COTTON RESEARCH CONFERENCE
5-7 September, 2017
CSIRO Discovery Centre, Canberra

Cotton science delivering impact

Abstract Book

Plenary Speakers

Dr Juan Landivar Bowles

UAS as an Integral Component of a High Throughput Phenotyping Assessment Platform

Dr. Juan Landivar Bowles earned a bachelor's degree in crop science in 1976, a master's degree in plant genetics in 1979 and doctorate in crop physiology in 1987, from Mississippi State University. In 1988, joined the Texas A&M System as Project Leader for cropping systems at the Texas A&M AgriLife Research and Extension Centre at the Corpus Christi.
Research areas include development of management strategies for the use of growth regulators in cotton, development a Crop Weather Station Network for the lower Coastal Bend Region of Texas, development of simulation models and management tools for cotton and sorghum. In 1998, Landivar joined Delta and Pine Land Co. as director of research and technical services for Latin America. Before returning to Corpus Christi, Dr. Landivar served as vice-president of the company's board of directors' joint ventures in Brazil. Currently (2008 to date) he serves as Centre Director at Texas A&M AgriLife Research and Extension Centres at Corpus Christi and Weslaco Texas, where he directs programs in the development of cropping systems for Cotton, Sorghum, Wheat, Citrus, Sugar Cane and Vegetables for South Texas, the development of mariculture technology, beef cattle reproductive physiology and nutrition and sustainable biofuel production systems.
His research has been in the development of crop management tools for the design of economic and environmentally sustainable cropping systems for Texas and beyond. Areas of research interest include: Physiology of crop growth and yield, development and usages of process level crop simulation models, mode of action and uses of plant growth regulators, development of remote sensing systems for research and precision management, development of UAS based platforms for high throughput phenotyping.
http://ccag.tamu.edu/juan-landivar-bowles-ph-d/

Dr Linda Smith

Plant Disease Epidemiology: The challenges to managing economically important pathogens in Australian cotton

Dr Linda Smith is a Plant Pathologist with the Department of Agriculture and Fisheries (DAF) based at the Ecosciences Precinct in Brisbane. She earned a bachelor's degree with honours in Agricultural Science in 1987 from the University of Western Australia, a master's degree in Microbiology/Nematology in 1995 and doctorate in Plant Pathology in 2006, from the University of Queensland. Linda started her working life in a small tissue culture laboratory in Cooroo in WA, initiating and propagating West Australian wildflowers for nursery production. In 1988 she moved to Queensland, and joined the Department of Primary Industries (DPI) Nematology team led by Dr Graham Stirling in 1989. She conducted research on bacterial and fungal antagonists of root-knot nematodes and their potential as biological control agents. In 1997 Linda joined the Banana Fusarium wilt team at DPI working with Ken Pegg and Dr Natalie Moore. Her research was primarily in the area of fusarium wilt disease management of banana. In 2002, she broadened her horizons into cotton pathology when Dr Moore moved to NSW. From 2006 to the present Linda has developed and led industry funded projects associated with the study of plant diseases and pathogens of cotton, including nematodes. The core focus of her teams' research has been to identify and respond to emerging pathology issues identified through extensive surveys in Queensland, provide a diagnostic service for cotton diseases and disorders, to improve the understanding of important plant pathogens, and provide growers with scientifically evaluated disease management strategies so that cotton can remain profitable to grow.

https://au.linkedin.com/in/linda-smith-97023a95

Prof David Tissue

Cotton in future climates

Professor David Tissue received his BSc from McGill University (Montreal), MSc from San Diego State University, PhD from University of California Los Angeles, and conducted post-docs at the Smithsonian Tropical Research Institute (Panama) and Duke University in North Carolina. He was an Assistant, Associate and Professor at Texas Tech University before moving to Western Sydney University in 2007 where he works in the Hawkesbury Institute for the Environment.

Professor Tissue is an international expert on the effects of climate change on ecosystems and has worked around the world, including temperate and tropical forests, deserts, grasslands, arctic tundra and agricultural systems. His current research program addresses the interactive effects of climate factors (elevated CO_2 and temperature) on plant response to climate extremes, including drought, floods and heatwaves on plant growth and physiology.

His goal is to determine the mechanisms that regulate and integrate the developmental and physiological processes that influence leaf level carbon balance and plant growth from the cell to the ecosystem level. This information will determine the impact of climate factors on carbon and water flux, and ultimately on growth, in natural and agricultural ecosystems, including cotton.

https://au.linkedin.com/in/david-tissue-57a303b

Dr Mary Whitehouse

What is the value of IPM in cotton Production systems?

Mary Whitehouse is a Senior Research Scientist in CSIRO Agriculture and Food. She completed her PhD at the University of Canterbury, New Zealand, in the early 90s working on behavioural plasticity in spiders. Mary has always focused on the innovative and unusual in her work. She demonstrated that after many fights spiders can learn to be winners and losers, and from this she developed a different way of interpreting animal contests; she worked in Venezuela applying theories on human warfare to battles between leaf cutter ants; and she developed the Functional Theory of Sociality through studying social spiders in the Israeli desert. Since joining CSIRO in 2001 she has addressed both practical and theoretical issues pertinent to the cotton industry, particularly in the field of Integrated Pest Management. She demonstrated that following IPM guidelines in mirid management did not affect yield and avoided costs; that key spider species are effective IPM tools against pests; and identified how Bt cotton influences invertebrate communities positively. In support of the Resistance Management Plan she challenged complacency on the efficacy of RMP tools; and identified conditions by which *Helicoverpa punctigera* could develop Bt tolerance epigenetically. She is also involved in collaborations with European researchers on moth migration and further developing radar and aerial

sampling techniques to monitor Helicoverpa movement; as well as working with Boeing to apply spider web construction to manufacturing challenges.
http://people-my.csiro.au/W/M/Mary-Whitehouse

Dr Paxton Payton

Breeding and biotechnology for the development of germplasm tolerant to abiotic stresses

Dr. Paxton Payton is a plant physiologist with a Ph.D. in Biology from Texas Tech University. He joined the USDA-ARS Cropping Systems Research Laboratory in 2002 and is and adjunct professor in the Departments of Biology and Plant and Soil Sciences at Texas Tech. His primary research is aimed at understanding molecular and physiological factors that influence abiotic stress tolerance. Of particular interest is how plants acclimate to drought and temperature stress and the development of crop management tools that allow growers to monitor stress and take advantage of plant acclimation responses to maximize yields with limited inputs.

In addition to developing irrigation scheduling tools, Dr. Payton's laboratory is examining germplasm for specific traits related to acclimation in collaboration with researchers in Australia. They are studying cultivar response to elevated CO_2, high temperature, and drought in both greenhouse and field studies in both countries. This work includes current elite cultivars, breeding lines, and transgenic cotton genotypes engineered for improved stress tolerance.
http://www.cottonleads.org/industry-profiles/dr-paxton-payton/

Filomena Pettolino

Designer Fibres

Filomena Pettolino is Group Leader of the Cotton Biotechnology Group at CSIRO Agriculture & Food. She completed a PhD in Biochemistry (Immunochemical studies of (1,4)-β-mannans) at La Trobe University and worked as a post-doctoral fellow at The School of Botany, University of Melbourne, focusing on cell walls and plant and fungal polysaccharide structure and applications. This work included the characterisation of polysaccharides from plant cells in suspension culture, polysaccharides with immunomodulatory activities, yeast mannoproteins involved in reducing visible haze in white wine and the development of plant-based fining agents for the brewing industry. She also studied cell wall assembly in barley and maize for the enhancement of quality, productivity and industrial value of crop plants through her expertise in complex carbohydrate analysis.

Filomena joined CSIRO in late 2010 to work in the Cotton Biotechnology Group. The group works to support a profitable and sustainable cotton industry using biotechnology to focus on protecting yield from the ravages of pests, diseases and a changing climate, enhancing yield and quality and developing novel cotton fibres. Filomena uses a combination of chemical, biochemical and genomic approaches to study cell wall and fibre development in different cotton varieties and fibre quality mutants to understand the relationship between the chemical structure of the cotton fibre cell wall and fibre properties. The long term aim of this work is to manipulate the composition of the fibre to generate fibres with novel properties that will expand the uses of this important natural fibre and enhance Australia's international fibre export competitiveness.
http://people.csiro.au/P/F/Filomena-Pettolino

Dr Warren Conaty

2015 Early Career Scientist Recipient

Who gave the Millennial this gig: do we really want a talk from a 'lazy, entitled narcissist'?

Dr Warren Conaty is a Research Scientist at CSIRO Agriculture & Food, Narrabri. He graduated with a Bachelor of Science in Agriculture with First Class Honours in 2006. During his undergraduate studies, he was a laboratory demonstrator and student mentor in the Faculty. In 2007 he undertook his PhD studies, collaborating with researchers in the United States Department of Agriculture, to implement a wireless canopy temperature monitoring system for irrigation scheduling. As a result he was named the NSW winner of the 2007 Science and Innovation Awards for Young People in Agriculture, Fisheries and Forestry. After submitting his PhD thesis, Warren worked as a Youth Ambassador in fruit tree breeding at the Plant Science and Agriculture Research and Training Institute in Mongolia. Warren now leads a project to develop physiology based screening tools for abiotic stress resistance, ultimately aiming to produce drought and heat tolerant cotton varieties. He was awarded the Early Career Scientist Encouragement Award at the 2015 Australian Cotton Research Conference in Toowoomba.

