2nd Australian Cotton Research Conference

Science securing cotton's future

8-10 September 2015

University of Southern Queensland, Toowoomba

Conference sponsors

Australian Government

Cotton Research and Development Corporation

University of Southern Queensland Australia

Cotton Seed Distributors

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Australian Government

Australian Cotton Research Conference

8-10 September 2015

University of Southern Queensland,
Toowoomba campus

Hosted by **The Association of Australian Cotton Scientists**

Promoting inquiry, networking and collaboration in the Australian cotton research community

Welcome to delegates

Dear Delegates,

On behalf of the organising committee and the AACS I would like to welcome you to Toowoomba for the 2015 Australian Cotton Research Conference. In developing the conference theme "Science Securing Cotton's Future", the committee considered the purpose of the conference and how the diversity of disciplines contributes to the Australian Cotton Industry. Science has played a big part in securing the success of the Australian cotton industry, and the levies from a flourishing industry have ensured wide ranging scientific endeavour. Over the next three days we have a unique chance to present and discuss ideas, and consider what developments are likely to continue securing cotton's future.

I thank our foundation sponsor the Australian Cotton Research & Development Corporation.

I also wish to acknowledge the support provided by Institute for Agriculture and the Environment of the University of Southern Queensland for providing such a great Conference venue. We are also grateful for the support and sponsorship provided by: CSIRO, CSD, Monsanto, QDAF, UWS, NSW DPI, and Australian Government.

Thank you to the committee for all of their efforts in preparing for this conference. In particular I would also like to thank Tonia Grundy (QDAF) and Anna Stephenson & Liz Neary (USQ) who have done a lot of behind the scenes preparation for this event.

Take the opportunity to get involved and make the most of the wide range of topics on offer.

Best wishes,

Paul Grundy (QDAF)
(Conference Committee Chair)

Other committee members:

Kristy Byers (QDAF)
Warren Conaty (CSIRO)
Kristen Knight (Monsanto)
Alison McCarthy (NCEA, USQ)
Ruth Redfern (CRDC)
Brajesh Singh (UWS)
Linda Smith (QDAF)
Gupta Vadakattu (CSIRO)
Duncan Weir (QDAF)

Dear Delegates,

Welcome to our second cotton research conference. Firstly I would like to thank Paul and his team for their efforts in pulling together this important event for our association. Like many successful aspects of the industry we support, the continued need for our own open and frank discussions are important to move ideas forward in addressing the challenges we face. I strongly encourage your engagement in discussions around yours and others science; 'be challenged and challenge'. The conference activities and invited speakers are in place to help this.

Our Association aims to provide a united and representative body to promote and enhance cotton research as a profession; to facilitate communication and collaboration between scientists; and to act as a point of contact between scientists, the Australian cotton industry and with the International Cotton Researchers Association. Please consider membership and attending our Annual General Meeting on the last morning of the conference. We would welcome your involvement and any of your ideas where the association can pursue its objectives. Enjoy the conference.

Yours sincerely,

Mike Bange (AACS Chairperson)

Dear Delegates,

On behalf of the Institute for Agriculture and the Environment I extend a warm welcome to the Toowoomba Campus of the University of Southern Queensland.

We are delighted to be a major sponsor of the 2015 Australian Cotton Research Conference. Our current research collaborations are focused on automated irrigation and fertiliser application systems, new weed control measures, on-farm energy efficiency, new harvest technologies, seasonal productivity forecasting and undertaking studies to develop the cotton industry's workforce.

For over 20 years USQ has been proud to play an important and continuing role in helping to build a national community of research excellence in cotton research. I wish you all the very best for a successful and informative conference.

Kind regards,

Professor Steven Raine
Executive Director, Institute for Agriculture and the Environment
University of Southern Queensland

Program summary

Tuesday 8 September	Wednesday 9 September	Thursday 10 September
7:30 Registration desk open 8:00 Tea & coffee	8:00 Tea & coffee (Registration desk open)	8:00 Tea & coffee (Registration desk open)
8:30 Housekeeping 8:40 AACS Welcome 9:00 Plenary Speaker - Tim Deutsch	8:30 Housekeeping 8:40 Plenary Speakers - Iain Wilson, Braj Singh	8:25 Housekeeping 8:30 AACS AGM 9:20 Plenary Speaker - Gary Fitt
10:00-10:30 Morning tea	10:30-11:00 Morning tea	10:20-10:45 Morning tea
10:30 Session 1 Stream 1: Farming Systems Stream 2: Weed Science	11:00 Session 4 Stream 1: Breeding Stream 2: Nutrition Stream 3: Natural resources	10:45 Session 6 Stream 1: Insect Resistance Stream 2: Irrigation
12:30-1:30 Lunch	1:00-2:00 Lunch	12:45-1:30 Lunch
1:30 Session 2 Stream 1: Farming Systems & Plant Science Stream 2: Entomology Stream 3: Energy	2:00 Session 5 Stream 1: Pathology Stream 2: Breeding Stream 3: Social Science	2:30 Session 7 Stream 1: Fibre science Stream 2: Entomology
3:00-3:30 Afternoon tea	3:30-4:00 Afternoon tea	3:30-4:00 Afternoon tea
3:30 Session3 Stream 1: Plant Science Stream 2: Carbon and climate	4:00 Plenary Student interaction	4:00 Plenary Poster presentations Speaker - Paul Barnett Closing comments
5:00-5:10 short break	5:00-5:10 short break	5:30 close
5:10-6:00 Devil's advocate at USQ refectory	5:10-6:00 Devil's advocate at USQ refectory	
6:15-8:00 Welcome function at USQ refectory	6:00 close	6:45-late Conference Dinner Featuring the band Celestino at Picnic Point

Contents

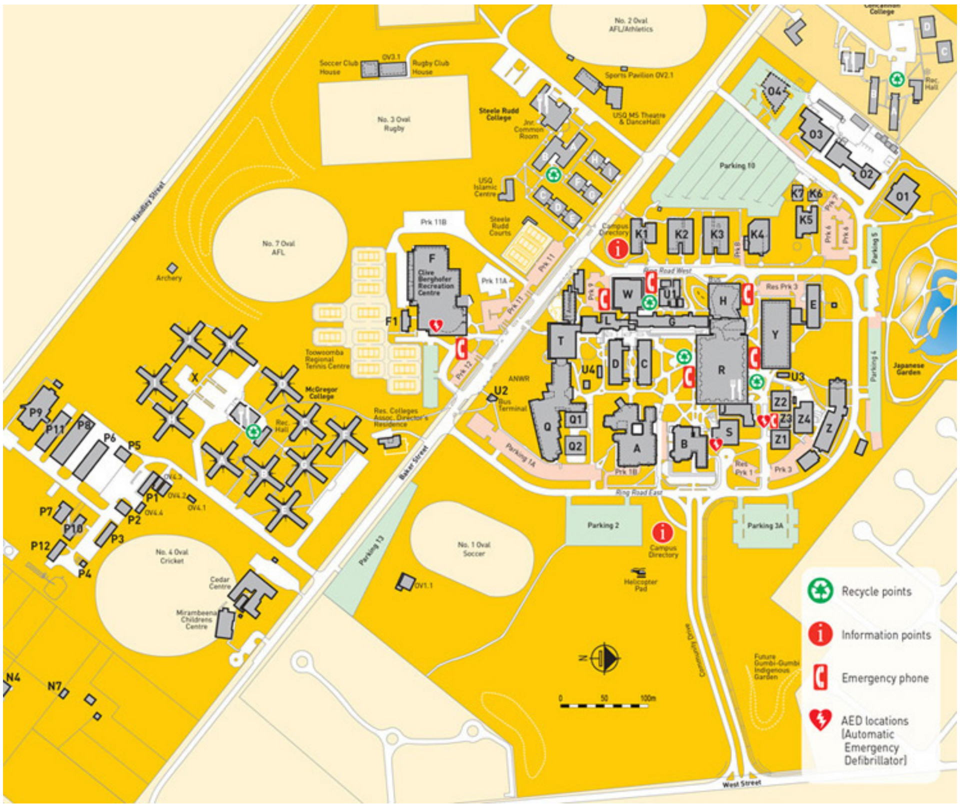
General information

Location

The 2015 Australian Cotton Research Conference is being hosted by the University of Southern Queensland's Institute for Agriculture and the Environment. The USQ Toowoomba campus on West Street is host to over 4000 students studying Business, Communication, Creative Arts, Health, Humanities, Education, Engineering and Spatial Science, Information Technology, Law, and Agricultural Sciences. USQ is recognised for its research in agriculture and climate science applications, regional development, and digital literacy and education.

Conference sessions will be held in the Allison Dickson main lecture theatre (Building H) and the L206 and Q1 rooms on campus. The registration desk is located in the foyer of the Allison Dixon Theatre.

Located about 125 km west of Brisbane, and the gateway to Queensland's Darling Downs, Toowoomba is a vibrant city of more than 100,000 people. With beautiful public gardens, interesting historical sites and museums, and national parks nearby, it is well worth a visit.



A larger campus map is available inside the back cover.

Find out more at www.southernqueenslandcountry.com.au/destinations/toowoomba/

Parking

Free parking for the conference is available in parking area 10.

Transportation

There are no motels within easy strolling distance of the venue.

Several urban routes service the university. Further information on routes and fares is available from Bus Queensland (busqld.com.au), or the Queensland Government's urban busses website (www.qld.gov.au/transport/public/transport/timetables/qconnect/toowoomba/).

Several taxi companies operate in Toowomba. Those with 13 numbers include:

13 3222	Garden City Cabs (Black and White Taxi Service)
13 1008	Taxis Toowoomba
13 2227	Toowoomba Cab Company
13 1924	Yellow Cabs

Conference merchandise

Merchandise is embroidered with the 2015 conference logo.

Caps $17
Surf hats $25 (sizes S-XL)
Polo shirts $25 (Mens sizes S - 5XL | Women's sizes 8 - 24)

Merchandise pre-ordered by 13 August will be available cor collection at the registration desk. Additional postage costs may be applicable for orders after this date.

Conference Wi-Fi

The University of Southern Queensland is making Wi-Fi available for conference attendees. Connect to the "USQ-Guest" (not Visitor) wireless access point and enter the following credentials:

Username: cotton
Password: Welcome123

AGM

The annual general meeting of the Association of Cotton Scientists will be held on Thursday morning in the Allison Dickson lecture theatre. Please come along and support your association.

See the flyer in your conference pack for more details.

Social events

Entry to both of the offical events for the conference is included in a delegate's registration fee (excludes day registrations).

Welcoming Reception

Tuesday 8 September, 6:15-8:00 pm at the USQ refectory.

Come along to catch up with old friends, meet new ones, and relax. Finger foods and drinks are included. The reception will follow on from Tuesday's Devil's Advocate session.

Conference dinner

Thursday 10 September, 6:45 pm-late at Picnic Point.

The conference's concluding celebratory dinner will be a night of fun with great food and drinks, awards (both serious and comical!) and live music from the band Celestino.

Picnic Point Toowoomba is one of Toowoomba's premier locations for events. It is situated approx. 700 metres above sea level and has panoramic views of the range escarpment and the Lockyer Valley.

Dress: Smart casual

Devil's advocate

Devil's advocate sessions encourage delegates as a group to freely discuss points of interest.

The sessions start with some wine. The Devils will take it in turns to express an opinion (possibly counter to their own) on an idea or theory from the day that is controversial or of interest. Delegates are invited to counter this perspective and potentially highlight or challenge some of the ideas and theories generated from talks during that day.

Sessions are managed by an adjudicator who will make sure that no delegate (or devil) talks for too long or too often, and that everybody "plays the ball not the player". At the end of the session the adjudicator summarises the day's events.

Plenary speakers

Timothy A. Deutsch
Global Director, Crop Harvesting Engineering (Retired)
John Deere Global Crop Harvesting Product Development Center, Illinois

Email: tadeutsch@windstream.net

Research and Development of the 7760 Cotton Picker!

Formerly a global director at the John Deere Global Crop Harvesting Product Development Center, Tim Deutsch is currently farming in Newton, Iowa, where he grows corn, soybeans, and hay and raises purebred Charolais cattle.

During his 36-year career, Tim played a significant role in the development of major cotton harvesting equipment for both emerging and existing markets worldwide. His products have included cotton pickers and cotton strippers produced for harvesting needs of cotton growers. He has been instrumental in bringing to market various cotton picker models, many of which have received AE50 awards for outstanding production innovation. He designed advancements into these products including the capability to harvest up to six rows (pickers) and nine rows (strippers) to increase machine productivity; innovative changes to operator stations; and hydraulic and electrical systems that have allowed further productivity and efficiency improvements. Through his guidance, these product and feature developments have resulted in enhanced productivity for the cotton grower and the cotton industry.

Tim Deutsch's vision and understanding of the cotton industry led to one of his major accomplishments, the development and introduction of the state-of-the-art 7760 Cotton Harvester that eliminated the conventional basket and replaced it with a nonstop round module process. This machine increased the productivity of cotton harvesting and reduced seasonal labour requirements, in addition to preserving cotton quality and increasing productivity for transporting, handling, and ginning. From 2001 to 2014, Tim had global engineering product development responsibility for cotton and sugar cane harvesting, as well as combines and front end equipment. He also demonstrated outstanding leadership in developing the next generation of innovative engineering leaders, through his mentoring of product development teams and design engineers.

A 37-year member of ASABE, Tim has contributed to Power and Machinery committees, including PM-23/7/3 Cotton Engineering and PM-50 Cotton Engineering. He has also provided expertise to various safety and lighting standards committees. He has been an active member of the Iowa section and has served on the membership committee and in helping to organize section meetings and tours. He is the recipient of an Iowa Section Young Engineer of the Year award and Engineer of the Year award. Tim was recognised in 2013 as one of John Deere's top innovators as the recipient of 40 priority patents. His other John Deere awards include a John Deere Chairman's Innovation award for 7760 Cotton Picker Project, John Deere Ag & Turf Division Presidents' Award of Excellence, and a John Deere Innovation Recognition - Board of Directors Technology Innovation Field Day award.

Tim Deutsch is the recipient of the ASABE 2015 Mayfield Cotton Engineering Award in recognition of his leadership and engineering innovations toward advancing the cotton industry through development of highly productive cotton harvesting machinery and new technology applications.

Other past professional membership activities include having served as a trustee of the National Cotton Council, and as a member of the Cotton Foundation Research Screening committee. Tim has served on the advisory boards of Iowa State University, Mechanical Engineering and Texas A&M University Cotton Engineering departments.

A native of a farm near Dixon, Illinois, Tim is a graduate of the University of Illinois with a bachelor's degree in Agricultural Engineering.

Dr Gary Fitt
Science Director,
CSIRO Biosecurity Flagship
Ecosciences Precinct
41 Boggo Road, Dutton Park, Brisbane

Email: gary.fitt@csiro.au

From grubs to Ebola: reflections on the ecological underpinning of pest management, resistance management and biosecurity

Gary Fitt obtained his PhD from the University of Sydney and joined CSIRO as an Experimental Scientist in 1977. During a 20 year career at the Australian Cotton Research Institute at Narrabri, NSW, he advanced to the level of Senior Principal Research Scientist before becoming the Chief Executive Officer of the Australian Cotton Cooperative Research Centre (CRC) in 1999, also based at Narrabri. In 2004 he became the Deputy Chief of CSIRO Entomology, and relocated to Brisbane, then Deputy Chief of CSIRO Ecosystem Sciences, the position he held until the establishment of the Biosecurity Flagship in 2012, where he is Science Director.

Gary has extensive research experience in agricultural sustainability with a focus on integrated pest management systems particularly in the development and deployment of transgenic cottons and the resistance management systems required to sustain this technology. His specific expertise is with the ecology, movements and resistance evolution of the Helicoverpa moth, one of the most damaging pests of Australian and global agriculture. In the Biosecurity Flagship he has broadened applications to address the wider biosecurity risks to Australia's people, industries and environment.

He has published more than 100 refereed publications, and contributed to more than 20 books.

He has held many other positions, including Board Director of the Cotton Catchment Communities CRC, Chair of an expert panel for the International Cotton Advisory Committee, Member Advisory Committee for the Australian India Strategic Research Fund and is currently Chair of the Science Advisory Body of the OECD Cooperative Research Program in Sustainable Agriculture. He is an Adjunct Professor at both the University of New England and the University of Sydney.

Dr Iain Wilson

Team Leader | Cotton Disease Markers
CSIRO Agriculture Flagship
Black Mountain Laboratories
Clunies Ross Street, Canberra

Email: iain.wilson@csiro.au

A Molly Bolly's guide to Cotton

Iain Wilson did his PhD on bacterial gene regulation at Melbourne University. His post-doctoral research was at the Department of Plant Biology, Carnegie Institution of Washington Stanford, investigating powdery mildew disease resistance in model plant Arabidopsis. During this period he was one of the first to apply microarray technology to survey gene expression in infected plants. In 1999 he joined Plant Industry and established a microarray facility where he collaborated in a wide range of research.

Iain's initial foray into cotton research was understanding the molecular basis for waterlogging tolerance in 2005. From 2009 onwards his has lead a team developing molecular markers to assist CSIRO cotton breeders enhance disease resistance in commercial varieties to a range of pathogens that are important to the Australian cotton industry.

Prof Brajesh Singh

Centre Director
Global Centre for Land-Based Innovation
Hawkesbury Institute for the Environment, University of Western Sydney
Bourke Street, Richmond

Email: b.singh@uws.edu.au

Integrating soil health and management strategies to enhance farm productivity and sustainability

Brajesh Singh completed his PhD on the interaction of pesticides with soil biology, at Imperial College, London in 2003. Some publications from these studies are listed as the most cited research within the discipline. He joined Macaulay Land Use Research Institute, Aberdeen (UK) in 2002 and was a Principal investigator on two national projects on soil health that led to the development of base-line indicators for soil health evaluation and monitoring at a national level. Braj is a well-known expert in crop-microbial interaction on roots and how this can be harnessed to increase farm productivity and adaptation of crops to extreme events and climate change.

In 2012 he became Theme Leader of Soil Biology and Genomics at the prestigious Hawkesbury Institute for the Environment. He has led/ co-led a number of national and international initiatives since then including the establishment of the Global Centre for Land-Based Innovation, Global Soil Biodiversity Steering Committee and the Global Soil Biodiversity Atlas. He serves on steering committees of two EU initiatives including one on pesticide impact of soil health and dryland ecosystems, currently serves on the editorial boards of six international journals, including as a senior editor, and holds honorary positions in the UK and China.

Braj's research is at the forefront of discovering the mechanisms and consequences of land use change and management practices on soil health and productivity. In particular, his research is providing key information about the link between soil health and ecosystem functions, including farm productivity, nutrient cycling, soil fertility and greenhouse gas emissions.

Paul Barnett

Managing Director
Impact Freelancer

Email: paul.b@rnett.co

Innovation pathways; from R&D to commercialisation

Paul is a freelance research management consultant providing advice to the innovation sector on strategy development, improved execution of plans and acceleration in delivery of impacts. Paul has also held senior positions in CSIRO where he was responsible for areas that included strategy development, partnering, knowledge brokering and business models. In Paul's career he has performed in a diverse set of roles including in government, corporate commercial and start-ups.

In 2014 for the Cotton Research and Development Corporation, Paul designed and delivered a creative process that identified 24 new concepts with the potential to add $4bn to the annual gross value of Australian cotton production. The project drew on strengths of the cotton industry while integrating a new set of knowledge and expertise that could help address the most important trends and challenges.

The innovation sector has changed. There is a trend towards less funding for research and an expectation from government, industry and communities that research is linked with net positive impacts for society, economy and environment. Paul will share his experience and thinking on how our ability to plan and clearly articulate pathways to our impacts is now critical to how we do research.

Full program - Tuesday 8 September

7:00 Registration desk open — Allison Dickson Foyer

8:00 Coffee/Tea — **Allison Dickson Foyer**

8:30 Housekeeping/Conference Purpose (Paul Grundy, AACS Conference Chair) — **Allison Dickson Theatre**

8:40 AACS Welcome Dr Michael Bange AACS President and Professor Steven Raine, Executive Director, Institute for Agriculture and the Environment, USQ

9:00 Plenary Session (Chair: Assoc. Prof. Craig Baillie USQ)

Mr Tim Deutsch, John Deere USA *Research and Development of the 7760 Cotton Picker!*

10:00-10:30 Morning tea — **Allison Dickson Foyer**

SESSION 1

Stream 1: Plant, Soil & Systems (Chair: Diogenes Antille) — **Allison Dickson**

10:30	Soil compaction and the John Deere 7760: side by side comparison of a controlled traffic and standard picker	John McLean Bennett
10:45	How much energy is required to overcome the soil compaction caused by the John Deere 7760 and what are the implications on yield?	Troy Jensen
11:00	Defoliation timing and moisture draw down as end of season management to limit soil compaction at pick	Stirling Roberton
11:15	Irrigation induced runoff and carbon balance in a cotton farming system	Gunasekhar Nachimuthu
11:30	Identifying microbial modulators of soil carbon storage under crop rotations in Cotton producing agro-systems	Pankaj Trivedi
11:45	Long-term changes in soil chemical properties of a Vertosol irrigated with tertiary treated sewage effluent	Nilantha Hulugalle
12:00	Composts addition may improve biology in cotton soils	Gupta V.V.S.R
12:15	Effect of sodicity on mycorrhizal colonisation of cotton (*Gossypium hirsutum* L.)	Samieh Eskandari

Stream 2: Weed Science (Chair: Ian Taylor) — **Room Q1**

10:30	Discrimination of Herbicide Drift Damage in Cotton Crops under Varying Stages of Growth and Chemical Dosages using Hyperspectral Sensor	Armando Apan
10:45	BYGUM – a new tool for BarnYard Grass Understanding and Management	David Thornby
11:00	Growth and development of three key summer grasses in Australian cotton systems	Michelle Keenan
11:15	Genetics of glyphosate resistance	James Hereward
11:30	Can patches of glyphosate-resistant *Echinochloa colona* be eradicated?	Jeff Werth
11:45	15 years of Roundup Ready® cotton: Weed species shift on Australian cotton farms	Meredith Conaty
12:00	Is Australia ready for triple gene herbicide stack technology?	Sudheesh Manalil
12:15	Discussion	

12:30-1:30 Lunch — **Allison Dickson Foyer**

SESSION 2

Stream 1: Plant, Soil & Systems (Chair:Warren Conaty) — **Allison Dickson**

1:30	Re-evaluating mepiquat chloride use in Bollgard II cotton	Sandra Williams
1:45	Winter sowing for more reliable boll filling in Central Queensland	Paul Grundy
2:00	Australian Cotton Systems in a 'Climate of Change'	Michael Bange
2:15	Climate change impact on crop productivity: legacy effect through plant-soil feedback	Yui Osanai
2:30	Chloride Mass Balance models are an economic method of assessing the effects of cotton farming systems on deep drainage in Vertosols	Tim Weaver
2:45	Thin oxodegradable film and profile soil water under cotton	Michael Braunack
2:50	Irrigation induced deep drainage losses of soil carbon in a cotton farming system of Australia	Mark Watkins

Stream 2: Applied Entomology (Chair: Kristen Knight) **Room L206**

1:30	Biology of Minute Two Spotted Ladybird	Jamie Hopkinson
1:45	IPM reduces risks from Silverleaf Whitefly	Lewis Wilson
2:00	Natural Mortality Helps to Mediate Silver Leaf Whitefly Development	Tanya Smith
2:15	The "Zappa" trap: A potential Light trapping system for monitoring and controlling *Helicoverpa* spp. and sucking pests in cotton crops	Alison Young
2:30	UAVs to detect pest damage in broad acre crops: Insect Damage in Sorghum and implications for cotton	Eduard Puig
2:45	Establishing Southern Cotton – Thrips threshold validation	Sandra McDougall

Stream 3: Energy (Chair: Jon Welsh) **Room Q1**

1:30	The feasibility of alternative energy sources in the Australian cotton industry	Gary Sandell
1:45	Economic feasibility of using solar energy to reduce diesel consumption in off grid cotton irrigation bores	John Hill
2:00	An overview of energy auditing lessons from recent projects in the Australian cotton industry	Gary Sandell
2:15	A Pilot Study - Cotton Gin trash to Bioethanol	Shane McIntosh
2:30	Cotton Gin waste Biofuel for Diesel Engine	Saddam Al-Iwayzy
2:45	Combustion of Cotton Seed Biodiesel in Diesel Engine	Saddam Al-Iwayzy

3:00-3:30 Afternoon tea — Allison Dickson Foyer

SESSION 3

Stream 1: Plant Science (Chair: Warwick Stiller) **Allison Dickson**

3:30	Canopy Temperature during Cotton (*Gossypium hirsutum* L.) Fibre Development: Associations with Fibre Quality	Onoriode Coast
3:45	Understanding the photosynthetic biochemistry that underpins cotton photosynthesis under future climate extremes.	Robert Sharwood
4:00	Growth and yield dynamics of different canopy layers of cotton in response to soil waterlogging	Najeeb Ullah
4:15	What they do while you're sleeping: Nocturnal transpiration in cotton	Warren Conaty
4:30	Investigating the Mechanisms of Heat and Water Stress Resistance of Cotton	Demi Gamble
4:45	The integrated effects of elevated CO_2 and temperature on early-stage cotton growth and physiology	K. Broughton

Stream 2: Carbon & Climate (Chair: Mark Howden) **Room L206**

3:30	Intro Talk for Session	Mark Howden
3:45	The impact of climate change on cotton in Australia	Allyson Williams
4:00	Cradle to export-port greenhouse gas assessment of cotton production in north-west New South Wales	Paul (Mehdi) Hedayati
4:15	Positioning Australia for its Farming Future	David Lamb
4:30	Determination of Emission Factors for Estimating Nitrous Oxide Emissions from Australia's Cotton Industry	Clemens Scheer
4:45	Sustainability reporting for agriculture – an overview of available reporting metrics on emissions	Richard Eckard
5:00	*Short break*	

5:10–6:00 Devil's advocate (Discussion with a glass of wine) **Student Refectory**

6:15-8:00 Welcome Reception — Student Refectory

Paul Grundy & Bruce Finney, CRDC

Nibbles and drinks

Full program - Wednesday 9 September

8:00 Coffee/Tea, Registration desk open — **Allison Dickson Foyer**

8:30 Housekeeping (Paul Grundy, Conference Chair) — **Allison Dickson**

8:40 Plenary Session (Chair: Dr Gupta Vadakattu, CSIRO)

Dr Iain Wilson, CSIRO — *A Molly Bolly's guide to Cotton*

Professor Braj Singh, UWS — *Integrating soil health and management strategies to enhance farm productivity and sustainability*

10:30-11:00 Morning tea — **Allison Dickson Foyer**

SESSION 4

Stream 1: Cotton Breeding (Chair: James Quinn)		**Allison Dickson**
11:00	Can breeding solve all our problems?	Warwick Stiller
11:15	The yield potential of cotton (*Gossypium hirsutum* L)	Greg Constable
11:30	Role of genotype × management synergies for cotton productivity	Shiming Liu
11:45	Sources of host plant resistance to thrips in cotton	Carlos Trapero
12:00	Development of an automated cotton plot picker for small scale trials	Max Barnes
12:15	Usefulness of nondestructive technologies for phenotyping in breeding high yielding cotton	Shiming Liu
12:30	Genome-Wide Association Studies: Hunting for Marker-Trait Associations in Plants	Washy Gapare
12:45	Genomics enabled fast forward genetics in cotton	Qian-Hao Zhu
Stream 2: Nutrition (Chair: Steve Yeates)		**Room L206**
11:00	In crop nutrient management, "Are we there yet"?	Chris Dowling
11:15	Application of Solvita test kit methodology to estimate soil N mineralisation	Francois Visser
11:30	Can optimising nitrogen fertiliser rate mitigate nitrous oxide loss from flood-irrigated cotton paddocks?	Graeme Schwenke
11:45	Response of irrigated cotton to applied nitrogen	John Smith
12:00	Optimising Water & Nitrogen Fertiliser Management in Australian Cotton Production Systems	Jon Baird
12:15	Opportunities for managing nutrient efficiency in cotton production	Mark Pawsey
12:30	Fewer control plots for rate response trials	Bruce McCorkell
12:45	Cotton root systems and recovery of applied P and K fertilisers	David Lester
Stream 3: Natural Resource Management (Chair: Jane Trindall)		**Room Q1**
11:00	Annual entitlement for the Condamine floodplain irrigators - is it really working?	Elad Dafny
11:10	Recharge processes at the St George Irrigation Area	Elad Dafny
11:20	The decline and rise of groundwater levels in the Maules Creek Catchment (Upper Namoi): implications for water resource management	Calvin Li
11:35	Detecting connectivity between an overlying aquifer and a coal seam gas resource using methane isotopes, dissolved organic carbon and tritium.	Charlotte Iverach
11:50	Quantifying the Potential Impact of Abandoned Exploration Wells on Groundwater	Mark Hocking
12:05	Impulse Response Groundwater Model of Western Border Rivers Catchment	Mukhlis Mah
12:10	Cotton soil salinity and nitrate profiles over 20 years of irrigation	Alice Melland
12:15	How many trees are enough? Using vegetation to combat deep drainage and seepage	Andrew Biggs
12:30	Carbon sequestration in riparian zones on cotton farms	Rhiannon Smith
12:45	Governing Uncertainty: the cotton industry's responses to resource uncertainty	Olive Hood

