIEW

TO COINCIDE WITH THE START OF THE NEW 2013-2018 STRATEGIC PLAN, CRDC WILL ALSO BE REVIEWING THE SUCCESS OF THE LAST FIVE-YEAR PLAN.

"There were lots of fantastic achievements over the past five years and this is a good opportunity to stop and reflect on these successes as well as see how far the industry has come in that time," say Bruce Pyke who was General Manager of R&D Investment at CRDC during this period.

"There is also so much research that is ongoing, some commenced prior to the last strategic plan and some which continues under the new plan which constantly provides new outcomes for the industry."

Bruce said stand-out examples included the Premium Cotton Initiative; spinning and ginning research; a broad range of farming systems research including crop rotation, nutrition and greenhouse emissions research; IPM, bio-pesticide and semio-chemical development; spray application training; *my*BMP; the joint venture which established the CottonInfo Team; and a range of human capacity R&D including the first comprehensive data on cotton workforce issues and needs.

"However one of the big highlights is the fact that despite having one of the worst pests for developing resistance in the world (*H. armigera*) Bt cotton in Australia has been successful for 18 seasons without any field failures," Bruce says.

"This is significant in itself but also when compared to how we sit globally, as problems do seem to be emerging in other countries (Brazil, China, India) for a range of reasons, but primarily because nowhere else has placed as much effort on having a pre-emptive resistance strategy like we have established in Australia.

"All this has been underpinned by our R&D effort into resistance monitoring and mechanisms which were supported even through the worst of the drought.

"Our successes are made even more important given that the last five years have been a time of significant change for the industry including a 30-year low and record-breaking levels of production.

"It really highlights the importance of having industry R&D and that when the opportunity arises growers are able to access and apply this work to their cotton farming system and continue to achieve ever improving yields."

A full report outlining the impact of CRDC's 2008-2013 Strategic Plan will be available early next year.

Dr Jason Norsworthy inspects a cotton field in the US that has been taken over by Palmer amaranth as a result of over-reliance on glyphosate as a control method.

HOW DID THEY GET TO THIS?

DUE TO HERBICIDE RESISTANCE IN WEEDS, 52 PERCENT OF ALL COTTON HECTARES IN THE US COTTON GROWING STATE OF ARKANSAS ARE NOW HAND-WEEDED AT A COST OF BETWEEN US$73 AND $370/HA.

Dr Jason Norsworthy, Endowed Farming Chair of Weed Science in the Crop, Soil, and Environmental Sciences Department at the University of Arkansas, is an international authority and key influencer in understanding and managing herbicide resistance. He spoke to *Spotlight* to share some stark realities with Australian farmers and researchers.

"In some areas of the world today, including the US, herbicide resistance is resulting in complete crop failures," he told *Spotlight*.

"The loss of glyphosate against key weeds has seen farmers rely on the next best herbicide and then subsequently it too become compromised by resistance.

"If we do not become proactive, we will soon see the day when there are no effective herbicides available for weed control in crops."

Until the recent evolution of widespread glyphosate resistance in the US, it was Australia that led the world in battling weeds with resistance to multiple herbicide modes of action, particularly annual ryegrass.

Internationally, experience continues to reveal that resistance evolves in areas where integrated weed management (IWM) is not practiced. Jason laments the unfortunate realities of the herbicide discovery pipeline.

"The commercialisation of new herbicide modes of action is not occurring to keep up with the loss of herbicides as a result of resistance," he says.

Jason's presentation at the Global Herbicide Resistance Conference in Perth earlier this year, (*Glyphosate-resistant Palmer amaranth in Southern US row crop production: impact and current management*) provided a scenario of the growing herbicide resistance issues in the US, resulting in huge control costs, crop failure, field abandonment and a return to hand-weeding fields.

HOW HAS GLYPHOSATE RESISTANCE AFFECTED FARM MANAGEMENT?

- Increased complexity and cost of weed management. Additional costs averaging upwards of US$100/ha.
- Complete crop loss
- Field abandonment
- Compromised conservation tillage (may mean farming fewer acres)
- Reduced harvest efficiency
- Subsequent failure of other broadleaf herbicides due to resistance
- Glyphosate being used just as a grass herbicide or an adjuvant

How has this happened?

Jason found the main contributing factors are:

- Weed control programs lacked diversity
- Solely planted glyphosate-resistant crops
- Solely relied on a single herbicide for weed control
- Applied reduced rates to save money
- Applications made to large weeds (reduce number of applications)

WHAT TO DO? - FOCUS ON THE SOIL SEEDBANK

Jason's message is clear: manage the weed seed bank in your soil and implement IWM. He recommends;

- Start clean and stay clean

- Be proactive don't allow a build-up of resistant weeds. This means no weeds at planting and overlaying early residual herbicides as a first line of defence
- Use more cultural and mechanical management tactics
- Prevent seed production – "zero tolerance" in-field and around the farm.
- Shut down as many avenues of seed movement onto your farm as you can – particularly vehicles and machinery.

In his recent research, Jason has focused on best management practices to mitigate the risks of herbicide-resistant weeds evolving in cotton and soybean crops.

His work is significant considering that unmanaged herbicide resistance holds an almost unthinkable consequence for the future of cropping industries.

"I hope my research will lead to reduction in herbicide reliance, expenditure and usage as well as improved weed management efficiency in crop," he said.

"The alternatives we provide need also to pose low risk to the environment.

"Greater emphasis must be placed on sustaining the effective tools (chemical and non-chemical) that are currently available if we as a society are going to feed the world's growing population.

"In the US, emphasis is now placed on 'zero tolerance thresholds'. Control tactics are focused on no weed being able to produce seed.

"This is the only way that the risks of developing and spreading resistance can become very low."

KEY POINTS

CONTROL THE SEEDBANK:
Ensure a 100 percent kill rate: driving down the seedbank drives down the threat of resistance.

DIVERSITY:
Of weed control methods (ie cultivation/rotation/chipping) and herbicide modes of action.

PATCH MANAGEMENT:
We can't afford to take a broad brush approach to weed management on farms any longer, manage outbreaks and problem areas individually.

TIMING IS ESSENTIAL:
For effective control, get in early when plants are young – they are easier to kill and this also avoids seed set.

NSW DPI Weeds Specialist Tony Cook is researching glyphosate resistance in sowthistle.

HERBICIDE RESISTANCE: IT'S EVERYONE'S ISSUE

ALL FARM MANAGERS WILL AT SOME STAGE FIND HERBICIDE RESISTANT WEEDS ON THEIR FARMS. SEEDS FROM RESISTANT PLANTS CAN EASILY BE CARRIED ONTO FARMS BY MACHINERY AND VEHICLES, WIND AND WATER.

The glyphosate-resistant weeds fleabane and windmill grass have seed designed for movement by wind and water. Flooding in many cotton growing regions in recent years has accelerated the movement of herbicide-resistant weeds throughout farms, waterways, roadsides and stock routes.

However NSW DPI Weeds Specialist Tony Cook says the news is good for growers and consultants if integrated weed management (IWM) is already in place.

"If usual on-farm weed control includes diversity of herbicides and other methods of control, and there is a willingness to monitor for and manage weed patches, growers should be able to withstand this threat," Tony said.

"The spread of resistant weeds from farm to farm and paddock to paddock is not only possible, but probable. It reinforces the need for the culture of Come Clean Go Clean on-farm and being part of an area-wide management approach to control."

Tony says that typically weed management focusses on in-field issues. However the challenge with herbicide resistance is that resistant patches often establish outside of the field along paddock boundaries, fence lines and channels. To manage resistance successfully it means controlling weeds in all areas of the farm not just the paddocks.

Neighbours will need to collaborate and co-operate for effective weed management on shared boundaries and where the potential exists for wind-borne seed to move from farm to farm.

"Talk with your neighbours about problem weeds and find out what control methods are working, how suspect patches of weeds are being identified, what routines are in place for monitoring the effectiveness of control tactics and most importantly, how everyone is responding to their weed survivors to stop them setting seed," Tony advises.

OUR LATEST STATS

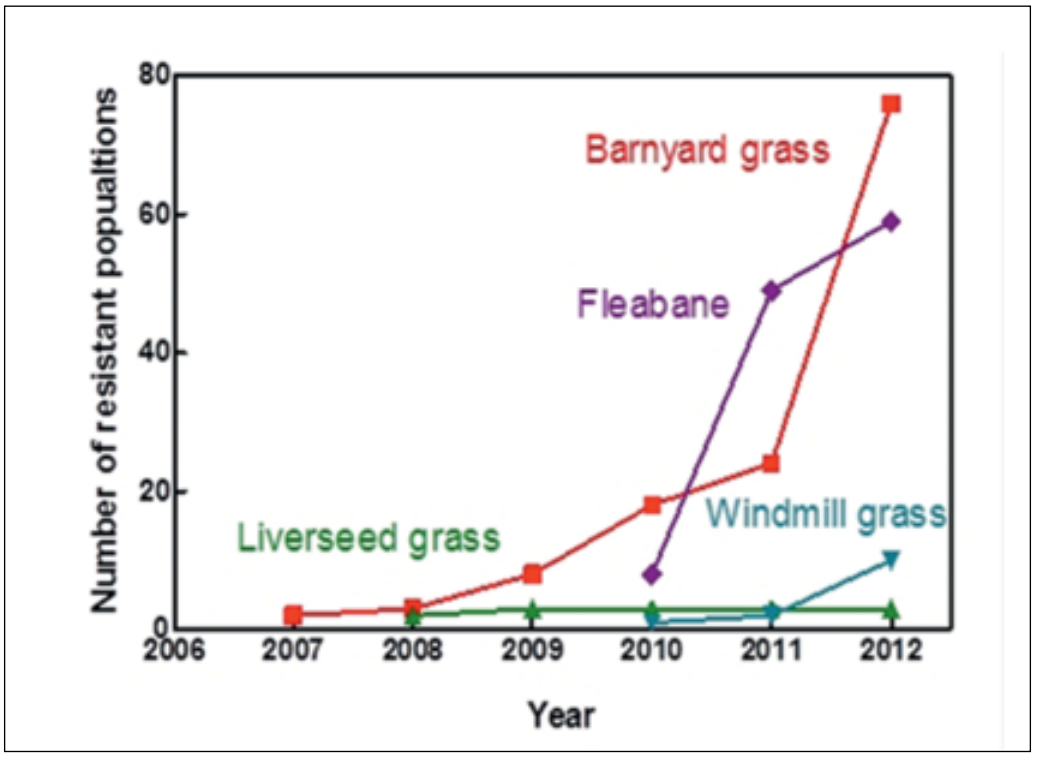
THE NUMBER OF WEED SPECIES RESISTANT TO HERBICIDES IS GROWING RAPIDLY IN AUSTRALIA.

In cotton-growing regions today there are now five weed species with confirmed glyphosate resistance. More worryingly perhaps is that others, such as sowthistle, are being investigated because resistance is suspected and further species are known to be under strong selection pressure.

There is cause for concern if scenarios develop in cotton growing regions similar to those in places in the United States where Palmer amaranth and other weeds have developed resistance not just to glyphosate, but a range of herbicides. In the US state of Arkansas, this has resulted in a step back in time with a staggering 53 percent of cotton hectares now requiring hand weeding/manual chipping.

And the signs are already there for Australia according to NSW DPI Weeds Specialist, Tony Cook.

He says the rapidly growing number of herbicide resistant weeds and the number of weeds becoming resistant to glyphosate mirrors the US



Increase in species and frequency of glyphosate resistant weeds since 2007
(Source: Australian Glyphosate Sustainability Working Group).

experience a few years ago.

"Resistance in problem weeds like fleabane, barnyard grass, annual rye grass, liverseed grass, windmill grass now, compared to just six years ago, shows that we need to look very closely at our weed management to stop us going down a path like the US," Tony said.

"Integrated weed management is critical to halt resistance.

"Monitoring is a big part of this. Not only for targeting the species we do know are resistant, but also because there is likely to be weeds species out there developing resistance that we don't yet know about.

"As researchers, we rely on people who are regularly on-farm to keep their eyes open for weeds they are finding hard to kill or the appearance of suspect patches in fields and to let us know.

"The sooner plants can be tested and resistance confirmed the sooner mitigation strategies can be implemented."

Building the resistance picture

Tony has been involved with surveying resistant weeds since 2000.

Survey data shows the most widespread resistant species in the major cotton growing areas include wild oats (resistant to herbicide Groups A, B and Z) and fleabane (resistant to Group M). Awnless barnyard grass and annual ryegrass are both resistant to glyphosate, and are found extensively throughout NSW and South East Queensland. Glyphosate resistant windmill grass seems to be a rapidly expanding issue although has only been confirmed in a handful of cases, mainly confined on the Central West Plains of NSW.