Mr Ross Searle

Experiences from an Ag Data Hackathon

Ross Searle is a data analyst and senior experimental scientist with CSIRO Agriculture and Food in Brisbane and led a CSIRO team in a three month agricultural data hacking competition run by the CSIRO at its AgCatalyst event last year with data provided by their industry partner, Lawson Grains. The intense and highly competitive hackathon involved creating a value-added product for a corporate farm. Ten teams were involved in the competition, eight of which were from CSIRO, one team from Queensland University of Technology and one from the University of Sydney. Ross, who led the winning team, is also completing his PhD at the University of Sydney's Faculty of Agriculture and Environment whilst working at CSIRO.
Ross will present his experiences of the hackathon and provide guidance for those wishing to do a similar exercise using data from an enterprise cotton farm.

http://people.csiro.au/S/R/Ross-Searle

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PROGRAM SUMMARY

All talks in the Optus Theatre unless otherwise indicated

Tuesday 5 September	**Wednesday 6 September**	**Thursday 7 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 (Conference App, tours, emergencies, mixer) 8:40 AACS Welcome - Mike Bange / CSIRO Welcome - John Manners 9:00 Plenary 1 Juan Landivar: UAS as an Integral Component of a High Throughput Phenotyping Assessment Platform	8:30 Housekeeping 8:40- 9:30 Plenary 3 Linda Smith: Plant Disease Epidemiology: The challenges to managing economically important pathogens in Australian cotton 9:30- 10:20 Plenary 4 Mary Whitehouse: What is the value of IPM in cotton Production systems? 10:20-10:30 2 x 3' pitch talks	8:25 Housekeeping 8:30 AACS AGM 9:20- 10:10 Plenary 6 Filomena Pettolino: Designer Fibres 10:10-10:20 2x 3' pitch talks
10:00-10:30 Morning Tea	10:30-11:00 Morning Tea	10:20-10:45 Morning Tea
10:30-11:20 Plenary 2 Ross Searle: Experiences from an Ag Data Hackathon 11:20-12:20 Session 1 Digital Agriculture 12:20-12:35 3x 3' pitch talks	11:00-1:00 Session 4 - Concurrent talks Stream 1: Pests & Pest management (Optus) Stream 2: Good & bad microbes; Cotton Breeding & Genetics (Building 1 Lecture Theatre)	10:45-12:45 Session 7 Cotton Fibres and Post-harvest Science
12:35-1:30 Lunch	1:00-1:45 Lunch	12:45-1:30 Lunch
1:30-3:00 Session 2 - Concurrent talks Stream 1: Irrigation & water use productivity (Optus) Stream 2: Weeds & Weed Control (Building 1 Lecture Theatre)	1:45-2:15 Plenary 5 Young Researcher Presentation Warren Conaty: Who gave the Millennial this gig: do we really want a talk from a 'lazy, entitled narcissist'? 2:15-3:15 Session 5 Looking forwards	1:30-2:00 Tours HPPC 2:00-2:50 Plenary 7 Paxton Payton: Breeding and biotechnology for the development of germplasm tolerant to abiotic stresses 2:50-3:00 2x 3' pitch talks
3:00-3:30 Afternoon Tea	3:15-3:45 Afternoon Tea	3:00-3:30 Afternoon Tea
3:30-4:00 Tours HPPC	3:45-5:45 Session 6 Farm systems & Ecosystems	3:30-4:20 Plenary 8 David Tissue – Cotton in future climates 4:20-4:30 2x 3' pitch talks 4:30-6:00 Session 8 Cotton physiology & Climate change science
4:00-6:00 Session 3 Nitrogen & Nutrients	5:45-6:15 Short Break 6:15 Buses leave to NMA	6:00-6:20 Closing Comments (CRDC) AACS Business wrap up (Mike Bange) – new AACS Exec. announced and next Conference hosts announced
6:15-8:00 Welcome Function CSIRO Discovery Centre	6:30-10:30 Conference Dinner National Museum of Australia	6:10 Conference Close

ePosters projected on screenshow in main theatre during all breaks and available on conference App.

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Tuesday 5th September

8:30	Housekeeping
8:40	AACS Welcome (Mike Bange, President AACS)
8:50	CSIRO Welcome (John Manners, Business Director CSIRO Ag &Food))
9:00-10:00	Plenary 1 (Optus Theatre) (Chair: Danny Llewellyn)
	P1: **Juan Landivar:** UAS as an Integral Component of a High Throughput Phenotyping Assessment Platform
10:00-10:30	**MORNING TEA**
10:30-11:20	Plenary 2 (Optus Theatre) (Chair: Jane Trindall)
	P2: Ross Searle – Experiences from an Ag Data Hackathon
11:20-12:20	Session 1 – Digital Agriculture (Optus Theatre) (Chair: Jane Trindall)
	S11: **Carlos Ballester:** Cotton nitrogen status monitoring and lint yield prediction from remote sensing imagery
	S12: **Alison McCarthy:** Automated camera-based cotton monitoring and variable-rate irrigation
	S13: **Hizbullah Jamali:** A practical method using a network of fixed infrared sensors for estimating crop canopy conductance and evaporation rate
	S14: **Luz Angelica Suarez Cadavid:** Crop sensing technologies for herbicide drift assessment in cotton
12:20-12:35	Pitch talks (3x 3')
	PT1: **Trudy Staines:** Increasing Capability in Cotton Science
	PT2: **James Latimer:** Stripping of soil organic nitrogen during initial phases of furrow irrigation
	PT3: **Stephen Leo:** Effect of cotton residues on N2O emissions and soil nitrogen following incorporation
12:35-1:30	**LUNCH**
1:30-3:00	Session 2 – 2 Streams
	Stream 1: Irrigation & water use productivity (Optus Theatre) (Chair: Warwick Stiller)
	S2S11: **Mike Bange:** Re-evaluating the prediction models for cotton development
	S2S12: **Michele Reba:** Water quality trends from production sized cotton fields in the Mid-South of the United States
	S2S13: **Ali McCarthy:** Benchmarking Water Productivity in the Australian Cotton Industry
	S2S14: **Rose Brodrick:** Evaluating Methods of Crop Water Use Estimation for Refining Irrigation Scheduling
	S2S15: Hizbullah Jamali: Canopy temperature - a plant-based method of irrigation scheduling in cotton
	S2S16: Wendy Quayle: Irrigation-Nitrogen interactions: Maximising Irrigation Profitability in Southern Cotton

Tuesday 5th September continued

Stream 2: Weeds & Weed Control (Lecture Theatre-Building 1) (Chair: Ian Taylor)

S2S21: David Thornby: The Diversity model: a multi-species, multi-herbicide tool for strategy development in Australian cotton cropping

S2S22: MD Asad Asaduzzaman: Hard to control weeds in the northern cotton farming system

S2S23: Asad Khan: Amaranthus: Emerging weeds of cotton systems in Australia?

S2S24: Jeff Werth: Eradication or mitigation? How to manage patches of glyphosate resistant Echinochloa colona

S2S25: Michelle Keenan: Growth and development of feathertop Rhodes grass (Chloris virgata Sw.).

S2S26: James Hereward: Transcriptomics and population genetics of glyphosate-resistant Conyza bonariensis (fleabane) populations

3:00-3:30 **AFTERNOON TEA**

3:30-4:00 **TOURS of HPPC**

4:00-6:00 Session 3 - Nitrogen & Nutrients (Optus Theatre) (Chair: Mark Peoples)

S31: Max De Antoni: Increasing options for tactical N management

S32: Clemens Scheer: Fertiliser Nitrogen Use Efficiency in Irrigated Cotton Systems

S33: Jonathan Baird: Optimising nitrogen use efficiency through irrigation management in an Australian cotton system

S34: Graeme Schwenke: The effects of different N application strategies on N runoff and NUE in northern irrigated cotton systems

S35: John Smith: The influence of enhanced efficiency fertilisers on lint yield and fertiliser NUE in irrigated cotton

S36: Pam Pittaway: Fertiliser N in root exclusion tubes monitored over a cotton growing season

S37: Ben Macdonald: Carbon and nitrogen emissions in a cotton-wheat-fallow rotation, Narrabri Australia

S38: Graeme Schwenke: Direct injection of nitrification inhibitors into pre-plant anhydrous ammonia reduced soil nitrous oxide emissions from irrigated cotton.

6:15-8:00 **MIXER FUNCTION – (Optus Foyer & Café)**

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Wednesday 6th September

8:30	Housekeeping
8:40-9:30	Plenary 3 (Optus Theatre) (Chair: Susan Maas)
	P3: Linda Smith – Plant Disease Epidemiology: The challenges to managing economically important pathogens in Australian cotton
9:30-10:20	Plenary 4 (Optus Theatre) (Chair: Susan Maas)
	P4: Mary Whitehouse: What is the value of IPM in cotton Production systems?
10:20-10:30	Pitch talks (2x 3’)
	PT4: Karen Kirkby: Verticillium wilt - The American perspective
	PT5: Richard Sequeira: Solenopsis mealybug - the new cotton IPM enforcer
10:30-11:00	**MORNING TEA**
11:00-1:00	Session 4 - 2 Streams

Stream 1: Pests & Pest management (Optus Theatre) (Chair: Paul Grundy)

S4S11: Peter Gregg: Thirty years of chasing moths in the bush, and what have we learnt?

S4S12: Ryan Kurtz: Overview of Cotton Incorporated’s Entomology Research Program and Insect Management in US Cotton

S4S13: Simone Heimoana: Management of emergent pests in GM cotton: refining experimental techniques for valid outcomes

S4S14: Kristen Knight: Contribution of Helicoverpa spp. to the Bollgard 3 system across Australian cotton growing regions

S4S15: Alice Del Socoirro: Abundance of Helicoverpa host plants in inland Australia before and after the Millenium Drought

S4S16: Dean Brookes: Invasion history and movement of Nezara viridula (the Green Vegetable Bug) relative to Australian cotton growing regions

S4S17: Warwick Stiller: Host plant resistance to silverleaf whitefly in cotton: identification of key traits

S4S18: Grant Herron: Linkage mapping of an indoxacarb resistance gene isolated from a field population of Helicoverpa armigera via genotype-by-sequencing

Stream 2: Good & bad microbes (Lecture Theatre-Building 1) (Chair: Hannah Hartnett)

S4S21: Linda Scheikowski: Verticillium wilt - rotation crops

S4S22: Kieran OKeeffe: Managing Black root rot in Southern NSW

S4S23: Gupta Vadakattu: Region-based differences in the diversity and abundance of fungal community in cotton soils

S4S24: Kathryn Korbel: Groundwater biota and water chemistry: influences of agricultural practices on ecosystem services.