1:00-2:00 Lunch — **Allison Dickson Foyer**

SESSION 5

Stream 1: Pathology (Chair: Lily Pereg)		**Allison Dickson**
2:00	The importance of cotton disease surveys in Queensland for monitoring endemic diseases and detecting new pathogens and pests	Linda Smith
2:15	What influences fungal communities in cotton soils	Gupta V.V.S.R.
2:30	NSW DPI Biosecurity Update on Defoliating strain of *Verticillium dahliae* 1A	Karen Kirkby
2:45	Efficacy of fungicide seed treatments on reducing seedling mortality in cotton in Australia	Peter Lonergan
2:55	Mycorrhizal status in cotton following rice	Joe Moore
3:10	Cotton leafroll dwarf virus detected in Thailand and Timor Leste	Murray Sharman
3:15	Nematodes of the Gwydir and Namoi	Oliver Knox
Stream 2: Social Science & People (Chair: Sandra Williams)		**Room Q1**
2:00	Is it just for the money? What are the motivations of an Australian Cotton Grower	Geraldine Wunsch
2:15	Integrated economic, environmental and social performance reporting of Australian Grown Cotton	Guy Roth
2:30	Adaptive learning pathways for cotton irrigation science	Jane Trindall
2:45	CottonInfo Extending Research	Lance Pendergast
3:00	Developing Education Capacity in Agriculture	Trudy Staines
3:15	Characteristics of technologies that are impacting adoption: Twelve reasons why your research could be ignored	Warwick Waters
Stream 3: Cotton Breeding – Fibre (Chair: Stuart Gordon)		**Room L206**
2:00	A remarkable secondary cell wall underpins cotton fibres as a textile. How is production of this wall regulated, and what can we use this knowledge for?	Colleen MacMillan
2:15	Using biotechnology to increase the utility of cotton fibre	Filomena Pettolino
2:30	Developing breeding strategies to maintain yield while improving fibre quality	Jenny Clement
2:45	Can a seed trait reduce ginning power requirements?	Scott Barnes
3:00	Effects of variety, growth location, scouring treatments, and storage conditions on dye uptake by cotton fabric	Genevieve Crowle
3:15	Discussion	

3:30-4:00 Afternoon tea — Allison Dickson Foyer

Plenary (Open session)		**Allison Dickson**
4:30	The ecosystem service of biological pest control: Valuing native vegetation	Nancy Schellhorn
4:00	Understanding the plant and the humans that manage it underpins solutions to crop production challenges and environmental impacts	Stephen Yeates

5:00 Short break

5:10–6:00 Devil's advocate (Discussion with a glass of wine) — **Student Refectory**

6:00 Close

Full program - Thursday 10 September

8:00	**COFFEE/TEA**	**ALLISON DICKSON FOYER**
8:25	**Housekeeping (Paul Grundy, Conference Chair)**	**Allison Dickson**
8:30	**AGM of the Association of Australian Cotton Scientists**	
9:30	**Plenary Session (Chair: Dr Geoff Baker, CSIRO)**	
	Dr Gary Fitt, CSIRO *From grubs to Ebola: reflections on the ecological underpinning of pest management, resistance management and biosecurity*	
10:20-10:45	**MORNING TEA**	**ALLISON DICKSON FOYER**

SESSION 6

Stream 1: Entomology- resistance (Chair: Gary Fitt) — **Allison Dickson**

10:45	Oviposition patterns of moths and parasitoids across a cotton-grain landscape: Linking land cover and seasonality	Cate Paull
11:00	From models to management: simulating Helicoverpa movement behaviour in complex landscapes and the implications for Bt resistance	Hazel Parry
11:15	Contribution of *Helicoverpa* spp. to the Bollgard II/Bollgard 3 system across Australian cotton growing regions	Kristen Knight
11:30	Establishing the critical exposure period required for developing tolerance in *Helicoverpa punctigera* to Bt toxin	Sharna Holman
11:45	The response of Helicoverpa to Bt toxins and refuges: the role of tolerance and the loss of efficacy	Mary Whitehouse
12:00	Characteristics of indoxacarb resistance in Australian populations of *Helicoverpa armigera*	Lisa Bird
12:15	Silverleaf whitefly resistance management	Jamie Hopkinson
12:20	Investigation of target site resistance mechanisms in sixteen Australian cultures of *Tetranychus urticae* (Tetranychidae: Acari)	Lauren Woolley
12:35	Valuing the contribution of the resistance management strategy to the cotton industry	Russell Gorddard

Stream 2: Irrigation (Chair: Guy Roth) — **Room Q1**

10:45	Image analysis and artificial intelligence-based approach for soil-water and nitrogen status estimation Alison McCarthy 11:00 A new way to estimate and monitor the water content of soil	Brett Robinson
11:15	Benchmarking and improving nitrogen use efficiency using IrriSAT – potential applications	John Hornbuckle
11:30	Smart automated furrow irrigation of cotton: A field demonstration	Jasim Uddin
11:45	The implications of gilgai on electromagnetic induction measurements with EM38 in the Borders rivers region	Mark Crawford
12:00	The value of measured plant water status versus inferred plant water status; canopy temperature versus ET.	James Mahan
12:15	Cotton Irrigation using Dynamic Deficits: identifying the value using OZCOT	David Johnston
12:25	IrriSAT – weather based scheduling and benchmarking technology	Robert Hoogers
12:30	A comparison of conventional and controlled traffic irrigated cotton water use efficiency, gross margins, yield and quality in Warren, NSW, Australia	Tim Bartimote
12:35	Discussion	

12:45–1:30 Lunch — Allison Dickson Foyer

SESSION 7

Steam 1: Fibre Science & Processing (Chair: Michael Bange) — **Allison Dickson**

1:30	Defining and Applying the Glass Transition Temperature (Tg) of Cotton	Chantal Denham
1:45	Cotton blended yarns as strain sensors for electronic textiles	Juan Xie
2:00	The Effect of Seed Cotton Moisture during Harvesting on Fibre Quality	Rene van der Sluijs
2:15	Management for premium cotton fibre	Robert Long
2:30	A Self-Adjusting Seed Finger System to Improve Gin Turn-Out	Stuart Gordon
2:45	Reducing the Scouring Requirement of Australian Cotton	Katherin Birrer

Stream 2: Entomology (Chair: Lewis Wilson) — **Room Q1**

1:30	Do Helicoverpa populations reflect the landscapes they are caught within?	Geoff Baker
1:45	Green mirids: Multiple host-use patterns and population connectivity in native and agricultural habitats.	Justin Cappadonna
2:00	Gene flow and host use in the Green Vegetable Bug, *Nezara viridula*	Dean Brookes
2:15	How aphids plug up plants: the role of callose in plant defences	Simone Heimoana
2:30	Discovery of novel biopesticides and semiochemicals for arthropod pest management in Australian cotton	Richard Spooner-hart
2:45	Effects of seedling stage defoliation on cotton growth and yield	Jianhua Mo

3:00-3:30 Afternoon tea — Allison Dickson Foyer

3:30 Poster Session presentations — **Allison Dickson**

Speakers: Various

(Chairs Mr Allan Williams & Mr Duncan Weir)

4:30 Plenary Session (Chair Mr Allan Williams)

Mr Paul Barnett (Impact Freelancer) I*nnovation pathways; from R&D to commercialisation*

5:30 Close

6:45 - Late

Conference & AACS Awards Dinner
Featuring band Celestino

Picnic Point Restaurant,
164 Tourist Rd, Toowoomba

1. Plant, Soil & Systems

Soil compaction and the John Deere 7760: side by side comparison of a controlled traffic and standard picker

J. McL. Bennett, D. Antille and T. Jensen
National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, QLD

With the revolution of on board module pickers has come a substantial increase in machine weight, driving up the stress applied to the soil at each wheel during traffic. This presentation will briefly describe the impact of the John Deere (JD) 7760 on a range of Australian cotton soils, highlighting the relationship between soil moisture and compaction in fine textured soils. More importantly, it will report on a side by side comparison of a standard JD7760 operating on a 2m track width and dual wheeled front axle, and a controlled traffic farming (CTF) JD7760 operating on a 3 m track width and inline single wheel front and rear axle. A field that had previously not been subject to traffic, except laser levelling, was prepared in a 1.0 m (40") and 1.5 m (60") row spacing system at Auscott, Warren. These were replicated throughout field in 12 m multiples. The CTF picker operated on four heads maintaining a 6 m frontage (to match the standard JD7760), allowing minimal modification to planting and cultivation systems. Soil bulk density, soil strength, yield and gross margin were monitored for 2 subsequent back to back cotton seasons. Results suggest that the CTF system is superior in terms of the soil resource, but also potentially in terms of bottom line. Importantly, the CTF system was conducted in a sub-optimal frontage and thus has good potential to provide further benefits. Stepwise farming system progression to a true CTF system is presented.

How much energy is required to overcome the soil compaction caused by the John Deere 7760 and what are the implications on yield?

T.A, Jensen, J. McL. Bennett and D. Antille
National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, QLD

Based on the trial layout initiated in 2012 where there were 3 replicates of 3 different tillage treatments (minimised treatment pupae bust (L), treatment comparable with standard for basket picker (M), and heavy tillage considered necessary due to weight of JD7760 (H)), the data was collected for the 2014 pick.

There was a slight increase in yield as the tillage intensity increased from 'L' – 'H' (3200-3650 kg/ha), or about a 14 % yield increase. This yield increase however, was not commensurate with investment in fuel in the preceding tillage operations, with approximately 2½ times more fuel being used to produce this additional yield (L – H) and twice as much fuel being used in the 'L' – 'M' comparison. If we look at a productivity measure (kg of cotton produced / litre of fuel burnt in preceding tillage / hectare of land), it is evident that the light tillage treatment (L) is 2½ times more productive than the heavy (H) tillage treatment. A word of caution, this is only one years data and the benefits of the intensive tillage may become evident over time and the impediments due to the minimal till may compound with time

Defoliation timing and moisture draw down as end of season management to limit soil compaction at pick

S. Roberton and J. McL. Bennett
National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, QLD

Given that more than eighty percent of Australia's cotton crop is picked by the John Deere 7760, the concern for soil compaction has rapidly become a hot topic in the cotton industry since the machine's inception in 2008. Weighing in at more than twice that of the previous basket picker, methods to manage impact on the soil resource are required. The 2013/14 and 2014/15 seasons had unseasonal wet finishes in some regions, which caused a tension for farmers in terms of managing pick timing: 1) defoliate prior to rain and risk a wet pick, or 2) defoliate post rain and wait for the field to become trafficable. This project set out to investigate the merit of soil moisture draw down from undefoliated cotton as a management method for compaction during wet season finishes. Existing data, and a field experiment located near Aubigny, Qld, were used to investigate the ability for undefoliated cotton plants to dry out the soil moisture profile. The field experiment imposed a defoliant black out via covering adequate green cotton with module tarps during defoliation processes, allowing replicates of defoliated and undefoliated cotton in the same paddock. Unseasonal rain and cold weather limited the field data, but this was reinforced with existing draw down information. Cotton water use at maturity was then modelled using this data and subsequent soil profile moisture contents compared to optimum moisture contents for soil compaction to weigh up the merit of the approach in managing soil compaction.

Irrigation induced runoff and carbon balance in a cotton farming system

G. Nachimuthu[1], N. Hulugalle[2], L. Finlay[1] and M. Watkins[1]

[1]NSW Department of Primary Industries, Australian Cotton Research Institute, Narrabri, NSW
[2]Fenner School for the Environment and Society, Australian National University, Acton, ACT

Soil health and productivity of cotton farming systems can be improved by better managing the soil carbon. In Australia, there is a lack of scientific data on carbon losses through soil erosion and runoff in irrigated cotton (*Gossypium hirsutum* L.) farming systems. A field investigation was conducted near Narrabri, New South Wales, to determine the annual amounts of carbon and sediment enrichment and losses in irrigated cotton farming systems. The experimental treatments included cotton monoculture and cotton-wheat or corn rotations with maximum or minimum tillage. During the 2014–15 cotton crop (six irrigation events) runoff from the plots with and without corn during the previous season was 26% and 35% of applied irrigation water, respectively. Cotton growth and yield after corn was greater than that in the control plots and lower runoff in treatments sown after corn may be attributed to higher water use. Total Organic Carbon (TOC) enrichment by irrigation water ranged from 6 to 13 kg TOC/ha/irrigation with a cumulative total of 64 kg TOC/ha over six irrigation events. Sediment enrichment ranged from 19 to 149 kg/ha/irrigation with a cumulative gain of 585 kg/ha over six irrigation events. Cumulative TOC losses in irrigation induced runoff events ranged from 19 kg TOC/ha to 28 kg TOC/ha over six irrigations. Similarly, the sediment losses ranged from 93 to 243 kg/ha. The DOC (dissolved organic carbon) was of the order of 86 to 93% of TOC.

Identifying microbial modulators of soil carbon storage under crop rotations in Cotton producing agro-systems

Pankaj Trivedi, Ian J Rochester, Jizhong Zhou, Ian C Anderson and Brajesh K Singh

Hawkesbury Institute for the Environment, University of Western Sydney, Penrith South, NSW; CSIRO Agriculture, Narrabri, NSW; Australia Institute for Environmental Genomics and Department of Botany and Microbiology, The University of Oklahoma, Norman, OK, USA

Understanding the influence of long-term crop management practices on the soil microbial community is critical for linking soil microbial flora with ecosystem processes such as those involved in soil carbon cycling. In this study, pyrosequencing and a functional gene array were used to investigate the shifts in microbial composition and functional gene structure in a medium clay soil subjected to various cropping regimes in long term "Cropping System Experiment" at Narrabri, NSW. Based on pyrosequencing data, we observed significant shifts in microbial community composition among different cropping treatments. Functional gene array-based analysis revealed that crop rotation practices significantly changed the structure and abundance of genes involved in C degradation and N cycling. Significant correlations were found among functional gene structure and the activity of enzymes involved in C degradation. We further integrated physical, chemical, and molecular techniques (qPCR) to assess relationships between soil C, microbial derived enzymes and soil bacterial community structure at the soil micro-environmental scale (e.g. within different aggregate-size fractions). Our results showed that each soil microenvironment supported a different amount of soil C and a distinct bacterial community. Microbial and soil C responses to cropping regimes declined with smaller soil particle sizes and especially with silt and clay micro-aggregates which exhibit high buffering capacity protecting microbial cells and soil C against environmental changes even after 12 years under different crop types. Our results suggest microorganisms are important modulators of soil C dynamics and the impact of crop rotations on soil C turnover varies between different sized soil aggregates.

Long-term changes in soil chemical properties of a Vertosol irrigated with tertiary treated sewage effluent

N.R. Hulugalle, T.B. Weaver, L.A. Finlay, V. Heimoana

NSW Department of Primary Industries, Fenner School for the Environment and Society, Australian National University

Treated sewage effluent is a potential source of irrigation water, although, long-term studies in Vertosols are sparse. The objective of this study was to assess long-term changes in soil properties in a grey Vertosol under conservation farming and irrigated with tertiary treated sewage effluent. The soil at the experimental site, which was located on a cotton farm near Narrabri, NSW, was a self-mulching, grey Vertosol. From 2000 to 2002 the experimental treatments were gypsum application (2.5 t/ha) and an untreated control. From 2003 until 2013 the gypsum-treated plots were subjected to a single pass with a combined aer-way cultivator and sweeps before sowing cotton whereas the wheat stubble in the control was undisturbed. The two management systems had little or no effect on the soil properties measured, whereas the combination of irrigation water quality and seasonal variations in weather did. Cultivation with an aer-way cultivator did not degrade soil quality, and

may be an option to control herbicide-resistant weeds. Irrigation water was alkaline, moderately saline and potentially highly dispersive. Irrigation with treated sewage effluent resulted in sodification, alkalinisation, and accumulation in the surface 0.10 m of Ca and K. Drought resulted in salt accumulation that was alleviated by a subsequent period of heavy rainfall and flooding. This was accompanied by a fall in exchangeable Mg. Salinity and exchangeable Mg were influenced by both seasonal rainfall and effluent quality, whereas ESP and exchangeable K changes were only affected by the effluent. SOC stocks declined until the flooding events but increased thereafter.

Composts addition may improve biology in cotton soils

Gupta V.V.S.R., Kroker, S.K., Hicks, M., Nidumolu, B. and Weir, D.
CSIRO Agriculture Flagship and QDAF

Composts can provide a source of organic carbon and nutrients for soil biota and increase soil fertility as well as provide other biological and structural benefits hence compost addition to cotton soils is seen as a way to improve cotton soil biological health and fertility. In a six month incubation experiment we analysed the changes in microbial populations and activities related to C and N cycling following the application of feedlot, poultry manure and gin trash compost materials. A significant variation in the chemical composition, e.g. major nutrients and trace elements, was found between the three compost products. The feedlot compost generally contained higher levels of dissolved organic carbon, total nitrogen and bicarbonate extractable phosphorus whereas the Gin trash compost had lower carbon and nutrient concentrations. The effect of compost addition @ 5 and 10t/ha generally increased microbial activity but the effect was only evident during the first two weeks of incubation. Composts effects on the abundance of total bacteria (16S), nitrifying (amoA), nitrogen fixing (nifH) and denitrifying bacteria (nosZ) and total fungi (ITS gene) varied between different composts. The addition of feedlot and poultry compost material significantly increased the levels of dissolved organic carbon (DOC) and nitrogen (DON) in soil compared to that in control soils while 'Gin trash' compost had no effect. These differences reflected in the microbial catabolic diversity changes in the compost amended soils. Therefore, chemical analysis of the compost material before application is recommended to more fully consider its' potential benefits.

Effect of sodicity on mycorrhizal colonisation of cotton (*Gossypium hirsutum* L.)

Eskandari, S., C.N. Guppy, O.G.G. Knox, D. Backhouse and R.E. Haling
University of New England

More than half of soils used for growing cotton are affected by sodicity. Cotton is reputedly a mycorrhizal dependent plant, but physical and chemical constraints of sodic soils might affect mycorrhizal colonisation of cotton. We investigated the development of vesicular-arbuscular mycorrhizas on cotton in two low-phosphorus, sodic soils (A and B with ESP of 21 and 20, respectively) in two glasshouse experiments for 6 weeks. Initially, cotton plants were grown with a commercial inoculum. In the second experiment, cotton was grown in the presence of a root based inoculum source, which was comprised of soil and highly colonised (91%) maize (*Zea mays* L.) root placed 3 cm below the seeds. Control treatments included an autoclaved non-sodic vertosols and sodic soils to which either no inoculum or autoclaved soil and maize root was added. No mycorrhizal cotton roots were detected either with commercial inoculum or the sterilised soil and maize root in soils A and B after 6 weeks. In the second experiment, percentage of root length colonized in control sodic soil A and B was 1% and 0%, respectively, which increased with inoculum to 18 % and 25% in soil A and B, respectively. The inoclulated autoclaved non-sodic soil had 37% colonisation, which was significantly higher than in sodic soil A. Zn uptake improved in inoculated cotton plants in sodic soil B and plant Na accumulation decreased slightly (P=0.06) by increasing colonisation in soil A. No significant enhancement was observed in P uptake of inoculated cotton plants.

2. Weed Science

Discrimination of Herbicide Drift Damage in Cotton Crops under Varying Stages of Growth and Chemical Dosages using Hyperspectral Sensor

Luz Angelica Suarez Cadavid, **Armando Apan**, Jeff Werth, Tim Neal, Troy Jensen

International Centre for Applied Climate Science; School of Civil Engineering and Sciences, University of Southern Queensland; Agri-Science Queensland, Department of Agriculture and Fisheries; National Centre for Engineering in Agriculture; PrecisionAgriculture.com.au

Herbicide drift on cotton crops can cause significant damage and yield reduction. The impact of drift depends on the amount of chemical reaching the crop (dosage) and the growing stage when the incident occurred (stage). Assessment of herbicide damage is difficult to achieve using traditional methods. In this study, we test the reliability of remote sensing techniques and particularly hyperspectral sensors in the discrimination of drift damage under varying stages and dosages. A field trial was conducted with nil, 5% and 50% of the fallow label rate of 2,4-D, which was applied to cotton at 4, 8 and 12 nodes. Then hyperspectral data was collected during the growing season at 4 different times after each application. Preliminary results show that Partial Least Square (PLS) Regression accurately ($R2 > 93\%$ and $0.44 < RMSEP < 0.68$) predicted drift damage on cotton at different dosages. Results suggest a higher uniformity of damage when the application occurred at middle-late stage than in early stage. When any chemical was applied, the PLS model required less components to predict stage of the crop. The accuracy of these predictions does not depend on the time when data was collected which was between two to forty days. More work is being done to evaluate the utility of multispectral satellite imagery and LiDAR 3D scanning technology in the assessment of herbicide drift damage to cotton crops.

BYGUM – a new tool for BarnYard Grass Understanding and Management

David Thornby[1] Jeff Werth[2]

[1]Innokas Intellectual Services [2]Department of Agriculture and Fisheries

Weed management has become increasingly challenging for cotton growers in Australia in the last decade. Glyphosate, the cornerstone of weed management in the industry, is waning in effectiveness as a result of the evolution of resistance in several species. One of these, awnless barnyard grass, is very common in Australian cotton fields, and is a prime example of the new difficulties facing growers in choosing effective and affordable management strategies. RIM (Ryegrass Integrated Management) is a computer-based decision support tool developed for the south-western Australian grains industry. It is commonly used there as a tool for grower engagement in weed management thinking and strategy development. We used RIM as the basis for a new tool that can fulfil the same types of functions for subtropical Australian cotton-grains farming systems. The new tool, BYGUM, provides growers with a robust means to evaluate five-year rotations including testing the economic value of fallows and fallow weed management, winter and summer cropping, cover crops, tillage, different herbicide options, herbicide resistance management, and more. The new model includes several northern-region-specific enhancements: winter and summer fallows, subtropical crop choices, barnyard grass seed bank, competition, and ecology parameters, and more freedom in weed control applications. We anticipate that BYGUM will become a key tool for teaching and driving the changes that will be needed to maintain sound weed management in cotton in the near future.

Growth and development of three key summer grasses in Australian cotton systems

Michelle D. Keenan[1], Jeff Werth[1], David Thornby[2] and Bhagirath S. Chauhan[3]

[1] Department of Agriculture and Fisheries, Leslie Research Centre, Toowoomba QLD
[2] Innokas Intellectual Services, Upper Coomera QLD
[3] Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Toowoomba QLD

Awnless barnyard grass, feathertop Rhodes grass, and windmill grass are important weeds in Australian cotton systems. In October 2014, an experiment was established to investigate the phenological plasticity of these species. Seed of these species were planted in a glasshouse every four weeks and each cohort grown for 6 months. A developmental response to day length was observed in barnyard grass but not in the other species. Days to maturity increased with each planting for feathertop Rhodes and windmill grass for the first six cohorts. Barnyard grass showed a similar pattern in growth for seeds planted from October to December with an increase in the onset of maturity from 51 to 58 days. However, the onset of maturity for cohorts planted between January and March decreased to between 50 and 52 days. All species had a decrease in the total number of panicles produced from the first four plantings. Feathertop Rhodes grass planted in October produced 41 panicles compared to those planted at the end of December producing 30 panicles, barnyard grass had a decrease from 99 to 47 panicles and windmill grass 37 to 15 panicles on average. By comparing the development of

these key weed species over 12 months, detailed information on the phenological plasticity of these species will be obtained. This information will contribute to more informed management decisions by improving our understanding of appropriate weed control timings or herbicide rates depending on weed emergence and development.

Genetics of glyphosate resistance

James Hereward

The University of Queensland

I will outline my work to date on the evolution of glyphosate resistance in barnyard grass (*Echinochloa colona*) and fleabane (*Conyza bonariensis*) and the genetics of resistance mechanisms in these two weeds. Some resistant barnyard grass lines have the target site (EPSPS gene) resistance mutations, but these appear heterozygous (barnyard grass is hexaploid in Australia). Other lines that are glyphosate resistant do not have the target site gene and therefore must have "Non-target site" resistance mechanisms. A transcriptomics approach has identified numerous genes that may be part involved in non-target sit resistance in barnyard grass, and more genes are differentially expressed in strongly resistant lines than those with intermediate resistance. None of the resistant fleabane lines have known target site resistance mutations in either of the two copies of the EPSPS gene present in their genome. I will also discuss future plans for elucidating further the non-target site resistance mechanisms in these weeds using imaging approaches.

Can patches of glyphosate-resistant *Echinochloa colona* be eradicated?

Jeff Werth, David Thornby, Michelle Keenan and Bhagirath Chauhan

Department of Agriculture and Fisheris. Innokas Intellectual Services. Queensland Alliance for Agriculture and Food Innovation

Glyphosate-resistant Echinochloa colona L. (Link) is becoming common in non-irrigated cotton systems. Echinochloa colona is a small seeded species that is not wind-blown and has a relatively short seed bank life. These characteristics make it a potential candidate to attempt to eradicate populations resistant to glyphosate when they are detected. A long term systems experiment was developed to determine the feasibility of attempting to eradicate glyphosate resistant populations in the field. After three seasons, the established Best Management Practice (BMP) strategy of two non-glyphosate actions in crop and fallow have been sufficient to significantly reduce the numbers of plants emerging, and remaining at the end of the season compared to the glyphosate only treatment. Additional eradication treatments showed slight improvement on the BMP strategy, however to date these improvements are not significant. The importance of additional eradication tactics are expected to become more noticeable as the seed bank gets driven down in subsequent seasons.

15 years of Roundup Ready® cotton: Weed species shift on Australian cotton farms

Meredith Conaty

Monsanto

Roundup Ready Flex® cotton currently accounts for around 98% of cotton planted in Australia. Since 2000 when Roundup Ready® cotton was first introduced, there has been a major shift in the weed control practices on Australian cotton farms, with a greater reliance on glyphosate for in crop weed control as well as a reduction in the use of other herbicides in cotton crops. Since the introduction of the Roundup Ready® trait, Monsanto has been randomly auditing at least 10% of all cotton farms each year to determine the effectiveness of Roundup® applications and monitor for the presence of resistant weeds. This audit has shown a significant shift in the types of weeds present on Australian cotton farms, with a reduction in the prevalence of previously dominant weed species, to an environment dominated by weeds harder to control with glyphosate. A shift in the types of weeds, and their prevalence has been observed across all growing areas, and in both grass and broadleaf weeds. The most significant shift in the weed landscape has been the increase in the prevalence of Fleabane (*Conyza bonarienses*) which was found in only 2% of fields in 2003, and now is found surviving a Roundup® application on over 15% of cotton fields surveyed. This data has implications for the risk management of glyphosate resistance in Australia, and presents one of the only long term studies of weed species present on Australian cotton farms.

Is Australia ready for triple gene herbicide stack technology?

Sudheesh Manalil[1], Jeff Werth[2], Rod Jackson[1], James Hereward[3], David Thornby[4], Graham Charles[1], Tony Cook[5], Bhagirath Singh Chauhan[36] and Christopher Preston[7].

[1]Australian Cotton Research Institute, New South Wales Department of Primary Industries, Narrabri, NSW
[2]Department of Agriculture and Fisheries, Leslie Research Facility, Toowoomba, QLD
[3]The University of Queensland, Toowoomba, QLD
[4]Innokas Intellectual Services, Upper Coomera, QLD
[5]New South Wales Department of Primary Industries, Tamworth, NSW
[6]Queensland Alliance for Agriculture and Food Innovation (QAAFI), QLD
[7]School of Agriculture, Food and Wine, The University of Adelaide, Glen Osmond, SA

Integration of multiple herbicide-resistant genes (trait stacking) into crop plants would allow over the top application of herbicides that are otherwise fatal to crops. The US has just approved Bollgard II® XtendFlex™ cotton which has dicamba, glyphosate and glufosinate resistance traits stacked. The pace of glyphosate resistance evolution is expected to be slowed by this technology. In addition, over the top application of two more herbicides may help to manage hard to kill weeds in cotton such as flax leaf fleabane and milk thistle. However, there are some issues that need to be considered prior to the adoption of this technology. Wherever herbicide tolerant technology is adopted, volunteer crops can emerge as a weed problem, as can herbicide resistant weeds. For cotton, seed movement is the most likely way for resistant traits to move around. Management of multiple stack volunteers may add additional complexity to volunteer management in cotton fields and along roadsides. This paper attempts to evaluate the pros and cons of trait stacking technology by analysing the available literature in other crop growing regions across the world. The efficacy of dicamba and glufosinate on common weeds of the Australian cotton system, herbicide resistance evolution, synergy and antagonisms due to herbicide mixtures, drift hazards and the evolution of herbicide resistance to glyphosate, glufosinate and dicamba were analysed based on the available literature.

1. Plant, Soil & Systems cont.

Re-evaluating mepiquat chloride use in Bollgard II cotton

Sandra Williams and Michael Bange
CSIRO Agriculture Flagship

Growers often query the benefits of using or not using Mepiquat Chloride (MC) on cotton. In particular, when to use MC and how will it affect the crop? During cotton growth, competition for water, nutrients and carbohydrates between vegetative and reproductive development is constantly occurring and is usually well regulated by the plant. However, this competition can become unbalanced and a growth regulator like MC (an anti-gibberellin) can be useful to slow vegetative growth. Previous guidelines for using MC were based on measuring vegetative growth rates (VGR) on conventional cotton varieties rather than high yielding GM cotton. Field experiments were conducted over the past three seasons to re-evaluate the guidelines for applying MC. We investigated different rates and timing of applications of MC and measured VGR throughout the season and the effect on plant growth, lint yield and maturity. MC reduced cotton height; however lint yield and maturity were only significantly affected in one out of three seasons. These results showed a good correlation between VGR at flowering and % lint yield response to MC. It also indicated that GM cotton with a high VGR is less responsive (effect on lint yield) to MC compared to conventional cotton in the past. The current recommendation of monitoring VGR for early season MC requirements are still relevant for GM cotton and should remain an important component of the decision making process.