"AS RESEARCHERS, WE RELY ON PEOPLE WHO ARE REGULARLY ON-FARM TO KEEP THEIR EYES OPEN FOR WEEDS..."

Since the discovery of resistance in the mid-1990s the number of species affected by resistance has steadily increased. The southern Australian experience has been that only a small percentage of resistant populations are ever confirmed through testing. Importantly though, the trends in confirmations over time have been accurate reflections of the bigger picture.

"Resistance has escalated due to repeated use of the same mode-of-action herbicide," Tony said.

"Spread of these weeds both through farming activities and by wind and water will increase the weed control problems throughout many parts of cotton growing regions. All farmers need to be on the look-out and ready for action."

Resistance is usually patchy for weeds that don't have wind-borne seeds, especially with weeds such as wild oats and barnyard grass. Sticking to the standard control options that led to resistance will ultimately see the patches expand. Fast action with responsive management can see these patches eradicated. The costs in terms of time and resources should be compared with permanent increases in the cost of weed control across the whole paddock or even the farm if action isn't taken.

"Many growers are already dealing with either summer or winter weeds with some type of herbicide resistance," Tony said.

"No longer can growers deal with each weed issue separately. They will be forced to solve more complex problems or risk the solutions for one resistance issue making another one worse."

THE MAJOR PLAYERS

Fleabane

Flaxleaf fleabane has become the most widespread weed species in the cropping regions of Queensland and the north and north-west of NSW.

Tony says this can be attributed to the equally widespread adoption of minimum or no-till farming and the ability of this weed to produce huge numbers of wind-borne seeds.

Comprehensive fleabane herbicide resistance surveys were completed in 2010, 2011 and 2012. The confirmation of glyphosate resistant populations grew from six in 2010 to 57 in 2012. Cases are spread through the Darling Downs and Northern NSW.

In conducting the surveys Tony found a great deal of variation in the responses of fleabane populations to glyphosate, depending largely on the history of glyphosate use. "Samples collected from non-cropping areas were susceptible to glyphosate whereas seed sourced from grain growing regions were more likely to be resistant," he said.

In 2011, a national non-cropping survey was completed. A further 35 populations from cotton growing regions were confirmed as glyphosate resistant. All these were from roadside locations, commonly managed with glyphosate.

The last completed survey in the region was aimed at trying to find any Group I resistant fleabane. Seed was collected from surviving plants in the summer fallow period. None of these populations were found to have Group I resistance.

Management issues:

Almost all management options for the control of fleabane are reliant upon some Group I chemistry (synthetic auxins). This understandably will put great selection pressure on this group of herbicides. Other herbicides that show good activity on this weed in research trials are those from Groups C and H. Further research needs to be conducted and registrations obtained prior to commercial use.

This weed is particularly susceptible to competition in the seedling stage, hence using competitive crops as part of an IWM strategy would be an advantage.

Another weakness in fleabane's life cycle is the seed's inability to germinate from depths greater than one centimetre. Farming systems that include strategic cultivation, such as cotton, should find fleabane emergence less abundant.

Despite all efforts aimed at in-paddock fleabane control some seed can be deposited from other areas such as fence lines, farm roadways and irrigation channels. Keeping these areas weed free should be as high priority as in-field control. Previous to 2012, diuron was the best option; however its registration for non-crop situations has been cancelled by the APVMA. NSW DPI currently has experiments underway to find suitable alternative treatments for fence line situations.

Glyphosate-resistant barnyard grass in a key supply channel at St George, along with fleabane - the most widespread weed in major cotton growing regions.

Awnless barnyard grass (BYG)

Collaborative resistance monitoring between NSW DPI, QLD DAFF and the Northern Grower Alliance started in summer 2011/12.

Of the 78 samples received, 58 percent (45 samples) were confirmed resistant.

"Prior to this work the national Glyphosate Resistance Register listed 21 confirmed cases. The findings from the survey represented a trebling of the confirmed resistance cases," Tony said.

Glyphosate-resistant BYG populations are spread throughout the area surveyed. Resistance occurs from Dalby in South East Qld down to Tamworth in Northern NSW, with a greater concentration of cases between Goondiwindi and Narrabri. A further confirmed case was also discovered in Western Australia at Kununurra in 2011.

The resistance survey was repeated in the 2012/13 summer with samples collected from a wider area. Most resistant biotypes were again from samples collected between Dalby and Narrabri. However isolated populations were confirmed resistant from Gatton, Wellington, Gunnedah and Warren. Low summer rainfall in the central west region of NSW limited the number of samples from that region. The register currently stands at 76 confirmed cases.

The 2011 national non-cropping survey also focussed on this weed. Areas such as irrigation channels were the main target. Nine samples were collected and three were confirmed resistant to glyphosate. Two of these were sourced from irrigation channels and one from a silo site.

Management issues

Glyphosate has been the premium herbicide of choice for BYG management in fallows. The lack of many registered pre-emergence herbicides in fallows and the lack of alternative knockdown herbicides give glyphosate resistant BYG it advantage.

The double-knock is a tactic for managing glyphosate resistant populations that preserves the flexibility of fallows in terms of next crop options. Following glyphosate with an application of paraquat five to seven days later offers effective control. The best timing interval and product rates are dependent on field conditions.

Tony Cook NSW DPI, Tamworth Agricultural Institute
02 67631250
tony.cook@dpi.nsw.gov.au

email us

Summary of the latest 2012/13 glyphosate resistance survey results

	Resistant	Marginal resistance	Susceptible	Total
No. of BYG samples	20	4	36	60

Monitor weeds after spraying and report any incidence of surviving or reshooting plants among the dead (as pictured).

IS SOWTHISTLE NEXT?

Sowthistle is a common weed on cotton farms and could be the next on the glyphosate resistant list.

Common sowthistle (*Sonchus oleraceus*) belongs to the Asteraceae family, the same family as fleabane, which is all too well known for its ability to become a hard to control weed.

Reports from growers and consultants of individual sowthistle survivors after glyphosate applications have led Tony Cook to undertake glasshouse trials to ascertain whether any of these survivors are resistant and if so, to determine the level of resistance expressed in these populations.

The looming threat of glyphosate resistance in yet another weed species has broad implications for all agriculture, indicating that the possibility is high that other weeds in Australia are also already developing resistance that we have not yet detected.

"This is a timely reminder of the importance of diversity in control tactics targeting key weeds to avoid resistance; and the importance of closely monitoring weeds after spraying to detect survivors or irregularity in efficacy and to take appropriate action," Tony says.

"The importance of keeping our eyes open and reporting any irregularities to industry scientists cannot be understated. It has often been said before that growers, their staff and consultants are the eyes of the industry when it comes to early detection of threats, whether it be weeds, pests or diseases.

"In relation to the cotton industry in particular, it is a sign to also be looking for alternative herbicides in cotton for sowthistle."

Tony's trials will be finished in October and he hopes to have the data available to industry by November 2013.

WHAT TO KEEP AN EYE OUT FOR AFTER SPRAYING

- LONE SURVIVORS AMONG DEAD PLANTS
- STANDS/PATCHES OF SURVIVORS
- PLANTS THAT MAY INITIALLY SUFFER THEN BEGIN TO REGENERATE

WHAT TO DO IF DETECTED

Contact a specialist for details of how to take, store and send a sample correctly. Avoiding the spread of seeds from suspect plants is vital, so correct handling of the weed to avoid this is imperative.

IN NSW: Tony Cook 02 6763 1250
tony.cook@dpi.nsw.gov.au
IN QLD: Michael Widderick 07 4639 8856
Michael.widderick@daff.qld.gov.au

email us

OFF-FARM VOLUNTEERS: A LOCAL THREAT

A RECENT SURVEY OF QUEENSLAND'S COTTON GROWING REGIONS HAS SHOWN THAT OFF-FARM VOLUNTEER COTTON HAS THE POTENTIAL TO SERIOUSLY IMPACT ON LOCAL PRODUCTION BY HOSTING DISEASES AND INSECT PESTS, IN PARTICULAR COTTON BUNCHY TOP (CBT) AND MEALYBUG.

Volunteer cotton beyond the farm gate has come under scrutiny through a survey conducted by QLD DAFF researcher Paul Grundy.

"The industry is aware that there are cotton plants growing in areas off-farm," Paul said.

"We know that cotton seed is spread off-farm primarily through overland flows associated with irrigation run-off into common drainage lines and via module road freight to gins."

Incidence of Off-Farm Volunteers

Paul said the research was to ascertain the presence of volunteer cotton plants in off-farm drainage areas and along roadsides associated with cotton production and transport throughout Queensland and parts of Northern NSW.

"The information was needed in order to identify risks to the cotton industry from off-farm volunteer cotton and to determine a management strategy for these rogue plants," he said.

The first phase of the survey started in Central Queensland in August 2012 and the research team worked their way south, finishing in October. The plants were characterised and recorded as either recent recruits or longer term perennially growing plants.

"The second phase of the survey, where we revisited sites where the longer term perennial plants had been recorded, was carried out from late February 2013 through until late May," Paul said.

"We wanted to get an idea of how many perennial plants were still growing six months later.

"The survey showed that there is very little cotton going rogue in the broader agricultural landscape, with the issue being generally localised just beyond the farm gate.

"Densities were highest adjacent to cotton farms, within a five-kilometre radius, and in close proximity to ginning facilities."

Cartage and seed transport

Findings from the survey indicate that while seed cotton spilt during module cartage is the primary source for rogue cotton plants, only a very low proportion of spilt seed successfully germinates and establishes a plant. Many roadside plants were associated with structures such as culverts and sign posts that provide a more favourable micro-climate or protection that enables plant establishment.

"It was found that the disturbance of roadside areas during road construction or maintenance can both greatly increase the recruitment rate (due to incorporation of seed cotton) and destroy volunteer cotton plants on roadways," Paul said.

"We also found that drainage channels associated with the Central Queensland and St George irrigation areas had a high incidence of volunteer plants, typically adjacent to cotton cropping areas."

Pleasingly, it was found that additional recruitment from seed produced by perennial rogue cotton plants is minimal. Furthermore, many of the off-farm volunteer cotton plants noted in the pre-season survey had perished by early autumn. Losses were due to climatic factors, competition with grasses, roadside mowing and spraying, roadside burning, and channel spraying.

Biological Sampling of Perennial Plants

In addition to recording the location of off-farm volunteer cotton, the team sampled the perennial plants for biological characteristics including disease status, transgenic heritage, and pest insect presence. The results are cause for concern with nearly half of all perennial plants sampled found to be positive for cotton bunchy top (CBT) disease.

"Our more detailed examination of those samples that were found to be positive for CBT showed that most came from locations in close proximity to farmers' fields," Paul says.

"Plants greater than five kilometres from cotton fields were virtually free of disease. This is a problem and risk closely associated with production areas."

During the survey pest insects were relatively infrequent although many plants had evidence of historical aphid activity and nearly all off-farm volunteer plants on roadsides north of Theodore hosted the mealybug (*Phenacoccus solenopsis)*. Paul believes the low incidence of aphids may have been due to the cooler than average winter that befell the pre-season survey.

"One of the main issues is that these plants are not part of the on-farm volunteer and ratoon cotton management activities. If there is a bad aphid year, they have the potential to be a significant vector for the high levels of CBT present in rogue cotton plants," he said.

Susan Maas, CottonInfo IPM Specialist, says it is important to remember when considering management of diseases spread by aphids not to rely on aphid control as the primary means of preventing infection from contaminated volunteer cotton from either on or off-farm.