Stream 3: Breeding & Genetics (Lecture Theatre-Building 1) (Chair: Hannah Hartnett)

S4S25: Iain Wilson: Improving disease resistance in cotton using marker assisted breeding

Wednesday 6th September

	S4S26: Shiming Liu: Phenotypic variability of yield components, fibre properties and seed characters in a multi-parent population of Gossypium hirsutum background **S4S27:** Washy Gapare: Genomic Selection: an additional toolbox for cotton breeding **S4S28:** Qianhao-Zhu: Accelerating cotton functional genomics and improvement by gene-editing
1:00-1:45	**LUNCH**
1:45-2:15	Plenary 5 (Optus Theatre) (Chair: Colleen MacMillan) **P5:** Warren Conaty: Who gave the Millennial this gig: do we really want a talk from a 'lazy, entitled narcissist'?
2:15-3:15	Session 5 - Looking forwards (Optus Theatre) (Chair: Colleen MacMillan) **S51:** Robert Sharwood: Prospects for Improving CO2 fixation in Cotton **S52:** Demi Gamble: Building climate change resilience through translational physiology **S53:** Thomas Wedegaertner: Elimination of gossypol in cottonseed will increase the value of cottonseed and help mitigate future protein shortages **S54:** Nicole McDonald: Skill Development: An opportunity to transmit the values that make work in the cotton industry a rewarding career option
3:15-3:45	**AFTERNOON TEA**
3:45-5:45	Session 6 – Farm systems & Ecosystems (Optus Theatre) (Chair: Juan Landivar) **S61:** Tim Weaver: Rocky's long term rotation trial - what rotation stands out after 21 years? **S62:** Paul Grundy: Winter sowing for more reliable boll filling in Central Queensland **S63:** James Mahan: An agro-centric analysis of rainfed cotton in the Southern High Plains of Texas **S64:** Tina Gray Teague: Plant Monitoring for Crop Termination Decisions in US Midsouth Cotton **S65:** Yui Osanai: Mechanisms of whole-profile carbon cycling in cotton-based cropping system **S66:** Gunasekhar Nachimuthu: Carbon flow in terrestrial hydrological pathways of cotton farming systems of Australia **S67:** Sean Brennan: Tracking sediment, carbon and nutrients using environmental tracers for enhanced cotton production **S68:** Anthony Ringrose-Voase: Tracer experiment demonstrates the contaminants moving rapidly through the soil with deep drainage
6:15	BUSES DEPART FOR NMA
6:30-10:30	**Conference Dinner - National Museum of Australia**

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Thursday 7th September

8:25 Housekeeping

8:30 AACS AGM (Optus Theatre)

9:20-10:10 Plenary 6 (Optus Theatre) (Chair: Stuart Gordon)

P6: Filomena Pettolino: Designer Fibres

10:10-10:20 Pitch talks (2x 3')

PT6: Michelle Mak: Exploring modes of action of novel biopesticides: from model cell line to target insects

PT7: Michael Braunack: Potential for a spray-on polymer to conserve soil water

10:20-10:45 MORNING TEA

10:45-12:45 Session 7 - Cotton Fibres and Post-harvest Science (Optus Theatre) (Chair: Kristen Knight)

S71: Stuart Gordon: The Contribution of Cellulose Crystallites to Upland Fibre Strength

S72: Colleen MacMillan: Not all secondary cell walls are the same: how the cotton plant has opened us to new discoveries

S73: Robert Long: Miniature cotton spinning capability at CSIRO

S74: Stuart Gordon: Assessing cotton fibre on predicted yarn quality: A new approach to marketing cotton

S75: Xin Wang: Pad-Knife-Pad coating of cotton fabric for versatile protection

S76: Houlei Gan: RAFT Polymers from Cottonseed Oil

S77: Rene van der Sluijs: The removal of plastic wrap during textile processing

S78: Greg Holt: Elimination of acid delinting of cottonseed: evaluation results from new mechanical delinter

12:45-1:30 LUNCH

1:30-2:00 TOURS of HPPC

2:00-2:50 Plenary 7 (Optus Theatre) (Chair: Iain Wilson)

P7: Paxton Payton: Breeding and biotechnology for the development of germplasm tolerant to abiotic stresses

2:50-3:00 Pitch talks (2x 3')

PT8: Kristen Knight: Monsanto's insect protected pipeline project- sucking pests

PT9: Hannah Hartnett: Quantifying seedling vigour: Laboratory based methods to better predict field establishment

3:00-3:30 AFTERNOON TEA

3:30-4:20 Plenary 8 (Optus Theatre) (Chair: Rose Brodrick)

P8: David Tissue: Cotton in future climates

4:20-4:30 Pitch talks (2x 3')

PT10: Richard Sequeira: One for you and one for me - Can we share cropping space with insect pests?

PT11: Murray Sharman: Diversity of Cotton leafroll dwarf virus in Thailand and Timor-Leste

Thursday 7th September

4:30-5:45 Session 8 - Cotton physiology & Climate change science (Optus Theatre) (Chair: Filomena Pettolino)

S81: Chris Nunn: The value of the POAMA seasonal forecast to cotton systems

S82: Katie Broughton: Field studies of integrated temperature and CO2 climatic changes on cotton growth and physiology

S83: Susan Yvonne "Evy" Jaconis: Plant sex: How hot is too hot? Reproductive screening for heat tolerance in cotton

S84: Oliver Knox: Border cells and Bollgard3

S85: Shiming Liu: Leaf sodium content at flowering can be used to screen sodicity tolerance in cotton

5:45-6:10 Closing Comments (Cleave Rogan, Deputy Chair, CRDC Board), AACS business wrap-up

6:10 **CONFERENCE CLOSE**

ePOSTERS (accessible below and through the conference App)

EP1: Brock et al: Cotton production in north-west NSW: climate change mitigation options

EP2: Gavrilenko et al: Cotton surface modification and functionalisation

EP3: Iqbal et al: How to manage glyphosate-resistant weeds in genetically modified cotton?

EP4: Leo et al: Effect of cotton residues on N2O emissions and soil nitrogen following incorporation

EP5: Mak et al: Exploring modes of action of novel biopesticides: from model cell line to target insects

EP6: Molesworth et al: Optimising poultry litter management in cotton production

EP7: Remadevi et al: Swelling of cotton fibres by amino acid treatment

EP8: Welsh et al: Utilising plant growth regulators to develop resilient future cotton systems.

P1:

UAS as an integral component of a high throughput phenotyping assessment platform

Juan Landivar-Bowles, Jinha Jung, Murilo Maeda, Anjin Chang and Junho Yeom
Texas A&M AgriLife Research and Texas A&M University, Corpus Christi, Tx, USA

AgriLife Research and Texas A&M, Corpus Christi have developed a UAS-based high throughput phenotyping system for cotton and other agronomic crops. Combined with image processing algorithms, visualization techniques, and geospatial data analysis, UASs offer an innovative opportunity for the development of high throughput phenotyping systems, and precision agriculture applications. Our team established an automated data processing workflow for a series of UAS data collected over the growing season to extract various phenotypic features such as plant height, canopy cover, canopy volume, bloom count, open boll count, vegetation indices, and canopy surface temperature. In addition, a growth analysis is performed by fitting non-linear models to the UAS-derived phenotypic features to represent temporal growth of cotton genotypes. This growth analysis provides the following information for each genotype: (1) growth rate related parameters such as maximum growth rate, timing of the maximum growth rate, duration and timing of the half maximum growth rate, increasing slope of growth rate in early season, and decreasing slope of growth rate in late season, and (2) efficiency related parameters such as the maximum normalized difference vegetation index (**NDVI**) and excessive greenness index (**ExG**), timing of the maximum NDVI and ExG, increasing slope of NDVI and ExG in early season, and decreasing slope of NDVI and ExG in late season. The proposed UAS-based high throughput phenotyping system provides unparalleled observation of individual cotton genotype responses to biotic and abiotic stresses, and it will significantly accelerate the identification and selection process of superior genotypes.

P2:

Experiences from an Ag data hackathon

Ross Searle

CSIRO Agriculture & Food, Ecosciences Precinct, GPO Box 2583, BRISBANE QLD 4001, Australia

Late last year I was fortunate to be part of a team that competed in the CSIRO AgData Challenge, run as part of the AgCatalyst Conference in November 2016. The challenge was sponsored by Lawson Grains, a large corporate grain farming enterprise, with farms located throughout NSW and WA. In recent years Lawson Grains have invested heavily in a range of new machinery and data acquisition technologies. They were keen to explore how they might use these data to help improve their understanding of their farms and help them improve their business.

They gave the teams involved in the challenge access to a broad range of their data including yield maps, soil tests, remotely sensed geophysics, farm management records, local climate and soil moisture data.

Our challenge was to try and bring these disparate sources of information together to try and develop some useful insights into the Lawson Grains farming enterprise. And a challenge it was.

During this plenary session we will explore some of the challenges our team faced in accessing and using the data, the types of analyses we did, and the pros and cons of the hackathon process.

P4:

What is the value of IPM in cotton Production systems?

Mary Whitehouse
CSIRO Agriculture & Food, Narrabri, NSW 2390.

In the late 1990s the Australian cotton industry nearly collapsed under pressure from the pest *Helicoverpa armigera*. Transgenic cotton used within the framework of Integrated Pest Management (IPM) saved the industry, and enabled cotton growers to aspire for yields thought impossible only a few years earlier. Today as growers continue to strive for the maximum yield possible physiologically, they are less likely to accept the philosophical framework of Integrated Pest Management, effectively dismissing that IPM is of value to modern cotton production systems. However this negative approach could be detrimental to the cotton industry, as it has been around the world in other cotton production systems.