Winter sowing for more reliable boll filling in Central Queensland

Paul Grundy[1], Steve Yeates[2], Jamie Iker[3], Gail Spargo[1], Ngaire Roughley[1] and Carlo Strangherlin[4]
[1]QDAF, [2]CSIRO, [3]Spackman Iker Ag Consulting, and [4]Cowral Ag

The Central Highlands region has a unique climate that presents both challenges and novel farming systems opportunities for cotton production. We have been re-examining the Emerald climate in a bid to identify opportunities that might enable the production of more consistent cotton yields and quality in what can be a highly variable climate. A detailed climatic analysis identified that spring and early summer is the most optimal period for boll growth and maturation. However, to unlock this potential requires unseasonal winter sowing that is 4 to 6 weeks earlier than the traditional mid-September sowing. Our experiments have sort answers to two questions: i) how much earlier can cotton be sown for reliable crop establishment and high yield; ii) can degradable plastic film mulches minimise the impact of potentially cold temperatures on crop establishment and early vigour. Initial data suggests August sowing offers the potential to grow a high yield at a time of year with reduced risk of cloud and high night temperatures during boll growth. For the past two seasons late winter sowing (with and without film) has resulted in a compact plant with high retention that physiologically matures by the beginning of January. Even with the spectre of replanting cotton in some seasons due to frost in August, early sowing would appear to offer the opportunity for more efficient crop input usage, simplified agronomic management and new crop rotation options during the late summer and autumn. This talk will present an overview of results to date.

Australian Cotton Systems in a 'Climate of Change'

Michael Bange
CSIRO Agriculture Flagship

Change has always been present however, agriculture systems in general is facing change at an unprecedented rate from a range of significant causes. We consider changes that Australian cotton systems face with: 'climate change' in the meteorological sense; regulatory issues; rising costs of production; and competition for scarce land and water resources from other commodities. In Australia for crops 'climate change' per se will influence production directly through rising CO_2 levels, exposure to higher temperatures, have less water availability, and be exposed to greater extremes in climate. Indirect effects will likely results from a range of government regulations aimed at climate change mitigation. To combat these changes, as well as dealing with increasing costs will mean that sustainable production will need to adopt practices in combination that will: increase and/or maintain high yields and quality; improve a range of production efficiencies (water, nitrogen, energy, emissions etc.); seek to improve a better return for products; or consider other cropping options as alternatives. We present impacts of these changes on production systems and highlight some options for adaptation. Cotton management and plant breeding options include high yielding/high quality stress tolerant varieties; exploiting GxExM; optimizing water and nutrition; manipulating crop maturity; varying planting time; optimizing soil and health for crop nutrition; and maintaining diligent monitoring practices for weeds, pests and diseases to enable responsive management.

Climate change impact on crop productivity: legacy effect through plant-soil feedback

Yui Osanai, David T. Tissue, Michael P. Bange, Ian C. Anderson, Michael V. Braunack and Brajesh K. Singh
University of Western Sydney

Plant-soil feedbacks play a central role in nutrient cycling. Changes in crop productivity, resource allocation and nutrient uptake can impact soil nutrient availability in both the short- and long-term, through changes in organic matter input into the soil. Projected changes in atmospheric concentrations of CO_2 and temperature have been shown to impact crop productivity. However, the short-term nature of most studies makes it difficult to assess the full extent of altered climate on crop productivity through plant-soil feedback, thus potentially limiting our ability to predict the long-term implications of these changes. Therefore, we examined the main and interactive effects of elevated CO_2 (CE) and temperature (TE) on cotton productivity in a controlled environment over two seasons to assess whether crop response was affected by the legacy of these treatments through plant-soil feedback, or remained consistent. A strong positive effect of TE on cotton yield was consistent between both seasons. However, we found a large difference in yield response to CE at ambient temperature (TA) between the seasons, with a significant yield reduction in the second season. Crop and soil nutrient analyses revealed reductions in soil nitrogen availability under CETA, while belowground carbon allocation was significantly increased by CE. These results indicate that the positive effect of CE on crop productivity may be dampened by negative plant-soil feedbacks that reduce nitrogen availability in long-term. Further research is needed to identify the underlying mechanism that drives such feedback effects to develop effective adaptation strategies to ensure sustainable agricultural production in future climates.

Chloride Mass Balance models are an economic method of assessing the effects of cotton farming systems on deep drainage in Vertosols

Timothy B Weaver and Nilantha R Hulugalle
Pulse Australia NSW DPI

Steady state and transient state chloride mass balance (CMB) models have been used to estimate deep drainage under different furrow irrigated cotton based rotations and tillage systems in Northern New South Wales since 2000 at the Australian Cotton Research Institute (ACRI) near Narrabri. The change in stored chloride in the soil profile allows these models to estimate drainage based on the concentration of stored chloride and volume of applied irrigation water and rainfall. The CMB models were validated against a variable tension lysimeter during the 2006/07 and 2008/09 cotton seasons. Deep drainage at 2 metres from the variable tension lysimeter during the 2006/07 and 2008/09 seasons was 74 and 54 mm whereas the chloride mass balance steady state model estimated 45 and 26 mm, respectively. The CMB models provided lower estimates of deep drainage due to their inability to account for by-pass flow via macro pores or preferential pathways created by earthworms, old roots and shrinkage cracks. Apart from these inabilities, these models do provide an economical and repetitive method to evaluate drainage under different management practices. The models have consistently shown that the minimum tilled cotton-wheat rotation at the ACRI (with standing wheat stubble retained) produces the highest deep drainage when compared to the maximum tilled cotton-wheat and continuous cotton treatments. Chloride mass balance models may provide lower estimates of deep drainage, however they have proven to be an economical and repeatable scientific method for comparing different farming systems.

Thin oxodegradable film and profile soil water under cotton

M. Braunack, H. McWhirter and P. Carter
CSIRO

Previous studies utilising oxodegradable thin film have shown that seedbed soil temperatures were elevated between 2-4°C, and seedbed moisture was conserved under the film compared without film. The issue of film restricting cotton emergence has been resolved by using slit film at planting. It is speculated that the thin film may result in preservation of profile soil water for longer than the area without film, thus conferring some benefit in the early growth of cotton possibly due to enhanced root growth. This study is being conducted to follow changes in profile moisture with and without film at two irrigated (Narrabri and Carrathool) and a dryland (Willow Tree) site. Multi-depth-soil-moisture-sensors were installed in the plant line to monitor changes in soil moisture at 10, 30, 50, 70 and 90 cm with the data being logged at three hourly intervals. Preliminary results indicate that profile water varied both under the film and bare control and over time at all sites, with the profile under the thin film being drier at one irrigated (Narrabri) and wetter at the dryland (Willow Tree) site and wetter at the second irrigated site (Carrathool). There was no difference in plant height, node numbers and open bolls at the end of the season between treatments at all sites. It is yet to be determined if differences in profile water will translate into greater lint yield at picking.

Irrigation induced deep drainage losses of soil carbon in a cotton farming system of Australia

M. Watkins, G. Nachimuthu, N. Hulugalle and L. Finlay

NSW Department of Primary Industries, Australian Cotton Research Institute, Narrabri, NSW. Fenner School for the Environment and Society, Australian National University, Acton, ACT.

A field investigation conducted during the 2014-15 summer cropping season in a Vertosol near Narrabri assessed carbon losses in deep drainage. The experimental design was a split plot design with 4 replications where the main plot treatments (in place since 1985) were: cotton monoculture sown either after conventional tillage or on permanent beds, and a cotton-wheat rotation on permanent beds. In the 2014-15 season, the subplot treatments were sown to cotton, however on alternate years these subplots were sown to corn. Individual plots were 190 m long and 8-24 rows wide. Samples were collected (9-12-2014, 16-1-2015, 25-2-2015) from ceramic cup samplers at depths of 60 and 120 cm within a week after the 2nd, 4th, and 7th irrigations. Only 26% of the plots had any drainage measured at the 120 cm depth. When the 120 cm depth was included in analysis, the rotations with corn had higher levels of total organic carbon (TOC) in leachate than rotations without corn (means of 90 and 81 mg/L, $p = 0.045$), whereas when only the 60 cm depth was analysed corn did not affect the level of TOC ($p=0.085$). Over the period of sampling there was no trend in the TOC concentrations in deep drainage at either depth with time.

2. Applied Entomology

Biology of Minute Two Spotted Ladybird

Jamie Hopkinson, Steph Kramer and Myron Zalucki
QDAF, UQ

The minute two-spotted ladybeetle, *Diomus notescens* is a natural enemy of cotton aphid, *Aphis gossypii*. While two-spotted ladybeetles are commonly found in Australian cotton very little is known about its biology. In a series of laboratory experiments we studied aspects of its development, reproduction and prey consumption. At 25°C immature development of *D. notescens* requires 21 days, 5d for egg, 11d for larva and 5 for pupa development. During larval development they consume a total of 130 aphids. Adult lifespan at 25°C last around 77 days and during this period a female ladybeetle can lay an average of 580 eggs. Prey consumption of adults is approximately 30 aphids per day. From this experiment we calculated an intrinsic rate of increase of 0.14 females/female/day for *D. notescens*. The prey preferences of *D. notescens* were tested using the Manly preference index. We compared preference for aphid nymphs or silverleaf whitefly eggs and found the ladybeetle had a strong preference for the aphid nymphs. Our studies into the biology and prey choices of the minute two spotted ladybeetle indicate it has a valuable role to play in pest management in cotton in particular suppression of cotton aphid populations.

IPM reduces risks from Silverleaf Whitefly

Lewis Wilson, Simone Heimoana and Tanya Smith
CSIRO Agriculture Flagship

Contamination of lint with honeydew by silverleaf whitefly (SLW) is a threat for the Australian cotton industry. Delaying SLW populations would reduce this risk. Life table studies found natural enemies decrease survival of eggs and nymphs of SLW. However, in both genetically modified (GM) and non-GM cotton, control of other pests with insecticides may disrupt natural enemies. In addition, crop consultants reported worse outbreaks of SLW in GM cotton, possibly due to differences in insecticide use compared with non-GM cotton effecting natural enemy populations. Small scale studies indicate slower development of SLW populations on cotton plants with okra leaf genotypes. We evaluated if (i) insecticides applied for other pests increased risks of SLW, (ii) GM cotton was more prone to outbreaks and (iii) okra leaf shape conferred useful resistance to SLW. Our findings indicated that GM-cotton was not more prone to SLW than non-GM cotton. Often non-GM cotton was often more attractive to SLW due to fresh regrowth following damage by Helicoverpa spp. Secondly, the okra leaf shape significantly delayed the build-up and peak population size, compared with normal leaf shape, possibly due to greater exposure of nymphs to unfavourable conditions on the narrow okra shaped leaves. Finally, cotton sprayed to control other pests had more SLW than unsprayed cotton, likely due to the disruption and hence reduced abundance of natural enemies. The combination(s) of GM-cotton, with okra leaf shape and use of selective insecticides to manage other pests offers potential to reduce risks from SLW.

Natural Mortality Helps to Mediate Silver Leaf Whitefly Development

Lewis Wilson and **Tanya Smith**
CSIRO

Silver leaf whitefly (SLW) is a significant pest in most Australian cotton growing regions. However, knowledge of factors affecting survival of SLW in crops, and especially of those that delay the development of populations is inadequate, though important for improving management. We measured survival of eggs and nymphs of SLW over three seasons on cotton plants in the field in the Lower Namoi Valley. We looked at SLW populations under protected (closed leaf cages), semi-protected (open leaf cages) and exposed conditions (no cage). We classed eggs or nymphs as healthy, eaten, parasitised (nymphs only), dead or missing for each time of measurement where possible. In association we presented potential predators with SLW eggs or nymphs to observe remains and confirm potential predation. Survival of eggs and nymphs was higher on the caged leaves than on open or non-caged leaves, strongly suggesting that biotic factors are reducing survival. Survival from egg to adult declined from about 45% in December to about 2.5% in March, possibly reflecting increasing beneficial populations and declining food quality. Key mortality factors varied between seasons but missing, parasitised and eaten categories remained important. Observations of known predation events found there were often no visible remains of eggs or nymphs. This suggests that much of the 'missing' category in the field was due to predation. The results indicate that practices that conserve or enhance natural enemies of SLW have the potential to delay the development of SLW populations.

The "Zappa" trap: A potential Light trapping system for monitoring and controlling *Helicoverpa* spp. and sucking pests in cotton crops

Robert Mensah, **Alison Young**, Andrew Woolley and Nicole Bell
NSW Department of Primary Industries

The use of transgenic cotton provides a strong platform for Integrated Pest Management (IPM) against *Helicoverpa* spp. Sucking pests, particularly *Creontiades dilutus* (green mirids) and *Nezara viridula* (green vegetable bugs), are not affected by the *Bacillus thuringiensis* (Bt) toxin. These pests are highly mobile, and their flight phenology is difficult to understand. In our opinion, the current sampling techniques for these pests may not be providing us with enough information about when these pests arrive on the farm and the numbers infesting the crop. Therefore, there is the need for an effective monitoring tool to determine arrival time and their numbers, which will lead to being able to predict peak activity of these pests within the crop enabling effective control measures to be applied in a timely fashion. A study, based on insect's phototaxis, was undertaken on a commercial farm near Narrabri during the 2014/15 season using two 3-4KV light trapping systems, one with a globe which emitted light with a wavelength of 365 – 380nm and the other which emitted a wavelength of 380 – 580nm . The results of the study showed that there were no differences in the capture rate per trap between the lower and higher wavelengths, except green mirids and green vegetable bugs where differences in capture rates do exist. The study also found that the lower wavelength traps were more selective against predatory beetles than the higher wavelengths. In conclusion, there is a potential for the "Zappa" traps to be utilized in commercial cotton farms to monitor sucking pests.

New developments in UAV remote sensing for pest management and the implications for cotton

E. Puig[1], F. Gonzalez[1], G. Hamilton[1] and P. Grundy[2]
[1]Australian Research Centre for Aerospace Automation (ARCAA) and Science and Engineering Faculty, Queensland University of Technology, QLD [2]Queensland Department of Agriculture and Fisheries, QLD

Efficient crop monitoring and pest damage assessments are key to protecting the Australian agricultural industry and ensuring its leading position internationally. An important element in pest detection is gathering reliable crop data frequently and integrating analysis tools for decision making. Unmanned aerial systems are emerging as a cost-effective solution to a number of precision agriculture challenges. An important advantage of this technology is it provides a non-invasive aerial sensor platform to accurately monitor broad acre crops. In this presentation, we will give an overview on how unmanned aerial systems and machine learning can be combined to address crop protection challenges. A recent 2015 study on insect damage in sorghum will illustrate the effectiveness of this methodology. A UAV platform equipped with a high-resolution camera was deployed to autonomously perform a flight pattern over the target area. We describe the image processing pipeline implemented to create a georeferenced orthoimage and visualize the spatial distribution of the damage. An image analysis tool has been developed to minimize human input requirements. The computer program is based on a machine learning algorithm that automatically creates a meaningful partition of the image into clusters. Results show the algorithm delivers decision boundaries that accurately classify the field into crop health levels. The methodology presented in this paper represents a venue for further research towards automated crop protection assessments in the cotton industry, with applications in detecting, quantifying and monitoring the presence of mealybugs, mites and aphid pests.

Establishing Southern Cotton – Thrips threshold validation

Sandra McDougall, Jianhua Mo, Scott Munro, Elizabeth Munn and Sarah Beaumont
NSW DPI

Cotton has continued to expand in the southern region with new areas growing cotton and the opening of two new gins in Hay and Carathool. Early establishment is seen as a key to good yields for southern cotton and that early season thrips are important insects to control. A CRDC funded project is looking at the validity of the cotton industry thrips threshold in southern grown cotton. One small plot and three commercial scale replicated trials were conducted at three sites in the Riverina. Two trials compared thrips treatment at 1 thrips/plant (positive control), 10 thrips/plant (industry standard) and unsprayed control. The third commercial scale trial evaluated treatments with and without phorate, and with and without thiomethoxam. The small plot chemical efficacy trial evaluated potential thrips insecticides. Onion thrips, *Thrips tabaci* was the dominant thrips species observed in establishing cotton comprising 71-90% and Western flower thrips, *Frankliniella occidentalis* was <5% of adult thrips observed. Overall yields were good with estimates of between 12 and 15.5 bales per hectare. Preliminary

analysis of total hand harvest yields found the phorate and thiomethoxam treatments had significantly higher yields, with approximately 12% higher yield compared to the untreated control plots. Neither of the commercial scale threshold trials nor the small plot efficacy trial resulted in any significant yield differences between treatment plots. This suggests that insecticide control of establishment thrips did not result in a yield benefit this season.

3. Energy

The feasibility of alternative energy sources in the Australian cotton industry

G.R. Sandell, J. Hopf, G. Chen, T.F. Yusaf and C.P. Baillie
NCEA

Australian cotton production is heavily reliant on fossil fuels to meet energy demands directly and indirectly to provide chemical and fertilizer requirements. Growers are aware of cost pressure on all of these inputs. Infield volatilisation of fertilizers and chemicals and the burning of fossil fuels release greenhouse gasses that contribute to global warming. Subsequently this global warming adversely affects yield and access to resources such as water and energy. With little published literature on the feasibility of alternative energy sources in the Australian cotton industry the CRDC commissioned research to explore possible solutions in this space. This paper presents the key findings of this work. In this project the performance and emission characteristics of commercially available alternative energy options was examined in the laboratory and in the field. Tariff and policy issues were considered for each fuel source. A survey was conducted to investigate industry interest in alternative energy and to profile existing users of alternative energy. An economic comparison ranked the various fuel sources in terms of grower cost per GJ of mechanical energy at the flywheel. Energy benchmarking, engine and pump efficiency and electricity tariff evaluation were shown to provide significant cost savings and emission reductions. Biodiesel blends that are invoiced as B5 or B20 can be economic as they still attract the fuel diesel fuel rebate. Other blends are less economic because there is no fuel rebate available. Cotton gin waste currently represents around 3 to 5 million GJ of unused energy available to the industry with another 26 million GJ available in the cotton plant in the field.

Economic feasibility of using solar energy to reduce diesel consumption in off grid cotton irrigation bores

John Hill
YellowDot Energy Pty Ltd

Interest is increasing is alternatives to diesel as an energy source for irrigation. The cost of grid infrastructure can prohibit conversion of an off grid diesel bore to an on-grid electric bore. The levelised cost of solar energy can be less than the cost of diesel energy for sites with the right seasonal profile and the presence of appropriate water storage. Current economics support a hybrid solar/diesel strategy. Energy requirements are determined using a top down and bottom up approach. The top down approach considers existing diesel consumption and the relative efficiency of an existing operation as compared with a replacement electrical operation. The bottom up approach makes assumptions about drawdown levels over the year and considers a complete pumping system efficiency stack. The assumptions embedded within each approach are based on site specific information. The objective is to ensure each approach produces a consistent outcome, thereby providing a robust basis for solar array sizing. In the event of inconsistency then initial assumptions are challenged. Experience has shown that system replacement can often result in efficiency improvements independent of any benefits of solar conversion. Existing system inefficiencies are found in mismatch in diesel motor sizing to load, the availability of more efficient modern diesel engines and eliminating gearboxes and right angle drives. The solar/diesel hybrid strategy ensures continuous power to the bore in the event of solar variability due to passing cloud. In the future it is expected that battery storage economics will improve to the point that the diesel component will reduce and will be ultimately removed altogether.

An overview of energy auditing lessons from recent projects in the Australian cotton industry

Gary Sandell
NCEA

Benefits of energy audits in saving money and reducing emissions are well established. Benefits of energy auditing is also established in the Australian cotton industry with examples of individual growers making significant savings. The paper investigates recent projects including "On-farm energy benchmarking", "Alternative energy sources" and, particularly, lessons from the recent "EEIG project". Available information and methodologies for assessing energy use in cotton production are still relevant to the industry. However, how this is delivered needs to be critically examined. These projects all show that pumping water consumes half of all direct energy consumption. These projects also show that the efficiency and performance of these capital items is poorly understood. Grower feedback shows that level 3 energy assessment, which measure the performance of an individual capital item, are more valuable as they provide specific feedback about how their individual energy efficiency can be improved. However, these are resource and time intensive to perform. Industry feedback shows that broader level 1 and level 2 assessments are important for a broader understanding of the industry. This paper explores how the cotton industry might utilise current tools and knowledge so that a grower can identify which capital will provide the greatest likely benefit from a detailed level 3 assessment and how the industry collectively can benefits from benchmarks produced.

A Pilot Study - Cotton Gin trash to Bioethanol

Shane McIntosh, Janice Palmer and Tony Vancov
NSW DPI

In the cotton industry, the ginning process generates about 60kg of cotton gin trash (CGT) per bale of cotton. CGT is composed of pieces of stems, leaves, motes, cotton lint and ash. The 2011/12 harvest reports 5 million bales were produced representing a renewable energy resource of over 300,000 tonnes of CGT which equates to approximately 95 million L of ethanol. CGT is an abundant resource, centrally stockpiled and has high holocellulose content making it ideal as a low-cost biomass feedstock for regional biorefineries. Besides solving their immediate waste disposal problems, using CGT as a biorefinery feedstock presents the cotton industry with a unique opportunity to convert 'trash into treasure' whilst mitigating green house gas (GHG) emissions. In this pilot study we identify appropriate pretreatment strategies to maximise sugar recoveries and determine the fermentation potential of CGT hydrolysates for bioethanol.

Cotton Gin waste Biofuel for Diesel Engine

Saddam H. Al-lwayzy and Talal Yusaf
NCEA

Renewable fuels have polarized the attention of the current research due to the increased demand on fuels, high fuel prices and emission gases that lead to global warming. The most attractive renewable fuels for diesel engine are in liquid form such as vegetable oil, biodiesel, water emulsion and alcohol. Cotton industry in Queensland is estimated to produce biomass waste that has the potential to be utilized as a valuable resource for renewable fuels. The energy can be obtained from the cotton industry in form of oil, biodiesel, ethanol, methane and/or direct burning of the waste. Generating ethanol from lignocellulose feedstocks produced from cotton gin has the advantage of not competing with human food. Ethanol can be blended with diesel fuel to increase the oxygen content which reduces the exhaust emission. Ethanol is immiscible in diesel, has low cetane number and low viscosity. Adding cotton seed biodiesel to form ternary mixture fuel has the advantages of increasing the fuel viscosity, cetane number and stability. The ternary fuel consists of 80% conventional diesel, 10% bioethanol and 10% cotton seed oil has the potential to significantly reduce the engine emission with minor reduction in the engine power due to the similar fuel properties to conventional diesel and higher oxygen content.

Combustion of Cotton Seed Biodiesel in Diesel Engine

Saddam H. Al-lwayzy and Talal Yusaf
NCEA

There is a substantial increase in demand on liquid fuels over the last decade for diesel engine, whilst the fossil fuels are depleting. This has contributed to higher fuel prices making renewable fuels a viable commercial alternative with less emission. Recently, cotton seed oil and biodiesel are increasingly used in IC engines and it is expected to be one of the alternative fuels in the future. Cotton seed biodiesel obtained from Queensland University of technology (QUT) was used in different blend ratio in a single cylinder diesel engine in the engine lab at USQ. The engine performance and exhaust gas emission were studied and compared with petroleum diesel. The results showed that the pure cotton seed biodiesel 100% CSB100% is suitable to run the diesel engine without modification. When the engine fueled with CSB100% at 2350 rpm, a reduction of 7.06%, 6.09%, 0.52%, 2.70%, 25.47% and 16.67% in the engine power, torque, BSFC, exhaust gas temperature, CO and NOx, respectively was observed. While an increase in the CO2 by 6.42% as compared to petroleum diesel was recorded.

1. Plant Science

Canopy Temperature during Cotton (*Gossypium hirsutum* L.) Fibre Development: Associations with Fibre Quality

Onoriode Coast[1], James R. Mahan[2] and Michael P. Bange[1]

[1]CSIRO Plant Industry, Narrabri, NSW
[2]USDA/ARS Plant Stress and Water Conservation Laboratory, Lubbock, Texas, USA

Canopy temperature, an indicator of water stress, is negatively associated with cotton yield. Water stress during sensitive fibre developmental stages has varying effects on fibre quality. Associations between canopy temperature during these stages and fibre quality parameters are unclear. Understanding these associations can aid the development of fibre quality simulation sub-models to improve existing models. Field experiments with a range of sowing dates and irrigation levels were conducted in Australia and USA to describe relationships between fibre quality (length, uniformity, strength, micronaire and elongation) and canopy temperature as well as weather variables at different developmental stages (first flower to mid flowering, fibre elongation and fibre thickening). Fibre qualities were more associated with canopy than air temperature. Length and uniformity were mostly correlated with maximum canopy temperature from fibre elongation through fibre thickening ($r = -0.761$; $P<0.001$ and -0.747; $P<0.001$ respectively). Similarly, micronaire and strength were associated with maximum canopy temperature ($r = -0.790$; $P<0.001$ and -0.542; $P<0.001$ respectively) but only during fibre thickening. While elongation was correlated with minimum canopy temperature ($r = - 0.593$; $P<0.001$) at fibre thickening. These results show strong associations between canopy temperature during fibre thickening and fibre quality. Knowledge of these relationships between canopy temperature and fibre quality could be incorporated into cotton simulation models (e.g. OZCOT) and also used to improve management practices like irrigation scheduling during fibre development to minimise stresses.

Understanding the photosynthetic biochemistry that underpins cotton photosynthesis under future climate extremes

Robert E. Sharwood[1], Oula Ghannoum[2], Balasaheb Sonawane[2], Renee Smith[2], Spencer M. Whitney[1], Michael Bange[3] and David Tissue[2]

[1]Research School of Biology, Australian National University, Canberra ACT
[2]Hawkesbury Institute for the Environment, University of Western Sydney, Richmond NSW
[3]CSIRO Narrabri NSW

Global climate change resulting in increased drought and higher ambient air temperatures may severely impact future productivity of the cotton industry. Identification of thermo-tolerant and water use efficient (WUE) cotton lines by CSIRO through plant breeding may be utilized to maintain future productivity. Six cotton genotypes, which include DP16 (old genotype), Siokra L23 (WUE), CS50 (decreased WUE), 64224-212 (heat tolerant), SICALA V2 (poor heat tolerance) and Sicot 71, were grown in a sun-lit glasshouse under non-limiting water and nitrogen conditions at mid-day maximum air temperatures of 28°C and 32°C. Gas-exchange measurements indicated photosynthetic capacity was increased in all genotypes when measured at 32°C compared to the identical lines at 28°C, irrespective of growth temperature. Stomatal conductance (g_s) measured under saturating light conditions varied across the genotypes with Siokra L23 displaying lowest g_s resulting in improved instantaneous WUE. This was coupled with an improved mesophyll conductance to CO_2 (g_m) hence CO_2 assimilation remained similar to the other genotypes. In vitro Rubisco catalytic measurements at 25°C indicated that cotton Rubisco has a high affinity for CO_2 (K_mCO_2) and a slow k_{cat} which was accompanied by a high specificity for CO_2 as opposed to O_2 (Sc/o). Analysis of Rubisco content revealed that Rubisco accumulates up to 45% of total leaf soluble protein indicating the significant investment of N into Rubisco synthesis. Therefore, future improvements in cotton photosynthesis could be achieved by improving Rubisco catalysis and reducing content to mitigate against the significant requirement for the large N investment into Rubisco.

Growth and yield dynamics of different canopy layers of cotton in response to soil waterlogging

Ullah Najeeb[1], Michael P. Bange[2,1] and Daniel K.Y. Tan[1]

[1] Department of Plant and Food Sciences, Faculty of Agriculture and Environment, The University of Sydney, NSW
[2] CSIRO Agriculture Flagship, Australian Cotton Research Institute, Narrabri, NSW

Field experiments were conducted to study how waterlogging influences cotton growth and yield by investigating the crop through different canopy layers. Due to indeterminate growth habit, we hypothesised that different canopy layers of cotton would variably respond to soil waterlogging. The crop was waterlogged

at early (WLearly, 77 days after planting [DAP]) and late reproductive phases (WLlate, 101 DAP) for 120 h. Plants were tagged, and data from different canopy layers such as bottom eight (MSN1-8), middle five (MSN9-13), and top main stem nodes (MSN14+) were collected one day (post-WL) and 7 days after termination of waterlogging (post-recovery). Both waterlogging events significantly reduced post-WL dry biomass, leaf N concentration and fruit development on MSN1-8. In addition, WLearly significantly reduced photosynthesis and increased total soluble sugars in MSN1-8 and MSN14+ leaves, although MSN14+ leaves restored photosynthesis and sugars at post-recovery. It suggested that WL plant could maintain photosynthesis in the top leaves by transporting N from the lower leaves. Lint yield reduction (22%) in WLearly cotton was mainly observed with loss of fruit on fruiting position-1 of the top and lowest fruiting branches i.e. FB1-5 and FB11+. Although WL plants compensated to some degree, fruit loss on FB1-5 by producing additional fruits on fruiting positions-2+3, no yield recovery on FB11+ indicated that despite growth recovery (photosynthesis and N assimilation), WL plants could not compensate yield loss in the top canopy layers. No significant reduction in number of bolls under WLlate suggested that the established cotton bolls were less sensitive to abscission.