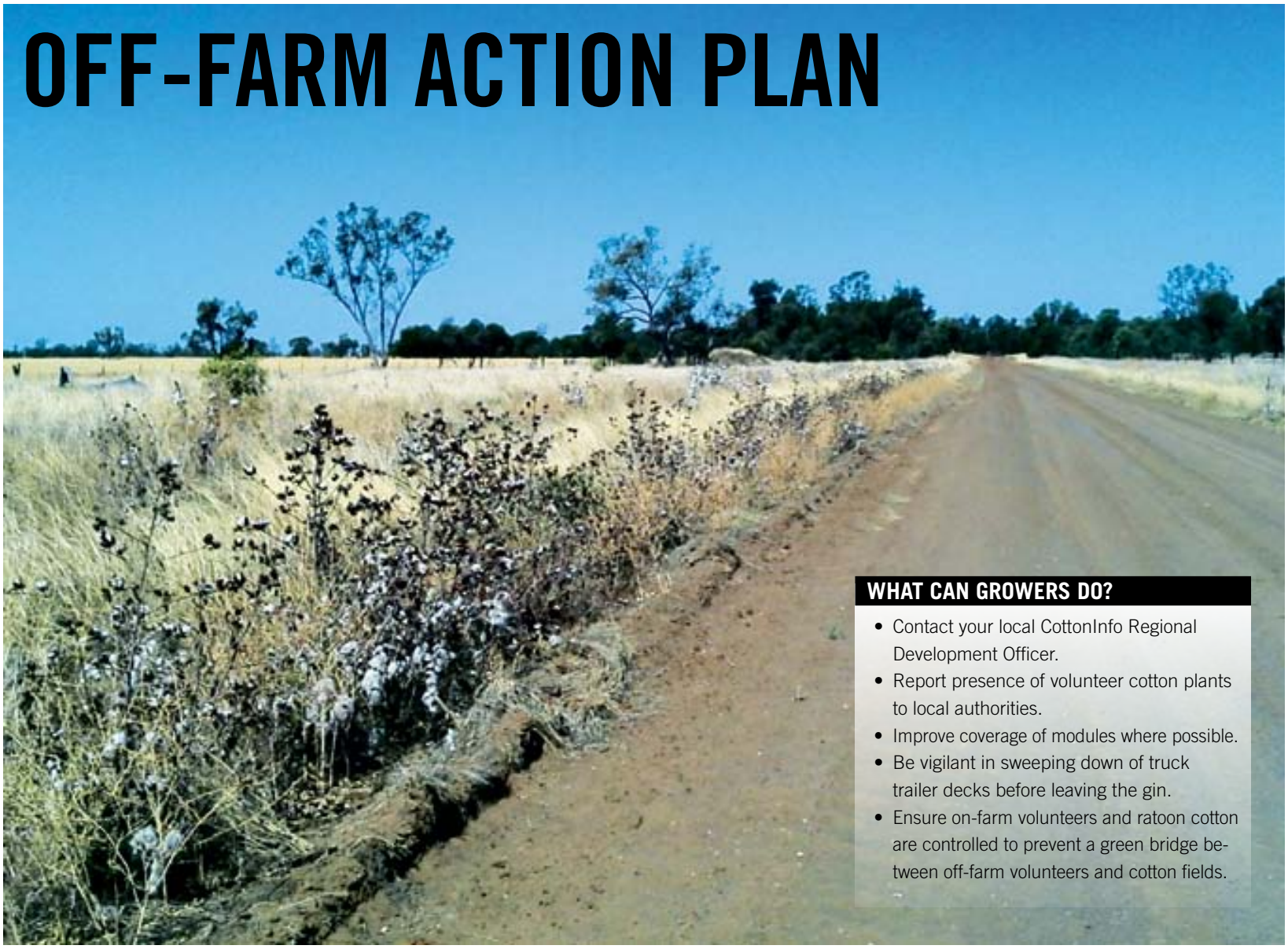
"Aphid management has become particularly challenging in recent years due to growing insecticide resistance issues," says Susan.

"Over use of insecticides to control aphids will make resistance issues worse."

Paul Grundy agrees, adding that "The industry as a whole needs to consider what is growing just beyond the farm gate when implementing strategies for pest and disease management".

QLD DAFF's Paul Grundy has been working to ascertain the presence of volunteer cotton plants in off-farm drainage areas and along roadsides associated with cotton production and transport throughout Queensland and parts of Northern NSW. He is pictured with Ngaire Roughley who will be working with industry's CottonInfo Team as the technical specialist focusing on managing rogue (volunteer and regrowth) cotton.

OFF-FARM ACTION PLAN



WHAT CAN GROWERS DO?

- Contact your local CottonInfo Regional Development Officer.
- Report presence of volunteer cotton plants to local authorities.
- Improve coverage of modules where possible.
- Be vigilant in sweeping down of truck trailer decks before leaving the gin.
- Ensure on-farm volunteers and ratoon cotton are controlled to prevent a green bridge between off-farm volunteers and cotton fields.

WITH MANY GROWERS AND THE INDUSTRY CONCERNED OVER THE ONGOING ISSUE OF OFF-FARM VOLUNTEER COTTON AND WITH THE RECENT FINDINGS FROM PAUL GRUNDY'S OFF-FARM COTTON SURVEY, ACTION HAS STEPPED UP AT ST GEORGE.

QLD DAFF's Paul Grundy explains the difficulties when plants of concern are growing just beyond the farm gate and their control is therefore the jurisdiction of external stakeholders including local councils, Department of Transport and Main Roads, and SunWater.

"We cannot have growers and individuals going out mowing, spraying or chipping along public roads and waterways," Paul says.

Growers take action

Sally Dickinson, CottonInfo Regional Development Officer, (Border Rivers, St George, Dirranbandi) assisted the CGA and concerned growers in the St George area to organise a meeting to address the problem in August 2013.

"It was recognised that the management of off-farm volunteer cotton requires an integrated, whole community approach," Sally said.

Glenn Rogan is a cotton grower in the St George area and was one of the key organisers of the community meeting.

"There were a few reasons I decided to initiate the community meeting," Glenn told *Spotlight*.

"Firstly, I am very aware of the significant impact that mealybug infestations can have on cotton fields, particularly with the images from the previous season's damaged fields in other regions.

"With volunteer cotton being a major source of mealybug contamination, controlling volunteer plants is a big issue.

"Secondly, it does not take a lot to control it (volunteer cotton). It will take even less effort if the community takes a co-ordinated approach.

"I was also forced to look at the issue with fresh eyes when I got in to a conversation with a bus load of Grey Nomads travelling through St George. They commented on the amount of cotton on road sides in the area.

"I realised that it is easy to become familiar with the sight of cotton along roadsides and become complacent about it."

Cross-industry action

Growers, agronomists and consultants, and representatives from CRDC, QLD DAFF, SunWater, QLD Transport, Balonne Shire Council, along with transport and ginning industry personnel all attended the meeting, which was labelled a success by the organisers.

Glenn was one of a number of growers at the meeting and he was "very encouraged" by the range of stakeholders who attended.

"After the presentations general discussion followed and it became apparent that everyone had come to realise that with cotton production being the single biggest contributor to our local economy, if this issue has the potential to affect the viability of the cotton industry then it is something we all need to be concerned about," he said.

Sally Dickinson said following on from the group's discussions everyone brainstormed ideas and developed a draft action list.

"We will now use the list to develop

It was found that the disturbance of roadside areas during road construction or maintenance can both greatly increase the recruitment rate (due to incorporation of seed cotton) and destroy volunteer cotton plants on roadways.

an Action Management Plan to be used as a reference document for the whole community," she said.

"Some of the actions suggested included improving module coverage where possible, more rigorous clearing of trailer decks before departing the gin, increased slashing of roadsides by council and additional herbicide control along main roads.

"In addition to these measures, everyone agreed that the most important action now is raising awareness of the issue and communicating the strategy.

"It was mentioned by some stakeholder representatives at the meeting that if the problem is raised by a group of concerned growers, rather than individuals, it is likely to become a higher priority for action.

"There was a genuine feeling of wanting to take a community approach to managing the issue of volunteer cotton off-farm and there was a real feeling of commitment."

ON-FARM ACTION

Glenn Rogan adds that there are things that growers can do on-farm to help too. "During the wait time for irrigation change we ask our irrigators to pull out volunteer cotton from channels and drains while they are waiting. We also employ someone at least once in summer and once in winter to remove volunteer plants from all around the farm. The way we see it is that it only costs us around $1000 each time to have some go around and clean up our volunteer cotton on farm, compared with the potential loss of hundreds of thousands of dollars if our crops become infested from bunchy top or mealybugs as a result of contaminated volunteer plants."

Pro-active growers like Glenn Rogan are working with all types of agencies to tackle volunteer cotton in public areas like roadways.

ROGUE COTTON HAS A NEW NEMESIS

IDENTIFYING THE NEED FOR GREATER ATTENTION TO THE MANAGEMENT OF ROGUE COTTON, THE INDUSTRY HAS ENLISTED NGAIRE ROUGHLEY TO HELP TACKLE THE ISSUE.

Based in Emerald, QLD, Ngaire Roughley has been appointed by QLD DAFF as the Development and Extension Officer in the region. Her first project is to work with the cotton industry's CottonInfo Team as the technical specialist focusing on managing rogue (volunteer and regrowth) cotton, an increasing problem for the whole cotton industry.

Ngaire said the scale of the problem was illustrated in the 2011/12 CCA survey, where 48 percent of consultants identified ratoon and volunteer cotton as more prevalent compared with the previous season and in many cases volunteer cotton was the dominant weed in the farming system. The annual disease surveys in NSW and QLD continue to find volunteers and ratoons on farms and in some cases even the same volunteer plants year after year.

"Volunteer cotton plants are a major threat to the sustainability of cotton production," Ngaire said.

"They provide a host for pests such as mealybug, silverleaf whitefly, pale cotton stainers and aphids enabling them to survive locally between seasons and infest crops early the following season.

"Regrowth cotton can also harbour diseases such as cotton bunchy top (CBT), black root rot, fusarium and verticilium wilt between seasons.

"In addition they increase resistance selection pressure on Bt cotton and may also act as a potential point of establishment for exotic pests, making ratoons a particular biosecurity risk."

Ngaire will be working in the existing *National Extension Development and Delivery* - Crop Protection project jointly funded by QLD DAFF and CRDC. The project aims to lead and co-ordinate a cotton industry-wide campaign for best practice management of volunteer and regrowth cotton which combines aspects of integrated pest, disease and weed management.

"Although my role has a national crop protection focus, I will also be involved with regional extension.

"Central Queensland is the only subtropical commercial growing region and as such, has a more diverse risk profile in relation to crop protection issues," says Ngaire.

"The project also seeks to build strategic linkages between the Central Queensland cotton community and cotton research nationally.

"I will also be collaborating with and supporting QLD DAFF's Moazzem Khan with his project looking at management of mirids, stinkbugs and Solenopsis mealybug, as well as Paul Grundy and his work on strengthening the Central Highlands cotton production system."

Ngaire says her aim in this role is to build on established successful relationships with growers, researchers, agribusiness, regional natural resource management bodies and industry stakeholders to see effective management of rogue cotton compliant with industry best practice.

email us

Ngaire.Roughley@daff.qld.gov.au

PROFILE

Ngaire Roughley

What attracted you to apply for a role in cotton?

I grew up on an irrigation property north west of Bourke, primarily throughout the drought so I got to experience first-hand the challenges of primary production. After completing a Bachelor of Agriculture at UNE in 2012 I decided that I wanted to join the cotton industry as it seems to have a really positive future in Australia. I find it particularly inspiring to see how the industry itself is constantly making an active effort to improve what they can do and how they achieve this.

What are your first impressions of the role?

The management of volunteer and ratoon cotton is a very complex issue with lots of different factors to consider. I am embracing the challenge and hope to achieve some real outcomes for the industry.

How do you think/hope research can make a difference in the future?

Effective pest and disease management is a cornerstone for sustainable production. My project aims to reduce these issues by developing effective tactics for the control of unwanted cotton as a weed that can harbour pests and pathogens.

NO REFUGE FOR BOLLGARD II VOLUNTEERS

GOOD PLANNING IS THE KEY TO MANAGING VOLUNTEER COTTON IN REFUGE AREAS. THE PRESENCE OF BOLLGARD II VOLUNTEER PLANTS IN REFUGE AREAS HAS BEEN A MAJOR REASON FOR GROWER NON-COMPLIANCE WITH THE BOLLGARD II RESISTANCE MANAGEMENT PLAN (RMP) OVER THE LAST TWO SEASONS.

In the 2011/12 season volunteers in refuges made up 37 percent of all non-compliance cases, according to Monsanto.

CottonInfo Technical Specialist Sally Ceeney spoke to *Spotlight* to reiterate why volunteer plants in refuge areas during the season, and around farms in general are such a big issue, and why we as an industry should be so concerned about it.

"It is in the interest of not just individual growers, but more importantly, for the industry across the board that eliminating volunteer cotton at any time of year is imperative," Sally said.

Typically, Bollgard II plants are likely to be a problem as volunteers when refuges are planted into areas that had Bollgard II cotton the previous season. The increase in area of cotton grown in most regions over the last couple of seasons has meant an increase in back-to-back fields and an increase in refuges being planted following a Bollgard II crop.

"The critical reason for growing refuges alongside Bollgard II crops is to provide a source of Helicoverpa moths that have not been exposed to the proteins contained in Bollgard II," Sally reminds us.

"The presence of Bollgard II volunteer plants within a refuge diminishes the value of a refuge, as some of the moths emerging from that refuge have had some exposure to the Bollgard II proteins.

"In particular, larvae may emerge and develop on the refuge (non-Bt cotton or pigeon pea) crop before moving on to a Bollgard II volunteer plant within the refuge.

"If they carry the gene for resistance (ie are heterozygous [RS] individuals), they may have a better chance of surviving to adults on the Bollgard II volunteer plants than susceptible (SS) larvae.

"In this way, selection could occur that will lead to an increase in the frequency of resistant individuals in the population."

The same risk to resistance from increasing exposure to the Bollgard II technology applies not only to Bollgard II volunteer plants within refuges but also in fallow fields and non-cropping areas.