In this plenary talk Whitehouse will provide a provocative perspective on the history of IPM in the Australian cotton industry and the importance of the IPM philosophical approach to pest management. She will provide a cautionary note on what can happen when the IPM philosophy is completely abandoned; but argues that an IPM framework supports players with both soft and hard approaches to pest management. She will discuss the advances that have been achieved along with the pitfalls, and how best to move forward. Whitehouse argues that to increase its value in the future, IPM is likely to incorporate more agronomy, adapt to the effects of climate change, and further tailor itself to the different growing regions. For example, as some pests behave quite differently in different regions, the IPM of each region could be further tailored to counter the pest behaviour unique to each region. Key to the success of IPM is its relevance to cotton growers. This is achieved using a collaborative and inclusive approach, and by recognizing that IPM is a continually evolving beast that works within a social context.

P5:

Who gave the Millennial this gig: do we really want a talk from a 'lazy, entitled narcissist'?

Warren Conaty
CSIRO Agriculture & Food, Myall vale, Narrabri NSW 2390

In 2015 I was awarded the Association of Australian Cotton Scientists Early Career Scientist Award. Unbeknown to me at the time, the catch to walking away with a surprisingly heavy piece of engraved crystal and cheque (nice!) was that I would be asked to present my path to becoming a cotton scientist with some highlights of my work at the next Australian Cotton Research Conference - in a plenary session. But hold on, the captivating plenaries I have attended have been those that synthesise a whole research career, or multiple careers from a research group. I've just got me, and a handful of years. This made me wonder, what sort of plenary talk can an early career scientist pull off? Then, to add insult to injury, the other day in the lunch room we were discussing how my generation, the Millennials, are inherently lazy, entitled and narcissistic. Is the AACS sure they want this presentation?

P3:

Plant Disease Epidemiology: The challenges to managing economically important pathogens in Australian cotton

Linda Smith
Queensland Department of Agriculture and Fisheries

Since the beginning of agriculture, generations of farmers have been developing practices for battling the various diseases suffered by their crops. Following the discovery of the causes of plant diseases in the early nineteenth century, our growing understanding of the interactions of pathogen and host has enabled the development of a wide range of methods for the management of specific plant diseases. In basic terms, to manage a disease, we need to reduce its progress and keep disease development below an acceptable level. This can be achieved through reduction of the initial inoculum, reducing the rate of infection, and by reducing the duration of the epidemic. These three major tactics for managing plant disease epidemics can be incorporated into our plant disease management strategy. In developing disease management strategies however, we also need to take into consideration the dynamics of plant disease, that is, the changes in the incidence and severity of disease in time and space. This is complicated by the fact that different diseases differ in their dynamics. Therefore, for each pathogen, we have to fit these tactics into an appropriate overall strategy based on epidemiological principles.

Three important economic pathogens/pest occurring in Australian cotton include *Fusarium oxysporum* f.sp. *vasinfectum* (Fov), the cause of Fusarium wilt; *Verticillium dahliae* (Vd), the cause of Verticillium wilt, and *Rotylenchulus reniformis* (Rr), also known as Reniform nematode. For all three organisms, the higher the inoculum level pre-plant, the greater the impact on cotton (and other susceptible hosts). However, epidemiology differs for each of these organisms. Therefore, aspects within the overall strategy required to manage each disease differs and needs to be specifically targeted. The challenges of each pathogen/pest, success of management strategies and possible inhibitors to successful management, will be discussed.

P6:

Designer Fibres

Filomena Pettolino, Colleen MacMillan, Vivien Rolland, Qinxiang Liu and Danny Llewellyn
CSIRO Agriculture & Food, Canberra ACT 2601, Australia

Each cotton fibre that is spun into yarn and woven into fabric is a single-celled seed trichome that at flowering emerges from the seed surface and begins the process of elongation followed by a period of secondary cell wall deposition to maturity. The composition and structure of the developing fibre cell wall, and that of mature fibre, are critical determinants of fibre properties including length, fineness, strength and maturity. For example, fibre cells can reach great lengths due to the controlled flexibility of the walls which allows them to elongate lengthwise, and the deposition and organisation of the cellulosic secondary cell wall is essential for strength.

To maintain a competitive industry we need to continue to improve fibre quality beyond what is possible by breeding alone and generate new fibre markets. Multiple approaches are being used to understand and control cell wall composition and its impact on fibre properties. We have undertaken a comprehensive analysis of cell wall composition and gene expression throughout seed fibre development; used fibre quality mutants to identify genes and pathways involved in determining fibre properties; and manipulated the expression of genes involved in fibre composition and quality.

New fibre markets are essential for cotton to compete with synthetic fibres. Recent studies have shown that synthetic fibres are releasing microplastic into our waterways and marine environments through wash water. This is not a problem with biodegradable fibres like cotton and whilst the synthetic fibre market works to make synthetics feel more like natural fibres, cotton can still have opportunities to be competitive, and in some cases more attractive. Our approach is to identify interesting functional and structural proteins found in nature that may be expressed in cotton to add some of the valued properties of synthetics such as high strength, elasticity and resilience to cotton fibre.

P7:

Breeding and biotechnology for the development of germplasm tolerant to abiotic stresses

Paxton Payton
USDA-ARS, Lubbock, Tx, USA

Nearly 2 decades have passed since the first commercially successful genetically engineered agricultural crops were launched. These first products were based, in large part, on simple monogenic traits, such as herbicide tolerance or insect resistance that did not require manipulation of complex molecular pathways. Engineering crops with improved abiotic stress tolerance has proven to be much more difficult due to 1) the multiple pathways involved in controlling native stress responses, 2) the complex ways in which plants respond to environmental conditions under field conditions, and 3) our lack of understanding of key traits that drive yield and the environmental stimuli controlling phenotypes. In cotton, as in all genetically altered crop plants, it is ultimately yield under specific field conditions that determines whether or not a specific gene or signaling pathway is of technological importance. The advent of high throughput phenotyping and genomics tools should allow us to more accurately characterize the production environments and direct trait and germplasm to selection to develop new paradigms for plant-envrionment interactions as well as tools to identify environment-specific traits. To this end, we have initiated a series of experiments to evaluate crop response to water-deficit and temperature stress in an attempt to identify key environmental drivers of plant productivity and develop management schemes to minimize the negative effects abiotic stress. Subsequently, these tools will be the foundation of phenotyping novel germplasm with enhanced stress tolerance. We have developed independent transgenic cotton lines that express the stress-associated regulatory proteins, both single genes and transcription factors, under control of constitutive or stress responsive promoters. The success and failures of our genetic engineering approaches and the potential of new approaches to detecting and managing crop stress will be discussed in the context of application of these tools in breeding and genomics-based selection for crop tolerance.

P8:

Cotton in future climates

David Tissue
Hawkesbury Institute for the Environment, Western Sydney University

Climate change is dramatically changing the landscape for cotton production. Rising atmospheric CO_2 and air temperature, coupled with more frequent extreme climate events such as flooding, drought and heatwaves, are challenges for growers today and into the future. Here, I present results from a suite of experiments in environmentally controlled conditions in glasshouses and the field that address the growth and physiological response of cotton to the main and interactive effects of elevated CO_2, elevated temperature and extreme climate events. In general, elevated CO_2 does not mitigate the negative effects of high temperature and extreme climate events on plant water use and cotton production. The long-term objective of our research program is to contribute to the generation of potential solutions to climate change through identification of the impacts of rising CO_2, temperature and extreme climate events on plant processes and plant-soil interactions using a mechanistic approach. If we can identify the mechanistic basis for plant and soil biotic response to climate in controlled environment experiments, then we can apply this knowledge to field-based systems, ultimately providing management options to mitigate the negative effects of these new climates on cotton production.

S11:

Cotton nitrogen status monitoring and lint yield prediction from remote sensing imagery

Carlos Ballester[1], John Hornbuckle[1], James Brinkhoff[1], John Smith[2] and Wendy Quayle[1]
[1]Deakin University. [2]Department of Primary Industries.

The present work assesses the usefulness of remote sensing data obtained from a drone for tracking spatial and temporal variability of plant nitrogen concentration (N%) in a commercial cotton farm located at the Irrigation, Research and Extension Committee (IREC) demonstration field site at Whitton, NSW. The study was performed in a 7.4-ha paddock where eight nitrogen (N) rate treatments ranging from 0 to 340 kg N/ha were applied. Multi-spectral images of the site were acquired across the season (from 62 to 169 days after sowing, DAS). Each set of images was then uploaded to a cloud-based application where the individual image captures were stitched together to produce a high-resolution GeoTIFF image of the whole site. The NDVI, NDRE and SCCCI vegetation indices (VIs) were computed from the composite images. The relationships between the VIs and N% measured at flowering, first cracked boll and maturity were explored. Moreover, the performance of these VIs at predicting lint yield across the season was also assessed. Results showed that at first flower, SCCCI was the only index correlated with N%. As the season progressed, correlations with N% improved for all the VIs, with NDRE and SCCCI yielding the highest R2. Surprisingly, SCCCI and NDRE performed better than NDVI at predicting lint yield early in the season (from 83 DAS). At 62 DAS, however, the treatments with the highest N rates (from 307 to 340 kg N/ha) had lower NDVI than treatments with lower N rates, suggesting that other factors other than fertilizer application affected plant growth at this early stage of crop growth. Overall, this study shows that drones are a practical tool to assess the spatial and temporal variability of cotton N status. It also shows the challenges of using multi-spectral data for fertilization recommendations at early stages of crop growth.

S13:

A practical method using a network of fixed infrared sensors for estimating crop canopy conductance and evaporation rate

Hamlyn Jones[1], Paul Hutchinson[2], Tracey May[3], Hizbullah Jamali[3] and David Deery [3]
[1]University of Dundee, [2] Hussat Pty Ltd., [3] CSIRO Agriculture & Food.