What they do while you're sleeping: Nocturnal transpiration in cotton

W.C. Conaty, A.J.E. Thompson and G.A. Constable
CSIRO Agriculture, Locked Bag 59, Narrabri, NSW 2390, Australia

It is now widely accepted that plants do not systematically close their stomata at night. Although nocturnal transpiration (En) may be considered wasteful for efficient water use, numerous theories as to why En occurs have been proposed. These include the recovery of xylem cavitation, oxygen supply to xylem and sustaining carbohydrate export for respiration (R). However, consistent empirical evidence to explain that this physiological phenomenon occurs has not emerged. Despite this knowledge gap, substantial En has been observed in numerous non-crop tree species, as well as lucerne, wheat, kiwifruit, apple, tomato and almond, with observed En of 5-55% of diurnal transpiration (Ed). Studies in cotton have been limited to nocturnal evapo-transpiration (lysimeter) in a single cultivar. In order to evaluate whether low En is a component of water use efficiency, this study investigated the nocturnal and diurnal transpiration in eight diverse Gossypium genotypes, with differing diurnal water-use characteristics. Our study revealed that under well watered field conditions: (i) average En can be as high as 11% of Ed; (ii) atmospheric vapour pressure deficit (VPD) is a major driver of En, where response of En to VPD is genotype dependent; (iii) the relationship between instantaneous leaf-level water-use efficiency (WUEleaf) and En varied with genotypes. This study reveals that there is potential for using En as a trait in drought-tolerant germplasm breeding. Future work would need to determine if is there is a consistent association between En and yield under water stress.

Investigating the Mechanisms of Heat and Water Stress Resistance of Cotton

Demi Gamble, Warren Conaty and Nicola Cottee
CSIRO Plant Industry

The detrimental effects of abiotic stresses such as heat and water deficit are projected to inflate as global climate change is predicted to increase the severity of aridity and heat waves. Therefore, selective breeding for heat and water deficit resistance is an arising priority among cotton breeding programs. A range of physiological responses such as photosynthesis, transpiration and chlorophyll fluorescence to the interaction of heat and water deficit were investigated across five conventional cotton genotypes grown in field conditions at the Australian Cotton Research Institute. It was uncovered that the genotype Siokra L23, had the lowest rate of transpiration, and thus high leaf level water use efficiency (WUE_{leaf}). This resulted in optimal performance under drought stress. Siokra L23 was also capable of protecting photosynthetic processes against heat-induced damage, as shown by favourable chlorophyll fluorescence. Although this genotype is out-competed in terms of lint production by modern, high-yielding cultivars such as Sicot 71, Siokra L23 may gain selective advantage in future conditions as the interaction between heat and drought stress saw performance depletion in Sicot 71. Although additional data on underlying biochemical and molecular stress responses is required in order to improve the validity of such findings, the study supports the use of screening for WUE and chlorophyll fluorescence as suitable methods for utilization in breeding programs for selection of heat and drought tolerant varieties.

The integrated effects of elevated CO2 and temperature on early-stage cotton growth and physiology

K. Broughton[1,2], D. Tan[2], P. Payton[3], D. Tissue[4], M. Bange[1]

[1]CSIRO, Agriculture Flagship, Narrabri, NSW
[2]Faculty of Agriculture and Environment, University of Sydney, Sydney NSW
[3]United States Department of Agriculture, Cropping Systems Research Laboratory, Lubbock TX
[4]Hawkesbury Institute for the Environment, University of Western Sydney, Richmond NSW

Changes in temperature, CO_2 and precipitation under the scenarios of climate change present a challenge to crop production, and may have significant impacts on the physiology and yield of cotton. Understanding the implications of varied environmental conditions for agricultural crops is critical for developing cropping systems resilient to stresses induced by climate change. A series of glasshouse and field experiments have explored the early growth and physiological responses of cotton to elevated [CO_2] and warmer temperatures. Elevated [CO_2] increases early cotton growth and impacts physiology and water use, although the magnitude of the response is largely dependent on air temperature and water availability. Data from these studies provides a basis for improving methods for investigating the potential impact of climate change on cotton production.

2. Carbon and Climate

The impact of climate change on cotton in Australia

Allyson Williams
International Centre for Applied Climate Science, University of Southern Queensland

Most future climate change scenarios for Australia project an increase in minimum and maximum temperatures and resultant longer growing seasons and more heatwaves. In terms of rainfall, the most certainty is for an increase in the frequency of extreme events (both heavy rainfall and droughts), however the change in the amount of annual and seasonal rainfall is one of the most uncertain variables. In general there is agreement that the overall impacts on cotton will most likely be adverse in the longer-term (by the end of the century) and adaptation will be required to maximise possible opportunities. The impacts on production that are likely to result from climate change are complex, spatially variable, and surrounded with varying degrees of uncertainty. Here we present the key concepts required for such an analysis of the potential impacts of climate change on cotton in Australia, including the usefulness of climate change risk assessments to identify the capacity of the industry to adapt and therefore the vulnerability of the industry to climate change.

Cradle to export-port greenhouse gas assessment of cotton production in north-west New South Wales

Mehdi Hedayati, Philippa M. Brock and Aaron Simmons
NSW Department of Primary Industries

This paper presents the results of a research study aimed to quantify the average greenhouse gas (GHG) emissions of cotton production in north-west NSW by using the Life Cycle Assessment (LCA) method. The GHG emissions were calculated for the functional unit of 1 tonne of cotton lint. The study accounted for the ratio of irrigated and rainfed cotton in the region. The system boundary of the study included the pre-farm stage (i.e. production of farming raw materials), the on-farm stage (i.e. field emissions), and the post-farm stage (i.e. the ginning process and transport to port). The study estimated the GHG emissions from the production of one tonne of cotton fibre (lint) as 788 kg CO_2-eq., of which approximately 21% of the emissions came from the pre-farm stage, 47% from the on-farm stage, and 32% from the post-farm stage. Among the various processes included in the LCA study, on-farm emissions associated with the application of synthetic nitrogen fertilisers contributed most to the total GHG emissions (~22% of the total GHG emissions). Other processes that contributed substantially to the total estimated GHG emissions are cotton stubble management (~11%) and energy use for seed cotton drying at the gin (~10%). The GHG emissions intensity for cotton production in north-west NSW is less than that reported for the cotton produced in other countries, mainly due to the high yield (10.5 bales/ha) of the irrigated cotton produced in north-west NSW, which reduces emissions intensity.

Positioning Australia for its Farming Future

David Lamb
Cooperative Research Centre for Spatial Information and Precision Agriculture Research Group, University of New England

The value of agricultural production in Australia in 2010-11 was $46 billion, with the value added by the agriculture industry accounting for 2.4% of GDP. Recent reports (Allen Consulting, 2008; Acil-Allen, 2012; Yule et al., 2013) identify that a coordinated, national positioning infrastructure for Australian farmers would yield a significant growth in the economic contribution of the agriculture sector to GDP and increase the uptake of precise positioning technologies on farm.

Presently only 9% of the country is served by network real-time kinematic positioning (NRTK) services, leaving remaining users in remote parts of the country to either build, operate and maintain their own ad hoc base-station system or to continue working without the gains and benefits real-time precise positioning can provide. An alternative mode of 'sub-decimetre positioning' made uniformly and consistently available across Australia, may assist in overcoming the barriers to adoption of precise positioning technologies that exist in our many agriculturally-productive regions.

The QZSS development is not aimed at replacing existing precise positioning methods available to farmers, for example networked CORRS or privately or corporate owned base-station (per farm) approaches, where they work. This is simply aimed at providing everyone, wherever they are, with access to a baseline (±2- 5 cm) positioning capability in a way that avoids the farmer or their consultant shouldering the responsibility of running/maintaining their own positioning systems. Working to provide growers with an alternative to the existing base-station or NRTK systems may be an important assistive step towards the uptake of future technology, including large and small autonomous systems by our farmers.

Determination of Emission Factors for Estimating Nitrous Oxide Emissions from Australia's Cotton Industry

Clemens Scheer, Iurii Scherbak, Peter Grace, Ben MacDonald and David Rowlings
Institute for Future Environments, Queensland University of Technology, Brisbane, QLD

Nitrogen fertilizer rate is the best single predictor of N_2O emissions from agricultural soils. The current global mean value used by the IPCC is 1%, after correction for background (0N) emissions, i.e. for every 100 kg of N input as fertilizer, 1.0 kg of N in the form of N_2O is estimated to be emitted directly from soil. A 1% Emission Factor (EF) assumes a linear relationship between N input and N_2O. As a significant user of N fertilizers (median of 200 kg N ha-1), the Australian cotton industry is a major source of N_2O emissions. The current EF for cotton production is Australia is 0.5%. The inclusion of new datasets would enable a more accurate estimation of emissions in both the National Greenhouse Accounts and in relevant methodologies developed under the Emissions Reduction Fund. Variable emissions factors (in response to N applied) would potentially provide greater incentive to reduce excess N fertilizer applications, driving greater abatement of greenhouse gases. We describe the development of a two component (linear + exponential) N_2O emissions response models to N fertilizer additions based on an analysis of peer-reviewed data from eight field experiments from Australia's cotton industry. It shows that EFs are low for modest N application rates, (0.31% at 100 kg N ha-1, 0.61% at 250 kg N ha-1) but increase exponentially for higher N rates (1.85% at 300 kg N ha-1). We conclude that a two component (linear + exponential) statistical model is more appropriate for estimating emission of N_2O from soils cultivated to cotton in Australia.

Sustainability reporting for agriculture - an overview of available reporting metrics on emissions

Richard Eckard
Primary Industries Climate Challenges Centre, the University of Melbourne

While market surveys show consumer preference is largely still price-based, the agricultural supply chain and processors are increasingly under pressure to provide metrics to underpin claims of sustainable production. While appropriate and equitable metrics are yet to be universally agreed, greenhouse gas emissions reporting provides some insights into the debate and likely directions for the future. The Intergovernmental Panel on Climate Change provides guidelines for national inventory reporting of greenhouse gas emissions for all sectors, including agriculture. While these metrics report on absolute or net emissions (NE) and trends, emissions intensity (EI) is emerging as a more equitable and agreeable metric for quantifying the carbon footprint of agricultural products and is emerging as a useful measure of farm efficiency. Using NE and EI as a case study, the paper will discuss the relative merits of a range of emissions reporting metrics, drawing on recent national and international developments in key target markets for Australian agriculture.

1. Cotton Breeding

Can breeding solve all our problems?

Warwick Stiller and Iain Wilson
CSIRO Agriculture

Worldwide, cotton producers have long looked to breeders to solve all their production issues with the development and release of new and improved cultivars. This has predominantly focused on yield, fibre quality, disease and insect resistance. In Australia, continued improvements in yield and fibre quality of new cultivars have played a major role in maintaining the financial sustainability of cotton growers together with the overall competitiveness of the industry. A key component of the yield increases has been the successful incorporation of resistance to important diseases. The first major success was bacterial blight followed by verticillium wilt and later, fusarium wilt. However, there is still considerable research required to attain the level of disease resistance desired by the industry for verticillium wilt, fusarium wilt, black root rot and cotton bunchy top. GM traits have also become critical for the industry to manage various insects and weeds, but considerable research has also focused on conventional traits targeted at arthropod pests not controlled by these GM traits. This presentation outlines the complexities involved in developing new cultivars for the Australian industry and discusses the question 'can breeding solve all our problems?'

The yield potential of cotton (*Gossypium hirsutum* L)

Greg Constable and **Michael Bange**
CSIRO Agriculture Flagship

Yield potential studies can assist in identifying the production constraints in any cropping system and economics at the farm level dictate a continual need to increase yield and profit for most crops. Here we defined yield potential as yields that can be obtained with current cultivars and systems under ideal conditions in the absence of poor weather, disease, soil or nutritional constraints with management and genetics optimised. We reviewed yield potential in cotton and particularly identify factors such as climate, soil health, nutrition, water, weeds, pests and diseases which affect yield. In particular, it is clear that a long growing season is required for high yields. Under irrigated conditions, lint yield of 3500 kg/ha is now being obtained and we use this value for yield potential under full season irrigated conditions. Yield potential for raingrown cotton production systems depends on soil water storage and rainfall but is about 800 kg lint/ha. We also derived the theoretical yield of cotton from three different methods and estimated yield to be about 5000 kg lint/ha. To achieve this yield, a long season is required, possibly with slower initial fruit set so canopy size is not restricted by high fruit load. Achieving these yields would be more challenged by nutrient uptake than the need for more water. Future research opportunities were identified in crop agronomy (nutrient uptake and use efficiency), plant physiology (modelling fruiting dynamics), breeding (longer season plant types with slower initial fruit setting) and biotechnology (increased photosynthesis).

Role of genotype × management synergies for cotton productivity

S. M. Liu[1], G. A. Constable[1], W. N. Stiller[1], P. E. Reid[1], R. Eveleigh[2], S. Ainsworth[2] and M. V. Braunack[1]
[1]CSIRO Agriculture, Narrabri, NSW [2]Cotton Seed Distributors, Wee Waa, NSW

Adopting new cultivars (genotypes, G) and better management practice (M) has contributed to the ongoing yield progress in cotton lint yield. Their synergistic interactions (G×M) also play an important role, but are difficult to be quantified. In this presentation a mixed model approach was employed to analyse two long-term lint yield datasets with the aims of estimating the relative contribution of G, M and G×M for yield gain in the past, as well as of identifying important components of G×M interactions. The datasets were from CSIRO advanced line trials conducted across all regions from 1980 to 2009 for conventional cotton as well as from CSD semi-commercial cultivar evaluation trials from 2004 to 2010 with records of management practices. The results from the CSIRO dataset demonstrated G×M interactions contributed 24% of yield gain, which was almost equivalent to M (28%), although they were smaller than G (48%), for eight conventional cultivars. Interestingly, G×M varied with the production region and tended to be higher in regions with longer growing seasons. In the CSD dataset, cultivars showed different interactive responses to crop rotation, plant stand, nitrogen and irrigation applications; and the responses indicated the optimal nitrogen and irrigation in Bollgard II cultivars was smaller than the highest amount currently applied in the industry. It was concluded that future research and exploitation of G×M synergies should concentrate on crop rotation, fertilizer and irrigation strategies comparing existing cultivars with potential future cultivars/traits in a range of production systems.

Sources of host plant resistance to thrips in cotton

Carlos Trapero, Lewis J. Wilson and Warwick N. Stiller
CSIRO Agriculture

Thrips (Thysanoptera: Thripidae) are important cotton pests during the early growing season. In this study, their feeding damage and population density were evaluated in the field in a range of cotton genotypes over the 2014-15 crop season. Genotypes evaluated included a diploid genotype, several *Gossypium hirsutum* commercial cultivars and two different sets of *G. hirsutum* isolines (genotypes having the same genetic background except for leaf hair density). Plant damage by thrips feeding was a good indicator of the resistance level, and we found significant differences between genotypes. Damage on the diploid genotype was significantly lower than that observed on *G. hirsutum* commercial cultivars such as Sicot 71. High hair density was also associated with a higher level of host plant resistance, but only in one of the two sets of isolines. On the other hand, differences in adults and larvae population between genotypes were generally small. Lower damage was associated with low thrips densities in the diploid genotype, but not in the very hairy genotype which showed resistance. This indicates the likelihood that different resistance mechanisms are involved in host plant resistance to thrips. This presentation will discuss the potential use of diploid species and leaf hairiness as sources of host resistance to thrips in cotton breeding.

Development of an automated cotton plot picker for small scale trials

Max Barnes and Chris Allen
CSIRO Agriculture, Narrabri, NSW

Plant breeding programs require the efficient measurement of yield and fibre quality across thousands of breeding plots located across multiple environments (sites). Initially, CSIRO's plot harvesters were modified two-row cotton pickers, where one head and the basket were removed, and a rear platform with a cotton bagging system was installed. This system was labour intensive (eight operators) and slow (maximum 600 samples/day), with variable accuracy. In the last twenty years the number of breeding plots in the CSIRO cotton breeding program has increased, placing pressure on labour and time resources. Subsequent enhancements to the plot picker included an on-board weighing and sub-sampling system which improved speed and accuracy and reduced the number of operators to six. As the seed from lines progressed in the breeding program is only collected from one site, an opportunity to split 'yield and seed' and 'yield only' harvesting was realised. A two-person automated plot picker was developed that weighs the cotton from each plot before releasing it into the picker's basket. During picking, a representative sub-sample is taken to determine gin turn-out and fibre quality. An on-board computer system allows the input of trial design for the automated collation of data. This also controls process operations, reducing driver fatigue and improving data accuracy. Not only has this picker reduced labour requirements, it has also increased the speed of harvest operations (1000 plots/day). This presentation describes the development of this picker which has allowed CSIRO's breeding effort to cope with the increased demand for breeding plots, ensuring the Australian cotton industry continues to have the best cultivars in the world.

Usefulness of nondestructive technologies for phenotyping in breeding high yielding cotton

S. M. Liu[1], A. Macolino[2], J. Price[1], W. N. Stiller[1] and G. A. Constable[1]
[1]CSIRO Agriculture, Narrabri, NSW
[2]Department of Biological Sciences, Macquarie University, North Ryde, NSW

High yielding cultivars continue to be an important factor behind profitability and sustainability of cotton production. In traditional cotton breeding, yield improvement has been largely achieved through breeding and selection over extensive test trials in target environments. With the advent of more sophistical sensor technologies, it has become possible to track crop development traits underlying the formation of harvestable yield and to integrate such information at selection decision making. In this presentation, we discuss possible breeding paths for future yield gain, and some nondestructive tools including Li-Cor 6400XT, Ceptometer, SPAD and GreenSeeker were examined to demonstrate their ability to identify the difference of breeding lines for traits associated with photosynthesis, light interception and canopy formation. Most nondestructive measures were positively related to similar measurements done on hand-harvested plant samples and even to yield at harvest. It was concluded that adding other high throughput measures to yield trials might capture another dimension of data associated with yield. Integrating such information may lead to improved selection effectiveness and efficiency in breeding for high yield.

Genome-Wide Association Studies: Hunting for Marker-Trait Associations in Plants

Washington Gapare, Qian-Hao Zhu, Warren Conaty, Shiming Liu, Iain Wilson, Warwick Stiller and Danny Llewellyn
CSIRO

Genome-wide association studies (GWAS) are a method for linking specific DNA markers with phenotypes using established populations of individuals. The approach was made possible by the discovery of literally millions of single nucleotide polymorphisms (SNPs) in the human genome and the development of high throughput platforms that provide genotypes simultaneously for hundreds of thousands of SNPs to link genes to human disease traits. The approach was rapidly adopted by plant and animal breeders who envisioned its application for marker-assisted selection (MAS). GWAS are relevant for complex traits with complex inheritance patterns (both genetic and environmental contributions) in plants. GWAS in crops usually use a permanent resource - a population of diverse cultivars that can be measured for many traits such as fibre quality, and only needs to be genotyped once. The major limitation with association genetic analysis is that crop cultivars are generally highly related, and unless the inherent level of relatedness is adequately defined, then associations can occur just via biases in the populations by common descent. Therefore to use this analysis methodology, relatedness among individuals (population structure) must be established prior to association analysis so adequate thresholds can be set to provide meaningful associations. With the rapid development of sequencing technologies, reduced costs and computational methods, GWAS are now becoming a powerful tool for detecting natural variation underlying complex traits in crops. Cotton is ideal for GWAS because of the availability of ready-made cultivars and the broader genetic variations with wider background for marker-trait correlations (i.e., many alleles evaluated simultaneously). There is also the possibility of exploiting historically measured trait data for association. This presentation will focus on the goals of GWAS, how such studies are performed, challenges in interpreting associations and some lessons learnt from GWAS. Lastly, we provide a summary output from a pilot study to establish a SNP marker-trait association analysis framework in cotton.

Genomics enabled fast forward genetics in cotton

Qian-Hao Zhu[1], Warwick Stiller[2], Danny Llewellyn[1] and Iain Wilson[1]
[1]CSIRO Agriculture Flagship, Black Mountain Laboratories, ACT [2]CSIRO Agriculture Flagship, Narrabri NSW

Mapping the location of causal mutations and cloning the corresponding gene using genetic crosses has traditionally been a complex, multistep and time consuming procedure, particularly for polyploid crops, such as cotton. Advances in the next-generation sequencing (NGS) technology and the availability of the cotton (Gossypium hirsutum) genome sequence now allows the rapid identification of causal mutations and cloning of the gene in a single step. When combined with precise phenotyping, NGS also provide a powerful and rapid tool for identifying the genetic basis for agriculturally important traits. We have used NGS and the G. hirsutum genome sequence to identify a large number of cultivar-specific single nucleotide polymorphism (SNP) in a number of G. hirsutum cultivars, and to fine map genes underlying qualitative traits. In this presentation, the general principals of mapping-by-sequencing will be presented, and we will show how we used SNPs identified between cultivars MCU-5 (normal leaf shape) and Siokra 1-4 (okra leaf) and targeted regional association analysis to uncover the gene determining the okra leaf shape in cotton.

2. Cotton Nutrition

In crop nutrient management, "Are we there yet"?

Chris Dowling
Back Paddock Company

With yield across most Australian cotton production areas achieving record levels in recent years and nutrient use efficiency being in the spotlight it is timely reconsider the season long management of crop nutrients. Currently the majority of crop nutrition decisions and actions are implemented pre-sowing based on a range of assumptions, with little objective assessment of nutrient status made post-sowing (Roth 2014). Options for post emergence modification to crop nutrient supply exist for a number of nutrients (N, S, K and trace elements). To be able to meet both yield and fertiliser use efficiency (FUE) objectives nutrient, peak nutrient demand needs to be matched by nutrient supply tactics that do not reduce efficiency, particularly for nutrient such as nitrogen for which significant losses can occur during each soil saturation event. Low adoption of existing in-crop nutrient monitoring tools such as leaf tissue and petiole analysis (Roth 2014) has been attributed to a number of logistic and science based issues ultimately being unable to broadly and conclusively demonstrate its worth in achieving increase profitability or FUE. A range of newer technologies have the potential to circumvent some logistic issues limiting use of current technology, however broad adoption still may be limited until the proven worth of in-crop nutrient management is conclusively demonstrated.

Application of Solvita test kit methodology to estimate soil N mineralisation

Francois Visser and Ammar Aziz
University of Queensland

Application of Solvita test kit methodology to estimate soil N mineralisation Research has shown that up to 60% of a cotton crop's N uptake may originate from soil mineralised N as opposed to fertiliser derived nitrogen. As this cheap and more reliable source of N may represent up to 50% of a cotton crop's N requirement, it is imperative that we are able to estimate this contribution accurately when developing N recommendations. It has also been shown that there is a poor correlation between the level of mineral nitrogen in the soil and the amount of mineralised N after a controlled period. However, the same study found that there is a very good correlation between the one day soil CO_2 respiration rate and the potential amount of N that can be mineralised from that soil. Based on a significant research over the past 30 years, Dalewood Laboratories in the US have developed the Solvita test kit methodology whereby mineral N contributions can reliably be estimated within 24 hours, requiring only basic laboratory facilities. The methodology is also valuable as an overall indicator of soil health. UQ is now in the process of validating / benchmarking the methodology and algorithms for Australian cotton growing conditions with the purpose of using the kits to benchmark the mineralisation parameters for the Nitrogen Optimisation Model that the team is currently developing. We will present preliminary results in this regard.

Can optimising nitrogen fertiliser rate mitigate nitrous oxide loss from flood-irrigated cotton paddocks?

Graeme Schwenke and Stephen Kimber
NSW DPI

The increasing atmospheric concentration of nitrous oxide (N_2O), a greenhouse gas, is contributing to global warming. Soil emissions of N_2O come from the natural biological processes of nitrification and denitrification, but inputs of fertiliser nitrogen (N) in agriculture has greatly increased N_2O production. Therefore, minimising excess fertiliser N should reduce N_2O emissions, especially in flood-irrigated cotton systems where saturated soil conditions are optimal for denitrification losses. The aim of this project is to investigate the effects of N fertiliser management on improving N use efficiency and on reducing N_2O emissions in commercial cotton systems. Current farmer practice, industry-recommended practice and regional alternatives are being tested in large-plot treatments in commercial paddocks at Gunnedah, Moree and Emerald. In 2014-15, treatments focussed on the total N applied to the crop, with three N rates including; the farmer's rate (220, 250, or 430 kg N/ha), a 25% lower rate and a 25% higher rate. From sowing until harvest, we monitored soil N_2O emissions using manual chambers located in the irrigated furrow, non-irrigated furrow and the crop bed. Initially, higher N_2O emissions came from the beds where N was applied pre-sowing. Later in the season, emissions often peaked in the non-irrigated furrows after rainfall and irrigation events, particularly after additional N was added in the irrigation water. Overall N_2O losses increased with N rate, but cotton yield was not related to N rate at all sites. Therefore, fertilising above the optimum plant N demand level reduced N use efficiency and increased environmental impact.

Response of irrigated cotton to applied nitrogen

John Smith and Mike Bell
NSW DPI; QAAFI, The University of Queensland

Like all high yielding farming systems nitrogen (N) is a key component to their productivity and profitability and Australian irrigated cotton growers are tending to apply more N than is required for the level of lint yield that is being achieved. This suggests either over application of N or inefficient systems limiting the response of cotton to N inputs. To investigate this four replicated trials were established in commercial fields during the 2014/15 season. The trials were aiming to measure the difference in response of irrigated cotton to the application of N under flood and overhead irrigation systems. The application treatments utilized eight upfront rates of applied N, ranging from 0 N kg/ha to a maximum of 410 kg N/ha, with three of the fours trials receiving a grower-determined in-crop application of N in the irrigation water. The two flood irrigation systems had lower lint yields from similar levels of N input compared to one of the overhead irrigated sites; the result from the second overhead site was impacted by disease. This paper discusses the response of plant N uptake, lint yield and fertilizer N recovery to N application.

Optimising Water & Nitrogen Fertiliser Management in Australian Cotton Production Systems

Jon Baird[1], Ian Rochester[2] and Rod Jackson[1]
[1]NSW DPI , Narrabri, NSW [2]CSIRO, Narrabri, NSW

The Australian Cotton industry in the last decade has enjoyed extraordinary growth in cotton lint yields, increasing from 7.4 bales/ha in 2003 to 10 bales/ha in 2014 (a). The growth in yield has been led by new developments in cotton varieties and better farm management strategies. One issue rising from the increase in production is the recent trend of applying high rates of nitrogen fertiliser to cotton crops. Despite past research showing that high yields can be achieved with nitrogen rates of 200 kg N/ha (b), industry audits are reporting many growers are applying in excess of 300 kg N/ha. Cotton industry financial performance benchmarking studies have further identified fertiliser input costs are increasing and potentially eroding farm profitability. To address the issue NSW DPI gained CRDC funding to establish a research trial on a commercial cotton farm in the Liverpool Plains of Northern NSW during the 2014-15 season. The aim of this research was to build on previous research and determine the impact of various irrigation and nitrogen rate treatments on plant growth, cotton lint yield, nitrogen use efficiency (NUE) and water use efficiency (WUE). The irrigation treatments (50, 70 & 100 mm soil water deficits) were the main plots, running the length of the field and 48 rows wide, which were split into smaller sub plots for the three N rates (200, 250 & 300 kg N/ha). At time of writing ginning is not completed so a full statistical analysis of WUE, NUE is yet to occur. However results and key findings from the research trial will be presented at the conference. References: a) Cotton Australia. (2015). Statistics. www.cottonaustralia.com.au/cotton-library/statistics. b) Rochester, I. & Filmer, M. (2007). Benchmarks Identified for Nitrogen Efficiencies. Farming Ahead, 190, pp 52.

Opportunities for managing nutrient efficiency in cotton production

Mark R Pawsey
SST Software Australia

With much of Australia's cotton grown on deep black cracking soils the argument is that soil variability is not a sufficient issue to implement precision agriculture. This assumption drives the adherence to a legacy program of a single soil test per field based on the argument that we will be applying a single rate of product anyway. Precision Agriculture is in fact nothing more than "best Practice" or digital agronomy. The 4R nutrient philosophy is about the Right product, time, rate and place and does not mean variable rate is required but it does mean that it needs to be considered among other techniques. Soil sampling a field with a single composite test virtually precludes any approach to managing sub field variability well before the crop is even planted. Identification of Management Zones in a field allows for decisions to be made with some evidence based approach to deciding how to manage nutrient efficiency. The technologies for improvements in nutrient efficiency in Australian Cotton production systems have been present for at least a decade in a usable form. The primary reason for the lack of uptake of these opportunities has been the lack of a locally focused "services supply chain" for information to the farmer and the confusion over data formats and systems. An opportunity exists to unite the industry around a single data construct that encourages and supports commercial services development, proprietary innovation and vendor competition as well as aggregate industry learning.

Fewer control plots for rate response trials

Bruce McCorkell
NSW DPI

How many control plots do you need for rate response trials? One of the perennial problems facing researchers testing levels and/or durations of application for a variety of materials and processes is the number of experimental units that should receive a zero application. A balanced experimental design (eg. RCB), to be analysed by analysis of variance, typically requires "zero" rates (ie. controls) for each treatment (ie. herbicide, fertiliser, etc.). An experimental design with a single set of controls, rather than controls for each treatment, is unbalanced but can be analysed using generalised linear modelling (GLM) and an analysis model that recognises the balanced orthogonal components within those trial data. Such an approach to rate response trials involves fewer resources (ie. fewer zero plots) and can be analysed with only a small reduction in precision resulting from fewer residual degrees of freedom. In this presentation I intend to demonstrate such an approach to data analysis.

Cotton root systems and recovery of applied P and K fertilisers

David Lester[1] and Michael Bell[2]
[1]Queensland Department of Agriculture and Fisheries
[2]University of Queensland

With potential to accumulate substantial amounts of above-ground biomass, at maturity an irrigated cotton crop can have taken up more than 20 kg/ha phosphorus and often more than 200 kg/ha of potassium. Despite the size of plant accumulation of P and K, recovery of applied P and K fertilisers by the crop in our field experiment program has poor. Processing large amounts of mature cotton plant material to provide a representative sample for chemical analysis has not been without its challenges, but the questions regarding mechanism of where, how and when the plant is acquiring immobile nutrients remain.