"It is a strong reminder for growers to ensure as part of their regular farm management plan to prioritise removing all volunteers in and around cropping areas," Sally says.

"In doing so farm managers are not only undertaking stewardship responsibly, but also alleviating biosecurity risks.

"A 'clean' farm reduces the resistance risk to Bollgard II technologies and is essential in removing hosts that can sustain and carry-over pests and diseases from one season to the next."

Sally Ceeney
msceeney@gmail.com

email us

MANAGING VOLUNTEERS IN REFUGES CAN INCLUDE:

- Location – planting refuges in areas that were either fallow or a refuge the previous season
- Pre-irrigating the refuge area so Bollgard II volunteers can emerge and controlled with herbicide prior to emergence of the refuge
- Herbicides – there are options for both pre and post emergent to control volunteer Bollgard II plants *(*refer to the ***2013-14 Cotton Pest Management Guide*** for details on herbicides registered for the control of volunteer cotton)
- In the time before the Bollgard II crop flowers, cultivation can be used in the refuge to remove volunteer Bollgard II plants in the furrows
- Manual chipping

CSIRO Ecosystems Science Entomologist Dr Sharon Downes monitors pest populations for resistance to Cry1Ac and Cry2Ab which provides an early-warning system for any onset of resistance to Bollgard II.

Bt RESISTANCE: MEASURING SUCCESS ONE SEASON AT A TIME

RESISTANCE IS THE GREATEST THREAT TO THE CONTINUED EFFECTIVENESS OF BOLLGARD II COTTON IN AUSTRALIA. WHILE MONITORING IN 2012/13 SHOWED NO CAUSE FOR ALARM, CSIRO'S SHARON DOWNES AND INDUSTRY TECHNICAL SPECIALIST SALLY CEENEY DISCUSS WHY THE INDUSTRY CAN'T TAKE THIS FOR GRANTED.

The current Resistance Management Plan (RMP) for Bollgard II was established to mitigate the risks of resistance developing to either of the proteins contained in Bollgard II cotton. The RMP is a pre-emptive management plan that aims to prevent field level changes in resistance.

The five elements of the RMP impose limitations and requirements for management on farms that grow Bollgard II. These impositions influence the way the pests interact with the Bollgard II crops to lower resistance risks. The principles behind the elements are;

- Less selection pressure/fewer generations exposed.
  Achieved through planting windows, controlling volunteer and ratoon plants, restrictions on the use of foliar Bt and the availability of sprayed non-Bt cotton as a refuge option.
- Dilute the resistance that does occur.
  Achieved through growing a refuge crop to produce susceptible moths and having it close to the Bollgard II crops where they will mix and mate with any moths that may have been selected for resistance.
- Target resistant individuals and destroy them.
  Achieved through cultivation of Bollgard II crop residues during winter, or in warmer climates, the use of late season trap crops.

Based on evolutionary principles and scientists' knowledge of Australia's Helicoverpa pests, the interaction of all of these elements should effectively slow the evolution of resistance.

How does the industry test whether the RMP is effective?

To evaluate the overall effectiveness of the RMP, the CSIRO, with support from CRDC, has a program that monitors pest populations for resistance to Cry1Ac and Cry2Ab. Monsanto Australia also operates a complementary program. Annual monitoring has taken place since 2002/03.

The monitoring data from these programs provides an early warning to the industry of the onset of resistance to Bollgard II. The results are used to make decisions about the need to modify the RMP from one season to the next to ensure its ongoing effectiveness at managing resistance.

Work has already commenced on monitoring field populations for levels of resistance to the new Vip3A gene which will be part of the Bollgard III technology. The baseline resistance levels will be used in assessing the risk of resistance developing to Bollgard III and will help in the development of the RMP for the product.

Types of testing

Highly sensitive testing methods have been developed to detect resistance in individuals before they are able to survive on Bollgard II plants. The resistance that currently occurs in Australian pests has to be inherited from both parents for it to be active. Researchers can detect individuals that have inherited the gene from only one parent. While these individuals would likely die on Bollgard II cotton, as their resistance isn't active, increases in their frequency in populations over time, could indicate that the RMP is not working as well as it needs to in order for resistance (survival) to remain rare in the future.

All the modeling of Bt resistance evolution predicts that small increases in resistance frequency can be followed very soon after by very large increases in resis-

tance. Hence researchers are very interested in what can seem, to the untrained eye, to be minor details in the data.

End of season results 2012/13

Helicoverpa egg and larvae samples were taken from all major cotton growing areas during the spring and summer. Across all valleys there were a total of 23,459 samples submitted to the CSIRO program. The majority of samples were eggs, with some larvae collections from chickpea, lucerne, canola, linseed, faba bean and pigeon pea.

Of the eggs submitted, 60 percent successfully hatched. Of the eggs that hatched and the larvae samples, 41 percent were *H. armigera*.

Resistance Status to Bollgard II toxins

Cry1Ac – In both *H. punctigera* and *H. armigera* the first individuals carrying resistance to Cry1Ac have only recently been detected. They remain relatively rare. One *H. punctigera* isolation from 2012/13 may be a different type of Cry1Ac resistance than those isolated previously and is the subject of ongoing investigation.

Cry2Ab – Resistance genes for Cry2Ab were easily detected before the use of Bollgard II was widespread. Currently (based on F_1 screens) in *H. armigera* five percent of individuals in the population carry Cry2Ab resistance inherited from one parent. This frequency is lower than for 2011/12 when it was eight percent. For *H. punctigera,* three percent of individuals in the population carry Cry2Ab resistance inherited from one parent. This frequency is lower than for 2011/12 when it was seven percent.

Seasonal variation in resistance frequencies is to be expected, but the trends in Cry2Ab resistance are currently the subject of scientific debate. While preliminary analyses of data from the F_2 screens suggests weak increases in the proportion of *H. armigera* and *H. punctigera* carrying Cry2Ab resistance from one parent; the shorter term F_1 data (since 2007), which start from higher baselines, do not show ongoing increase over time.

Importantly for the users of the RMP, there have only been seven individuals detected (of each species) expressing Cry2Ab resistance inherited from both parents, that is, they would be able to survive a dose of the toxin. This is in-line with expectations based on overall frequencies of individuals that carry one copy of the gene.

Why do Helicoverpa larvae sometimes survive in Bollgard II?

Since 2005–06 there have been occasional reports of larvae surviving for several weeks at threshold levels in Bollgard II fields. All affected fields were at mid-flowering to late-flowering and the survivors included *H. armigera* and *H. punctigera*. There have been no reported field failures of Bollgard II and the occasional occurrence of threshold levels of Helicoverpa in some Bollgard II fields is not due to Bt resistance or because of the absence of Bt genes in the cotton.

Recent work suggests that larvae exhibit strong behavioural responses to the Bt proteins in Bollgard II plants. Detection and avoidance of the Bt toxins results in frequent movement of larvae, potentially within and between plants, resulting in an apparent feeding preference for flowers. These behaviours, coupled with the sometimes temporal and spatial variability of Bt toxin expression in Bollgard II cotton, can result in a proportion of larvae becoming established.

What is the baseline resistance to the toxins contained in Bollgard III?

Bollgard III is based on the current platform of Bollgard II (ie: Cry1Ac and Cry2Ab), with an additional toxin, Vip3A. Vip3A resistance has been detected in populations of *H. armigera* and *H. punctigera* in cotton cropping regions. Currently in *H. armigera*, six percent of individuals in the population carry Vip3A resistance inherited from one parent (based on F_2 data), while in *H. punctigera* the frequency is four percent of individuals in the population (based on F_1 data).

Is the current RMP adequate for controlling increases in resistance frequencies?

There have been no reported field failures of Bollgard II due to resistance but the relatively high baseline frequency of Cry2Ab genes in *H. armigera* and *H. punctigera* is a major concern. It is imperative that all users of Bollgard II steward the technology responsibly. In particular, it is critical that close attention is paid to the management of refuge crops for Bollgard II fields, that the removal of volunteer cotton is a high priority, and at the season's end, effective pupae busting occurs in a timely fashion.

Future transgenic cottons are likely to rely on either of the two existing insecticidal genes within Bollgard II. In particular, Monsanto's third generation Bt-cotton, Bollgard III, will build on the existing Bollgard II cotton platform. Protecting Bollgard II cotton therefore also represents an investment in the protection of future transgenic technology for the Australian cotton industry.

If field resistance to Bollgard II cotton were to eventuate it may make it more difficult to market new transgenic products in cotton, and the perceptions of other industries, growers and the public could be unduly affected. Modelling undertaken by CSIRO also suggests that Cry2Ab resistance levels in *Helicoverpa spp.* at the time of introducing Bollgard III will directly impact on the requirements for the RMP for that technology. Therefore, it is critical that the industry complies fully and effectively with the RMP for Bollgard II.

Sharon Downes
sharon.downes@csiro.au
Sally Ceeney
ms.ceeney@gmail.com

email us

The Bollgard III Efficacy Team: University student Katherine Grellman, CSIRO/CSD Assistant Jamala Gordon, CSIRO Technical Assistant Susie Thompson and CSIRO's Trudy Staines.

‘MOST VALUABLE’ INFORMATION RESOURCE

VOTED BY CONSULTANTS AS THEIR MOST VALUABLE INFORMATION RESOURCE, THE COTTON PEST MANAGEMENT GUIDE SUPPORTS THOSE WHO PROTECT COTTON CROPS FROM INSECTS, WEEDS AND DISEASE.

Published annually in partnership with Greenmount Press the guide condenses the knowledge from three decades of crop protection research into a resource for planning and implementing best management practices. It aims to provide crop managers with world-leading information on how to best protect their crops.

Guide editor Susan Maas says updates for the 2013/14 season highlight the value in a team approach for both pest and weed management.

“Cotton insect pests, weeds and diseases are not confined by fences and farm boundaries - they move through cotton landscapes and can affect even the best-managed farms,” Susan said.

“Working together, neighbourhoods of consultants and growers can create synergies in their pest and weed programs.”

The value of teamwork is particularly evident in the weed management chapters.

“The time to prepare for potential resistance has passed, it’s now a reality in our cotton farming systems. Migration of resistant weed seed across the landscape by vehicles, machinery, wind and water means that no one is immune,” Susan said.

The continued success of consultants and growers in managing pests, weeds and diseases places the Australian industry at the forefront of sustainable management practice. Since the introduction of Bt cotton, insecticide use in Australian cotton has fallen to very low levels and has remained low.

“The Australian system isn’t experiencing the replacement of sprays targeting Helicoverpa with sprays targeting other pest species in the same way as other cotton producing countries,” Susan says.

“We believe that this is at least in part due to having robust sampling techniques, thresholds we are confident protect yield and a clear framework for insecticide selection that conserves beneficial insects and delays the evolution of resistance and these are all products of industry R&D.”

Emerald-based crop consultant Jamie Iker says more than anything else, the guide is valuable to his work because of the range of information it contains. “It’s based on research we trust and it’s up-to-date, which helps with decision making. It’s also a useful reference when we’re training staff who are new to cotton,” he says.

UPDATES 2013/14 EDITION:

- IPM strategies for year-round suppression of insect pests and in-crop management.
- Seasonal IPM planner.
- The latest information on resistance trends for insecticides and Bollgard II.
- Weed Tactics Toolbox for implement the ‘2+2+0’ formula for combating herbicide resistance.
- Description of Reniform nematode
- Condensed spray application section – more resources in *my*BMP.
- Summary of label changes from the APVMA product reviews.

JOHNELLE ROGAN

BEE ALERT!

The cotton growing environment can be high risk for bees. *The Cotton Pest Management Guide* contains information about bee sensitivities to insecticides and how to protect bees in the cotton landscape. The CottonInfo Calendar includes a BEE Alert tab to help improve communications with apiarists and also outlines products with specific label instructions for bees are indicated in the key pest tables.

KEY POINTS

- Data collected over 13 cotton seasons shows that pigeon pea is, on average, about twice as effective as unsprayed, non-Bt cotton in producing *Helicoverpa spp.* pupae.
- There is a much higher incidence of parasitism of Helicoverpa pupae now under refuge crops compared with the same refuge types grown previously with Ingard cotton. However there is no difference in parasitism levels between pupae from pigeon pea and non-Bt cotton refuges.
- There is some (limited) evidence that Helicoverpa production has decreased in time in both pigeon pea and cotton refuges.

PIGEON PEA REFUGES – A SMART CHOICE FOR DELAYING Bt RESISTANCE

REFUGE CROPS ARE THE KEY TACTIC FOR DELAYING RESISTANCE TO BOLLGARD II COTTON.

The Australian cotton industry has been growing refuges as part of its Helicoverpa Resistance Management Plan (RMP) since the introduction of transgenic cotton in 1996.