We describe the development and testing of a novel thermal infrared sensor incorporating a dry reference surface for incorporation into field wireless sensor networks (WSNs) that allows the estimation of absolute transpiration rates and canopy conductance. This 'dry reference' sensor provides a physical reference surface that mimics the temperature of a non-transpiring canopy and can therefore be used in conjunction with canopy temperature to estimate either canopy transpiration or canopy conductance. The dry reference sensor is based on a hemispherical surface that mimics the distribution of shaded and sunlit leaves in non-transpiring canopy. Three dry reference sensors were deployed in a commercial cotton crop from which canopy transpiration and conductance was estimated for the entire season. We provide evidence that fixed infrared sensors with a dry reference surface, when combined with limited meteorological data, can provide useful continuous monitoring of crop water use and canopy conductance that is potentially of value for irrigation management and crop phenotyping applications. Key to the success of this dry sensor application is the requirement that the spectral absorptance of the sensor is tailored to match the crop of interest.

S14:

Crop sensing technologies for herbicide drift assessment in cotton

Luz Angelica Suarez Cadavid and Armando Apan
University of Southern Queensland.

2,4-dichlorophenoxyacetic acid (2,4-D) herbicide drift causes losses of millions of dollars to the cotton industry. Traditional (visual) assessment of damage is often imprecise and inaccurate. Using crop sensing techniques to monitor bio-chemical and bio-physical alterations in the plant offers a fast, non-destructive and reliable approach to predict yield loss caused by herbicide drifts.

Our study aimed to assess the capabilities of proximal and remote sensors for the prediction of damage caused by 2,4-D herbicide drift in cotton crops, using two study cases, located at Jondaryan, Queensland. A factorial randomized complete block using dose and timing of exposure as factors, was examined at four different days after the exposure (DAE). A hyperspectral sensor and a terrestrial laser scanner (TLS) were evaluated to assess their ability to predict yield loss, dose and canopy structure variability. The second case used Landsat 8 satellite imagery for yield loss assessment in an uncontrolled exposure of cotton crops to 2,4-D. Rigorous statistical methods were applied to ensure the transferability of the methods implemented in this study.

The proximal sensing techniques proved to be reliable and accurate to predict yield (R^2 = 0.88) and dose (> 70%) soon after the exposure (~ 7 DAE). Furthermore, estimated canopy height and canopy volume was highly correlated with yield (r > 0.88) as soon as 2 DAE. Prediction models from Landsat 8 data yielded accurate fitted values (R2 up to 0.69) while vegetation indices alone proved to be incapable to predict cotton yield under 2,4-D influence.

From these results, we concluded that the procedures can be implemented as part of crop monitoring programs, as some of the alternatives are easily available at relative no cost (i.e. Landsat 8-OLI or Sentinel-2 satellite imagery), facilitating regular access to data while the most robust approaches (hyperspectral and LiDAR) can be implemented to calibrate prediction models in different areas and conditions.

S12:

Automated camera-based cotton monitoring and variable-rate irrigation

Alison McCarthy[1], Warwick Waters[2] and Joseph Foley[3]
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There can be over 200% variation in soil water holding capacity, crop growth and water requirements within a single field. This variability can be managed using site-specific irrigation volumes applied to each management zone in the field. A management zone may be a set of surface irrigated rows, or small area under a centre pivot or lateral move irrigator instrumented with variable-rate hardware. Management of variability requires the ability to measure variability, determine crop water requirements from these measurements, and variably apply irrigation to deliver the crop water requirements. NCEA has developed software 'VARIwise' that incorporates data from a range of sources (historical and forecast weather, soil characterisation and plant imagery) with a model-based adaptive control system to automatically develop irrigation prescription maps for surface and overhead irrigated cotton crops. Model-based control uses an industry crop production model executed with a range of irrigation volumes and timing to determine the combination that achieves the desired performance objective (e.g. maximise predicted yield).

Field trials in 2016/17 were conducted to evaluate components of VARIwise for the Rural R&D for Profit project 'Smarter Irrigation for Profit' led by Cotton Research and Development Corporation. This presentation provides an overview of these evaluations: (a) plant imagery for variability monitoring; (b) crop production model for in-season yield prediction; and (c) site-specific irrigation prescription map developed using an adaptive control system and calibrated crop production model. The plant imagery system was evaluated at sites in Yargullen (QLD), Talwood (QLD), Griffith (NSW) and Boggabri (NSW). Images were collected using UAVs controlled by CottonInfo extension officers. Image analysis algorithms detected flowers and bolls and these were linked with the cotton production model OZCOT to predict yield. Variable-rate irrigation using prescription maps developed from these data streams was evaluated on a centre pivot cotton field at Yargullen (QLD).

S2S11:

Long term water-use productivity trends in Australian irrigated cotton

Guy Roth
The University of Sydney

Recent media stories have prompted renewed interest in cotton irrigation. This presentation will summarise key advances from the Australian scientific research effort. At least 80% of the Australian cotton-growing area is irrigated using gravity surface-irrigation systems. Over 23 years, cotton crops utilised 6-7 ML/ha of irrigation water, depending on the amount of seasonal rain received. The seasonal evapotranspiration of surface-irrigated crops averaged 729 mm over this period. Over the past decade, water-use productivity by Australian cotton growers has improved by 40%. This has been achieved by both yield increases and more efficient water-management systems. The whole-farm irrigation efficiency index improved from 57% to 70%, and the crop water use index is >3 kg/mm.ha, high by international standards. Yield increases over the last decade can be attributed to plant-breeding advances, the adoption of genetically modified varieties, and improved crop management. Also, there has been increased use of irrigation scheduling tools, furrow-irrigation system optimisation evaluations and automation. This has reduced in-field deep-drainage losses. The largest loss component of the farm water balance on cotton farms is evaporation from on-farm water storages. Many farmers are changing to alternative systems such as centre pivots and lateral-move machines. These systems can achieve considerable labour and water savings, but have significantly higher energy costs associated with water pumping and machine operation. Research into the optimisation of interactions between water, soils, labour, carbon emissions and energy efficiency is on ongoing and other future research needs will be raised

S2S11:

Re-evaluating the prediction models for cotton development

Michael Bange[1], James Quinn[2], James Mahan[3], Paxton Payton[3], Nicolas Finger[1], Jane Caton[1]
[1]CSIRO Agriculture & Food; [2]Cotton Seed Distributors; [3]USDA-ARS

Key management recommendations rely on accurate estimates of crop development using a 'day degree' approach. Currently, the day degree approach used in Australia is not entirely robust to accommodate sometime extremes of climate (heat/cold), and has not been validated for use with current cotton cultivars. The aim of this research was to refine an approach for cotton development for temperature extremes, and ensure it can be used confidently in new cotton regions (e.g. Griffith). Crop development data was collected from observations (a total of 29 field locations) by CSIRO in Australia, USDA in USA, and from the Cotton Seed Distributors Ambassador program from 2002 until 2017. Using this data we developed and validated new algorithms to predict first square and first flower including: i) the existing Australian industry day degree function (base temperature 12°C); ii) the existing industry function with modifications for cold shock; iii) new day degree models with base temperatures ranging from 12°C to 17°C combined with an upper threshold temperature ranging from 30°C to 36°C; and iv) and a function that represented the biological rate response to temperature generated from controlled environment studies undertaken in the Phytotron in Canberra. Approximately half the data was used to build algorithms and the other half was used for validation.

The results showed that there were significant improvements in the RMSD (root mean square deviation representing the variation of observed versus predicted outcomes) of algorithms over the existing industry function that: i) had a base temperature of 15°C, combined with an upper threshold of 32 to 36°C; and ii) used a function that represented a biological rate response. The rate response function also helped consolidate the use of 15°C as an appropriate base temperature. Another key component of these functions was no need for adjustments for cold shock.

S2S12:

Water quality trends from production sized cotton fields in the Mid-South of the United States

Michele Reba[1], Niroj Aryal[2], Tina Gray Teague[3], Michael Daniels[1], Sharna Holman[1] and Carlo Stangherlin[4]
[1]USDA-ARS-Delta Water Management Research Unit, [2]North Carolina A&T, [3]Arkansas State University & [4]University of Arkansas

Excess nutrients from agriculture influence local and regional water quality. In the Lower Mississippi River Basin (LMRB) of the United States, the regional concern is most noted in the hypoxic zone in the northern Gulf of Mexico. In order to determine the local losses of excess nutrients from agriculture in the region, a state-wide network of agricultural edge-of-field (EOF) monitoring sites was established in 2010 in Arkansas and two new Conservation Effects Assessment Project (CEAP) sites were established in the LMRB in 2015. The state-wide network is made up of approximately 30 monitoring sites, on 12 separate farms where rice, soybean, cotton, corn, poultry and beef are produced. The objective of the network was to collect scientifically sound data at field scales under typical and innovative management for the region.
This study consists of EOF sites in central and north-eastern Arkansas that are part of the network each with two fields (control and treatment field). Water quality estimates of sediment, nitrogen (nitrate, nitrite, and total) and phosphorus (soluble and total) were measured at each site. Each monitoring station was equipped with a flow outlet structure such as a flume, weir or open-channel pipe. The outlet structure was outfitted with flow sensors, data loggers and communication devices. This study presents data from the four cotton sites within the network between 2011 and 2015. More recent data collected in 2016 illustrates preliminary findings from foliar applied N and tillage treatments. Two CEAP sites are used to illustrate fate and transport of nutrients and sediment in stream through two contrasting watersheds and to illustrate differences in collection techniques, namely passive samplers, grab sampling, and continuous monitoring with sondes. Findings from these sites inform the utility of conservation practices in the region.

S2S13:

Benchmarking Water Productivity in the Australian Cotton Industry

Iain Hume[1], Beverley Orchard[1], <u>Ali McCarthy</u>[2], Janelle Montgomery[3] and John Hornbuckle[4]
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Introduction

Water is the most limiting resource to Australian cotton production. Benchmarking studies have shown that Australian growers have improved water productivity by 40% over the past decade, making Australia the most water efficient of the major cotton producing countries. The industry recognises the importance of improving water productivity and communicating this with the community.

Water use indices can be based on either crop water use index (CWUI) (ML transpired / ML of irrigation water) or crop production (bales of cotton / ML of irrigation water). These indices require farm-specific information on; irrigation water diverted to the farm, rainfall, and the change in the amount of water stored in soil and storages. Productivity indices require further bale yield or quality data. A benchmarking tool utilised for this is IrriSAT; a rapid remote sensing method to estimate crop water use at field, farm and regional scales.