Dry matter measured early in the growing season (squaring, first white flower) have demonstrated a 50% increase in crop biomass to applied P (in particular), but it represents only 20% of the total P accumulation by the plant. By first open boll (and onwards), no response in dry matter or P concentration could be detected to P application.

A glasshouse study indicated P recovery was greater (to FOB) where it was completely mixed through a profile as opposed to a banded application method suggesting cotton prefers a more diffuse distribution. The relative effects of root morphology, mycorrhizal fungi infection, seasonal growth patterns and how irrigation is applied are areas for future investigation on how, when and where cotton acquires immobile nutrients.

3. Natural Resource Management

Annual entitlement for the Condamine floodplain irrigators – is it really working?

Elad Dafny
University of Southern Queensland

Rigorous analysis of monitoring bores hydrographs demonstrates that since 2008 the water table in the central part of the Condamine Floodplain has stabilized, ending several decades of a consistent decline in groundwater levels. It seems that the stabilization is a result of the 2007 revised water pumping restrictions scheme in the Condamine Groundwater Management Area (CGMA). Prior to 2007, water allocations were set only at the heart of the 'cotton land', between Pampas and Macalister, where the focal of groundwater drawdown was observed. However, this measure had no noticeable impact on groundwater levels. From that year onward, water allocations were also set at the peripheral parts of the CGMA, including the southern part ('sub-area 4'). In this area, groundwater from the upper alluvial valleys, as well as large parts of the basaltic ridges, merge and flow laterally toward the central alluvial aquifer. In other words, pumping reduction in the southern area resulted in an increase in the lateral flow toward the central area, which act to compensate and prevent further drawdowns. These observations emphasise the need in integral water management for the entire floodplain, including target values for sustainable yield for different zones within the basin. Further monitoring and modelling could assist this task.

Recharge processes at the St George Irrigation Area

Elad Dafny
University of Southern Queensland

Since the 1950s, irrigated cropping has taken place in the St George Irrigation Area (SGIA), following clearance of the native vegetation and construction of water canals, carrying river water to the agricultural lands. The change from open-forest to arable lands mostly irrigated involved changes to the groundwater balance and in turn, groundwater quality. Deep-drainage and leaks from the water canals and dams, to name two possible water sources, which carry different amounts of salts into the sub-surface, may affect the groundwater salinity.

The groundwater under the SGIA ranges in quality from fresh water, with about 50 mgCl/L, to salty water, with ~10,000 mgCl/L. We analysed all of the available bore water samples, to detect any on-going salinity trends (rising/stable/falling) and identify potential sources. Results indicate the existence of four end-members, namely, saline formation water, brackish deep-drainage, slightly brackish flood-recharge water, and fresh imported river-water. Each of these has a typical geochemical composition, which allows reconstructing the past and the current recharge processes in the SGIA. The groundwater composition at many bores varied over time, to reflect the changes in the dominant end-member.

This study demonstrates that effective changes in groundwater quality can occur in a relatively short time-frame.

The decline and rise of groundwater levels in the Maules Creek Catchment (Upper Namoi): implications for water resource management

Calvin P Li[1], Martin S Andersen[1], Bryce F J Kelly[1], Gabriel C Rau[1] and Andrew M McCallum[2]
[1]Connected Waters Initiative Research Centre, UNSW Australia, Sydney, NSW [2]Affiliated with CWIRC

In semi-arid environments, groundwater often offers a reliable irrigation water resource. Yet over-development can stress aquifers and affect streamflow, especially during droughts. We examined the contribution of stream leakage to groundwater recharge in the Maules Creek Catchment, NSW. Groundwater levels declined by as much as 5m during the droughts in 2002-03 and 2006-07, which were moderate compared to the Federation Drought (1895-1902). Variations in local precipitation are linked to the El Niño Southern Oscillation climate index. Following the transition from El Niño to La Niña, multiple medium to large rainfall events (130-260 mm per month) in the headwater area caused streamflow and mountain-front discharge. Along ephemeral reaches of Maules Creek, where pumping-induced abstraction had created a zone of drawdown, transmission loss during flow events between 2010 and 2013 provided significant recharge and the water table rose to near or above pre-irrigation (~1980) levels. Away from Maules Creek, however, groundwater levels were 0.5-2m lower than pre-abstraction levels l and exhibited a declining trend since the 1980s. Moreover, sections of the Namoi River that changed from gaining to losing after the onset of large-scale abstraction did not restore to the pre- abstraction conditions. Results show individual storms provide a limited contribution to aquifer recovery. However, groundwater does respond to large floods, and pumping does affect streamflow. These aspects both highlight the presence of good recharge pathways from ephemeral streams. Opportunities for implement managed aquifer recharge should be explored to enhance aquifer recovery and assist with "banking" water to drought-proof the irrigation community.

Detecting connectivity between an overlying aquifer and a coal seam gas resource using methane isotopes, dissolved organic carbon and tritium

Charlotte P. Iverach[1], Dioni I. Cendón[1,2], Stuart I. Hankin[2], David Lowry[3], Rebecca E. Fisher[3], James L. France[4], Euan G. Nisbet[3], Andy Baker[1] and Bryce F.J. Kelly[1]

[1]Connected Waters Initiative Research Centre, UNSW
[2]Australian Nuclear Science and Technology Organisation, Lucas Heights NSW
[3]Royal Holloway, University of London, Egham Hill, Egham, Surrey, United Kingdom
[4]School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom

There is public concern that coal seam gas (CSG) production will affect groundwater quality and quantity in overlying aquifers used to support irrigation, stock and domestic water supplies. To assess this risk there is a need to map pathways of hydraulic connectivity using geochemical and isotopic measurements. We demonstrate that measurements of methane (CH4) concentration and isotopic composition, dissolved organic carbon (DOC) concentration and tritium (3H) activity data highlight potential pathways of hydraulic connectivity between the Walloon Coal Measures (WCM – the target formation for CSG production) and the Condamine Alluvium, south-east Queensland, Australia. At 19 locations, both groundwater and degassing air samples were collected from irrigation bores. Degassing air samples were pumped into 3 L Tedlar bags. This air was analysed for both its methane concentration and isotopic signature. The groundwater was analysed for 3H and [DOC]. To determine the isotopic signature of the WCM, CH4 ambient air samples were collected adjacent to CSG co-produced water holding ponds. We use isotope mixing plots to identify the isotopic source signature of CH4 in the air samples from the degassing irrigation bores and those adjacent to CSG water holding ponds. Within the mixing plots samples graph along clear trend lines, which allows gas sources to be assigned. These trends in the mixing plots indicate potential local hydraulic connectivity between the WCM and the overlying Condamine Alluvium.

Quantifying the Potential Impact of Abandoned Exploration Wells on Groundwater

Mark Hocking, Craig Beverly and Bryce Kelly

UNSW/HGEC, DEDJTR & UNSW

In March 2014 UNSW Australia, Royal-Holloway, University of London and CSIRO measured methane in the near-surface atmosphere throughout the Condamine Catchment using a mobile methane analyser. The survey identified both natural and human sources of methane. One significant source was abandoned exploration wells. Results suggest at these sites there is a pathway between the Walloon Coal Measures (WCM) and the surface. This raises the question, what impact do these abandoned wells have between Coal Seam Gas (CSG) production and the alluvial aquifers used to supply irrigation water? To examine this question a groundwater model was developed using the analytical element method (AEM). Two impact scenarios are considered 1) the present situation where there is a 2 metre upward groundwater-level gradient, where groundwater recharges the Condamine River Alluvial Aquifer (CRAA) from the WCM, and 2) the potential future case where the WCM groundwater level is lowered 50 metres below the CRAA (conservative CSG development conditions). Calibration constrained Latin hyper-cube uncertainty analysis was used on the steady state multi-layer groundwater model. The modelling found that a single exploration well (open diameter 96 mm) had for scenario 1) a median upward leakage of 44 ML/year into the CRAA, and scenario 2) a median downward leakage of 1067 ML/year into the WCM respectively. In the gas fields of southern Queensland Australia, there are over 130,000 uncased or unsealed mining exploration wells. This research has identified the need to locate these abandoned wells so that they can be incorporated into regional groundwater impact assessments.

Impulse Response Groundwater Model of Western Border Rivers Catchment

Mukhlis Mah and Bryce Kelly

Connected Water Initiative Research Centre, UNSW

Impulse response modelling, a subset of time-series analysis, allows for the description of groundwater level fluctuations as a function of precipitation, river flow (and stage), irrigation deep drainage and evapotranspiration. In contrast to traditional process based water balance modelling methods like MODFLOW, the Predefined Impulse Response Function In Continous Time (PIRFINCT) methods uses simple statistical distributions to define the relationship between a forcing (for example rainfall) and the groundwater level response. The program Menyanthes, which employs the PIRFINCT method, was used to conduct this analysis on bore records in the western segment of the Borders River Catchment, between Goondiwindi and Mungindi, to gain an insight into groundwater recharge processes. A total of 58 bores were analysed of which 40 gave satisfactory model results, with 16 bores displaying a fit of over 95%. For multi-year hydrological records the

models indicated that precipitation accounted for the majority of the observed fluctuation in groundwater levels, whilst river stage (an indicator of potential streamed recharge) was negligible. The poor correlation between stream stage (which also contains the flood signal) is likely due to the length of record selected for modelling. Attempts to incorporate recharge from irrigation were also unsatisfactory. Further work, including comparison to traditional time series analysis models, is required to before we can obtain reliable insights on recharge using the PIRFINCT method.

Cotton soil salinity and nitrate profiles over 20 years of irrigation

Alice R. Melland[1], Andrew Biggs[2], Mark Silburn[1,2] and Elad Dafny[1]

[1]National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, QLD
[2]Department of Natural Resources and Mines, Toowoomba, QLD

Around 15% of bores used for irrigation in the Condamine Alluvia have salinity levels higher than the cotton threshold and require blending with fresh water. To identify the long term impact of irrigation with blended water on soil salinity, soil chloride profiles in two paddocks that were sampled four years after irrigation began, in 1996, were re-sampled in 2014. One paddock was furrow irrigated and the other used subsurface tape. Both paddocks received bore water only (2600-3600 µS/cm) for the first four years, followed by overland flow (c.a.300 µS/cm) water with or without bore water. In the subsurface-irrigated paddock, use of bore water ceased in the early 2000s due to grower concerns over crop yield penalties due to soil salinity. In the 18 years between soil samplings, chloride has leached from the rootzone (0-0.9 m) at a rate of about 0.1 t/ha/yr, and in 2014 the rootzone soil salinity was low (ECse 1.4 dS/m). In the furrow-irrigated paddock, a large accumulation of salt occurred in the early stages of irrigation and despite a higher rate of leaching since 1996 (0.35 t/ha/yr), soil salinity in 2014 (ECse 4.6 dS/m) restricted crop choice. As well as chloride, nitrate also readily leaches with water. Stores of 54 and 200 kg nitrate-N/ha were measured below the rootzone (0-9 – 1.6 m) in the subsurface and furrow-irrigated paddocks respectively. Reducing salt inputs to soil via irrigation water has the potential to improve crop production and choice, and improve both water and nitrogen use efficiencies.

How many trees are enough? Using vegetation to combat deep drainage and seepage

Andrew Biggs

Dept. of Natural Resources and Mines

Deep drainage and seepage from infrastructure are an unavoidable consequence of irrigated agriculture. Many strategies can be employed to minimise losses in-field but ultimately, mitigation will often be required. Mitigation strategies will vary from farm to farm, but they must possess a number of key characteristics. They must be low cost to establish, robust, low maintenance, seamless with the farming enterprise and ideally provide other benefits. Lateral seepage from storages and channels can create multiple impacts on adjoining land, most commonly loss of productivity. The problem often cannot be resolved without earth works that may be cost-prohibitive. Interception of seepage using vegetation belts is a viable option to prevent continued impact on adjoining land. Creation of vegetative cover in the seepage zone reduces evaporation and concentration of salts at the soil surface. Vegetated strips do not necessarily involve trees, but can be native or improved pasture species, thus providing a potential resource to growers who still run livestock. Where appropriate, native or planted tree belts serve many functions on-farm, including acting as a pump to remove excess deep drainage and groundwater. A native strip of poplar box 50 m wide has been found to successfully intercept seepage from a ring tank on permeable red soil. Brigalow and belah are more salt/waterlogging tolerant and we have estimated their water use to be at least 10% of the typical deep drainage from irrigated cotton. On some farms, the remaining vegetation therefore plays a vital role in reducing excess deep drainage.

Carbon sequestration in riparian zones on cotton farms

Rhiannon Smith[1], Stacey Vogel[2], Francois Visser[3], Jon Welsh[2]

[1]Ecosystem Management, University of New England
[2]CottonInfo Team
[3]School of Agriculture and Food Sciences, University of Queensland

Recent research has shown the value of native vegetation in semi-arid regions for sequestering large amounts of carbon, particularly in El Niño years. In 2011, above-average rainfall led to significant vegetation growth and a 'greening' of inland Australia. During the period 2008–12, we measured growth rates and biomass accumulation of river red gums on cotton farms in the lower Namoi. Our data suggest that river red gums can grow up to 6 cm (diameter at 1.3 m above ground) per year and sequester just over 2 t C ha-1yr-1 during high rainfall and flood conditions. In general, trees in riparian zones grow significantly faster than trees on the floodplain and trees in dense stands grow slower than widely-spaced trees. The health of trees (i.e. the degree of crown dieback) also impacts tree growth. This information will be incorporated into a carbon calculator tool currently under development for the cotton industry. The carbon calculator will highlight carbon sources and sinks on cotton farms and allow carbon conscious growers to become carbon neutral or even better, generate carbon credits. Our research has shown that healthy riparian corridors sequester large amounts of carbon and may be the key to achieving carbon neutrality in the cotton industry.

Governing Uncertainty: the cotton industry's responses to resource uncertainty

Olive Hood
University of Southern Queensland

The Australian cotton industry's future is related to the continued availability of and access to friable soils, potable water and richly bio-diverse environments. Yet the future availability of the industry's required environmental conditions and assets is uncertain for emergent ecological, economic and socio-political reasons. Increasing resource uncertainty makes an examination of the industry's participation in environmental governance a timely endeavour. As part of a study commissioned by the industry, this paper reports on observations of its environmental governance participation during 2010. At the time of this study, the Murray Darling Basin Authority was preparing to release its draft plan for redirecting a proportion of mainly irrigation entitlements within the basin towards the maintenance of ecosystem functions and the provision of cultural flows. At the same time, the Queensland and Australian governments were preparing to approve two international Coal Seam Gas projects with contested impacts on the resources that support communities within Queensland cotton catchments. During this time, the industry was observed to share a privileged position in governance arrangements by both being externally recognised by others (e.g. government and mining) as sharing legitimate environmental governing logics (i.e. environmental governmentalities) whilst at the same time it was observed to be actively ensuring the internal maintenance of these governmentalities. This paper proposes that the Australian cotton industry may benefit from considering the implications of its environmental governmentality choices on its future.

1. Cotton Pathology

The importance of cotton disease surveys in Queensland for monitoring endemic diseases and detecting new pathogens and pests

Linda Smith, Linda Scheikowski and John Lehane
DAF

The cotton industry in Australia funds biannual disease surveys conducted by plant pathologists. The objective of these surveys is to monitor the distribution and importance of key endemic pests and record the presence or absence of new or exotic diseases. Surveys have been conducted in Queensland since 2002/03, with surveillance undertaken by experienced plant pathologists. Monitoring of endemic diseases indicates the impact of farming practices on disease incidence and severity. The information collected gives direction to cotton disease research. Routine diagnostics has provided early detection of new disease problems which include 1) the identification of *Nematospora coryli*, a pathogenic yeast associated with seed and internal boll rot; and 2) *Rotylenchulus reniformis*, a plant-parasitic nematode. This finding established the need for an intensive survey of the Theodore district revealing that reniform was prevalent across the district at populations causing up to 30% yield loss. Surveys have identified an exotic defoliating strain (VCG 1A) and non-defoliating strains of *Verticillium dahliae*, which cause Verticillium wilt. An intensive study of the diversity of *V. dahliae* and the impact these strains have on cotton are underway. Results demonstrate the necessity of general multi-pest surveillance systems in broad acre agriculture in providing (1) an ongoing evaluation of current integrated disease management practices and (2) early detection for a suite of exotic pests and previously unknown pests.

What influences fungal communities in cotton soils

Gupta, V.V.S.R., Linda Smith, Karen Kirkby, Linda Scheikowski and Ian Rochester
CSIRO Agriculture Flagship, Glen Osmond, SA and ACRI Narrabri; Qld DAFF, Brisbane; NSW DPI, ACRI Narrabri; Arizona State University, USA

Soilborne diseases such as Fusarium wilt, Black root rot and Verticillium wilt have significant impact on cotton production. Fungi are an important component of soil biota with capacity to affect pathogen inoculum levels and their disease causing potential. Very little is known about the soil fungal community structure and management effects in Australian cotton soils. We analysed surface soils from ongoing field experiments monitoring cotton performance and disease incidence in three cotton growing regions, collected prior to 2013 planting, for the genetic diversity and abundance as influenced by soil type, environment and management practices and link it with disease incidence and suppression. Results from the 28S LSU rRNA sequencing based analysis indicated a total of 370 fungal genera in all the cotton soils and the top 25 genera in abundance accounted for the major portion of total fungal community. There were significant differences in the composition and genetic diversity of soil fungi between the different field sites from the three cotton growing regions. Results for diversity indices showed significantly greater diversity in the long-term crop rotation experiment at Narrabri (F6E) and experiments at Cowan and Goondiwindi compared to the Biofumigation and D1 field experiments at ACRI, Narrabri. Diversity was lowest in the soils under brassica crop rotation in Biofumigation experiment. Overall, the diversity and abundance of soil fungal community varied significantly in the three cotton growing regions indicating soil type and environmental effects. These results suggest that changes in soil fungal community may play a notable role in soilborne disease incidence in cotton.

NSW DPI Biosecurity Update on Defoliating strain of Verticillium dahliae 1A

Karen Kirkby[1], Toni Chapman[2] and Grant Chambers[2], Peter Lonergan[1], Bethany Cooper[1], Sharlene Roser[1], and Rafael M. Jiménez Díaz[3]
[1]NSW Department Primary Industries, Australian Cotton Research Institute (ACRI), NSW
[2]NSW Department Primary Industries, Elizabeth Macarthur Agricultural Institute (EMAI), Menangle, NSW
[3]Departmento de Agronomia, Universidad de Córdoba, Campus de Excelencia, Internacional Agroalimentario, ceiA3, and Institito de Agricultura Sostenible, CSIC, Córdoba, Spain

The NSW Department of Primary Industries (NSW DPI) has been making quantitative assessments of disease incidence and severity in cotton for over three decades, with the first commencing in 1983/84. NSW DPI has maintained a culture collection from these surveys. Laboratory testing in late 2014 of the NSW historic culture collections indicated the presence of the defoliating strain of Verticillium dahliae. This was recently confirmed by further testing by an independent diagnostic laboratory in Spain. The 1A strain was identified and confirmed in a samples from 1983/84, 2010/11, 2013/14 seasons and further samples from this season. The cotton industry identified the defoliating strain of Verticillium dahliae as a high priority pest through its Industry Biosecurity Plan.

Since then pathologists have conducted surveillance for the presence/absence of this pest in the field based on symptoms. Suspect samples have been collected and cultured for V. dahliae and molecular VCG testing is being conducted. This paper is a NSW DPI Biosecurity update on the incidence of the new strain 1A in NSW cotton and what it means.

Efficacy of fungicide seed treatments on reducing seedling mortality in cotton in Australia

P.A. Lonergan, K.A. Kirkby, B. Cooper and S. Roser

NSW Department of Primary Industries

Seedling diseases of cotton (*Gossipium hirsutum* L.) cause major production losses in Australian cotton production each year. Pre and post-emergent seedling diseases are caused by fungal pathogens that are favoured by environmental conditions that delay germination, emergence and seedling growth. The most common pathogens include *Pythium* spp., *Rhizoctonia solani* and *Thielaviopsis basicola*. Strong expansion of the cotton industry south wards into the cooler and shorter growing season areas of the Lachlan and Murrumbidgee regions means the need for effective plant establishment is greater than ever. Data collected by NSW DPI pathology team showed the estimated the average seedling mortality for NSW in 2013/2014 cotton season was 33.5%. Mortality ranged from 29.7% in the Namoi to as high as 41.6% in the southern region of Murrumbidgee.

Mycorrhizal status in cotton following rice

J R Moore, J E Pratley, R Malone, K O'Keeffe and K A Kirkby

Graham Centre for Agricultural Innovation (An alliance between NSW Department of Primary Industries and Charles Sturt University); Wagga Wagga Agricultural Institute, NSW DPI, Wagga Wagga, NSW; Elders Rural Services, Griffith, NSW; CottonInfo, Regional Development Officer, Southern NSW; Australian Cotton Research Institute, Department of Primary Industries, Narrabri

Early vigor in cotton is related to its ability to access nutrients present in the soil. Mycorrhizal associations are known to benefit cotton establishment by enhancing nutrient and moisture acquisition, particularly phosphorus and zinc. If the colonisation of arbuscular mycorrhizal fungi (AMF) is incomplete, the cotton crop may be restricted in its establishment and growth. The need for vigorous germination, strong emergence and establishment at appropriate densities becomes paramount to subsequent crop development and ultimate yield. Commercial mycorrhizal testing of 'pre-plant' soil samples showed a wide range of spore counts (4-100 spores/g), dependant on the crop rotational circumstances. Additionally, a field site previously used for rice that displayed growth differences between old bank lines and the adjacent rice bay area was utilised for soil sampling. Paired soil core samples from these areas were taken in PVC tubes (100mm diameter, 250mm depth). Plant height and establishment rates were measured in the field at time of sampling. Plant heights at time of soil core sampling between bank and bay areas were significantly different ($p < 0.001$). Subsequently, PVC tubes were then sown with cotton and utilised in a pot experiment. Cotton plants were grown for six weeks in a temperature controlled glasshouse (day/night cycle 30°C/20°C). Roots were then washed, stained and mycorrhizal colonisation was determined in each sample. Mycorrhizal colonisation was greater in soil cores sampled from old bank areas compared with the adjacent bay ($p < 0.05$). This paper discusses the relationship between crop rotations and their effect on colonisation of mycorrhiza in cotton and the implications of converting old rice bays into raised beds for cotton production.

Cotton leafroll dwarf virus detected in Thailand and Timor Leste

M.Sharman[1], J. D. Ray[2], C. F. Gambley[1], S. Lapbanjob[3] and V. Quintao[4]

[1]Department of Agriculture and Fisheries, Queensland
[2]Department of Agriculture, Australian Government
[3]Department of Agriculture, Thailand
[4]National Directorate of Quarantine and Biosecurity, Timor Leste

Cotton leafroll dwarf virus (CLRDV) has been reported as the causal agent of the industry limiting Cotton blue disease in India, Brazil and Argentina. This is a significant biosecurity threat to the Australian cotton industry and the CRDC has funded preparedness in the form of the development of a diagnostic protocol and a Contingency Plan. As part of this work, CLRDV has now been confirmed for the first time in Thailand samples of "cotton leaf roll" disease. In addition, CLRDV has been recently detected in non-symptomatic *Gossypium barbadense*. This was collected from Timor Leste (East Timor) as part of an annual plant health survey collaboratively conducted by the Timor Leste Ministry of Agriculture and Fisheries, and the Australian Government Department of Agriculture. While the resulting partial genome sequence had high identity to CLRDV, it has not yet been confirmed that the detected virus from Timor Leste could cause cotton blue disease in *G. hirsutum*. Published reports for a closely related virus indicate CLRDV may have a wider host range than originally thought including non-symptomatic members from the Fabaceae. Further CRDC-funded research on the biology and prevalence of this virus in the Timor Leste region, and surveys in nearby areas in Australian are planned to better understand the potential for incursions into Australia.

Nematodes of the Gwydir and Namoi

Oliver Knox and Bryan Griffiths
UNE and SRUC

Nematodes are small soil dwelling worm like organisms that generally nurture a range of beneficial soil functions. However, a few are plant parasites and can affect crop production systems. There has been recent interest in the reniform nematode, which has resulted in cotton production issues in Theodore, however, outside of this area most nematode studies have focused on grains or citrus systems. We have looked at nematodes under cotton in the Gwydir and Namoi valleys. Our work has investigated improving recovery of nematodes from heavy clay vertosols, looking at differences between verticillium affected and unaffected fields, establishing if change is occurring since the loss of aldicarb and looking at nematode movement in vertosols. We've observed regional differences in abundance and community structure, some change in the plant parasitic nematodes associated with verticillium, more stable nematode communities developing without aldicarb and that nematodes struggle to move vertically in vertosols. These observations and their significance to cotton production will be discussed.

2. Social Science & People

Is it just for the money? What are the motivations of an Australian Cotton Grower.

Geraldine Wunsch

School of Linguistics, Adult and Specialist Education, USQ

Food and fibre are fundamental for survival. The farmers who grow this food and fibre endure an environment that is complex, risky and stressful and their own survival can be at the mercy of the elements. Each season brings with it a new set of variables, the goal posts keep changing.

So what motivates an Australian cotton grower to grow cotton? It's not all about agronomic, environmental, economic factors. It is therefore important to know, because without Growers cotton cannot grow.

Is it just for the money? An increase in input costs of fertilizer and fuel, as well as extreme price fluctuations driven by the Australian dollar finding new highs, extreme climatic conditions leading to a focus on water and land availability, and the shift of labour resources to other industries presents as a question to growers. What motivates me to grow cotton and do what I do?

The average Australian cotton farm is family-owned and the average age of a grower is 39 years (Cotton Australia, 2013) which is significantly younger than the average age of a grain farmer at 52 years (National Farmers Federation, 2012). According to the Australian National Farmers (2012) there are 2.5 jobs available for every agriculture graduate. These are two crucial factors for this research project because both are expected to contribute to the elements of experience that sustain career and work engagement.

A New Perspective: Growers' views on these seasonal variables influencing their decision making will give insight into retention factors affecting them. This research will determine the psychological and characteristic adaptations that may affect grower motivation and work/life satisfaction.

Integrated economic, environmental and social performance reporting of Australian Grown Cotton

Guy Roth[1], Angela Bradburn[2], Jane Trindall[3] and Allan Williams[3]

[1]Roth Rural, PO Box 802 Narrabri, NSW, 2390, guyroth@roth.net.au.
[2]Cotton Australia, Sydney, NSW, www.cottonaustralia.com.au.
[3]Cotton Research and development Corporation, Narrabri, NSW, www.crdc.com.au.

There are multiple market driven sustainability initiatives around the globe that expect good data to be available on food and fibre production, which is not always easy to achieve. Sustainability reporting is the practice of measuring, disclosing and being accountable for performance towards the goal of sustainable development and is considered synonymous with other terms used to describe for accounting for economic, environmental and social impacts such as triple bottom line or corporate responsibility. An inventory of potential Australian Cotton Industry sustainability indicators was developed which reviewed the material issues of stakeholders and the literature (Roth 2010). This set of potential sustainability indicators was assessed and updated by the cotton industry's environmental assessment working group, taking into account recent developments in international supply chain sustainability initiatives such as the Better Cotton Initiative, Cotton LEADS™, and the Expert Panel on Social, Environmental and Economic Performance of Cotton Production of the International Cotton Advisory Committee (SEEP 2013). A meta-analysis of the Australian cotton research literature was completed. A report was compiled using the Global Reporting Initiative for Sustainability Reporting Framework using economic, environmental and social indicators. In preparing the report, the Australian Cotton Industry considered more than 100 sustainability indicators and consulted stakeholders to report on 45 aspects of sustainability. The report, Australian Grown Cotton Sustainability Report 2014 was released by Cotton Australia and CRDC. The report can be found at http://www.crdc.com.au/publications/australian-grown-cotton-sustainability-report. The project will be producing an updated 2016 version in time the Australian Cotton Conference 2016.

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Adaptive learning pathways for cotton irrigation science

Jane Trindall, Jenny Foley and Janelle Montgomery

CRDC, Q DNRM and NSW DPI

Over the past two years cotton irrigation scientists have actively sought to accelerate the journey of research concept through to adoption and eventually impact for their science. Initially, in 2014 the inaugural IRRICOMM brought together irrigation researchers to explore research ideas, identify current and future tools in the cotton irrigation toolbox and ways to integrate these technologies through explicit links between the projects.

The tools that cotton irrigators are using to manage their irrigations have not changed dramatically over the last 20 years. The aim of the 2015 cotton irrigation technology tour was to bring irrigation researchers onto cotton farms across three cotton growing valleys to demonstrate new and emerging irrigation technologies and hear feedback on the practicalities and gaps in the research.

Participants were asked to identify if they would like more extension of any of the irrigation technologies in their region and specify which technologies. The data points to a good deal of interest across all the technologies, with the participants intending to adopt ranging between 42 and 80 percent of respondents.

The paper will discuss various concepts relating to how we can utilise adaptive learning pathways to overcome some of the challenges to technology uptake across the various sectors of the industry. Workshops like the EM38 and Irrisat workshops are only a starting point. We have to be innovative not just with the technologies – but with how we bring them into common use.

CottonInfo Extending Research

Lance Pendergast
DAF

There are many ways in which research messages and findings can be extended to the expansive cotton community. As everyone learns differently it is crucial that information is delivered in a variety of ways to meet the various learning needs of the CottonInfo team's broad audience. In addition different cotton production areas often require targeted information to address specific challenges. Successful implementation of innovative research outcomes typically relies on a history of cultivated communication between the researcher and the end-user, the grower.