A team of researchers from the University of Arizona recently looked at 77 studies worldwide to determine why *Helicoverpa spp.* in some cases develop resistance quite quickly and in other cases (such as Bt cotton in Australia) resistance has been delayed by up to 15 years. The key strategy for delaying the evolution of resistance was the use of refuges.

The Australian cotton industry is currently looking at third generation Bt technology. So with refuges being such a vital component of the resistance management plan, it is important to understand if the options being grown are still performing as we originally expected them to in terms of producing moths.

Refuge options

The current RMP options for irrigated Bollgard II refuges are; 100 percent sprayed non-Bt cotton; 10 percent unsprayed, non-Bt cotton; or five percent pigeon pea (relative to the area of Bollgard II cotton grown). In 2012/13, pigeon pea refuges covered 85 percent of the total Bollgard II cotton grown. One of the big advantages for growers in using pigeon pea as a refuge, rather than unsprayed cotton, is the reduced area required.

However, there are a number of management issues associated with growing pigeon pea. Pigeon pea can be difficult to establish, particularly in cooler regions and is prone to waterlogging. In-crop weed control can be challenging and the crop is susceptible to glyphosate spray drift. A stressed pigeon pea crop, from any cause such as waterlogging or moisture stress, will delay flowering, which may mean the crop flowers later than its corresponding Bollgard II cotton crop, reducing its attractiveness at this crucial time for resistance management.

Conversely, while non-Bt cotton refuges have some advantages in their synchronicity of management with the Bollgard II crop, there are also some disadvantages in growing non-Bt cotton refuges such as having a higher growing cost (such as fertiliser and seed prices), greater area requirement and the potential for these crops to harbour secondary pests such as silverleaf whitefly and mealy bug. Often, unsprayed non-Bt cotton refuges are observed to not be as attractive as pigeon pea in the later stages of the season.

Given the management issues associated with unsprayed refuge options, are the crops being grown performing as well as they should be in reducing resistance risk in Bollgard II?

The role of refuges

The aim of a refuge crop is to generate significant numbers of susceptible Helicoverpa moths from larvae that have not been exposed to the Bt proteins in Bollgard II. Moths produced in the refuge will disperse to form part of the local mating population where they may mate with any resistant moths emerging from Bollgard II crops, delaying the development of resistance. This strategy works because resistance to the Bt proteins is inherited recessively. Thus, if a resistant moth (rr) from the Bollgard II crop mates with a susceptible moth (SS) from the refuge, the offspring they produce (rS) are also killed by the Bt toxins.

The current unsprayed refuge options for Bollgard II of five percent pigeon pea or 10 percent non-Bt cotton were initially derived from models which showed that to delay Bt resistance in Helicoverpa it was necessary to ensure that 10 percent of the Helicoverpa population were exposed to a non-Bt crop or, put in another way, that 10 percent of all Helicoverpa eggs were laid on plants not containing Bt toxins.

Efficacy of pigeon pea

In the mid-1990's CSIRO research showed that on average pigeon pea produced twice as many susceptible moths as unsprayed cotton, so only half the area is needed to produce the same amount of moths (five percent pigeon pea refuge). Sorghum and corn used to be refuge options but were removed when resistance genes to Cry2Ab were shown to be increasing in *H. punctigera* which do not regularly use these plants as hosts.

No matter which refuge is grown, it is critical that they are managed to be most attractive to Helicoverpa moths when Bt cotton is also most attractive.

The productivity of refuges can vary considerably in space and time, both between and within individual crops and also seasons. Not every dedicated refuge will produce large numbers of susceptible moths, but they need to have the capacity to potentially do so. By chance, some refuges may not be colonised by moths. Others may harbour abundant natural enemies of Helicoverpa (eg parasites and diseases). CSIRO research at St George has clearly shown that a few refuges within a landscape (approximately 25 percent) may produce most (>50 percent) of the refuge-derived moths. It is the collective performance of refuges within landscapes that is paramount to success.

For a refuge to be most effective, it must be planted close to its corresponding Bollgard II crop to improve the chance that its moths will mate with moths emerging from the Bollgard II fields. Helicoverpa are capable of migrating long distances, but during the cropping season a significant part of the population will remain localised on preferred hosts and move only a few kilometres. The Bollgard II RMP requires refuges to be located within two kilometres of the corresponding Bollgard crop.

The RMP also requires growers to ensure that their refuge crops receive adequate nutrition, irrigation (for irrigated refuges), weed and pest management (excluding Helicoverpa sprays) so that they remain attractive while Bollgard II is growing. Growing an attractive refuge ensures that the refuge has the potential to perform its role effectively in reducing resistance risk.

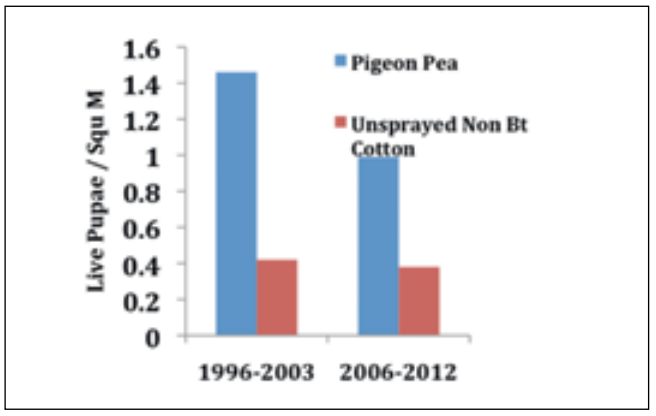


Figure 1

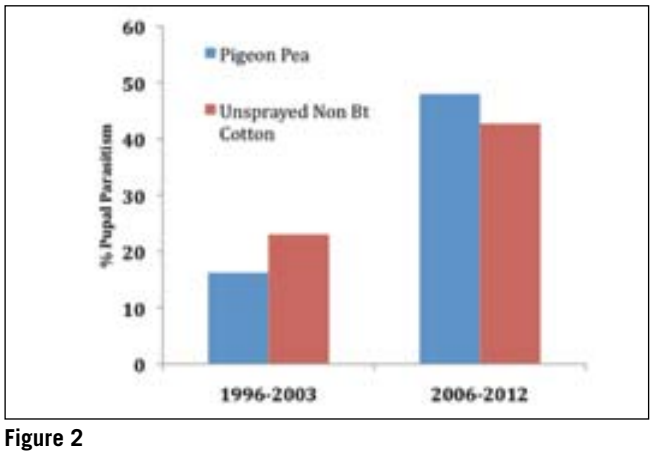


Figure 2

Refuge performance

Research on the relative performance of pigeon pea and unsprayed cotton refuges has been carried out by Geoff Baker and Colin Tann at CSIRO from the introduction of Ingard in 1996 until 2012. Over this time, a total of 750 surveys of pigeon pea refuge crops and 395 surveys of unsprayed, non-Bt cotton refuges have been conducted for *Helicoverpa spp.* pupae.

Pupae digs for this research have covered nearly 12 kilometres of crop (7220 m pigeon pea and 4701m unsprayed cotton) across seven cotton growing valleys at several times throughout each growing season. In most years, pigeon pea significantly surpassed unsprayed, non-Bt cotton in the number of pupae recorded across all survey sites.

In only one year, slightly more pupae were recorded under cotton, but this was not statistically significant. The overall average number of pupae/m² was 1.14 for pigeon pea and 0.40 for cotton refuges (Figure 1). Pigeon pea refuges were therefore on average approximately two to three times as effective as unsprayed conventional cotton refuges in producing pupae. This research supports the 2:1 ratio set out in the Bollgard II RMP (10 percent unsprayed cotton: five percent pigeon pea).

Continuous performer

The research also found that whilst pupae numbers in individual crops varied greatly between different years, pigeon pea consistently outperformed unsprayed, non-Bt cotton across the individual months within cotton seasons. In essence, the research supported the theory that it is the overall (regional) production of refuges that counts, despite variations in individual refuge performance.

Some of the differences in pupae numbers could be attributed to parasitism of Helicoverpa within the refuges. Baker and Tann's research project looked at levels of parasitism in Ingard and BGII refuge crops by rearing the live pupae collected in the samples.

Most notably, the levels of parasitism have increased greatly in Bollgard II refuges compared to Ingard refuges (Figure 2). However, the research showed no difference in the levels of parasitism between pigeon pea and non-Bt cotton refuges. The overall higher levels of parasitism in refuge crops could be attributed to the changes in landscape management that have occurred during this time and, in particular, the much lower use of pesticides following the introduction of Bollgard II.

While the numbers of Helicoverpa emerging from refuge crops may be slightly less now than in years gone by (Figure 1), populations of these moths have probably also diminished more broadly across cotton production regions. Concurrent with the trends observed here for refuge crop production, Tann and Baker's long-term monitoring of both *H. armigera* and *H. punctigera*, using a grid of pheromone traps situated over many square kilometres near Narrabri, has shown that the abundance of these pests has declined substantially at landscape scale in recent years. Thus, currently, a slight reduction in refuge performance is somewhat to be expected.

This research has shown that pigeon pea refuges continue to perform effectively as Bollgard II refuges in producing Helicoverpa moths. However, it is the ongoing good management of refuges, whether pigeon pea or non-Bt cotton, that is crucial in ensuring they deliver on their potential as a key resistance management tactic. Growing an effective refuge can be viewed like an insurance policy towards protecting the future of Bt cotton for the Australian industry.

This article was prepared by CSIRO's Geoff Baker, Sharon Downes, Colin Tann and CottonInfo's Sally Ceeney.

MAINTAINING AND IMPROVING PIGEON PEA REFUGES

PIGEON PEA IS THE REFUGE CROP OF CHOICE FOR THE MAJORITY OF BOLLGARD II GROWERS, BUT MAINTAINING ITS EFFICACY MAY REQUIRE EXTRA EFFORT IN THE FUTURE.

Refuges are a key tactic used in Australia to delay the evolution of Bt resistance in the cotton industry's primary pest nemesis, Helicoverpa.

Helicoverpa armigera has a history of developing resistance to a range of insecticides including DDT, pyrethroids and carbamates within 10 to 15 years of their introduction. It is now 18 years since the introduction of Ingard cotton and 10 years since the transition to Bollgard II. Refuges are an integral part of the Helicoverpa Resistance Management Plan (RMP), which has been very successful in maintaining the efficacy of Bt cotton.

"To date, the RMP's success has helped maintain the efficacy of the two gene version of Bt cotton since 2003," says Dr Mary Whitehouse, Senior Research Scientist with CSIRO Ecosystem Sciences.

"However to maintain this success, we need to be vigilant against subtle changes to refuges over time that could alter the effectiveness of the RMP."

Mary has been leading research into the refuge efficacy of current pigeon pea varieties and says that the overwhelming majority of refuge crops of pigeon pea are derived from the Quest variety.

"However pigeon pea refuges can be highly variable, not only in the look of the crop, but in their attractiveness to Helicoverpa," she said.

"A key element determining whether pigeon pea is attractive to Helicoverpa is whether it is flowering and when. In order to flower, pigeon pea crops must be well managed and not water stressed."

However, Mary says, healthy pigeon pea crops also may not flower.

Mary cited the work of Dr Rao Rachaputi, a pulses crop physiologist working in Kingaroy as part of the Queensland Alliance for Agriculture and Food Innovation. He found the problem is that, in general, pigeon pea crops are sensitive to day length triggering flowering, and that the original pigeon peas were triggered by short day length. That is, they would not flower until late in the season when the day length had dropped to a certain level.

Quest, when it was originally developed, was selected so that it would flower on a relatively longer day length, and therefore flower earlier in the season.

"Unfortunately, the Quest variety used in the cotton industry has not been maintained as a variety for nearly 25 years," Mary said.

"As pigeon pea is known for outcrossing, it is possible that some of the pigeon pea we now use as refuges has digressed to its original state of short day length sensitivity, and therefore may only flower late in the season, no matter how well it is maintained.

"Thus there could be a problem with pigeon pea seed purity which needs to be explored."

QLD DAFF's Paul Grundy has recently screened 320 cultivars of pigeon pea from the National Genetic Resource Centre for Tropical Legumes with interesting results.

In particular, this preliminary work has shown a large variability in the flowering dates of pigeon pea seed and shown that only a handful of cultivars initiated flowering in January with most lines only flowering late in February and March which was too late to be effective as a refuge. Within these plantings Quest was one of the earlier flowering cultivars but not the earliest.

"To establish if this degree of variability is reflected more generally among refuges planted by the cotton industry, we need to record when pigeon pea refuges flower," Mary said.

"A large range of flowering dates could indicate that some of the pigeon pea had digressed to its short day length form, and indicate that there is a need to improve seed purity to improve refuge efficacy."