Method

Irrigation productivity and crop water use indices were calculated for 40 fields in the 2014-15 season and 76 fields in the 2015-16 season. Farm irrigation and yield data were obtained via the CSD Ambassador Program or consultants. Each field was identified as a polygon in the IrriSAT app and its crop water use calculated using SILO gridded weather data.

Results

- There was a large variation in production (7.2-16.8 bales/ha) and water productivity (0.1-6.1 bales/ML of irrigation water).
- The top 5% of producers achieved a productivity of over 16 bales/ML at a crop water use of 1.5 -3.5 bales/ML and a CWUI of 0.9-1.9 ML/ML.
- Water productivity increased in all but one region across seasons.

Conclusions

The cotton industry continues to improve its water productivity and there is an ongoing need for communicating continual improvements.
IrriSAT provides an efficient means to estimate crop water use and is a useful benchmarking tool.

S2S14:

Evaluating methods of crop water use estimation for refining irrigation scheduling

Rose Brodrick[1] and James Mahan[2]
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Irrigating cotton for high yields is a balancing act between providing abundant water leading to excessive vegetative growth and minimising plant water stress that impacts on yield. In Australian furrow irrigated systems the target soil moisture deficit (refill point) is approximately 50% of plant available soil water (PAWC). In high yielding systems the impact of exceeding the optimum deficit can be significant with up to 3% yield loss per day of stress during flowering so it is important for producers to have an accurate method to predict when the soil water will reach this target deficit to determine when to irrigate. The availability of ETo (reference evapotranspiration forecasts) may enable for better predictions of crop water use to be made than traditional estimates of crop evapotranspiration (ETc). We compare three methods of calculating ETc against measurements of soil water the day of each irrigation even across three years in a fully irrigated furrow irrigated crop.

1. ETc-weather based with crop coefficient using published values for crop stages.
2. ETc weather based with crop coefficient based on LAI measurements
3. ETc weather based with crop coefficient based on LAI measurements and corrections based using soil moisture probe readings.

The comparison showed that the 3rd method was the most accurate with predictions of ETc and hence irrigation date varying from the actual soil moisture measurements by up to 3 days. In particular the measurement of soil water soon after an irrigation was particularly important to keep the ETc predictions from varying significantly from the actual soil water. With new technologies using NDVI satellite imagery or UAVs making the use of calibrated crop coefficients more accessible to producers this study showed the importance of using soil moisture or some other measure of real-time crop stress/water use to accurately predict irrigation timing.

S2S15:

Canopy temperature - a plant-based method of irrigation scheduling in cotton

Hizbullah Jamali, Rose Brodrick, Tracey May and Michael Bange
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Timely application of irrigation is critical for maintaining yield and quality in cotton. Canopy temperature is a plant-based measure which is strongly related to soil water availability. Plants release their heat load through transpiration, however as access to water is reduced, plants close their stomata resulting in increased canopy temperature. Environmental factors such as solar radiation and relative humidity affect the relationship between canopy temperature and soil water availability, therefore important to account for when interpreting canopy temperature data for irrigation scheduling decision making. As plant's ability to access soil water is influenced by many factors including environmental conditions, root development, crop development stage and soil compaction, a plant-based measure such as canopy temperature may help optimize irrigation scheduling as plants integrate the effect of soil and other environmental conditions. Canopy temperature can be measured continuously using infrared sensors that are commercially available in Australia. CRDC supported research at CSIRO, Myall Vale over the last decade has shown strong relationships between canopy temperature and yield in cotton. The experiences of using canopy temperature for irrigation scheduling in cotton and its limitations will be discussed.

S2S16:

Irrigation-Nitrogen interactions: Maximising irrigation profitability in Southern cotton

Wendy Quayle[1], James Hill[2], Carlos Ballester[1], James Brinkhoff[1], John Smith[3] and John Hornbuckle[1]

[1]CeRRF, Deakin University; [2]Point Farms, Darlington Point; [3]NSW DPI

Automated surface irrigation systems and layouts matched to soil type enable the accurate application and rapid drainage of water off paddocks with reduced labour. Understanding how these new on-farm infrastructure systems can be operated so that the delivery of moisture and nutrients is closely synchronised with seasonal plant demand and response is vital to drive further water, nitrogen and other management efficiencies in cotton. In this study three different irrigation deficits were interacted with two different nitrogen rates at commercial field scale for input and yield optimisation, lint quality and maturity assessment. The variety was SICOT 746BRF, grown in 2016-17 on a Chromosol in the Murrumbidgee Valley. Irrigations were triggered when soil tension reached -30 kPa (short), -70 kPa (standard) and -110 kPa (long) at 23 cm soil depth as the main factor with 180 kg urea-N ha^{-1} (reduced) and 270 (full) kg urea-N ha^{-1} in a split plot design. The results showed that overall, the short irrigation strategy produced 1 bale/ha more than the other strategies. However, the short treatment required an extra defoliation and matured 26 days later than the long deficit and 19 days later than the standard practise, risk considerations in the short growing season of the southern region. Micronaire, moisture content, maturity, fibre length and consistency were all statistically significantly affected by irrigation schedule although all treatments were of satisfactory quality. There was no significant impact on lint quality by fertilizer or the interaction between the two factors. The data highlights that short irrigation deficits optimized cotton yield but need to be carefully balanced against production costs, excessive fertilizer and chemical use and risk associated with delayed harvest date and cotton prices.

S2S21:

The Diversity model: a multi-species, multi-herbicide tool for strategy development in Australian cotton cropping

David Thornby[1], Jeff Werth[2], James Hereward[3], Michelle Keenan[1] and Bhagirath Chauhan[4]
[1]Innokas Intellectual Services; [2]Queensland Department of Agriculture and Fisheries; [3]University of Queensland; [4]Queensland Alliance for Agriculture and Food Industries, University of Queensland

Because herbicide resistance evolves in very large populations over periods of several (or many) years, modelling has been an important tool for investigating the dynamics of the problem. More recent models can also simulate spatial evolutionary and management dynamics. In some cases, models have been used to develop on-ground strategies for dealing with developing, nascent, or dominating resistant populations. The Diversity model builds on existing modelling efforts but goes a step further: it tracks the evolution of resistance to three herbicides in four weed species in the same environment. The Diversity model has been designed to test strategies for use in new cropping cotton varieties with multiple herbicide tolerances, in an Australian context. The Diversity model is constructed in Python 3, extending the existing mono-gene resistance model SHeRA. It tracks resistance as single-gene and poly-gene traits, and as target-site, non-target-site, and gene amplification mechanisms, and includes both the three target herbicides and a complete range of other weed management options for use in prospective strategies. We understand now that diversity is the answer to herbicide resistance. Stacked herbicide tolerance in new crop varieties offers greater potential for herbicide diversity, but the results of their use in vivo will take time to emerge. With the Diversity model, we aim to quantify just how diverse 'diversity' actually is, and to develop and release strategies of practical use in time to defend the herbicide susceptibility that remains.

S2S22:

Hard to control weeds in the northern cotton farming system

Eric Koetz and Md Asaduzzaman
NSW Department of Primary Industries

In the 2015-16 cotton season a random survey was conducted across 7 cotton farming regions in Queensland and NSW. The survey aimed to determine the level of resistance to glyphosate of 5 major weeds identified by the cotton industry as potentially resistant to glyphosate or at risk of developing resistance. The major weeds were Awnless barnyard grass (*Echinochloa colona*), Feathertop Rhodes grass (*Chloris virgata*), Fleabane (*Conzya bonariensis* L), Windmill grass (*Chloris truncata*) and Sowthistle (*Sonchus oleraceus* L). In total 144 fields were sampled from 50 farms across all cotton farming valleys. Sampling was coordinated to occur after post emergent application of glyphosate to collect seed from survivors. Three grasses were screened to glyphosate rate 1.29 kg ai ha^{-1} at mid-tillering stage. Feathertop Rhodes grass populations were most sensitive to glyphosate followed by Barnyard grass and Windmill grass populations. A total of 72% of the population of Barnyard grass were resistant including 22% were potentially resistant. About 30% of the population of Windmill grass were resistant and additionally 50% were categorised as potentially resistant to glyphosate (total 80% resistant). Glyphosate at 0.68 kg ai ha^{-1} was sprayed on 37 populations of Fleabane at rosette stage. More than 95% of the population were resistant to glyphosate. An additional dose (0, 0.34, 0.68, 1.36, 2.72, and 5.44 kg ai ha^{-1} of glyphosate) response study of four selected extremely resistant weed populations determined the resistance index (RI) with values ranging from 3.5 to 7. Modelling showed that glyphosate rates required to give 100% control in these selected populations are 3-4 times higher than the rate needed for control of the reference susceptible population. Glyphosate, along with other non-glyphosate based integrated weed management strategies are need to be used in cotton farming systems to manage or slow the spread of glyphosate resistance in this species.

S2S23:

Amaranthus: Emerging weeds of cotton systems in Australia?

Asad Khan[1], James Hereward[1], Jeff Werth[2], Gimme Walter[1] and Bhagirath Chauhan[3]
[1]University of Queensland, [2]Queensland Department of Agriculture and Fisheries, [3]Queensland Alliance for Agriculture and Food Innovation

Cotton growers in Australia face significant challenges eradicating weeds from the cotton cropping system. Poor weed management can cause up to 90% yield loss in cotton due to competition with the crop for nutrients and water. Amaranthus species continue to be a problem for the cotton crop in Queensland and NSW. Studies are not available on the ecology and biology of these species in Australia, so a Ph.D. research project has been initiated on major problem (or potential problem) weeds - *Amaranthus hybridus*, *A. powellii*, *A. mitchilli*, *A. retroflexus* and *A. viridis*. These are the most widespread, troublesome, and economically damaging agronomic weeds of genus Amaranthus in Australia. Numerous factors have enabled these species to become dominant and difficult-to-control weeds. These factors include rapid growth rate, high fecundity, genetic diversity, and ability to tolerate adverse conditions. Further, several species in the genus have become major pests in the USA by evolving resistance to glyphosate. The research currently underway will address the knowledge gaps in the biology and ecology of Amaranthus species in Australia. The project includes field experiments and laboratory studies to better understand weed biology relevant for the development of effective control tactics for these emerging weed species. Obtaining information on dormancy patterns as well as the persistence of weed seed banks under current management systems would allow cotton growers to make informed decisions about their weed management programs. In addition, information on the phenology of these weed species along with their seed production would be useful for decision-support systems helping managers select the best management strategies and, thereby, improving their control. Seeds of different populations of the three species will be collected and screened with glyphosate. If resistant biotypes are found, studies will be conducted to determine the mechanism of resistance. A brief overview of experiments conducted and planned for research on these species will be presented.