The CottonInfo team, supported by a joint venture between Cotton Seed Distributors, Cotton Research Development Corporation, Cotton Australia and other collaborative partners, represents a unique model of extension in Australian agriculture. Industry research is extended via regionally based Regional Development Officers backed by support from Technical Specialists.

The 2015 Cotton Irrigation Technology Tour is one example of a successful CottonInfo capacity building activity. This tour took seven CRDC funded irrigation-specific researchers to Emerald, Moree and Nevertire to showcase their research and technologies. These events provided irrigators and consultants with the opportunity to hear first-hand from researchers about their technologies and how they could be applied onfarm. This tour was an example of how the CottonInfo team can connect growers and researchers, not only to provide an avenue for growers to learn about the latest irrigation research, but for researchers to receive feedback about their current and future irrigation research.

Developing Education Capacity in Agriculture

Trudy Staines and Sharon Downes
CSIRO Agricultural Flagship, Australian Cotton Research Institute (ACRI), NSW

One of the main challenges facing agriculture is the shortage of skilled labour made worse by low retention and attraction rates, an aging workforce and having to compete with the resource sector. For the past 9 years CSIRO has worked with the cotton industry to address this issue through a project which engages schools, universities and agribusiness to improve the supply of suitably qualified professional personnel to meet future needs. For example, we engage primary school students by having them write a story on an agricultural and environmental issue with the best entries being published as booklets that are distributed to other schools across catchments. An example of our engagement with secondary schools is through the Primary Centre for Science Education (PICSE) five day camp that showcases regional agricultural organisations to students during an influential period in their education. In another initiative, students studying agriculture related courses at University are identified and placed into agribusiness service roles by matching their skills with employer needs. We will outline the impact of these initiatives using case studies which follow our involvement with students from high school through to their eventual placement as professionals within the cotton industry.

Characteristics of technologies that are impacting adoption: Twelve reasons why your research could be ignored

Warwick Waters
CottonInfo

The scientific method quite rightly focuses attention on knowledge discovery and problem solving. Unfortunately, successful discovery or problem solving is no guarantee that end users are going to adopt a management practice or technology. The literature, such as Rogers (2003), Pannell et al (2006) and Vanclay (2004), has identified a range of technology attributes that impact the rate, reach and effectiveness of adoption. These attributes impact a range of social, economic, cultural and environmental factors that should be considered in the adoption process. The CottonInfo program seeks to work with the cotton research community to consider the characteristics of a technology that can impact adoption. A framework of questioning is presented that works through twelve characteristics that can either be optimised for adoption during the research and development process, or accounted for in the extension process.

3. Cotton Breeding: Fibre

A remarkable secondary cell wall underpins cotton fibres as a textile. How is production of this wall regulated, and what can we use this knowledge for?

Colleen P. MacMillan, Filomena A. Pettolino, Liz Brill, Liz Dennis, Pinghua He and Danny Llewellyn
CSIRO Agriculture, Canberra, ACT

The use of cotton as major global textile is based on the long strong fibres that grow on its seeds. Cotton seed fibres are single plant cells wrapped up in a thick 'secondary' cell wall made of more than 90% cellulose, a material extremely high in tensile strength. What makes this fibre secondary cell wall remarkable is its purity compared to other secondary cell walls found in other cotton tissues and plants that are lignocellulosic and contain only around 30% cellulose. These fibres are also extraordinary because they are some of the longest plant cells known, each cell being 3-4 cm long, or more. Virtually nothing has been known about what regulates the production of the fibre secondary cell wall. To answer this, we have compared global gene expression between cotton seed fibre and cotton stem cells, two tissues that make very different secondary cell walls. We have identified some key genes linked to the control and production of the highly cellulosic fibre secondary cell wall. We highlight some transgenic cotton results focusing on confirming the function of transcriptional regulators identified in controlling cotton fibre quality (maturity ratio, linear density and micronaire), and yield (fibre weight per boll and fibre weight seed). Finally, we suggest how this knowledge could be used, for example to find markers linked to the control of cotton fibre secondary cell wall production, and to generate transgenic cotton with altered fibre quality properties.

Using biotechnology to increase the utility of cotton fibre

Filomena Pettolino, Qinxiang Liu, Colleen MacMillan and Danny Llewellyn
CSIRO, Agriculture

The irony of cotton fibre being competed out of the textile market by man-made fibre is that there is a push for man-made fibre to behave more like a natural fibre. Considering that cotton fibre already has a number of attractive intrinsic properties, one way to keep cotton prominent in the market is to explore the potential to alter its functionality and therefore increase its utility. Using a biotechnological approach, cotton fibre properties could be manipulated by modifying the existing components of the fibre, such as the waxes or polysaccharides, or by adding new molecules to the existing structure. There is reasonable understanding of how plant cells build and regulate cell walls and hence cotton fibre, which can translate to the modification of fibre quality. Via the second approach, there is a diverse array of natural biomolecules with interesting functional properties that are amenable to molecular techniques for their introduction into cotton fibre. These include proteins and enzymes and the products of their reactions. The possibilities, and the benefits and pitfalls of such approaches will be discussed.

Developing breeding strategies to maintain yield while improving fibre quality

J.D. Clement, G.A. Constable, W.N. Stiller and S.M. Liu
CSIRO

Cotton breeders are primarily focused on improving yield. This is primarily due to the fact that the returns producers receive are largely based on the quantity they produce. While the fibre must meet a certain base grade for quality to prevent discounts, it can receive premiums for exceptional quality. The cultivars that are able to achieve these premiums are generally lower yielding. This is due to a well-documented negative relationship between yield and fibre quality, with fibre strength having the strongest association. While this makes it an unattractive trait for producers, it is highly desirable to the end user, the textile mills. Cotton fibre quality is important for spinning mills which process the fibre into yarn and ultimately apparel. In spinning, the fibres are twisted together to form yarn, then woven to form cloth. Length, strength, and fineness are the most important fibre quality traits for yarn spinning, all contributing to the strength of the yarn. The better the quality the more premiums the mill receives for their yarn. This presents a challenge for cotton breeders to improve fibre quality while maintaining yield in order to keep cotton a competitive product. This presentation details breeding strategies that aim to decrease the negative association by improving fibre quality while maintaining yield.

Can a seed trait reduce ginning power requirements?

Scott Barnes, Stuart Gordon and Warwick Stiller
CSIRO

The rising cost of energy necessitates evaluation of how cotton germplasm can be developed to affect lower energy loads in saw ginning. CSIRO have developed cotton lines where the longer staple fibres have lower attachment strength to the seed coat, potentially reducing the force required to separate fibre from the seed during ginning. In this study we report on the power consumption by an industry scale saw gin processing one such line in comparison to a standard commercial cultivar (Sicot 71BRF). Trials involved running multiple 50 kg replicates of each cultivar at a constant feed rate through CSIRO's saw gin. Seed roll load, motor current and frictional heat within the seed roll were measured at two saw speeds. The lower attachment strength line required 15 percent less power to gin at the faster ginning speed. Gin turn-out, fibre and seed properties were affected by saw speed.

Effects of variety, growth location, scouring treatments, and storage conditions on dye uptake by cotton fabric

Genevieve Crowle, Stuart Gordon, Christopher Hurren
CSIRO Manufacturing Flagship; Institute for Frontier Materials, Deakin University

Dyeing of cotton is influenced by a range of chemical and physical interactions between dye molecules and fibres. It is essential that consistent quality dyeing is maintained with shade variations being costly to fix, reducing profits and productivity. To ensure consistency dyers select cotton varieties based on similar high volume instrument (HVI) properties, yet despite this control there are still many instances where dyed appearance of cotton products differs on a time/batch basis. This experiment aims to compare and assess dyeability of cotton samples of multiple varieties grown in a single location, and of varieties grown in multiple locations. The effect of various scouring pretreatments and different storage environments on dye uptake is also of interest. Colour difference could indicate chemical or structural properties in the cotton samples that may cause dyeability differences other than routinely measured HVI properties known to cause shade variation such as maturity and micronaire. Instrumental analysis of the dyed samples will be carried out to determine if there are discernible colour, structural and chemical differences caused by the various scouring treatements and storage conditions. Acknowledgements: The authors gratefully acknowledge the funding by the Cotton Research and Development Coorporation, Australia.

Plenary session (open to students)

The ecosystem service of biological pest control: Valuing native vegetation

Nancy A Schellhorn
CSIRO

Globally the economic value of natural pest control is estimated at $400 billion per year worldwide. The ecosystem service of natural pest control in cotton is a critical component of sustainable production. In this special session open to USQ students, Nancy will share research, and insights and highlights of being a scientist. She will discuss why she became interested in science, aha moments, and the opportunities that students should seek to build confidence, and enthusiasm, and as they focus and grow their careers. Nancy will weave these insight into her presentation that focuses on the value of native remnants and perennial habitat for beneficial arthropods. Using examples from experiments and observation, Nancy will show that beneficial arthropods that provide pest control live and reproduce on native plants and perennial habitat in the cotton-grain landscape; they move from these habitats into newly emerging crops; and suppress pests. However, the high demands for agricultural products and lack of arable land will allow for relatively small management interventions for ecosystem services on farms dominated by production. To overcome this challenge Nancy will suggest targeted measures to secure the continuity of resources throughout the life cycle of service-providing organisms. Such measures are likely to increase the stock, flow and stability of pest control, while balancing the needs of production.

Understanding the plant and the humans that manage it underpins solutions to crop production challenges and environmental impacts

Stephen Yeates
CSIRO Agriculture Flagship, Ayr, QLD

For all plants, success is determined by the interaction of the plant's genotype and the environment it is growing in. However, for plants used in agriculture there is another dimension: interaction with the farmers that manage them. Using cotton as an example, I'll describe the use of science to understand how cotton grows and responds to the environment and to develop management solutions that solve abiotic and biotic constraints to production. The need to anticipate and avoid unintended environmental impacts of new management solutions as part of the research and adoption process is also discussed. Examples from my own research in tropical Australia include:

- understanding and exploiting cotton's capacity to compensate from fruit loss due to abiotic stresses (low solar radiation, sub and supra optimal temperatures), and
- nitrogen nutrient management that both improves uptake efficiency by synchronising N availability with plant demand, and minimises wet season leaching of fertiliser NO_3^- to the wider environment.

The talk will include some highlights of a 'tropo' crop scientist's odyssey.

1. Insect Resistance Management

Oviposition patterns of moths and parasitoids across a cotton-grain landscape: Linking land cover and seasonality

Cate Paull, Melissa Dobbie, Tobin Northfieldk, Myron Zalucki, Michael Meissle and Nancy Schellhorn
CSIRO Agriculture,CSIRO Digital,James Cook University, University of Queensland and Agroscope Switzerland,CSIRO Agriculture

Agricultural landscapes are characteristically dynamic resulting in, proportions, composition and configuration of land use that changes from season to season. Rarely do we know how arthropods respond to these changes across a region and over multiple seasons. Here, over five years and across the landscape of the Darling Downs, we studied oviposition by *Helicoverpa armigera*, *H. punctigera* and their egg parasitoid, *Trichogramma* spp. Using machine learning and parametric statistical analysis we show that temporal variables explain the largest amount of variation in eggs being laid in crops for both *H. armigera* and *H. punctigera*. However spatial factors also drive oviposition behaviour. For *H. punctigera*, most of the variation in egg lay can be explained by cotton development, and the amount of fallow land at 1km surrounding cotton. However, for *H. armigera* most of the variation in egg lay can be explained by more local dynamics, e.g., some landscapes repeatedly have significantly more eggs being laid than others, and egg lay increases with large areas of Bt cotton (> 2km in diameter). Interestingly, egg parasitism by *Trichogramma* spp., also can be explained by temporal variables, with increasing parasitism related to cotton development, and increasing numbers of *H. armigera* eggs. This large spatio-temporal data set combined with novel analytical approaches has illuminated the drivers of oviposition behaviour for these arthropods of cotton. These results have implications for the capture of biological pest control for surrounding Helicoverpa- susceptible crops, and for resistance management.

From models to management: simulating Helicoverpa movement behaviour in complex landscapes and the implications for Bt resistance

Hazel Parry, Myron Zalucki, Tony Ives, Cate Paull and Nancy Schellhorn
CSIRO, Brisbane, Australia University of Queensland, Brisbane, Australia University of Wisconsin, Madison, USA

Bt has revolutionized pest control in cotton, with many benefits. However, should resistance to Bt develop, this method of control will be limited. Obtaining empirical evidence on the efficacy of the current resistance management system, 'refuges', is very difficult: processes operate at multiple spatio-temporal scales, complex interactions exist, Helicoverpa are highly mobile and we must consider both the dynamics of the refuge and the landscape, as well as the pest itself. Agent-based simulation modelling allows us to explore emergent egg distribution patterns and landscape use by Helicoverpa based on empirical studies of underlying processes (such as movement and oviposition behaviour). The model allows us to form hypotheses about which refuges may function better, and when, that could then be tested in the field. Results from the model indicate that there are some landscape characteristics that interact with moth resource preferences to have an important influence on the egg density in Bt cotton, the relative egg density (compared to other, non-Bt crops) and the 'efficacy' of refuges. The results of the model indicate that existing refuge schemes could be deficient in preventing the evolution of resistance in a complex landscape context and/or at certain times of year. However, the model also enables a better understanding of how/when refuges are most effective, with the potential to inform better refuge design as part of area-wide management of Helicoverpa.

Contribution of *Helicoverpa* spp. to the Bollgard II/Bollgard 3 system across Australian cotton growing regions

Kristen Knight
Monsanto Australia

Structured refuges are an integral part of the Resistance Management Plan (RMP) for Bollgard II and the proposed RMP for Bollgard 3. Monsanto developed a novel method for analysing adult lepidopteron species for plant secondary metabolites, including gossypol which is diagnostic of larval feeding on cotton. From 2006-2009 Helicoverpa armigera moths were trapped and collected from Bollgard II/ unsprayed cotton refuge systems in several cotton growing regions. Helicoverpa punctigera were included in the 2009/10 season. Analysis for the presence of gossypol indicated that the majority of moths captured throughout the season were generated from hosts other than cotton. In the 2014/15 season *Helicoverpa* spp. moths were collected to establish if the contribution by other hosts is still at a high level. Contribution of moths from hosts outside the Bollgard/refuge system has positive implications for resistance management of the technology.

Establishing the critical exposure period required for developing tolerance in *Helicoverpa punctigera* to Bt toxin

Sharna Holman, Mary Whitehouse, Mahbub Rahman, Tanya Latty and Sharon Downes
University of Sydney, CSIRO Agricultural Flagship, University of Adelaide, University of Sydney, CSIRO Agricultural Flagship

Helicoverpa are key pests of Australian cotton that are largely managed by Cry1Ac and Cry2Ab toxins produced by transgenic cotton. While larvae can develop resistance to these toxins, laboratory studies indicate that non-genetically resistant larvae fed small amounts of toxin can develop tolerance and pass this onto their offspring. How tolerance is passed on, its impact on the development of resistance and how it affects the behaviour of the larvae is unclear. We exposed Helicoverpa punctigera at different larval stages to 2% or 5% of the discriminating dose of Cry1Ac toxins to establish if there is a critical time when larvae develop tolerance and whether it affects life history characteristics of the exposed generation. We confirmed that after exposing one generation of Helicoverpa to low levels of Cry1Ac toxins, their offspring were able to tolerate significantly higher levels of toxin than the controls. Larvae exposed as latter instars had higher survival rates, tried to avoid Bt-laced food (a response not seen in larvae continually raised on Bt-laced diet) and produced offspring that displayed the highest levels of tolerance to Bt toxins. Thus the critical time for exposure was during later instars. These results indicate that a threat to Bt cotton efficacy may come from larger larvae moving off other crops into Bt cotton. These larvae are more likely to survive on Bt toxin, actively search for parts of the cotton plant that express less toxin, and produce offspring more tolerant to Bt toxin, increasing pressure on Bt cotton's efficacy.

The response of Helicoverpa to Bt toxins and refuges: the role of tolerance and the loss of efficacy

Mary Whitehouse, Mahbub Rahman, Tom Walsh, Tek Tay and Sharon Downes
CSIRO Agricultural flagship University of Adelaide

As Bt cotton has been almost universally adopted, the maintenance of low levels of resistance by *Helicoverpa* spp to Bt toxins is a testimony to the effectiveness of the resistance management program (RMP). Yet in Bt cotton there are still Helicoverpa survivors. Quantifying how many Helicoverpa emerge from Bt cotton and how they are surviving in Bt crops, will identify potential obstacles that could derail resistance management. We found the number of moths emerging from all Bt cotton was much higher than expected, and was equal to the amount emerging from refuges. While moths emerging from Bt cotton did not carry more resistance genes, there was evidence that the grandchildren of moths emerging from Bt cotton were able to tolerate higher concentrations of Cry1Ac toxin. Laboratory results showed that larvae from susceptible laboratory colonies were able to develop tolerance to Bt toxins, and that rare resistant genes could become established when colonies were exposed to sub-lethal levels of toxins. Field and laboratory results also showed that susceptible larvae fed on parts of the plants with low levels of toxin, particularly parts of the flower and boll. These results indicate that Bt cotton efficacy could be threatened by larvae developing tolerance to Bt toxins, and that there is an interaction between tolerance and resistance to Bt toxins that needs to be better understood in order to support the RMP.

Characteristics of indoxacarb resistance in Australian populations of *Helicoverpa armigera*

Lisa Bird
NSW Dept. of Primary Industries

Indoxacarb is an important option for selective control of *Helicoverpa* spp. in cotton and other crops that play host to these pests. Unlike broad-spectrum insecticides, indoxacarb has remained effective against *Helicoverpa* spp., with low levels of resistance recorded in *Helicoverpa armigera* since commercialization of this product in 2002. From 2002 to 2012 indoxacarb resistance was determined from traditional screening methods involving topical application of a discriminating concentration of insecticide to larvae in the F0 generation. Although topical bioassays have proved useful for measuring resistance to broad-spectrum contact insecticides where resistance is mediated by dominant alleles, they may be less effective for determining resistance to selective insecticides, firstly because F0 screening underestimates frequency of non-dominant resistance alleles, and secondly because selective insecticides are primarily active by ingestion. In 2013, F2 screening by diet incorporation for synthetic insecticide resistance was introduced. This represented a new industry standard in monitoring resistance to insecticidal chemistries, which significantly increased capacity for detection of low frequency resistance. Consequently, in 2013 the first documented case of genetic indoxacarb resistance was isolated from field populations of *H. armigera*. The resulting indoxacarb-resistant strain (designated GY7-39) was subjected to quantitative genetic analysis involving specific crosses and bioassays. Results from these analyses

suggest indoxacarb resistance in the GY7-39 strain is conferred by an autosomal gene, and resistance is partially dominant (DLC=0.75). Initial results from complementation tests for allelism to other iso-female families with enhanced survival to indoxacarb indicate a single mechanism confers indoxacarb resistance in Australian populations of *H. armigera*.

Silverleaf whitefly resistance management

Jamie Hopkinson, Steph Kramer, Richard Lloyd and Paul Grundy
QDAF

Silverleaf whitefly (SLW) is a major late season pest of cotton due to its potential to contaminate cotton lint with honeydew. To prevent this, management is often reliant on the use of insecticides to control SLW populations. With selection pressure SLW develop resistance to insecticides they are exposed to, resulting in spray failures. Our lab tests resistance levels in SLW populations collected from across the cotton industry. In this presentation I will provide an update of emerging SLW resistance issues the cotton industry is facing.

Investigation of target site resistance mechanisms in sixteen Australian cultures of *Tetranychus urticae* (Tetranychidae: Acari)

Lauren K. Woolley, Yizhou Chen and Grant A. Herron
Elizabeth MacArthur Agricultural Institute, Narellan NSW

Tetranychus urticae is considered a significant pest and its control relies on the use of insecticides, however; their efficiency is often compromised by resistance. Monitoring pesticide resistance is crucial for sustainable management and done by bioassay and/or DNA based methods. Genotyping and frequency prediction can be employed as an alternative to bioassay for resistance monitoring. Numerous molecular mechanisms, including those associated with mutations on acaricide target site genes, are responsible for the toxicodynamics of resistance. In this study, resistance mechanisms attributed to known target site mutations in *T. urticae* were investigated in sixteen Australian cultures. Direct sequencing of PCR products amplified from pooled samples of each strain demonstrated the presence of two mutations: G119S in strain AW and I1017F in strain Nashee. Previous bioassay data confirms the involvement of the G119S mutation in organophosphate resistance in strain AW. To date, there is no bioassay data to demonstrate an association between etoxazole resistance and the I1017F mutation in "Nashee". Significantly, this study found no evidence of knockdown (kdr)-mediated resistance in a strain (Cd) known to be highly pyrethroid resistant. Similarly, there was no link in an abamectin-resistant strain (Carson) to known target site mutations. These results suggest the involvement of other molecular mechanisms (such as unidentified target site mutations or the up-regulation of insecticide detoxification through the enzymatic activities of P450 monooxygenases, glutathione-S-transferases and/or esterases) and highlight the complexity of the task and the need for continued research into molecular based methods to detect resistance in *T. urticae*.

Valuing the contribution of the resistance management strategy to the cotton industry

Russell Gorddard[1] Art Langston[1] Stuart Whitten[1] and Sharon Downes[2]
[1]CSIRO Land and Water Flagship Black Mountain Canberra, ACT
[2]CSIRO Agriculture Flagship, Australian Cotton Research Institute, Narrabri, NSW

A resistance management strategy (RMS) for BT cotton has been used in Australia for nearly two decades. This talk provides an update on a CRDC funded project that aims to evaluate the costs and benefits of having the RMS during this period. We present upper and lower bounds on estimates of the contribution of the resistance management strategy to the profitability of farms and the industry, and identify the characteristics of the cotton industry and pest biology that affect the value of the RMS. We also examine how having an RMS over the last two decades may influence the future profitability and viability of cotton farms. We describe how possible futures may affect the value of the RMS, and explore the potential value of indirect effects of RMS. In particular we examine how the RMS has contributed the ability of the industry to manage for future pest problems.

2. Irrigation Science

Image analysis and artificial intelligence-based approach for soil-water and nitrogen status estimation

Alison McCarthy[1], Tai Nguyen[2] and Steven Raine[3]
[1]National Centre for Engineering in Agriculture, University of Southern Queensland
[2]Computational Engineering and Science Research Centre, University of Southern Queensland
[3]Institute for Agriculture and the Environment, University of Southern Queensland

Optimal crop yields require optimisation of both water and nitrogen application. Industry standard soil-water sensors require contact with the soil and provide information for a single point in the field although there is often spatial variability in soil type and crop growth. Nitrogen content is typically determined using destructive manual soil coring followed by laboratory testing. It is often not practical to install multiple soil-water sensors in a commercial field situation or to conduct multiple soil cores throughout the cotton season. A non-contact soil-water and nitrogen estimation system offers growers potential savings by optimising water and fertiliser management and efficiency and crop productivity. Existing non-contact approaches typically have low spatial resolution and cannot discriminate plants from soil. An alternative approach is a camera-based sensing system that estimates soil-water and plant nitrogen status. This project has developed a proof-of concept infield camera-based plant sensing system and model that estimates soil-water, plant nitrogen status and fruit growth for cotton. A data fusion algorithm was developed that can determine current and predict future soil-water, nitrogen and fruit load of cotton plants based on day of the season, weather data and visual plant response captured using cameras. These models have potential to be used instead of industry-standard models APSIM and OZCOT to predict crop production throughout the season as part of automated control systems to optimise irrigation and fertiliser application. The procedure used to develop the model could be applied to any crop.

A new way to estimate and monitor the water content of soil

Brett Robinson, David Freebairn, David McClymont, Steve Raine, Erik Schmidt, Victor Skowronski, Alison McCarthy, and Jochen Eberhard
University of Southern Queensland, Toowoomba. DHM Environmental Software Engineering, Toowoomba

In dryland systems soil water provides a buffer to support crop growth between rainfall events. In irrigated systems, soil water status sets the scene for the irrigation season, and when tracked, provides a basis for irrigation scheduling. A simple and reliable estimate of soil water content can guide key management decisions: whether to plant or delay, how to better match inputs to yield expectations when determined by soil water stress. A Soil Water App for smartphones (SWApp) has been developed and is ready for testing by users over the next 12 months. SWApp uses rainfall inputs from Bureau of Meteorology sites, a local rain gauge - or a wireless rain gauge being developed. A number of soil water sensors are being trailed whose readings can be entered manually or added wirelessly. Growers and consultants will be able to track soil moisture during a fallow and up to anthesis in a crop for any number of paddocks. The SWApp is being further developed specifically for irrigators.

Benchmarking and improving nitrogen use efficiency using IrriSAT – potential applications

John Hornbuckle[1], Janelle Montgomery[2], Wendy Quayle[1] and Jamie Vlesshouwser[3]
[1]Centre for Regional and Rural Futures, Deakin University, Griffith, NSW
[2]NSW DPI, Moree, NSW
[3]CSIRO Land and Water, Brisbane, QLD

IrriSAT is a satellite and ground station based sensor network that provides information on near real time and forecast crop water use across large scales (Australia wide) and at high resolution (30x30m). A current CRDC project is using the IrriSAT technology for benchmarking water use and yield performance of cotton crops across the Australian cotton growing regions. The system provides information on crop water use and additionally provides a seven day forecast. This information can be used for irrigation management and assisting in making irrigation decisions and well as tracking seasonal water use for benchmarking productivity. Increasing nitrogen use efficiency and better use and management of nitrogen within the cotton growing industry is an important issue for the industry. The IrriSAT platform offers two potential avenues for improving nitrogen use efficiency within the cotton industry which is discussed in the presentation. This includes improving irrigation management through the use of IrriSAT for irrigation management to improve nitrogen use efficiency and

secondly using recently launched satellite sensors available in the IrriSAT platform for measuring leaf/canopy chlorophyll and nitrogen contents. The recently launched European Space Agency (ESA) Sentinel -2 satellite has an additional "red edge" spectral band which is offers the potential to estimate crop nitrogen content on a 5 day cycle at 20m resolution. This presentation describes these approaches with examples of irrigation management effects on nitrogen use efficiency and discusses future applications of IrriSAT for providing combined water and nitrogen use management and benchmarking information across the Australian Cotton Industry.

Smart automated furrow irrigation of cotton: A field demonstration

Jasim Uddin, Rod Smith, and Malcolm Gillies

National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, QLD

Furrow irrigation is widely used for field crops and is the most popular irrigation method for cotton, although it is labour intensive and traditionally less efficient due to the significant losses of water through deep drainage and runoff. However, it is shown that a well-designed and managed furrow irrigation system can have application efficiencies up to 90% to 95% making it comparative with other more energy intensive pressurised irrigation systems. Towards this, National Centre for Engineering in Agriculture (NCEA) in partnership with technology company Rubicon Water has developed and demonstrated a smart automated furrow irrigation system for cotton funded by CRDC. The prototype smart automation system consists of automation hardware and software for the flow control of open channel delivery system throughout the farm along with sequencing of the irrigation of fields and sets of furrows, specifically designed in-field flow control infrastructure for control of flows into the furrows and the sensing and simulation required for the real-time selection of optimum time to cut-off for each furrow set. A demonstration trial has shown that the automation of furrow irrigation in cotton is feasible, practical and able to be implemented immediately using commercially available equipment and innovative in-field design. Real-time optimisation (or prediction of time to cut-off) using a simple field specific algorithm can deliver improved application efficiencies easily and reliably. The system is equivalent to the pressurised centre pivot and lateral move machines in terms of water and labour savings at a lower capital cost and without the on-going energy costs.

The implications of gilgai on electromagnetic induction measurements with EM38 in the Borders rivers region

Mark Crawford, Andrew Biggs and Jenny Foley

Department of Natural Resources and Mines (DNRM) Qld

Cotton growing regions of Qld and NSW are dominated by heavy clay Vertosol soils. Gilgai patterns, inherent features of these soils, occur in many forms and can influence the wetting-up pattern, the water available for plant uptake and ultimately crop yield. With the growing use of electromagnetic induction (EMI) in the cotton industry to measure soil electrical conductivity (ECa), it is prudent to assess the potential implications of gilgai on soil ECa. In this study an EM38 was used over multiple dates in an area of native vegetation (brigalow/belah), on a Grey Vertosol in the Borders River region displaying classic mound and depression type gilgai. Plant available water for trees was calculated from a linear calibration curve. The results from three sample dates demonstrated a clear pattern of mound and depression and the wetting up patterns after rainfall. Spatio-temporal moisture dynamics, microrelief patterns and subtle effects on water movement in the landscape caused by gilgai could be identified. How variations in soil properties influence soil conductivity in native vegetation was also assessed. In a paddock with strong (prominent) gilgai, the underlying soil physical factors still remain after laser levelling. This could cause variations in water movement/storage and soil properties. Understanding the patterns of gilgai and how they affect the EMI signal will aid in accurate soil sampling and analysis of ECa maps and yield data.

The value of measured plant water status versus inferred plant water status; canopy temperature versus ET

James R. Mahan

Plant Stress and Water Conservation Lab, USDA/ARS, 3810 4th ST, Lubbock, TX USA 79415

Information on the water status of a crop over time is an essential element in efficient irrigation management in terms of irrigation amount and timing. Irrigation management, the determination of the amount of water to apply and when to apply it can be accomplished using evapotranspiration models that are widely used and often finely tuned. These models predict plant water use based on measurements of a suite of environmental factors and crop physiology. Irrigation management can also be based on direct measurements of the crop. Measurement of canopy temperature (CT) and application of water to maintain it within a desired range is a crop-based irrigation strategy. Both ET and CT determine crop water status; ET from the environment and CT from measurement of the plant. Both approaches have strengths and limitations that should be considered determine their suitability for irrigation management in a given setting. The following comparisons of approaches will be discussed.