Mary Whitehouse
Mary.whitehouse@csiro.au

email us

Pigeon pea refuges can be highly variable, not only in the look of the crop, but in their attractiveness to Helicoverpa. Screening of 320 pigeon pea cultivars (above) has shown a large variability in flowering dates. Late flowering crops are less effective as Bollguard II refuges.

WHY PIGEON PEA REFUGES BECAME PART OF THE RMP

The use of planted refuge crops in delaying resistance is based on early theoretical work by eminent Professor of Entomology, Rich Roush, and others. The work indicated that in order to delay the development of resistance by at least 20 generations, 10 percent of the Helicoverpa population must develop on non-Bt plants. As conventional (non-Bt) cotton is assumed to be as attractive as Bt cotton to a laying moth; and larvae developing on conventional and Bt cotton have the same mortality risks (apart from the Bt toxin) then planting 10 percent of the area planted in Bt cotton to conventional cotton will provide this level of protection against resistance.

The work of researchers Colin Tann and Geoff Baker (CSIRO) and others has, over the years, demonstrated that pigeon pea crops are excellent refuges, attracting heavy Helicoverpa egg lays and producing large numbers of Helicoverpa moths. For this reason, a pigeon pea refuge needs to cover only five percent of the area planted in Bt cotton. The lower costs/ha to establish and manage pigeon pea compared to cotton and the loss of a smaller area from crop production combine to deliver to the cotton farmer a very efficient option for protecting the value of Bt cottons for the longer term.

PROFILE

Dr Onoriode Coast is a Nigerian-born Crop Physiologist now based at the Australian Cotton Research Institute near Narrabri.
Onoriode joins CSIRO as a Post-doctoral Fellow following time as a Lecturer at the University of Benin, Nigeria, where he had earlier studied and attained a First Class Honours Degree in Crop Science.
His post graduate studies took him to the UK, where at the University of Reading, on a Felix Scholarship he completed a PhD in Agriculture.
During these studies, he was affiliated with the International Rice Research Institute in the Philippines where he investigated reproductive stage resilience of cultivated rice to temperature stress.

TESTING CANOPY SENSORS FOR IRRIGATION SCHEDULING

IRRIGATION WATER IS A LIMITED RESOURCE FOR AUSTRALIAN COTTON GROWERS WHO ARE STRIVING TO MAKE THE MOST EFFICIENT USE AND BEST ECONOMIC RETURN PER DROP OF WATER AVAILABLE TO THEM. AS SUCH GROWERS NEED MORE DECISIVE MEANS TO MINIMISE PLANT WATER STRESS AND YIELD LOSSES.

The CRDC project, *Applying Plant Based Measurements for Irrigation in Water Limited Environments* undertaken by Dr Onoriode Coast aims to investigate the feasibility of using continuous monitoring of canopy temperature as a tool for scheduling irrigation in limited water scenarios.

The research will firstly involve testing canopy temperature-based irrigation schedules compared with existing practice across various cotton growing regions of Australia. The project will run for three years and will utilise the expertise of cotton scientists from the CSIRO and the United States Department of Agriculture, in Texas.

"In many instances irrigation scheduling practice has mostly been guided by relating soil moisture conditions to plant stress," Onoriode says.

"These non-plant based approaches while successful, do not always reflect the water status of the plant and fail to account for variable and sometimes extreme weather conditions.

"Plant canopy temperature integrates information about soil moisture condition, plant water content and atmospheric conditions."

CSIRO's Dr Rose Brodrick is overseeing Onoriode's project and has been involved in the development of the use of canopy sensors for irrigation and has used them in her recent research into understanding the value of dynamic irrigation deficits based on short term weather forecasts.

"This past cotton season, the CSIRO-developed continuous canopy temperature (ARDU) sensors were deployed in a number of experiments in other projects at ACRI, Narrabri," Rose said.

"This technology worked well and will be used across several experiments in the 2013-2014 cotton season.

"It is being used by researchers at ACRI as a more informative and reliable measure of plant stress than traditional soil moisture measurements.

"Real time canopy temperature data collection and ease of automation has seen it applied to schedule cotton irrigation in the US, however its use thus far has been limited to irrigation scheduling in drip, pivot and lateral systems.

"The Australian cotton industry is mostly furrow irrigation using much greater deficits so modifying this plant-based sensor-irrigation schedule to work well in our furrow irrigated system will provide opportunities for making more efficient use of limited water."

The cotton industry has welcomed Dr Onoriode Coast, who will further investigate the use of canopy sensors to refine irrigation scheduling.

The approach has already attracted keen interest from cotton growers.
In response, field experiments testing the use of canopy temperature for irrigation scheduling on-farm are also underway this season at Emerald, in collaboration with Water Use Efficiency Specialist (QLD), Lance Pendergast and local cotton grower, Cam Geddes.
In Moree in Northern NSW research is being undertaken with Gwydir Valley Irrigators Association and Australian Food and Fibre.

More information

Onoriode Coast
Onoriode.coast@csiro.au
Rose Brodrick
Rose.brodrick@csiro.au

email us

RAINING DOLLARS

HAVING ACHIEVED A 40 PERCENT IMPROVEMENT IN WATER USE EFFICIENCY (WUE) OVER THE PAST DECADE, THE COTTON INDUSTRY HAS SET ITSELF THE GOAL TO ACHIEVE THE SAME AGAIN OVER THE NEXT DECADE.

Achieving this will require investment in both science and innovation to create better irrigation systems with smarter application triggers that maximise the contribution of in-crop rainfall.

Spotlight spoke with CSIRO Cotton Physiology Scientist, Dr Rose Brodrick to find out where the science of plant-water interactions is up to and what this means for future approaches to irrigation scheduling.

"Current irrigation strategies rely heavily on visual cues from the crop and soil moisture deficits, but we are revisiting the trigger because we believe a new approach can create opportunities for irrigators to optimise water use," Rose said.

The background to Rose's work lies in research undertaken as far back as the 1960s, which showed plant responses to soil water deficits were affected by the evaporative demand.

Her recent work with modern cotton cultivars, grown with modern management techniques, has again demonstrated the principle, that plant stress response to soil water deficit changes in response to evaporative demand.

"That is, when evaporative demand is high, a plant will experience higher stress at lower soil moisture deficits, and conversely, when evaporative demand is low, a plant might not be stressed, despite higher moisture deficits," Rose said.

Industry surveys show that currently, decisions around when to irrigate cotton tend to be based on reaching a target soil moisture deficit. The deficit is either measured with probes or recognised visually through previous experience with cotton in particular fields.

"The opportunity for improvement lies in working out a reliable method for assessing the degree of stress being experienced by the plant and how stressful conditions will become if irrigation is delayed," Rose said.

"Our experiments are investigating the idea that yield per mega litre of water is optimised when the trigger for each irrigation is dynamic.

It is common in clay soils for cotton to be irrigated when the soil moisture deficits reaches 80 mm. Under average summer evaporative demand this equates to eight mm per day and a 10-day irrigation cycle. Under lower evaporative demand of five mm per day, it would be 16 days until the deficit is reached.

"However we are working out how to account for the stress levels actually being experienced by the crop under these conditions," Rose says.

"The irrigation interval could be longer than 16 days, saving irrigation water and increasing the opportunity to capture and utilise rainfall to its maximum effect. A dynamic deficit approach could potentially improve irrigation efficiency by taking into account the current crop stress, the current soil moisture, and how the weather forecast affects crop stress."

Researchers at the Australian Cotton Research Institute are leading the way in developing and testing crop sensors to give a more informative picture of plant stress than traditional monitoring equipment.

"In our experiments over the past three seasons, irrigating later in response to weather forecasts for low evapotranspiration (ETo), has not resulted in any yield penalty.

"We use Australian Government Bureau of Meterology four-day forecasts of ETo to schedule our dynamic deficit treatments."

Last season Rose and her team at CSIRO Narrabri achieved similar yields from irrigating on a larger deficit at cut-out in response to low forecasted ETo, compared to using a fixed deficit approach using only neutron moisture meters. The average yield in this trial was 13.7 bales per hectare, indicating that these approaches are being developed in commercially relevant yield scenarios.

"The treatment where irrigation was delayed by six days at cut-out received one less irrigation over the season. It highlights to us the future opportunities for water savings by being able to take advantage of periods when crops are experience low levels of stress," Rose says.

"The opportunity can be tailored to the seasonal conditions as they occur."

Rose Brodrick
Rose.brodrick@csiro.au

email us

WATERPAK: ONE-STOP SHOP FOR WATER MANAGEMENT AND IRRIGATION INFORMATION

THE LATEST MUST-HAVE RESOURCE FOR GROWERS AND CONSULTANTS IS THE NEW WATERPAK MANUAL, LAUNCHED AT THE SOUTHERN COTTON CONFERENCE IN JULY.

CRDC R&D Manager Jane Trindall and Cotton Water Technical Specialist Janelle Montgomery launched the on-line publication on behalf of CottonInfo Team at the Southern Cotton Expo.

With so much research (nearly $30 million over the past seven years) being undertaken since the first edition of WATERpak, the industry took advantage of this to launch the new resource.

"There is so much valuable advice contained in irrigation and water management research over the past five years," Jane said.

"WATERpak provides an avenue for quality control to ensure irrigators receive credible information which they can easily access and use with confidence.

"It is imperative that this information gets into the hands of growers and consultants, which is the aim of WATERpak.

"This new edition provides the best available information for achieving further improvements in water use efficiency and water management. More broadly it is a supporting information resource for the industry's Best Management Practice program *myBMP*."

Keeping step with research, included in this edition are new chapters looking at tools and information for decision making, irrigation system selection, storages and channels, pumps, fertigation, and management decisions in limited water use situations as well as a new section dedicated to irrigation management of grain crops.

WATERpak has now been designed to be read electronically on tablets and notebooks, with links to other on-line information sources so further information can be readily accessed. As new research comes to hand, this is further developed by the CottonInfo Team. WATERpak will be regularly updated and distributed electronically to growers and their advisors.

To download a copy go to
www.myBMP.com.au

see our website

ADVANTAGES IN PLANTING LATER

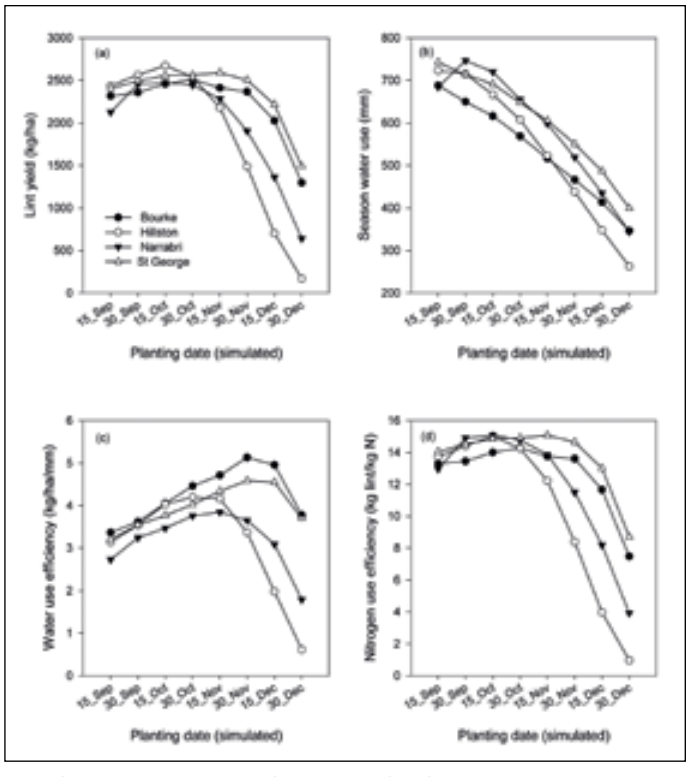
EXAMINING THE EFFECT OF PLANTING DATE ON COTTON'S RESOURCE USE EFFICIENCY HAS FOUND THAT LATER DATES CAN OFFER WATER USE EFFICIENCY ADVANTAGES IN THE HOTTER, LONG-SEASON REGIONS.

CSIRO's Dr Michael Braunack, lead researcher in the first Australian study to examine the effect of planting date on cotton's resource efficiency, said it is important to continually revisit and refine crop management strategies to determine if greater efficiencies can be attained.

"Variable weather patterns, water scarcity, rising input costs and greenhouse gas emissions are all factors in the equation for driving improved efficiencies," Mike told *Spotlight.*

"Utilising more of the Bollgard II planting window could afford growers flexibility at the start of the growing season and potentially provide opportunities to plant on rainfall rather than using irrigation water resources."

With support from the former Cotton CRC, field experiments were conducted over two seasons at Narrabri to investigate the effects planting date has on lint yield, lint quality, and the crop's water and nitrogen use efficiencies. A range of Bollgard II cultivars with differing growth habits and maturity were used.