S2S24:

Eradication or mitigation? How to manage patches of glyphosate resistant *Echinochloa colona*.

Jeff Werth[1], David Thornby[2], Michelle Keenan[1], James Hereward[3] and Bhagirath Chauhan[4]
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Glyphosate-resistant *Echinochloa colona* L. is a common weed in non-irrigated cotton systems. *E. 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 resistant populations when they are detected. A long-term systems experiment was developed to determine the feasibility of eradicating glyphosate resistant populations using different tactics under field conditions. The glyphosate only treatment had consistently higher emergences and plants remaining throughout the four-year experiment. In this experiment, the BMP treatment which contained two non-glyphosate tactics in crop and fallow were shown to be effective at managing glyphosate resistant *E. colona* populations. Treatments that included additional eradication tactics were significantly better at times, however this was not always the case. It is recommended that the BMP (2+2) approach should be used as a baseline combined with monitoring, so that additional eradication tactics can be included as required.

S2S25:

Growth and development of feathertop Rhodes grass (*Chloris virgata* Sw.).

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Feathertop Rhodes grass is an important summer weed in cotton systems. To measure the impact of time of emergence on growth and development of this weed, two glasshouse experiments were established in 2014 and 2015. Plantings commenced in October, and were repeated at four-weekly intervals. Each planting was grown for 24 weeks before above-ground biomass was harvested.

Analyses were undertaken on plantings from October to April. There was a significant interaction between year and time of planting, so data was analysed separately for each year. Time of planting was significant ($p < 0.001$) in relation to dry-weight biomass, maximum height, tiller production to anthesis, panicle production and panicle length.

For the 2014 plantings, the October planting had the largest biomass (43.8 g), tiller number (15.4) and panicle number (41) than later plantings. The April planting had the lowest biomass (1.4 g) and grew, on average, to 22.6 cm compared to 141.7 cm for the November planting. Tiller production was lowest in late December plantings (3.0) and panicle production lowest in the February planting (7.8). Similarly for 2015, October plantings had the largest biomass (31.9 g) and grew taller at 139.2 cm, while the April plantings had the lowest biomass (1.1 g) and height (29.9 cm), but produced the highest number of tillers (11.3). Panicle production was greatest in March plantings (46.2) while November plantings produced the lowest number of tillers (2.8) and panicles (15.4). In both experiments seed production was greatest from October plantings (44 355 and 29 696 seeds, 2014 and 2015 respectively).

This research shows feathertop Rhodes grass growth and development is influenced by time of emergence. Management efforts should focus on, but not be limited to, early emerging plants to minimise weed seed set and competition with cotton crops.

S2S26:

Transcriptomics and population genetics of glyphosate-resistant *Conyza bonariensis* (fleabane) populations.

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Glyphosate-resistant populations of *Conyza bonariensis* were first detected in 2005 in north-eastern cropping regions of Australia. The *EPSPS* gene is present in three copies in this species: *EPSPS1* and *EPSPS2* are the result of an ancient duplication, but *EPSPS2* and *EPSPS3* diverged more recently. Initial Sanger sequencing independently targeting *EPSPS1* and *EPSPS2* indicated no target-site mutations, and a transcriptomics approach was taken to investigate non-target-site resistance. Three individuals from each of five lines (two susceptible and three resistant) were sampled for RNAseq prior to, and 48 hours after, glyphosate treatment. Many genes were differentially expressed (DE) following glyphosate treatment (over 20,000 in all lines) but more genes were DE in susceptible lines than resistant lines. A list of all DE genes in susceptible lines was constructed, representing the differential expression of genes as part of the glyphosate-induced death process. When these genes were subtracted from the list of DE genes in resistant lines, under 4000 DE genes remained. One of these (a member of the major facilitator superfamily of genes) is involved in cell transport and is a candidate for non-target-site resistance. There were no differences in *EPSPS* gene expression across susceptible and resistant lines. When the transcriptome reads were mapped to each of the three *EPSPS* genes independently, however, there was a low level of target-site mutation (2 to 10% of reads) in EPSPS2. Because *C. bonariensis* is an allopolyploid with three genome progenitors, each *EPSPS* gene is present in six copies, and the number of target-site resistant alleles detected is equivalent to one copy out of six for the *EPSPS3* gene. This low level of target-site resistance does not play a major role in resistance because it is present both in very strong and very weak resistant lines.

S31:

Increasing options for tactical N management

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A modelling experiment was conducted to assess the potential of using a decision support system (DSS) to define best nitrogen (N) fertilisation strategies for different management zones. The test assessed two management zones (heavy clay and loamy-clay soil) in an irrigated wheat-cotton rotation on the Darling Downs. For each management zone, the experiment focused on i) identifying correlations between key crop parameters (LAI and leaf N) and final yield, and ii) determining the optimal N fertilisation rate. Simulations were conducted within the Decision Support System for Agrotechnology Transfer (DSSAT) environment and assessed the impact of four N fertiliser rates.
Both LAI and leaf N content were strongly correlated with final lint yield. Across all fertilisation treatments and soil types, LAI and leaf N content values exhibited a substantial correlation with lint yields, with r^2 values of 0.90 and 0.89, respectively. In the clay soil there was a linear response between lint and fertiliser N rates, with an average of +30 kg lint yield per extra kg N applied. In the loamy-clay soil however, the magnitude of lint yields increments decreased with increasing N fertiliser rates. Using these relationships it was possible to identify the response index above which additional fertiliser application was financially worthwhile.

In this study the minimum response index *(Cost of additional N to achieve benchmark ($) / Lint price per tonne ($) x 100)* required to at least achieve the financial breakeven point was 4% extra lint yield per extra kg N applied. Using this assessment, the DSS if run just before the second top dressing and calibrated with the remote sensed information available to date, would have advised to reduce the N rate in the management zone with the loamy-clay soil by 50 kg N ha^{-1} compared to the clay soil. These results show the potential of strategically using a DSS to define best fertilisation strategies for different management zones and guide farmers and their advisers in making in-season fertiliser management decisions.

S32:

Fertiliser nitrogen use efficiency in irrigated cotton systems

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Increasing fertiliser nitrogen use efficiency (fNUE) is essential for maintaining profitability. We assessed fNUE on the Darling Downs at different sites under furrow and centre pivot irrigation. Each of the sites compared the grower normal practice regarding N application with a 30% reduction in N application. We also included nitrification inhibitors (DMPP as ENTEC®) and slow release polymer urea based fertilisers, both at the reduced rate of 30% of the grower's normal practice. We used a stable isotope (15N) technique to track the fate of the fertiliser and compared this method with Apparent Recovery (AR), which is widely used to determine fNUE. The average yield across sites for the three main fertiliser treatments (DMPP, Urea and Farmer's Practice) was 11.9 bales/ha with no significant differences between sites or treatments indicating that growers could potentially reduce their N fertiliser inputs by 30% without any negative impact on lint yield. On average, only 20% of the N taken up by the crop was derived from fertiliser while 80% of N was derived from mineralisation of soil organic matter, and approximately 60% of the N applied as fertiliser was completely lost. Considering the rates applied by these growers (125-200 kg N/ha) were at the lower end of the industry average (250 kg N/ha), N losses from fertiliser across the industry could potentially be higher than 60%. The AR method showed inconsistent results and suggested that reliable estimates of fNUE cannot be provided with this method. Hence, a recommendation is to use 15N studies in future field-based research on N use efficiency. Our on-farm data is in stark contrast to a survey by Roth Rural (2013) who reported that grower's perceive that 68% of the fertiliser N is taken up by the plant and only 20% is lost and indicates that there is significant scope to reduce the N fertiliser rates in the cotton industry.

S33:

Optimising nitrogen use efficiency through irrigation management in an Australian cotton system

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Optimum irrigation management has an impact not only on crop water use, but also nutrient availability and crop nutrient uptake. Understanding the impact and influence of water application on nitrogen uptake and loss pathways will lead to improved nitrogen and water use efficiency. In a furrow irrigated cropping system, a major nitrogen loss pathway is through irrigation induced tail water runoff (excess irrigation water that leaves the field).

Research conducted in Northern NSW explored the impacts of irrigation and nitrogen management) on nitrogen use efficiency of cotton. The research evaluated the impact of pre-plant nitrogen rate, nitrogen product, and nitrogen application timing, as well as water volume applied and water placement within the flood furrow system. Results showed that up to 26 kg N/ha (10% of applied nitrogen) can be lost through excess irrigation water from a cotton field in the first irrigation event alone. The loss from the first irrigation was more than 50% of total nitrogen loss through tail water for the whole cotton season. The research highlighted that modifications such as applying irrigation water to the furrow opposite the nitrogen fertiliser band and increasing applied water volume reduced nitrogen loss through tail water run-off in the first irrigation by up to 40%. Irrigating down the opposite furrow also improved nitrogen uptake by 19 kg N/ha, and nitrogen use efficiency by 7%. Our research showed that nitrogen loss in tail water peaked in the first irrigation event after the bulk nitrogen application, with losses from subsequent irrigations reducing to <1 kg N/ha by the 4th irrigation event. Future research will focus on reducing the amount of nitrogen lost in the first irrigation event, which will significantly improve nitrogen use efficiency from irrigated cotton systems.