• local versus regional
  ET- from region to the plant
  CT- from the plant to region

• management of water deficits
  ET- measures entire profile and assumes availability/extraction
  CT- measures water extraction directly with few assumptions

• ability to self correct
  ET- errors in availability/extraction do not self-correct
  CT- errors in availability/extraction self-correct

• effect of errors in measurement
  ET- requires accurate measurement of environmental parameters
  CT- requires accurate measurement of CT…a 2°C error can be significant

Cotton Irrigation using Dynamic Deficits: identifying the value using OZCOT

David Johnston and Rose Brodrick
CSIRO Agriculture

Forecasts of evapotranspiration (ETo) are now available from the Bureau of Meteorology. We investigated whether using the ETo forecast to adjust irrigation timing in the cotton model, OZCOT, could boost crop water use efficiency? Simulations were run for a 52 yr period for six cotton producing regions in Australia. Irrigation rules using a range soil water deficits were used along with 3, 5 and 7 d forecasts of ETo. Dynamic deficits rules were implemented to adjust the irrigation trigger values by delaying irrigations (larger deficits) when ETo was low and irrigating early on a smaller deficit during periods of high ETo. The impact of each approach was determined for yield, number of irrigations and water use efficiency. Results varied by region but overall, delaying irrigations in response to forecasted low ETo proved to be of more benefit than irrigating earlier when ETo was high. At Myall Vale, for example, when using an 80 mm deficit, delaying an irrigation until a 112 mm deficit was reached when there was 3 d forecast of low ETo increased lint yield by 112 kg and saved an average of 0.5 irrigations/year. These simulations support field experiments which have also shown benefits in delaying irrigations but none for irrigating earlier. The benefit of delaying an irrigation when low ETo is forecast is that this may increase the potential to capture rainfall which is often associated with these periods of low evaporative demand.

IrriSAT – weather based scheduling and benchmarking technology

Robert Hoogers[1], John Hornbuckle[2], Janelle Montgomery[3], Edward Joshua[4], Iain Hume[5] and Jamie Vleeshouwer[6]
[1]NSW DPI, Yanco NSW [2]Centre for Regional and Rural Futures, Deakin University, Griffith, NSW [3]NSW DPI, Moree, NSW [4]NSW DPI, Dubbo NSW [5]NSW DPI, Wagga Wagga, NSW [6]Land & Water Flagship: CSIRO, Dutton Park, QLD

IrriSAT is a weather based irrigation management and benchmarking technology that uses remote sensing to provide site specific crop water management information across large spatial scales. IrriSAT uses satellite imagery to estimate crop coefficients (Kc) at a 30 m resolution. IrriSAT calculates Kc from a linear relationship with satellite derived Normalised Difference Vegetation Index (NDVI). Daily crop water use is determined by simply multiplying Kc and daily reference evapotranspiration (ETo) observations from a nearby weather station. A seven day forecast of ETo is also produced. A delivery platform is being developed using the Google App Engine. The app will provide access to the IrriSAT crop water use data, which coupled with weather and crop water use (ETc) forecasts will enable irrigators to track their soil moisture deficit and better manage irrigation schedules. IrriSAT will complement existing irrigation scheduling tools with the advantage of low cost and complete spatial coverage IrriSAT can also be used to benchmark crop productivity when combining yield and water use (ETc) data. Preliminary trials of the IrriSAT technology as a benchmarking tool have successfully benchmarked crop productivity for cotton grown under different row configurations and irrigation systems. The benchmarks identify over/under performing fields and this holds the key to improving water productivity.

A comparison of conventional and controlled traffic irrigated cotton water use efficiency, gross margins, yield and quality in Warren, NSW, Australia

Timothy Bartimote[1], Richard Quigley[1], John McLean Bennett[2], Rose Brodrick[3] and Daniel Tan[1]

[1]Plant Breeding Institute, Department of Plant and Food Sciences, Faculty of Agriculture and Environment, The University of Sydney, Sydney, NSW
[2]National Centre for Engineering in Agriculture, The University of Southern Queensland, Toowoomba, QLD
[3]CSIRO Agriculture Flagship, Narrabri, NSW

Meeting crop water requirements is essential to achieving desirable yields. However, water is the most limiting resource in the production of irrigated cotton in north-west NSW. Improving Water Use Efficiency (WUE) is important in maintaining production where water is scarce. Compaction caused by machinery also affects cotton yields. It increases soil strength and reduces soil porosity, hindering root growth, moisture and nutrient uptake. Machine controlled traffic can minimise compaction, but 1 m cotton does not accommodate conversion of pickers to 3 m wheel tracks. Further, it is theorised that 1 m cotton is less WUE than wider row spacings. The aim of this study is to determine differences in cotton yield, WUE, cost efficiency and fibre quality between wide 1.5 m rows and 1.0 m conventional rows.

The experiment was conducted at Auscott Warren over two seasons (2013-14, 2014-15) with a RCB design that had nine replicates of 1.0 m and 1.5 m treatments. The paddock scale whole block was two large field blocks of 1.0 m and 1.5 m treatments. WUE of the two treatments was determined through establishing a comprehensive water balance involving remote and in-field technologies. The efficiency of each treatment was based on bales/megalitre. Allowing the the cumulative effect of row spacing and controlled traffic methods on input and output efficiency to be observed.

The 1 m cotton yielded 1.8 bales/ha and 3 .6 bales bales/ha higher than the 1.5 m cotton in the machine picked and hand-picked replicated experiment respectively, in the 2013-14 season. In the 2014-15 season the 1.5 m cotton yielded 5.7 bales/ha higher and 0.7 bales/ha lower in the hand-picked and machine picked replicated experiment, respectively. Yield of 1.0 m cotton mainly came from fruiting nodes 1-8, position 1. In contrast, yield in 1.5 m cotton predominantly originated from vegetative branches. Fibre quality was similar in both row configurations. Gross margins were similar at approximately $2,000 per ha but water savings in the 1.5 m cotton in the 2014-15 season was possibly the result of higher than average rainfall.

The 1.5 m controlled traffic row cotton may provide higher water use efficiencies than 1.m row cotton and can be a better risk management strategy during seasons where irrigation water is limited.

1. Fibre Science and Processing

Defining and Applying the Glass Transition Temperature (Tg) of Cotton

Chantal Denham, Michael Huson, Stuart Gordon and Xungai Wang
CSIRO / Deakin

The glass transition temperature is a thermal transition at which a polymer goes from a firm glassy state to a more soft pliable form. Within the cotton industry, knowledge of the Tg of cotton has the potential to improve the resilience of cotton fibres during post harvest processing, for example ginning. It is known that the atmosphere (temperature and humidity) within the gin plays a significant role in the quality and yield of the final product but currently, finding the optimum parameters relies on trial and error. On a more global scale, knowledge of the temperature and humidity at which the properties, such as heat capacity, elasticity, refractive index, conductivity and diffusion of cotton and cellulose change may have an impact on multiple industries such as wood and paper pulping, pharmaceutical (eg drug excipients) and manufacturing. Currently there is no definitive answer as to what this temperature and humidity is for cotton cellulose, with a number of authors even claiming that it does not exist. The aim of this research is to find a reliable and reproducible method of determining the glass transition temperature of cotton in an effort to improve the performance of current cotton processing methods and reduce damage to fibres. Investigating cellulose of varying origin will aid this evaluation.

Cotton blended yarns as strain sensors for electronic textiles

Juan Xie[1,2,3], Stuart Gordon[1], Hairu Long[2,3,] and Menghe Miao[1]
[1]CSIRO Manufacturing Flagship, Belmont, VIC
[2]College of Textiles, Donghua University, Shanghai, China
[3]Key Laboratory of Textile Science & Technology, Ministry of Education, China

Conductive yarns and fabrics can be utilised in a wide range of textile applications, such as antistatic and electromagnetic shielding protection, and conductive threads and strain sensors for electronic textiles. Commercially available conductive yarns are mostly metallic wires (continuous filaments) with or without being commingled with textile materials and silver-coated textile yarns. Metallic filaments have low extensibility and tend to break during fabrication due to flexural fatigue. Silver coated textile yarns gradually lose their conductivity due to wearing and laundering. Our research focuses on conductive yarns spun from a mixture of cotton fibres and short-length stainless steel (SS) fibres. Uniform fibre mixing is achieved through a sliver blending strategy to ensure consistent yarn conductivity. By changing the blending ratio between the two types of fibres, yarns with a wide range of conductivity can be produced for the whole spectrum of applications. The electrical percolation characteristics of the cotton/SS yarns are experimentally determined and compared with widely known conductive materials such as conductive particle-filled polymer composites. The cotton/SS fibre conductive yarn is much stronger than pure SS yarn and can be used as strain sensor on its own. Knitted fabrics from the conductive yarn expand the extensibility and sensing range by many folds and provide a route for integration into smart textiles, particularly garments. Characteristics of the yarn-to-yarn contact resistance, which plays a critical role in the sensitivity of knitted fabric strain sensors, is studied. The electro-mechanical behaviours of the final fabric strain sensors are characterised experimentally and through structural modelling.

The Effect of Seed Cotton Moisture during Harvesting on Fibre Quality

M.H.J van der Sluijs and R.L. Long
CSIRO Manufacturing Flagship

It is generally accepted that harvesting and storing of seed cotton above a moisture content of 12% prior to ginning will compromise fibre quality. This advice stems from research conducted on harvesting seed cotton with the conventional basket and separate module building system. It is hypothesized that the 12% moisture content limit will also hold true for harvesting seed cotton in a high production system using alternative harvesters. The latest generation of harvesters such as the John Deere (JD) 7760 with on board module building capacity producing smaller round modules, have greater horsepower, traction and fan capacity which enables them to harvest cotton when traditionally field conditions would have made harvesting difficult. This study examined the fibre quality of Upland cotton, harvested from one field using a JD 7760 at two moisture levels, <12% and >12%, and storing the harvested modules for 12 weeks prior to ginning. There was a significant difference between the two moisture levels for fibre colour and trash, with seed cotton harvested at >12% resulting in fibre that was yellower, with lower reflectance and more trash than the seed cotton harvested at <12% treatment. There was no significant difference between the two moisture levels in terms of fibre length and strength, but fibre micronaire was higher for the higher moisture content. There was no significant difference between the moisture levels for total nep count, but the seed cotton harvested at >12% had larger neps and more seed coat neps.

Management for premium cotton fibre

Robert L. Long and Michael P. Bange
CSIRO

Cotton fibre quality is affected by a large number of interacting factors; cultivar, seasonal conditions, crop and harvest management, and ginning. These can all determine whether or not the spinner's requirements are met. Indeed with the advent of premium fibre varieties there may be a need to have tailored management regimes to ensure that these varieties produce premium quality cotton and ensure that growers attract the maximum return for production that offset lower lint yields. A large scale field experiment was conducted in Narrabri to establish the value of specific pre- and post- harvest management practices to deliver high quality cotton. The experiment used the cultivars Sicala 340BRF (a premium fibre type) and Sicot 74BRF (popular industry cultivar) grown with two management regimes ('Standard' and 'Wise' management). The 'Wise' management treatment involved targeted irrigations at flowering, a later defoliation (avoiding use of boll opening chemical), and using late season growth regulator to ensure that crop maturity avoided inclement weather. Cotton fibre produced under the 'wise' management system was longer and had better length uniformity and lower short fibre content, and was lower in the incidence of fibre entanglements (neps). Interesting interactions were captured between experimental variables for fibre maturity, fibre fineness, and for fibre width. The 'wise' management strategy tended to produce fibre that was lower in fineness and width which was attributed to those practices having a direct influence (reduction) on fibre perimeter.

A self-adjusting seed finger system to improve gin turn-out

Andrew Krajewski, **Stuart Gordon** and David Fox
CSIRO Manufacturing Flagship

Gin stands are responsible for the removal of fiber from cotton seed. Care must be taken during ginning to ensure the seed is not over-ginned, causing seed damage and seed coat neps. Alternately it is important the ginner removes as much of the lint from the seed as possible to ensure the highest turnout for the grower. Seed fingers are an important part of the gin stand and are used to control the seed roll load, which controls these aspects. A new device that can self-adjust the angle of the seed fingers while seed-cotton is processed is introduced. The device combines partitioned seed fingers pivoted on a shaft that are controlled by electric actuators able adjust the angular position of each partition according to the load exerted by the seed-roll on the particular partition. This paper describes the system and reports on early trials in industry, which showed significant correlations between residual lint on the ginned seed and the angle of the seed finger shaft. Correlations were also observed between the angle of the seed finger shaft and gin motor power consumption.

Reducing the Scouring Requirement of Australian Cotton

Katherine Birrer[1,2], Rob Long[1], David Cahill[2], Warren Conaty[3] and Nicola Cottee[3]
1CSIRO Manufacturing 2Deakin University 3CSIRO Plant Industry

Cotton fibres are coated with an outer cuticular layer comprised of waxes and other non-cellulosic components which provide an important hydrophobic barrier that protects the fibre and helps to disperse fibre and seeds in water ways. From a manufacturing standpoint wax provides benefits such as protection from weathering and lubrication during the spinning process. The hydrophobic nature however necessitates its removal from fabric prior to dying. Wax is removed using hot caustic scouring, a process requiring significant effort and energy which poses potential environmental risks due to the nature of the waste produced. A potential solution to this problem is to develop a low wax cotton variety which requires less scouring. To do this a greater understanding of the chemical and molecular basis of this wax is required. An important factor known to influence increased deposition of wax on the vegetative tissue of crop species including cotton is environmental stress. To determine whether the same is true of fruiting tissue in cotton a number of varieties with varying tolerances to stress were grown in field conditions and exposed to heat and/or water stress. Fibres were then harvested and the wax extracted for analysis. Analysis showed that in stressed cotton there were significant increases in both the amount of total cuticle and in the percentage of wax within the cuticle compared with the control. Demonstrating that stress leads to increased deposition of wax within the fibre cuticle may assist in the development of strategies to produce a low wax cotton variety.

2. Entomology

Do Helicoverpa populations reflect the landscapes they are caught within?

Geoff Baker and Colin Tann
CSIRO

Bt resistance in *Helicoverpa* spp. remains a major threat for the cotton industry and refinements to the Bt Resistance Management Plan (RMP) are ongoing. Our previous research has identified the most productive mandatory refuge crop (pigeon pea), suggested that its performance in providing susceptible moths in the landscape is likely to be highly variable in space and time, and shown that mating of Helicoverpa is random with respect to plant host origin. However, our understanding of the degree of movement / spatial mixing of moths from different origins within and between regions is still very limited. Such knowledge is critical to an effective RMP, and likely to be especially so where landscapes vary in land-use complexity.

Our current research includes 1) long-term monitoring of moth abundance near Narrabri (NSW) (using pheromone traps), and 2) analyses of trapped moths to determine plant host origins (using stable isotope signatures) within two other, markedly different, cotton producing regions, Maranoa and Darling Downs (Qld). The Narrabri study demonstrates that local habitat can influence the numbers of moths that are caught. The Maranoa and D. Downs study, which always set traps alongside attractive cotton crops, shows that cropping complexity at landscape & regional scale is not necessarily a reliable predictor of the population origins of the moths that are present. That in turn suggests that resistance development may well be substantially influenced by factors beyond the cotton / mandatory refuge system.

Green mirids: Multiple host-use patterns and population connectivity in native and agricultural habitats

Justin Cappadonna, James P. Hereward and Gimme H. Walter
School of Biological Sciences, The University of Queensland

To understand why insects invade agricultural systems, we need to appreciate the ecology of the species in both its native and agricultural habitats. Green mirids, *Creontiades dilutus* (Stål) (Hemiptera: Miridae), are insects endemic to Australia that feed on a broad variety of native plants, crops, and invasive weeds. In eastern Australia, green mirids are now the primary pests of cotton crops. The ultimate source of green mirids in eastern cotton-growing regions is likely to be from host plants in the arid continental interior, but the factors that lead to agricultural invasions are poorly known. Green mirid host associations were quantified across a vast geographic range to determine where mirid populations build-up, and thus piece together their spatio-temporal dynamics. Field surveys were conducted in the cotton growing regions of Queensland and New South Wales, as well as portions of their native habitat within western Queensland and the Simpson Desert in South Australia. Molecular analyses of individuals collected during these surveys have assessed the connectivity of green mirid populations in eastern and central Australia. By understanding the connectivity between mirid populations, crop managers can better prepare for potential invasions when mirid populations are predicted to be building up at distant locations. These findings will be discussed in the context of recent weather patterns and crop management techniques. This study also provides insights into the ecological mechanisms associated with the host plant associations of generalist insect herbivores across diverse habitats.

Gene flow and host use in the Green Vegetable Bug, *Nezara viridula*

Dean Brookes, James Hereward, Lewis Wilson and Gimme Walter
University of Queensland, Australian Cotton Research Institute

With the widespread use of Bt cotton, plant-sucking insects have become more significant pests in cotton crops. One of these pests is the Green Vegetable Bug (Hemiptera: *Nezara viridula*; GVB), a globally significant pest that probably arrived in Australia soon after European settlement. In cotton, these bugs feed on developing bolls and destroy them, but only occasionally reach numbers that require control. Similar patterns are found for many of the crop hosts GVB feed on. The fluctuations in GVB populations and their sporadic appearance in an area (or on a particular crop) make predicting when and why GVB will be present in damaging numbers in a particular location or crop challenging. Our research aims to understand more deeply the relationship between GVB and its hosts in Australia, and to establish the relationships between Australian GVB and international populations of the pest. We are investigating the spatial and temporal population dynamics of GVB using both phylogenetic and population genetics approaches. We will thus investigate gene flow between hosts and geographic areas within Australia and then compare these results with those from overseas. This information will be used to contextualize the global research on GVB to Australian growing regions, thereby aiding the development of appropriate management strategies for GVB.

How aphids plug up plants: the role of callose in plant defences

Heimoana, S.C. ,Wilson, L. J., Constable, G. A. and George, D. L.
CSIRO, Cotton Research Unit The University of Queensland

Aphids feed by using fine tubular stylets that penetrate plant cells to ingest sugar rich phloem sap, the product of photosynthesis. Intense and/or prolonged aphid infestations negatively affect leaf photosynthesis in cotton, ultimately reducing yield. However, why aphid feeding reduces photosynthesis is poorly understood. To effect sap removal, aphids probe into plant tissue to reach the phloem vessels, a series of interconnected sieve tubes and plates, which are highly sensitive to any form of disturbance. Plants respond to aphid attack by producing callose, a defence compound that plugs up the sieve plates between the tubes, thereby interrupting the flow of phloem sap. This experiment investigated if aphid infestation led to a build-up of callose in leaves, and if infested leaves had higher sugar levels that could lead to negative feedback effects which would reduce photosynthesis. It was confirmed that upper canopy leaves colonised by aphids for 30 days had significantly higher levels of callose than uninfested leaves. Further, older leaves contained significantly more callose than younger leaves due to longer exposure to aphid feeding. However, while increases in aphid populations corresponded to significant reductions in photosynthesis, we found no rises in leaf sugar levels of infested leaves. This suggests that mechanisms other than feedback effects play a role in the decline of photosynthesis after aphid infestation, for instance, reduced transpiration due to (i) damaged stomata (ii) elevated callose causing stomatal closure or (iii) abscisic acid induced stomatal closure.

Discovery of novel biopesticides and semiochemicals for arthropod pest management in Australian cotton

Robert Spooner-Hart[1], Robert Mensah[2], David Leach[1], Frank van der Kooy[1], Zhonghua Chen[1] and Karren Beattie[1]
[1]University of Western Sydney, Penrith NSW
[2]Australian Cotton Research Institute, NSW Department of Primary Industries, Narrabri NSW

Australian cotton farmers have achieved substantial reductions in insecticide use from their adoption of GM technology to control *Helicoverpa* spp. However, problems associated with pests that were once incidentally controlled, such as green mirid, cotton aphid, white fly and spider mites often require use of older, often broad-spectrum insecticides likely to face increased regulatory scrutiny, and which also kill beneficial species or induce pest resistance. There is therefore need to develop new alternative pesticides, such as those derived from natural materials (biopesticides) and chemicals that mediate interactions between organisms (semiochemicals). Two CRDC-funded projects: Fungal biopesticides and semiochemicals for control of cotton pests and bollworm pupae (ACRI), and Novel insecticides and synergists from endemic and exotic flora (UWS), aim to develop new IPM products for Australian cotton. To date, the ACRI project has screened 80 entomopathogen isolates and 15 plant extracts against Helicoverpa, identifying 23 efficacious isolates and four efficacious extracts. The UWS project has screened 270 plant extracts against Helicoverpa, cotton aphid and two-spotted mite with four extracts showing high activity against all target species, and seven with high activity against two. Selected extracts have been fractionated to identify their active constituents, and to determine novelty.

Effects of seedling stage defoliation on cotton growth and yield

Jianhua Mo, Sandra McDougall, Mark Stevens, Scott Munro, Elizabeth Munn and Sarah Meaumont
Yanco Agricultural Institute, NSW DPI

Thrips are common pests of cotton seedlings. Heavy infestations are often associated with clubbed leaves, which reduce leaf area and photosynthesis. To investigate the effects of early leaf area loss on cotton yield and maturity date, we conducted two artificial defoliation trials during the 2013-2014 and 2014-2015 cotton seasons on a commercial farm near Darlington Point in southern NSW. From emergence to the 10th leaf stage, cotton seedlings were defoliated weekly by hand. The 2013-14 trial compared 100% defoliation in all plants, 100% defoliation in 75% of the plants, and no defoliation.The 2014-15 trial included an additional treatment of 75% removal of the area of individual leaves. Both trials showed some reduction in plant size and delayed maturity in defoliated plants, however the effects were more pronounced in the 2013-2014 trial. Complete defoliation of both 75 and 100% of plants during the seedling stage reduced plant height and number of harvestable bolls. Boll maturity (60% cracked bolls) was delayed by 14-18 days and lint yield by 22-45%. In the 2014-15 trial, the impact of early defoliation on plant height was also detected but only during the pre-flowering stage. Defoliated plants produced similar number of harvestable bolls as the un-defoliated plants. Cotton samples from this trial are yet to be ginned but analysis of raw weight suggests no impact of early defoliation. There was, however, a delay in maturity of 8 days by the 100% defoliation treatment. The effects of 75% defoliation (by whole plant or by individual leaf area) were negligible. In both trials, compensation by un-defoliated plants adjacent to defoliated plants was evident in the split treatment of 75% defoliation by plant.

Posters

*Influence of crop rotation and residue management on surface soil shrinkage in a grey Vertosol

N. R. Hulugalle[1] and T. B. Weaver[2]

[1]Fenner School for the Environment and Society, Australian National University, Acton, ACT
[2]Pulse Australia, Wee Waa, NSW

Comparative studies of the influence of crop rotation and residue management on soil shrinkage in irrigated cotton (Gossypium hirsutum L.) based cropping systems in Australian Vertosols are sparse. Our objective was to quantify soil shrinkage in beds under four cotton-based cropping systems sown on permanent beds in an irrigated Vertosol with subsoil sodicity. The experimental treatments were: cotton monoculture; cotton–vetch (Vicia benghalensis L.) rotation; cotton–wheat (Triticum aestivum L.) rotation; and cotton–wheat–vetch rotation, with wheat stubble retained as in-situ mulch and a summer fallow. Vetch in the cotton-vetch sequence was sown immediately after cotton picking and bed renovation in May and slashed/sprayed out during September whereas that in the cotton-wheat-vetch sequence was sown during February and slashed/sprayed out during August. The experiment was laid out in 3 RCB. Soil shrinkage was evaluated in clods (4) extracted from 4 locations in each plot during late September 2009. Specific volume was determined after coating soil clods with paraffin wax and plotted against the corresponding soil water content to derive shrinkage curves. The shapes of the curves and the shrinkage parameters suggested that surface compaction was present in the cotton phases of the rotations that included a wheat crop, and confirmed by the pore size distribution. Compaction was probably caused by trafficking on beds during wheat harvest. Until 2010 wheel and axle widths of the wheat harvester used in this site were incompatible with the cotton system's 1-m bed configuration.

*Cotton picker trials & adjustments

David Lester, Peter Want, Lawrence Smith, Mike Bell and Rod Obel

Qld Dept of Agriculture & Fisheries; University of Qld; CRDC

From purchasing our project picker to adjusting it to be able to transport, harvest, weigh and sample lint from field studies.

*From Field to Laboratory

Peter Want, David Lester and Mike Bell

Qld Dept Agriculture & Fisheries.; University of Qld

Reducing mature cotton plants to a sufficiently uniform material that can be subsampled and analysed for nutrient content has been a time consuming exercise. Previously bolls were removed by hand, raw cotton ginned and then seed and cotton plants were ground separately. This method limited the number and size of samples that could be collected due to labour and time constraints.

Possible interaction between *Thielaviopsis basicola* and *Verticillium dahliae*

Sharlene E. Roser and Karen A. Kirkby

NSW DPI

Anecdotal evidence suggests a possible interaction between high incidence of Black root rot and Verticillium wilt. A pilot study was carried out in 2014 to test this. A replicated, randomised pot experiment was set up in a growth room. There were 4 soil treatments: control, soil inoculated with *T. basicola*, soil inoculated with *V. dahliae* and soil inoculated with both pathogens. The inoculum level of *V. dahliae* was 355 propagules per gram soil. The inoculum level of *T. basicola* was 115 chlamydospore chain fragments per gram soil. Sicot 72BRF seeds (supplied by CSD) were germinated in root training books filled with each of the treatment soil, and were grown in the growth room at 18-22°C . After 4 weeks, the seedlings were carefully removed from the root training books and assessed for severity of Black root rot using a scale 0-10, where 0 = no blackening of the tap root, 5 = 50% and 10 = 100% tap root blackened. Plants were then transplanted into 3L pots and maintained in a glasshouse at 20-24°C. This experiment has shown that there is significant interaction ($p<0.001$) between Verticillium and Black root rot. A larger experiment will be carried out examining presence of external symptoms, plant height, and severity of black root rot. We will also do soil isolations on each pot after the experiment has finished to establish the Verticillium inoculum levels.

*Poster printed in these proceedings (p66-68)

Determining effect of timing and rate of BT toxin on *Helicoverpa punctigera* larvae

Steven Harden, Mary Whitehouse, Sharna Holman, Tanya Latty, Mahbub Rahman and Sharon Downes
NSW DPI

Four cohorts of insects were monitored over a period of fifty days. Insects were fed a diet laced with the BT toxin (Cry1Ac) at 2 rates and at 3 timings (+ a nil control). For each observation each insect still alive was classified into one of seven growth stages (Instar 1 to Instar 6 or Adult). Counts were also made of dead insects and the number of missing insects was inferred from prior observation. This sort of data (ordinal), where we have counts of the number of subjects classified into ordered categories is often analysed inappropriately. The ordered nature of the categories is ignored and standard methods for nominal variables are used. (e.g. Pearson Chi-squared test of independence for two-way contingency tables). This loss of information reduces the power of the analysis. Alternately, scores are assigned to each category (e.g. 1-6 for Instar stages 1-6 and 7 for an adult) and standard methods such as ANOVA are used on the data. This infers more information in the data than is present. The 1 to 7 numerical scale is arbitrary and the particular value for each larval stage has no significance other than to establish the ranking/ordering of the data. The poster will discuss analysing these ordinal data and comment on missing values (dead or missing insects), repeated measurement over time, random effects (four groups of insects) and the testing of treatment effects.

Susceptibility of the silverleaf whitefly parasitoid *Eretmocerus hayati* to insecticides used in cotton.

Jamie Hopkinson and Stephanie Kramer
Department of Agriculture and Fisheries, Toowoomba, QLD

An important natural enemy of silverleaf whitefly is the wasp Eretmocerus hayati. It is however susceptible to insecticides applied to cotton to control whitefly and other pest insects. We studied the toxicity of five insecticides that are registered for pest management in cotton by testing direct exposure and residues. The products we tested included; cyantraniliprole, sulfoxaflor, flonicamid, clothianidin and fipronil. We tested the effect of direct exposure and then residue at 1, 2 and 8 days after application. For cyantraniliprole and sulfoxaflor direct exposure was more toxic than residues. For the other products there was no difference between direct exposure and residue. Direct exposure of flonicamid was significantly less toxic than the other insecticides. Clothianidin residue was significantly more toxic than the residue of the other insecticides. Overall clothianidin was the most toxic insecticide followed by sulfoxaflor, fipronil, cyantraniliprole and flonicamid was the least harmful.

Interactive effects of extreme weather events, elevated CO_2 and temperature on cotton productivity and soil nutrient status

Yui Osanai, David T. Tissue, Michael P. Bange, Ian C. Anderson, Michael V. Braunack and Brajesh K. Singh
University of Western Sydney

The impacts of projected climate change on agricultural production are relatively unknown. Increases in global atmospheric concentration of CO_2 (CE) and global mean temperature (TE) are predicted, as well as changes in precipitation and frequency of extreme weather events in future climates. Agricultural production is highly sensitive to such climatic variability. However, our knowledge regarding the interactions between extreme weather events, CE and TE is limited, thus potentially generating underestimations of the impact of future climates on agricultural production. Therefore, we examined whether two extreme climate events (flooding and drought) affected the main and interactive effects of CE and TE on cotton productivity in two soils (black and grey vertosols). Flooding induced immediate physiological responses in plants, and strongly reduced soil nitrogen availability, particularly at TE. Flooding substantially reduced vegetative growth and caused a significant yield reduction in plants grown at TE. Drought had a detrimental impact on plant physiology, growth and yield in all climate treatments, and resulted in a large amount of residual nitrogen in the soil, particularly at TE. There were some differences in yield response to flooding and drought between the two soils. Our results demonstrated that TE increased yield under well-watered conditions, but that greater yield loss under flooding and drought at TE suggests that inter-annual variability in yield is likely to increase under more extreme climate events. Adaptation strategies should focus on both plant and soil responses to extreme weather events to minimise yield loss under future climates.