The simulated effect of planting date on lint yield, crop water use, crop water use efficiency and nitrogen use efficiency for a short-season (Hillston), mid-season (Narrabri) and two long-season (St George and Bourke) cotton regions. Simulations generated using the OZCOT model, accessing 53 seasons of climate data for each region.
Further Information; Michael.Braunack@csiro.au
***Field Crops Research* Journal (2012), Volume 137, pages 1-11.**

Crop simulation with the OZCOT model was also used to test outcomes over a wider range Australian cotton regions and historical seasonal conditions.

In the Narrabri field trials (2007-08 and 2008-09) yield was reduced with late planting, however there were trade-offs between yield and fibre quality. While delayed planting decreased yield, it increased fibre length and strength and reduced micronaire.

The vigorous, tall cultivars had similar water use efficiencies to the compact cultivars, though there were trends in late November/early December plantings towards the compact cultivars maintaining higher water use efficiency. Cultivars all performed similarly in terms of nitrogen use efficiency for all planting dates.

The researchers found that overall; the productivity of the crop was reduced by very late planting, demonstrating that the current planting time – late September to late October – gets the balance right. This window maximises yield as well as water and nitrogen use efficiencies in the Narrabri long season climate.

This was confirmed through crop simulation using the OZCOT model.

"Compared with the experiments, the model provides a reasonable estimate of yield, but does tend to underestimate water use efficiency and over-estimate nitrogen use efficiency," Mike explained.

"There were clear differences between the short and mid-season regions (Narrabri and Hillston) and the hotter, long-season regions of Bourke and St George.

"In the hot regions there is a wider planting window for maximising yield as yields were similar for planting dates September 30; October 15 and 30; November 15 and 30.

"Yields were only substantially reduced by very late planting."

The modelling revealed the opportunity for improving the water use efficiency of Bollgard II cultivars in these regions by delaying planting beyond October 15 and utilising the later part of the Bollgard II planting window (ending November 15).

Mike said the improvements in water use efficiency are driven by partial avoidance of high evaporative demand periods during the season. He hypothesises that changes in leaf area and fruit setting pattern may also be influencing water use during periods of high evaporative demand, however cautions that this relationship has not been explicitly tested.

"Flexibility in planting date in some environments is now more practical. Because transgenic cotton provides better insect control, there is higher fruit retention and a shorter fruiting cycle," he said.

"This allows later plantings to maintain yield and fibre quality. Planting date can now be considered as part of the strategy for maximising the use of limited water.

"The simulation analysis highlighted differences between regions and that there is more opportunity to improve crop water use efficiency in long season areas with later planting, however Mike says further field studies need to be undertaken to confirm this across regions."

UNDER A NEW CRDC PROJECT RESEARCH IS UNDERWAY TO BENCHMARK AQUIFER WATER QUALITY AND QUANTITY.

STUDY TO ASSESS WATER CONNECTIVITY IN THE CONDAMINE

The project, led by Associate Professor Bryce Kelly from the Connected Water Initiative Research Centre at the University of New South Wales, will assess the extent of hydraulic connectivity between aquifers used for gas production from within the Walloon Coal Measures and aquifers used by farmers in the Condamine Catchment in South-East Queensland.

This will be achieved by examining the chemistry of the groundwater, measuring the concentration of methane in the groundwater and air, mapping the geology of the region in 3D, analysing the historical groundwater level and chemical data sets, and examining pumping impact scenarios.

"We will sample the groundwater from 30 irrigation bores in 'priority areas', these will be selected based on their proximity to new CSG production and exploration wells in the Condamine Catchment," Bryce said.

"To quality assure these data we will also sample some bores where CSG producers and government hydrogeologists have already sampled the groundwater.

"This will allow us to quantify the potential long-term impacts on farmers' access to good quality groundwater for irrigated agriculture in the Condamine Alluvium."

CRDC R&D Manager Jane Trindall will oversee the project and says "in the public domain, there is a lack of hydrogeological data to give the community and farmers confidence in our knowledge of baseline conditions and our capacity to quantify potential long-term impacts".

"One aim of the project is to provide information that can be used to inform the implementation of best management practices as the CSG industry rapidly develops to safeguard water resources critical to the cotton industry," Jane said.

Bryce will lead the project in collaboration with Professor Euan Nisbet and Dr Dave Lowry from Royal Holloway, University of London, Dr Dioni Cendon based at Australian Nuclear Science and Technology Organisation (ANSTO), and hydrogeologist Mark Hocking.

PROFILE

Associate Professor Bryce Kelly has a decade of experience working internationally with the oil and gas sector.

Associate Professor Bryce Kelly brings extensive knowledge to the new CRDC project. He has a decade of experience working internationally with the oil and gas sector, and over the past decade he has specialised in improving our knowledge of the hydrogeology of the alluvial aquifers throughout the Murray-Darling Basin. Recently he co-authored a background paper on *New South Wales Geology: With a Focus on Basins Containing Coal Seam Gas Resources* for the Office of the NSW Chief Scientist and Engineer.

QUICK FACTS

- As groundwater moves through the aquifers the chemistry is altered by contact with various sediments and rocks.
- By mapping the changes in the chemistry across a catchment, potential pathways of hydraulic connectivity can be mapped.
- By measuring groundwater levels and the chemistry of the groundwater it may be possible to determine where the Surat Basin is hydraulically connected to the water supplies within the Condamine Alluvium, and where there is a potential hydraulic link between the CSG development in the Walloon Coal Measures and the groundwater used for irrigated agriculture.
- Methane concentration can be an early indicator of connectivity between coal seam gas developments and aquifers used as water supplies. There are no extensive baseline measurements of the methane concentration in the groundwater or air in the Condamine Catchment.

The Methane Indicator

"Results from coal bed and shale gas production regions in the US show that if a gas production well is poorly constructed then there is a risk of groundwater contamination at a local scale" Bryce said.

This leakage can be detected as an elevated concentration of methane in the groundwater or in the air near the ground surface. However, methane also occurs naturally throughout the landscape. Biological processes in the groundwater and soil produce methane. This subsurface methane is slowly released to the atmosphere.

Therefore, to determine an elevated concentration, the baseline methane concentration must be measured, and currently there are no extensive baseline measurements of the methane concentration in groundwater or air throughout the Condamine Catchment.

Professor Euan Nisbet and Dr Dave Lowry, in association with colleagues from Royal Holloway, will conduct an air quality survey to map the concentration of methane in and around the irrigation districts and CSG production areas. In addition, UNSW researchers will measure the concentration of methane in the groundwater used for irrigation. They will 'fingerprint' the potential origin of the methane, by measuring the isotopes of carbon within the methane molecules. >

Tracking water

As groundwater moves through aquifers the chemistry is altered by contact with various sediments and rocks. By mapping changes in the major ion chemistry of the groundwater across a catchment, potential pathways of hydraulic connectivity can be mapped. Dr Dioni Cendon will lead a team from ANSTO who will measure the major ion chemistry and the isotopes of carbon, hydrogen and strontium in the groundwater.

"Isotope measurements are used to determine the age of the groundwater and this helps with quantifying transit time," Bryce said.

WHY TARGET THIS AREA?

The Surat Basin underlies a highly productive agricultural industry encompassing grazing, dryland broadacre and irrigated farming. A variety of crops are grown, including cotton. All are dependent in one way or another on the quantity and quality of the surface and ground water.

Over the past decade CSG exploration and production has expanded rapidly in the Queensland portion of the Surat Basin, targeting the coals within the Walloon Coal Measures. The Walloon Coal Measures is hydraulically connected to the aquifers of the Great Artesian Basin (within the Surat Basin) and in some locations immediately underlies the Condamine Alluvium. This research will improve knowledge about the hydraulic interactions between the Walloon Coal Measures and the aquifers within the Condamine Alluvium.

"Gas production from the Walloon Coal Measures will eventually result in hundreds of thousands of megalitres of groundwater being extracted each year; this will depressurise the groundwater systems in the Walloon Coal Measures and adjacent geological formations," says Bryce.

"The full extent of the impacts due to this volume of groundwater extraction will take multiple decades to be transmitted throughout the aquifers of the Great Artesian Basin and the Condamine Alluvium."

Interested in being part of the study?

Cotton growers in the Condamine Catchment in regions adjacent to CSG exploration and production who would like to participate in this study are encouraged to contact Associate Professor Bryce Kelly at bryce.kelly@unsw.edu.au

email us

NORTHERN BASIN: 2015 AND BEYOND

THE NORTHERN MURRAY-DARLING BASIN HAS ITS OWN DISTINCT TRAITS WHICH DIFFER FROM OTHER PARTS OF THE BASIN.

More than 50 delegates from 35 organisations came together in Narrabri earlier this year to discuss water science in the Northern Murray-Darling Basin at the Northern Basin Water in Catchments Science Forum 2013. Representatives were from a diverse range of organisations including irrigation and cotton organisations, universities, aboriginal community groups, local councils as well as representatives from the Northern Basin Advisory Committee.

CRDC Program Manager Jane Trindall was involved in the event and says the speakers highlighted how the Northern Murray-Darling Basin differs from the Southern Basin and as such requires regionally-relevant research and implementation.

"The hydrology in the north is seasonally different to the Southern Basin and much more variable," Jane explained.

"Rivers, floodplains and ecosystems are also different so the presentations on a wide range of topics relating to systems, plants, animals and catchments in the Northern Basin were really valuable.

"A common theme that emerged throughout the forum was that we have pockets of high quality research and knowledge for some catchments, rivers and reaches.

"For example Glenn McGregor from the Queensland Department of Science illustrated a fantastic example of his team's research highlighting the response of golden perch to environmental flows.

"However, beyond these focus areas our knowledge of base resources (water, soils, plants and animals) and how these resources interact is relatively poor."

Guy Roth of Roth Rural was involved in organising and co-ordinating the event which was initiated by the former Cotton CRC.

"However, the forum was not only for the cotton industry but for the broader agricultural industry and stakeholders in the Northern Basin catchments," Guy said

"The forum was aimed at better informing attendees on current water science projects and what these activities might deliver by 2015 and beyond.

Participants at the Northern Basin Water Science Forum agreed there was a need to get people and organisations together in one place to discuss a multitude of projects.

"There was a need to get people and organisations together in one place to discuss a multitude of projects to provide a snapshot of water science in Northern Basin and get them to provide their ideas to assist with formulating a vision for a well co-ordinated targeted science plan for water in the Northern Basin."

At the end of each session attendees were invited to participate in discussions on short (to 2015) and long term (to 2020) science gaps and opportunities.

Speakers and attendees identified the need to think beyond the water only solution and investigate the role of other stressors (eg pest species, land degradation) on system responses. One of the key messages from the forum was the need for better integration of water management and land management programs.

"Despite massive recent investment in water buy-backs and infrastructure improvement, water research funding is at a 20-year low," Guy said.

"While there are pockets of quality research, effort in the Northern Murray-Darling Basin is fragmented and data and information sharing is far from optimal.

"The forum was a great success and we achieved what we set out to achieve. The group articulated a vision for a coordinated, cross-jurisdictional body to be formed to drive forward, oversee and collate the research effort in the Northern Basin.

"The Northern Basin Advisory Committee was suggested as key group to assist with the co-ordination of this meeting."

A workshop summary and a booklet of available abstracts can be found on the CRDC website: www.crdc.com.au

see our website

A total of 63 percent of cotton growers indicated they have a riparian zone on their farm. On average, they have nine kilometres of river frontage and most of it is actively managed for conservation values.

A RIPARIAN REGENERATION

COTTON GROWERS HIGHLY VALUE AREAS OF RIPARIAN TREES AND VEGETATION ON THEIR FARMS.

In the Northern Murray-Darling Basin, river red gums and coolibah growing along river banks provide important habitat for both terrestrial and aquatic animals, and provide habitat for beneficial predators of pest insects that readily migrate into crops close by.

"Most would agree that without these iconic riparian trees, the Northern Basin would be a very different place," says Griffith University researcher, Dr Sam Capon, who has recently started a new project with support from CRDC.

"Riparian trees influence runoff, stream flows and patterns of erosion and sedimentation and are integral to the health of these riverine landscapes.

"Despite their significance, very little is known about how sustainable current populations of riparian tree species are in the region."

Titled *Critical Thresholds for the Regeneration of Riparian Vegetation*, the project will examine patterns of riparian vegetation regeneration across the Northern Basin with a focus on the Condamine-Balonne and Barwon-Darling systems.

"There are many questions we are seeking answers for, starting with tree recruitment. We'd like to know whether recent levels of seedling establishment and survival have been sufficient to maintain the present distribution of riparian trees," Sam said.

"Why do some riparian areas in the Northern Basin support dense thickets of tree seedlings while other areas have virtually none? And, what are the main factors influencing the germination, growth and survival of riparian tree seedlings?"

The project will seek to identify the key factors that determine where in the landscape seedlings of common riparian plant species establish and survive to become adults.