Impact of waterlogging on soil nitrification and ammonia-oxidizing community in cotton farming

Linh Nguyen, David Tissue, Ian Anderson, Michael Braunack, Michael Bange, Yui Osanai and Brajesh Singh

Hawkesbury Institute for the Environment University of Western Sydney, Penrith, NSW

In Australia, cotton is often grown on heavy clay soils which drain slowly after irrigation. This characteristic may lead to waterlogging in the soil if drainage is inadequate due to poor irrigation management or intense precipitation. Waterlogging causes soil O_2 depletion affecting soil nitrification – a process to contribute to increased plant - available nitrogen in the soil, resulting in the negative impacts on cotton crop productivity. The oxidation of ammonia to nitrate is mediated by ammonia oxidizing bacteria (AOB) and ammonia oxidizing archaea (AOA). In this study, potential nitrification rate (PNR) and the abundance and structure of AOB and AOA communities were quantified to investigate the impact of waterlogging on soil nitrifying process in a field study in Narrabri. PNR significantly decreased upon waterlogging treatment. The abundance of bacterial amoA genes identified by real-time polymerase chain reaction (qPCR) reduced approximately 10 fold after treatment whereas archaeal amoA gene abundance slightly decreased. Both AOA and AOB abundance have significant relationship with soil NO_3^- ($R2 = 0.54$, $P< 0.05$). The community structure of AOB and AOA determined by terminal restriction fragment length polymorphism (TRFLP) showed more variation in community structure of AOA than that of AOB. Similar to the abundance of bacterial and archaeal amoA genes, shifts in AOB and AOA community structure were observed. In particular, dominant TRF-55 and TRF-74 significantly decreased after waterlogging treatment for AOB and AOA, respectively. The results suggest that soil nitrification and ammonia-oxidizer communities respond negatively to waterlogging, subsequently reducing plant available nitrogen in the soil that could lead to lower crop productivity.

Towards automated machine vision-based irrigation tracking using Remotely Piloted Aircraft

Derek Long, Cheryl McCarthy and Troy Jensen

University of Southern Queensland, National Centre for Engineering in Agriculture; Cotton Research and Development Corporation

Surface irrigation accounts for a large percentage of water use in all agricultural sectors, particularly cotton. However, efficiency of surface irrigation systems can be as low as 50 to 80%. Existing computer models and optimisation algorithms can calculate the optimal cutoff time (i.e. time to turn off water), but only with dynamic information on the progress of the irrigation event. Currently, constant surveillance of in-progress irrigation must be done manually and is labour intensive for farmers. There is potential for Remotely Piloted Aircraft (RPA) to automatically perform surveillance of in-progress irrigation. Navigation is a difficult task for a robot operating outdoors, and there are multiple ways to approach the task. It is envisaged that the same system is used to record the irrigation data and to navigate. Machine vision was the sensing method that could also aid in navigation. Algorithms can be applied to the aerial images to extract water front positions, and Simultaneous Localisation and Mapping (SLAM) algorithms can georeference the RPA relative to the ground. Machine vision can also be implemented in the ground station software to improve it for consumer use by designing field boundary extraction for automation of flight waypoint generation. Initial results of the field extraction are positive in the case of a green field from a dark soil boundary. As RPA ground station software uses mapping plugins such as Google Earth, only visible spectrum information is immediately available for use. Further work is needed to determine the possibility of detection of a darker field.

Soil compaction in Australian cotton farming systems: future research and development requirements

Diogenes L. Antille, John McL. Bennett and Troy A. Jensen

University of Southern Queensland, National Centre for Engineering in Agriculture

The effects of traffic-induced soil compaction on Australian cotton farming systems and the environment were examined. The main impacts of traffic compaction on cotton-based systems appear to be: (1) Increased gap between attainable and potential yields, (2) Increased cost of energy and labour associated with tillage repair treatments, (3) Reduced fertiliser and water use efficiency, (4) Increased tillage intensity, which enhances oxidation of SOC, compromises soil N supply and increases reliance on N fertiliser. Knowledge gaps that merit a research priority within soil compaction work for cotton-based systems were identified. These are: (1) Identification of soil compaction impacts on the wider aspects of farm economics to guide decision-making and development of decision support systems that capture the effects of soil compaction on fertiliser, water, and energy use efficiency, (2) The potential for canopy management at terminal stages of the crop cycle to manipulate soil moisture deficits prior to crop harvest, and therefore, optimise trafficability conditions for harvesting equipment, (3) The role of controlled traffic farming (CTF) in mitigating GHG emissions and loss of SOC, and enhancing fertiliser and water use efficiencies, (4) The role and cost-effectiveness of low ground pressure tyre technology in mitigating soil compaction, and (5) Catchment-scale modelling that incorporates changes in arable land-use, such as increased area under CTF to assess the potential of this technology to mitigate impacts on water quality in intensively-managed arable catchments. A key aspect to managing soil compaction appears to be the need to encourage a shift toward increased adoption of CTF.

Preliminary evaluation of field- and plant-level 3D point clouds from aerial and ground-based photogrammetry

Cheryl McCarthy[1], David Lamb[2] and Craig Baillie[1]

[1]National Centre for Engineering in Agriculture, University of Southern Queensland [2]University of New England

Three dimensional (3D) models of plants and crop canopies have use in plant growth studies and visualisation of plant and crop condition. 3D models can be generated using photogrammetry software applied to camera images from ground-based platforms (e.g. tractors) or aerial platforms (e.g. Remotely Piloted Aircraft (RPA), also known as drones).

A preliminary evaluation was performed of 3D point clouds generated by Pix4D photogrammetry software for images of two cotton fields and a vineyard. The ground resolution of the images was 20 mm / pixel for the cotton fields, 20 mm / pixel for the vineyard and 1.5 mm / pixel for 2 m spans of the grapevine canopy. A fixed wing RPA, multi-rotor RPA and ground-based platform were used for the different image datasets, respectively. The broadleaf shape of cotton is comparable to the leaf shape of grapevines.

Visual inspection of 3D point clouds generated with Pix4D revealed that individual rows of the cotton crop and the vineyard were visually discernible, enabling canopy-level anomalies to be detected. Very fine detail (e.g. less than 5 mm) was resolved from high-resolution ground-based images of the grapevine canopy. The 3D point cloud consisted of individual vines (i.e. stems) and leaves. The time for Pix4D to process image sequences into 3D point clouds ranged from one hour (for 2 m spans of canopy) up to one to two days (for a 70 Ha field), using a 2.5 GHz Core i7 quad-core processor with 16 GB RAM. Acknowledgement: The authors are grateful to the Queensland Government Accelerate Fellowship for funding support, and Ian Hayllor and Queensland College of Wine Tourism for field sites.

Low tyre inflation pressure to reduce soil compaction from cotton pickers

Diogenes L. Antille, John McL. Bennett and Troy A. Jensen

University of Southern Queensland, National Centre for Engineering in Agriculture

The soil contact pressure from tyres can be reduced by using the tyres at low inflation pressure. This provides improved tractive performance and reduced soil deformation, since the average soil contact pressure under the tyre is approximately equal to the inflation pressure plus the pressure caused by tyre carcass stiffness. This approach has primarily been used for low to medium weight farm machinery. With the introduction of the round baler cotton picker now weighs in at 32 Mg empty but ranges up to 38 Mg as modules are built and carried. Hence, the role of low ground pressure tyre systems in reducing soil stresses, particularly in the subsoil, merits investigation. A controlled experiment was established where soil was wetted-up using an irrigation grid to achieve a range of moisture contents throughout the profile, as follows: 1) field capacity throughout (depth range: 0-800 mm), 2) field capacity in the top 400 mm and near-optimum compaction moisture content in the 400-800 mm depth interval, and 3) near-optimum moisture content throughout the profile. Subsequently, the soil was trafficked using a JD7760 cotton picker (unladen) with the tyres at the manufacturer's recommended inflation pressure and 50% lower. Soil bulk density, cone index and torsional shear strength measurements were performed to the full depth to compare how the depth of compaction was affected by the interaction between soil moisture conditions at the time of traffic and tyre inflation pressure. The implications of these results are discussed in terms of energy requirements for tillage repair treatments

Organic amendment of crop soil and its relation to hotspots of bacterial nitrogen cycling

Lily Pereg, Mary McMillan and Sind Aldori
University of New England

Crop production requires a high use of fertilisers, including N, P and K for continues utilisation of the soil. Growers often grow summer crops in rotation of winter crop, such as cotton in rotation with wheat, in the same field. Growers are getting more and more aware about sustainability of the soil resources and the more adventurous ones use soil amendments, such as organic supplements in addition to the chemical fertilisers. We have collected soil samples from fields that were cultivated in preparation for planting cotton and tested the soil for bacterial groups with potential to perform different functions, including those related to the nitrogen cycling. One of our aims was to determine whether organic amendments create hotspots for bacterial functions, in particular those related to bacterial nitrogen cycling. This pan of the project will be discussed in this presentation.

Short-term greenhouse gas emissions from fertigated cotton under furrow and overhead irrigation

Diogenes L. Antille and Alison C. McCarthy
University of Southern Queensland, National Centre for Engineering in Agriculture

A field-scale fertigation trial was conducted to determine short-term greenhouse gas emissions following fertigation and assess the agronomic performance of fertigated cotton crops based on fertiliser nitrogen (N) recovery. Fertigation was conducted on two cotton crops under furrow and overhead irrigation, respectively. Urea ammonium nitrate (UAN, 32% N w w-1) was applied with irrigation water at a rate of 135 L ha-1 of fertiliser over a single irrigation event in late January 2015. Fertiliser-treated crop was compared with a control crop (no fertigation). Gas samples were taken prior, during and within five days of irrigation or fertigation for determination of N_2O and CH_4 using the static chamber technique. Soil samples were taken at three depths (0-200, 200-400, and 400-600 mm, respectively) and subjected to determination of mineral N (NH_4^+-N + NO_3^--N) to assess soil N status and distribution within the soil profile. Short-term N recoveries in plant material and crop yield were determined to investigate the effect of method of fertigation (furrow vs. overhead) on short-term N uptake and agronomic efficiency. The implications of the results derived from this study are discussed in terms of N management and use efficiency within intensively-managed cotton crops.

Developing strategies to reduce nitrogen losses and improve nitrogen use efficiency for cotton production

Diogenes L. Antille, Clemens Scheer, David Rowlings, Max De Antoni Migliorati, Peter R. Grace.
University of Southern Queensland, National Centre for Engineering in Agriculture; Queensland University of Technology, Institute for Future Environments

A three-year research project has been undertaken to reduce the uncertainty that exists with respect to the magnitude of N losses and the role of SOM in supplying mineral N for cotton production. The goal is achieve a reduction of 25% in N-fertiliser inputs across the industry without negative effects on productivity. Surveys suggested that the industry is over-fertilising crops to reduce risk, which is at the expense of reduced profit margins. Growers do not appear to take advantage of mineral N supply from SOM. Estimates indicated that gaseous losses of N fertiliser applied to cotton are in excess of 40%, particularly in intensively-managed irrigated-systems. This project was developed to quantify total gaseous N losses and N supplying potential of SOM, and to investigate the effects of fertiliser placement, timing of split N applications, and fertiliser type on N_2O emissions and NUE. In the Australian cotton industry, there is a lack of up-to-date information available on N fertiliser placement, timing of application and the role of enhanced efficiency fertilisers in improving NUE. This project will also construct accurate N budgets, which quantify N contributions from both fertiliser and SOM. The information produced will enable for further development of existing BMP for optimising uptake of applied fertiliser N, reducing N losses and minimising N fertiliser costs. Experimental data will be used to update N budgeting tools and inform extension. Popular decision support systems and simulation models will be assessed to assist N-fertiliser management decisions and enhance the profitability of the industry.

Influence of crop rotation and residue management on surface soil shrinkage in a grey Vertosol

N.R. Hulugalle[1,2] & T.B. Weaver[1,3]

Introduction

Comparative studies of soil shrinkage in two and three crop rotations in irrigated cotton (*Gossypium hirsutum* L.) based cropping systems under varying stubble management practices are sparse. Our objective was to quantify soil shrinkage in beds under four cotton based cropping systems sown on permanent beds in an irrigated Vertosol near Narrabri, north western New South Wales.

Material & Methods

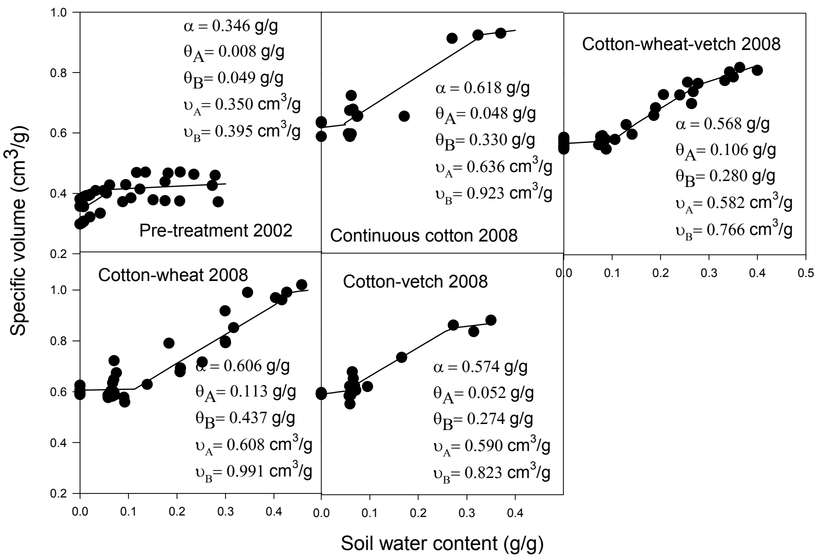
The experiment was located in a deep, self mulching, grey Vertosol, at the Australian Cotton Research Institute, near Narrabri (149°47'E, 30°13'S) in NSW. Mean particle size distribution in the 0–120 cm depth was: clay 64 g/100 g, silt 11 g/100 g, and sand 25 g/100 g. Prior to the commencement of this experiment the site had been under intensive tillage with frequent in season cultivation to control weeds.

The experimental treatments were: cotton–cotton; cotton–vetch (*Vicia benghalensis* L.); cotton–wheat (*Triticum aestivum* L.), where wheat stubble was incorporated; and cotton–wheat–vetch, where wheat stubble was retained as i*n situ* mulch. Vetch was terminated during or just before flowering by a combination of mowing and contact herbicides, and the residues retained as *in situ* mulch. The experimental design was a randomised complete block with 3 replications. Individual plots were 165 m long and 20 rows wide. After cotton picking, the cotton was slashed and incorporated into the beds with a disc hiller (to facilitate *Helicoverpa* spp. pupae destruction).

During September 2002, before treatment implementation, a single soil pit was dug.in each replicate and soil clods extracted from the exposed profile. The results pertain to those taken from the surface 10 cm. The clods were taken back to the laboratory, coated with saran resin dissolved in ethyl-methyl ketone, and volume and weight changes determined as they dried out (Cresswell and Hamilton, 2002). Soil clods in the surface 10 cm were again sampled from 4 locations in each plot during September 2008, taken back to the laboratory, coated with paraffin wax and changes in weight and volume determined (Cresswell and Hamilton, 2002). All data were analysed by fitting the results to the three stage model of McGarry and Malafant (1987), and the following indices calculated:

θ_B, soil water content and ν_B, specific volume, at the swelling limit; θ_A, soil water content and ν_A, specific volume at the air-entry point at the "end" of the normal shrinkage zone, and ∞, specific volume at a soil water content of 0 g/g.

Results & Discussion



- Soil compaction was high during 2002, and characterised by a small normal shrinkage zone and a negligible residual shrinkage zone.
- By 2008, compaction had been alleviated, presumably due to the imposition of permanent beds. This was characterised by expansions of the normal and residual shrinkage zones, increases in values of ∞, and air-filled porosities.
- Among the 4 crop rotations, the shrinkage curves of the two that did not have a wheat component were more similar to each other. Shrinkage curves of the two rotations that had a wheat component were also similar to each other.

Conclusions

Surface soil compaction was mainly alleviated by imposition of permanent bed systems, with crop rotations having a secondary effect.

References

Cresswell HP, Hamilton G (2002). Bulk density and pore space relations. In 'Soil physical measurement and interpretation for land evaluation'. (Eds N McKenzie, K Coughlan, H Cresswell) pp. 35–58. (CSIRO Publishing: Melbourne)

McGarry D, Malafant KWJ (1987) The analysis of volume change in unconfined units of soil. *Soil Science Society of America Journal* **51**, 290-297.

Australian Government Cotton Research and Development Corporation

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Cotton Catchment Communities CRC

[1]NSW Department of Primary Industries
[2]Present affiliation: Fenner School for the Environment & Society, ANU, Acton, ACT
[3]Present affiliation: Pulse Australia, Wee Waa, NSW

Cotton picker trials & adjustments

David Lester[1], Peter Want[2], Lawrence Smith[1], Mike Bell[3], Rod Obel[2]

1. Department of Agriculture and Fisheries, Toowoomba.
2. Department of Agriculture and Fisheries, Kingaroy.
3. University of Queensland, Gatton.

The challenge

Conducting field fertilizer research programs, especially involving different application and placement strategies, requires a large experimental footprint in order to get an accurate measure of yield responses to fertilizer treatments against a background of in-field variability. This requires large plot sizes and experimental units that fit with commercial equipment used to grow and manage the crop. Depending on the crop and plot lengths the picker can average about 20 plots per hour. Mechanized harvesting is therefore essential, and needs to be readily transportable.

Kingaroy DAF has a Prime mover & Low Loader for Picker Transport

The response

In 2010 a John Deere two row 9930 model cotton picker was purchased to be converted into a picker for harvesting research plots. The first iteration removed the internal augers, compaction system and reduced bin height to 5m to allow trailer transport. An internal weighing bin was installed and a external shoot to allow on the go collection of lint subsamples.

In 2013 it was decided to replace the internal bin due to the continued need to clear away cotton from the bin outlet and the reduced storage in the basket. A set of weigh cells were installed under a false floor and this has allowed more efficient picking and weighing of plot yields. However on windy days the time taken to reach a stable weight was a problem.

In 2014 solid side walls were installed to try to overcome this load cell fluctuation in windy conditions. However, this did not prove as successful as hoped, with increased rigidity in the floor hopefully solving this problem in 2015.

2010 internal weigh bin & external sampling shoot installed

2013 internal bin removed with weigh cells added under a false floor

2014 solid walls were installed in an attempt to reduce any wind effect when weighing.

More information

Department of Agriculture and Fisheries

Name: David Lester
Phone: 07 4639 8886
Email: david.lester@daf.qld.gov.au

Australian Government
Cotton Research and Development Corporation

Queensland Government

From Field to Laboratory

Peter Want[1], David Lester[2], Mike Bell[3]

1. Department of Agriculture and Fisheries, Kingaroy.
2. Department of Agriculture and Fisheries, Toowoomba.
3. University of Queensland, Gatton.

Only one way

Reducing mature cotton plants to a sufficiently uniform material that can be subsampled and analysed for nutrient content has been a time consuming exercise. Previously bolls were removed by hand, raw cotton ginned and then seed and cotton plants were ground separately. This method limited the number and size of samples that could be collected due to labour and time constraints.

Within our PKS in Cotton Project (UQ1302) supported by CRDC, DAF and UQ a system has been developed to enable more efficient processing of cotton plant samples. This system allows larger plant samples that are more representative of the field plots to be collected, processed and subsampled for nutrient analysis. This capability allows much better estimates of the recovery of fertilizers applied to the crop.

Dried Mature Cotton Plants

Brentwood Shredder – AZ5

Funded by: DAFF's Scientific Equipment Fund

Retsch – SM 300 - Cutting Mill

Funded by: Cotton Research & Development Corporation

Retsch - ZM 200 Ultra - Centrifugal Mill

Funded by: DAFF's Scientific Equipment Fund

			Random subsamples from the bulk ground sample						
		Single sample selected from ground plant sample	Subsample a	Subsample b	Subsample c	Subsample d	Subsample e	**SS mean**	**SS stderr**
%P	Treat 1	**0.19**	0.2	0.2	0.2	0.18	0.17	**0.19**	**0.006**
	Treat 2	**0.18**	0.2	0.21	0.19	0.2	0.16	**0.19**	**0.009**
	Treat 3	**0.19**	0.21	0.21	0.21	0.21	0.2	**0.21**	**0.002**
								SS mean	**SS stderr**
%K	Treat 1	**1.39**	1.37	1.38	1.4	1.37	1.37	**1.38**	**0.006**
	Treat 2	**1.38**	1.34	1.38	1.32	1.29	1.31	**1.33**	**0.015**
	Treat 3	**1.4**	1.41	1.38	1.43	1.42	1.45	**1.42**	**0.012**
								SS mean	**SS stderr**
%S	Treat 1	**0.23**	0.24	0.23	0.24	0.22	0.21	**0.23**	**0.006**
	Treat 2	**0.21**	0.22	0.23	0.21	0.22	0.18	**0.21**	**0.009**
	Treat 3	**0.22**	0.24	0.23	0.25	0.24	0.23	**0.24**	**0.004**

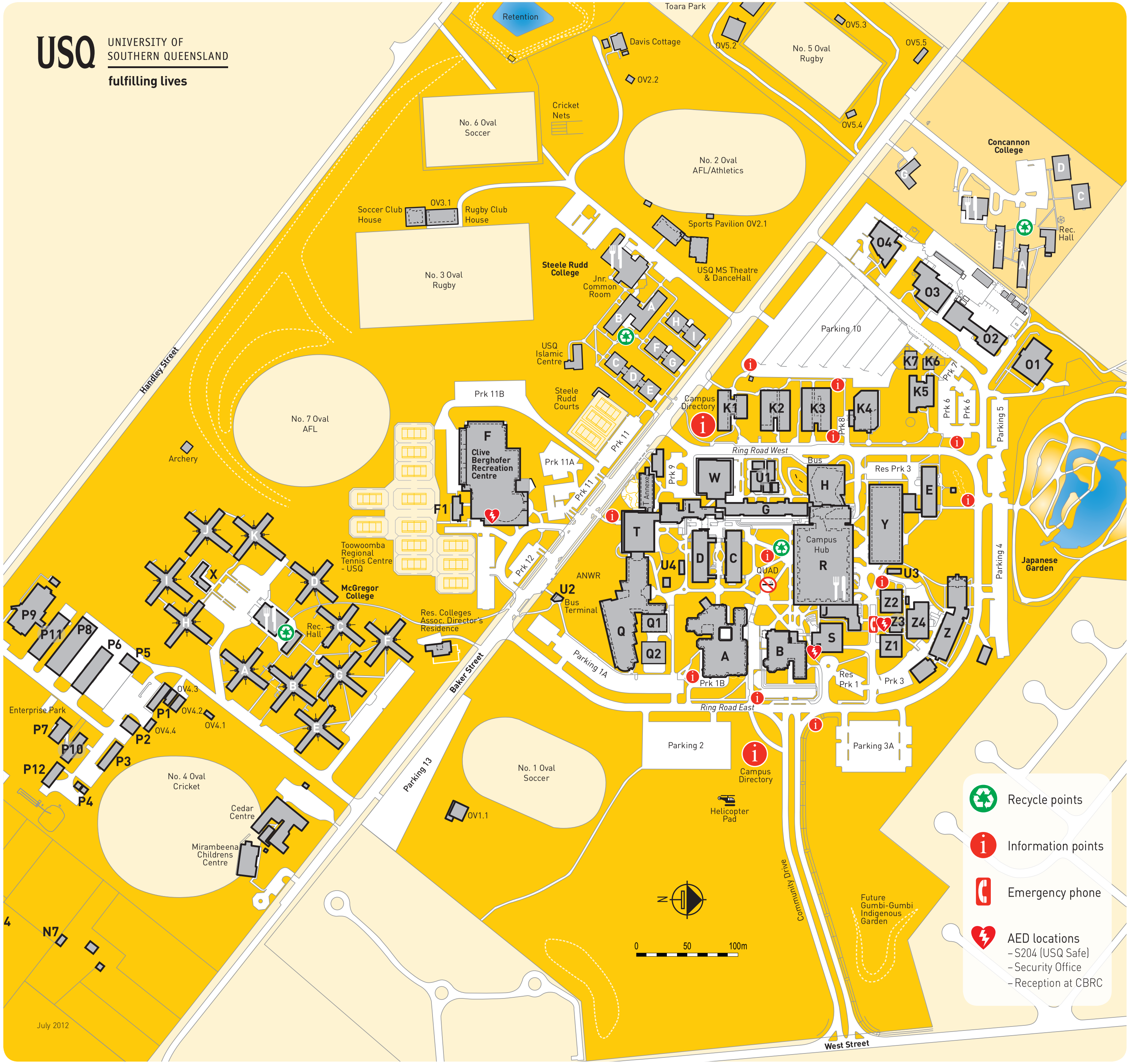
Repeated sub-sampling of the plant material after final grinding illustrates the uniformity of the final sample produced.

More information

Department of Agriculture and Fisheries
Name: Peter Want
Phone: 07 41 600 700
Email: peter.want@daf.qld.gov.au

Australian Government
Cotton Research and Development Corporation

Queensland Government



A **Arts**
Music, Theatre, Visual Arts Studios

B **ADMINISTRATION**
University Executive, Student Management Division, Legal Office

C Sciences (Biological & Physical), Heritage Building Society, bankmecu, USQ Environmental Office (The Lilypad)

D Sciences (Physical, Mathematics & Computing, Centre for Systems Biology)

E **ICT** (Information & Communication Technology Services)

F **CLIVE BERGHOFER RECREATION CENTRE**

F1 Toowoomba Regional Tennis Centre – USQ

G Education, Student Services, Sciences (Chemistry, Physics), Darling Heights Post Office, The Workshop (Careers & Employment)

H **ALLISON DICKSON LECTURE THEATRE**
Bus Terminus 1

J Finance, Procurement

K1 Computer Laboratories, Classrooms

K2 Open Access College, Classrooms, Parents' Room, Education Leadership Research

K3 Open Access College

K4 The Club

K5 Student Guild, ICT Training Labs, Multi Faith Centre

K6 ICT Computing Facility

K7 ICT Computing Facility

L Business and Law, Sciences

N1 Residence

N2, N3, N4, N5, N6, N7
Sheds

N8 Workshop

01 Student Management Division – Marketing

02 Campus Services Central Store, Mailroom, Maintenance, Grounds Sheds (02.01–02.13)

03 Campus Services, USQ Printing Services, Motor Pool Compound (03.01–03.03)

P1, P2, P3, P4, P6, P7, P10, P11, P12
Engineering & Surveying, CEEFC (Centre of Excellence for Engineered Fibre Composites)

P5 NCEA, LOC Composites Tenancy

P8 LOC Composites Tenancy

P9 CEEFC (Centre of Excellence for Engineered Fibre Composites) Offices & Laboratories, Office of Commercialisation, Gas Retentions

Q **THE PHOENIX BUILDING**
Arts (Administration, Mass Communications, Humanities & International Studies, Theatre Design, Visual Arts Studios, McGregor Schools), Artsworx, Faculty of Business and Law Student & Academic Support, Harvard Rooms, CRRAH (Centre of Rural & Remote Area Health)

Q1 **CONCERT HALL**

Q2 Arts (Workshop, Sculpture Studio)

R Student Hub (Learning Ctr), The Library, Refectory, Arts (Media Studies),Postgraduate Facility, Central Plant Room, Bookshop, Print Express)

S LTS (Learning & Teaching Support), Human Resources, USQ Safe, Corporate Media Office, Council Conference Room, Research Office, Office of External Relations, Computer Laboratories, Engineering & Surveying Remote Access Lab

T **THE LINDSAY J BARKER BUILDING**
Business and Law, Student Management Division, International, Classrooms

T ANNEXE
ACSC (Australian Centre for Sustainable Catchments), CAIK (Centre for Australian Indigenous Knowledges)

U1 Sciences (Lab Prep Areas, Glasshouses & Workshop)

U2 Bus Terminus 2

U3 End of Trip Cycle Facility

U4 End of Trip Cycle Facility

W Sciences (Administration, Nursing & Midwifery, Psychology)

X Colleges Administration, Heathwood Room

Y Student Management Division, USQ Support Centre, Australian Digital Futures Institute, Multicultural Centre, Creative Media Services, LRDS (Learning Resources Development Support)

Z Engineering & Surveying

Z1 Engineering & Surveying Laboratory II

Z2 NCEA (National Centre for Engineering in Agriculture)

Z3 Security, Post Graduate (Eng) Study

Z4 Engineering & Surveying Laboratory I

RESIDENTIAL COLLEGES
Concannon Blocks (A–D)
McGregor Blocks (A–K)
Steele Rudd Blocks (A–I)

OVALS

No.1 Soccer, Sports Pavilion (OV 1.1)

No.2 Australian Rules, Cricket, USQ MS Theatre & Dance Hall Precinct, Sports Pavilion (OV 2.1), Grounds Shed

No.3 Rugby Club House (OV 3.1)

No.4 Cricket, Toilet Block (OV 4.1), Residential Grounds, Sheds (OV 4.2–4.4)

No.5 Toara Park – Clubhouse and Change Facilities (Ov 5.1 & 5.2), Sheds (Ov5.3 & Ov5.4)

No.6 Soccer

No.7 Australian Rules