"Large-scale environmental variables, such as climate and hydrology, will be considered along with local factors including topography and land management practices such as grazing.

Over the next three years, seed dispersal, germination, seedling growth and mortality will all be examined through a combination of field surveys and glasshouse experiments. Aerial photos and satellite images will also be used to investigate historic patterns of riparian vegetation regeneration.

"Overall, the research will aim to inform management decisions for environmental outcomes across a range of scales," Sam said.

"At a farm scale, answers to our questions will help with the management and restoration of riparian areas. At a whole of catchment scale, the work will be relevant to the management of environmental water.

"I would love to hear from anyone in the Northern Basin about their observations of seedling responses to recent floods in the region.

"After a recent trip through the Lower Balonne and Barwon-Darling, I am also particularly interested to hear from anyone with knowledge of significant recent river red gum regeneration."

WANT TO BE PART OF THE STUDY?

Contact Sam via email at s.capon@griffith.edu.au or on 0402 217 899.

email us

Dr Sam Capon is researching seed dispersal, germination, seedling growth and mortality of the Northern Murray-Darling Basin's iconic riparian trees.

BLUE SKY FARMING: *In this new section of the Spotlight magazine, we look to highlight new ideas and technologies that are innovative and have a potential application to cotton farming. CRDC is also looking to investment in blue sky farming ideas which have the potential to transform the cotton industry of the future. Profiled here are just a few ways that people are starting to transform the way cotton is farmed.*

EMBRACING TECHNOLOGY AT MOREE

B&W RURAL IN MOREE NORTHERN NSW IS EMBRACING TECHNOLOGY AS THEY PREPARE TO USE UNMANNED AERIAL VEHICLES (UAVS) AS PART OF THEIR AGRONOMY SERVICES.

B&W's Brad Donald and Peter Birch are enthusiastic about the use of drone technology in agriculture, and foresee benefits in productivity and efficiency for growers and consultants alike.

Aerial crop inspections will provide another dimension for consultants, as they gain a bird's eye view of the entire crop, which is otherwise nearly impossible, short of hiring a plane. They record and live stream images back to the vehicle as well as provide an assortment of data collection, depending on the type of technology fitted.

B&W Agronomist Brad Donald has been given the go ahead by manager Peter Birch to investigate and build some prototypes, which include a fixed wing radio control test plane and a fixed wing automated drone.

Data collection will mainly be based around the capture of images through multi spectral cameras to produce Normalised Difference Vegetation Index (NDVI) images for the use in irrigation and broad-acre farming situations. Brad said the main advantages in this technology for consultants and growers are "increased efficiency and more specific, targeted, crop management; such as in-crop chemical and fertiliser treatments as well as long term soil amendments".

"These UAVs allow us to go places in broad-acre and irrigation paddocks where we couldn't go without a very long and time consuming walk, or with a plane," he said.

"From an efficiency angle, inspecting crops can be a time consuming job in a very large field. UAVs should also make the use of current NDVI imaging techniques more cost effective and hopefully in the long term increase farm productivity.

"The advantage of these UAVs is that we can program them and leave them to fly over a paddock, freeing us up to do other things while they go to work as well.

"We think our model will be able to cover 250-500Ha per hour depending on the height above ground level flown and wind speeds at the time.

"From a management perspective, it will allow us to easily identify areas in a field where there are variations in crop vigour, weeds, and general crop health, and manage these areas accordingly."

B&W will start using the service as soon as they have the appropriate accreditation needed under Civil Aviation Safety Authority (CASA) ruling when planning to use UAVs for commercial purposes. Having several pilots on the staff puts B&W Rural in a good position to up skill to meet all the CASA requirements.

Peter Birch says the introduction of this technology adds another dimension to agronomy and farming.

"Agronomy and agriculture is really getting more interesting and diverse every day," Peter said.

"As ground-breaking technology developed for the likes of the military, like GPS a few years ago and now drones becomes more accessible, agriculture is drawing on technology from these high-tech industries.

"It just adds another dimension to our already diverse industry.

"Pulling together the various disciplines required to make this a reality will be a challenge but we really view this as a part of the future of agriculture.

"Therefore we are prepared to start to spend the time and money during this experimental phase so that we can take advantage of the new advances as they come through."

"IT ADDS ANOTHER DIMENSION TO AN ALREADY DIVERSE INDUSTRY."

Dr Cheryl McCarthy says research is advancing in regard to sensors, autopilot with centimetre-accuracy and data interpretation from drones.

RESEARCH WELL UNDERWAY

DR CHERYL MCCARTHY ATTENDED A GLOBAL UNMANNED AERIAL VEHICLE CONFERENCE RECENTLY AND SAYS DRONE TECHNOLOGY IS ADVANCING QUICKLY AND BENEFITS TO GROWERS AND CONSULTANTS ARE AVAILABLE NOW.

Cheryl is a research fellow in mechatronic engineering at The National Centre for Engineering in Agriculture (NCEA) in Toowoomba, QLD and says drone research is currently a dynamic blend of robotic engineering, computer and spatial science.

"Current off-the-shelf unmanned aerial vehicles (UAVs) or 'drones' from some manufacturers are very easy to use, with on-board sensors and autopilot control taking care of the drone's mid-air stability," Cheryl says.

"All the pilot has to do is steer the drone to the desired position, or set up GPS waypoints which the drone will follow autonomously.

"The drone can land safely and automatically with the press of a single button."

At the global UAV-g Conference Air Show held in Germany in September, attendees were invited to pilot drones by exhibitors and were impressed with their ease of use, even for participants with little or no prior flying experience. However, training is recommended so that pilots can handle unexpected situations without autopilot.

"Drones are foremost a mechanical device and training is required to ensure safety guidelines are followed," Cheryl says.

According to Cheryl, drones, and in particular microcopters, have reached a phase where the physical platforms have not changed significantly in the last couple of years. However, research is advancing on sensors, autopilot with centimetre accuracy and data interpretation from drones.

Selected drones can carry large digital cameras which have a large image sensor and can capture high resolution images. These images are useful for farmers and consultants to visually assess the crop.

"The technical papers at the UAV-g conference covered new hyperspectral cameras (which can detect plant condition by analysing narrow bands of light) and new techniques in image processing for drones," Cheryl said.

"New sensing techniques potentially enable more detailed crop information to be detected, in addition to Normalized Difference Vegetation Index (NDVI), which assesses the amount of green vegetation.

"Other information that might be detected automatically includes crop disease or weed infestation, which can assist the farmer immediately by highlighting areas of crop which require follow-up action.

"The immediate opportunity for Australian agriculture is identifying an appropriate off-the-shelf drone platform, and a user-friendly protocol where the drone performs a flight over a crop and provides useful data autonomously and in real time to the farmer or consultant."

Further information

Dr Cheryl McCarthy
Cheryl.mccarthy@usq.edu.au

email us

FLYING HIGH DOWN SOUTH

GROWERS IN SOUTHERN NSW ARE USING DRONE TECHNOLOGY TO IMPROVE DECISION MAKING AND INCREASE YIELD.

MIA Rural's Technical Services and Machinery Manager Mark Norvall has developed two machines to take NDVI (Normalized Difference Vegetation Index) images on farms in the southern cotton growing region around Griffith and Whitton.

The drones can cover 500ha in 20 minutes, flying a set grid using satellite navigation.

Mark has used the drones for two seasons now, working with two growers on a total of 1500ha and is hoping to double the amount of hectares this year.

"The first season in 2011-12 was more of a look-see and a feasibility study, but last year was far more serious when we introduced infrared imagery," he said.

The upgrade to a higher resolution infrared camera has paid off, with Mark being able to take biomass images to understand crop temperature and using the data for variable rates of pesticide.

The aim is to get a more even yield across a paddock, and it's already working.

"You can look at the pictures straight away on the laptop," he says.

"The idea is to be able to pick up early patterns in the paddock that we can fix, whether it's insects, nutrition, water distribution or weed patches.

"If you get 20 per cent of the crop yielding less, it drags the yield right down very quickly."

Both farmers involved saw an increased yield.

"On one farm in particular there was a problem paddock. We used a number of aerial images to pick up the patterns in the bad areas then started aerial sprays at variable rates to improve it."

Rob Houghton grows between 200 and 300ha of cotton on "Ravensbourne", about 10km east of Whitton, and said the drones have already been beneficial.

"You can pick up a lot from the area in terms of crop health, thickness and colour," Rob said.

"We pinpoint those areas and we can do some more research. It's already resulted in a variable rate of fertiliser application, saving time and money."

Rob said more accurate decisions were made based on different portions of the crop.

"Instead of treating the whole crop with the same amount of fertiliser, I've reduced in some areas and increased it in others," he said.

Mark says the drones are most successful between the emergence of one to three nodes and 10 to 12 nodes.

"It's best if there's an earlier pre-plant flight to pick out any differences in the soil and post emergent at one node to pick up plant numbers, then once every two weeks over a period of two and a half months," he said.

"Then we can zoom in for plant counts once we have the video to give us a very accurate and wide plant establishment figure."

Jon Welsh is keen to help growers and consultants navigate a carbon farming future, reduce emissions and save money.

SPECIALIST ON BOARD TO NAVIGATE A CARBON FARMING FUTURE

INDUSTRY'S NEW CARBON TECHNICAL SPECIALIST WILL ASSIST GROWERS IDENTIFY AND UNDERSTAND PRACTICES TO IMPROVE EFFICIENCY, REDUCE EMISSIONS AND HIGHLIGHT OPPORTUNITIES AVAILABLE UNDER THE CARBON FARMING INITIATIVE.

The appointment of Jon Welsh to the CottonInfo Team as the Carbon Technical Specialist is a significant step in the new Carbon Farming Futures Extension and Outreach project funded by the Australian Government Department of Agriculture.

Jon will lead the industry effort to develop and distribute information and research findings relevant to carbon sequestration and greenhouse gas emissions. Jon has moved from Coolah in the Liverpool Ranges to take up the position. He is looking forward to working with growers to improve understanding of the various climate (forecasting) models and how they can assist with on-farm decision making processes.

"I believe that by increasing growers' understanding of seasonal climate indicators, practices can be adjusted to improve resource use efficiencies such as nitrogen and water," he said.

"As part of a mixed farming business producing rain-fed winter and summer crops along with rangeland and intensive livestock production, I am fully aware that it is critical for farmers to manage climate risk in an environment where extreme weather events are becoming more common.

"There is nothing like shovelling cottonseed and lopping kurrajong trees for hungry stock during drought with no end point in sight to motivate oneself to gain a deeper understanding of seasonal climate indicators.

"Thankfully seasonal forecasting has come along way in the last five years in terms of applications to agriculture. Some of the information available to growers is very useful and those prepared to invest the time in understanding climate models and their limitations will have more confidence in their decisions."

Recent research findings investigating the interaction of temperature and irrigation/rainfall on nitrogen losses may also help farmers in high input farming systems gain greater efficiencies from better nitrogen application timing and placement, reducing fertiliser costs and at the same time reduce emissions.

"Early feedback suggests industry consultants and growers alike are keen to understand detailed modelling on nitrogen plant uptake and loss factors in both irrigated and dry land systems," Jon said.

"Most growers were directly impacted by the global price shocks in nitrogen supply during 2008/2009 where urea prices reached $1200 per tonne, and are acutely aware that these circumstances could arise again.

"We are keen to identify areas in nutrition management where growers can gain their greatest efficiencies to minimise the impacts of price shocks while improving our environmental footprint."

As growers move into a "carbon farming" future, understanding what it involves and the opportunities that may exist for their businesses is imperative.

Jon says that by understanding the Carbon Farming Initiative (CFI) from a national and international perspective, as well as from a production point of view may help growers take advantage of potential future opportunities in the carbon market. The focus of the project will be to provide growers with a better understanding of climate models and how to use and interpret those models to improve input efficiencies resulting in improved economic and environmentally sustainable outcomes.

"My role is primarily to source a wide cross section of research and draw down those elements which are most applicable to the project objectives of the CFI in cotton/grain production systems and associated natural assets," he said.

"In turn, I will collaborate with the other CottonInfo Team Technical Specialists and Regional Development Officers to deliver research material and results to growers and industry by the most effective means possible."

Jon.welsh@cottoninfo.net.au
allan.williams@crdc.com.au
Ian.taylor@crdc.com.au

email us

The industry's project 'Carbon Farming in the Australian Cotton Industry' is funded by the Australian Government Department of Agriculture as part of its Carbon Farming Futures Extension and Outreach Program. Managed by CRDC, the project proposal was formulated through the Cotton Industry joint venture (CRDC, Cotton Australia and Cotton Seed Distributors) as well as CSIRO, The University of New England, NSW Trade and Investment, Queensland University of Technology, Grains Research and Development Corporation and the QLD Alliance for Agriculture and Food Innovation.