S34:

The effects of different N application strategies on N runoff and NUE in northern irrigated cotton systems

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Nitrogen (N) fertiliser is one of the largest input costs for irrigated cotton production in Australia. Many cotton growers are currently outside the optimum nitrogen use efficiency (NUE) range of 12.5-16 kg lint/kg N, either through under- or over-application of N fertiliser, or through inefficient N use caused by either N losses or other growth limiting factors. With a wide range of N application practices and products now in use, there is a need for greater knowledge over how N application and irrigation management interactively affect NUE.

In 2016-17 a field-length replicated experiment was conducted to compare the following treatments: (a) applied N rate [0, 260, 360 kg N/ha] across two irrigation deficits [50 mm, 70 mm], (b) three split N applications [70:30, 30:70, 0:100], (c) three in-crop methods of urea application [broadcast, side-dress, water-run], (d) three water-run products [urea, UAN, ammonia], (e) pre-plant urea coated with a nitrification inhibitor [ENTEC®, Incitec Pivot Ltd] vs urea, and (f) broadcast urea coated with a urease inhibitor [Green Urea-NV®, Incitec Pivot Ltd] vs urea.

Nitrogen runoff losses during the first irrigation after pre-plant N application increased with N rate from 1.4 kg N/ha for the nil N control, up to 12.5 kg N/ha for the 70:30 split 260 or 360 kg N/ha treatments. ENTEC-coated urea lost 9.5 kg N/ha less of the 182 kg N/ha applied up to that date compared to uncoated urea. The mineral N in runoff from subsequent irrigations was generally less than that applied in the irrigation water suggesting a net gain in those irrigations - except where water-run N products were used. Runoff losses of mineral N totalled 24%, 29% and 35% of the water-run UAN, ammonia and urea, respectively.

Treatment effects on cotton lint yields and NUE will be discussed.

S35:

The influence of enhanced efficiency fertilisers on lint yield and fertiliser NUE in irrigated cotton

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Enhanced efficiency nitrogenous (N) fertilisers (EEFs) are available in controlled release and N-stabilised forms, and offer a potential management option for improvement in fertiliser nitrogen use efficiency (NUEF) in irrigated cotton production systems. The mode of action of these forms of EEF differ, but both aim to reduce the concentration of nitrate-N present in the soil at any time prior to crop uptake, reducing the risk of N loss during irrigation and rainfall events.

Three EEFs representing two modes of action (urea granules coated with a nitrification inhibitor (NI) or with polymer coats (PC) with two different release patterns) were compared to urea at a rate of 100 kg N ha^{-1}. The duration of NI action is dependent on temperature, ranging from <28 days to approximately 70 days. The first polymer coated urea product (PCU1) has a release pattern that commences 30 days after application through to approximately 90 days after application The second polymer product (PCU2) releases N from the granules over a 40-90 day period after application, dependent on temperature. Fertilisers were applied at three different times: all prior to planting (upfront), 1/3 upfront and 2/3 applied in-crop prior to first flower, and 2/3 upfront and 1/3 in-crop prior to first flower. Fertilisers were also applied as either single products or in blends of 1/3 urea and 2/3 EEF across the different times of application.

Lint yield was significantly influenced by fertiliser product ($P<0.001$) and by the interaction between the fertiliser product and timing of fertiliser application ($P=0.001$). Overall PCU1 produced the highest predicted lint yield of 12.5 bales ha-1 but this was not significantly different from PCU2, urea or the urea+NI mix. No one particular fertiliser product or timing of application provided a consistently higher lint yield as a result of the significant interaction between the two factors.

Fertiliser nitrogen use efficiency will also be discussed however, sample processing and analysis has not been completed at the time of abstract submission.

S36:

Fertiliser N in root exclusion tubes monitored over a cotton growing season

Pam Pittaway, Dio Antille and Alice Melland
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Root exclusion tubes have been used in forestry and cropping to follow the fate of nutrients in soil without interference from growing roots. By flowering, the concentration of N in soil from within tubes was more than double that of soil sampled from immediately outside. The higher concentration of N remaining within the tubes improved the accuracy of monitoring microbial transformations of the urea fertiliser over the growing season. The fertiliser treatments were an unfertilised control, farmer rate urea, and farmer rate urea plus the nitrification inhibitor DMPP. Farmer rate at the Clapham property was twice the rate at the Naas property due to the narrow fertiliser row configuration used at Naas.

Nitrogen fertiliser transformations were monitored using a novel soil water extract method, adding 4M KCl 1:1 by volume to produce a 2M KCl extracting solution. Results were compared with a standard 2M KCl soil extraction. Ammonium (NH_4-N), nitrate (NO_3-N) and nitrite (NO_2-N) were monitored after rain or irrigation at emergence, squaring, flowering, peak bloom and harvest. At both properties DMPP significantly delayed nitrification, with less nitrate available for cotton uptake at the peak demand phases of first square and peak bloom. This may not be a problem if cotton roots take up both ammonium and nitrate-N.

Preliminary conclusions from the first cotton season indicate the use of root exclusion tubes may improve the accuracy of N supply calculations over the growing season. The water extract method for monitoring microbial transformations of urea was more sensitive for NH_4-N, NO_3-N and NO_2-N at lower concentrations. However, recoveries of NH_4-N were substantially higher with the conventional 2M KCl soil extraction method. Further work is required to determine if this NH_4-N fraction is plant-available in the soil solution, or bound to clay layer lattices.

S37:

Carbon and nitrogen emissions in a cotton-wheat-fallow rotation, Narrabri Australia

Ben Macdonald, Tony Nadelko Yvonne Chang, Ian Rochester and Kellie Gordon
CSIRO Agriculture & Food

In furrow irrigated cotton production systems the application of nitrogen fertiliser is required for high yielding crops. If excessive nitrogen fertiliser is added then nitrous oxide is produced (N_2O). The field average emission of N_2O from an application 240 kg N ha^{-1} produced 4.17±0.56 kg N_2O-N ha^{-1} during the season. The largest fluxes occurring during the first 3 months. This indicates that excessive N was present in the soil and was converted to N_2O during nitrification and denitrification. The emissions from the hill and the skip and irrigation furrows were different. The hill had the greatest N_2O emission and the skip and hill furrows had emissions significantly great than the background. The emissions from the furrows were caused by the deposition of N in the irrigation water or by leaching of N from the hill.

Methane was a small component of the greenhouse gas inventory and approximately 1 kg CH4 ha^{-1} was consumed by the soil over the 2 year rotation. The CO_2 emissions were significant different between the hill and the irrigation furrow during each season. The wheat and cotton net ecosystem flux was positive from the hill due to the presence of the plants, whereas the furrows were strongly respiring. The overall carbon balance indicates that the cotton-wheat-fallow rotation is losing 5t C ha^{-1} soil carbon during the 2015-16 crop rotation. To improve the carbon balance is these cropping systems the bare fallow and farrow needs to be eliminated or modified.

The results show that chambers must be deployed in the hill and skip and irrigation furrows to quantify the greenhouse gas emissions. Further the measured soil temperature and volumetric moisture content and atmospheric temperature, vapour pressure deficit and CO_2 concentration were periodically different to the field. These differences may result in increased nitrogen and carbon cycling in the chambers relative to the field. In terms of modelling the emissions generated in the chamber will potentially not equate to field conditions and a correction factor will need to be applied.

S38:

Direct injection of nitrification inhibitors into pre-plant anhydrous ammonia reduced soil nitrous oxide emissions from irrigated cotton

Graeme Schwenke and Annabelle McPherson
NSW Department of Primary Industries

Pre-plant nitrogen (N) fertiliser application produces a large pool of mineral N in the soil that, once nitrified to nitrate, is at risk of gaseous loss during anaerobic conditions through denitrification - a process that produces nitrous oxide (N_2O), a greenhouse gas, and N_2. Nitrification inhibitors restrict the conversion of ammonium to nitrate, thus potentially reducing the N_2O emitted during the pre-sowing and early crop establishment phases of irrigated cotton production. Nitrification inhibitors are not currently available in Australia to apply with anhydrous ammonia (AA). This research aimed to assess the efficacy of DMPP [3,4-dimethylpyrazole phosphate] (Big N-sure®, Incitec Pivot Ltd) and nitrapyrin [2-chloro-6-trichloromethylpyridine] (N-Serve®, Dow Agrosciences Ltd), when directly injected into the AA stream during pre-plant N application for commercial irrigated cotton production at Emerald (Qld) and Gunnedah (NSW).

N_2O emissions at the Gunnedah site were approximately 10 times higher than at the Emerald site due to that site having higher initial soil moisture and heavier clay soil, and a long pre-plant period with high in crop rainfall. In comparison the Emerald site had a short pre-plant period with minimal in crop rainfall. Both nitrification inhibitors restricted nitrification of the applied ammonia for 2-3 months. At the Gunnedah site, cumulative N_2O emitted during the study period was reduced by 84% (DMPP) and 58% (nitrapyrin), compared to untreated ammonia. At Emerald, both inhibitors reduced N_2O loss by an average of 66% in the period between their application and an in-crop side-dress of urea. However, apart from boosting plant population at the expense of bolls/plant at Emerald, neither inhibitor had a significant effect on cotton lint production at either site. This is probably because at Emerald denitrification losses were minor, and at Gunnedah the large N rate applied (375 kg N/ha) compensated for the N lost through denitrification.

S4S11:

Thirty years of chasing moths in the bush, and what have we learnt?

Peter Gregg
University of New England

In 1987, a group of entomologists from several institutions embarked on a long-term study of Helicoverpa ecology in non-cropping areas of inland Australia. This work has continued intermittently until this year, with funding from CRDC, GRDC, RIRDC, ARC and the Cotton CRC. We made a total of 79 field trips to the region, which encompassed inland areas of NSW, Qld, SA, WA and NT. Over 2000 sweep net samples for Helicoverpa spp. larvae have been made on over 230 different plant species, mostly natives. *H. punctigera* was by far the most common species, with 50.5% of samples yielding larvae. Only 4.2% of samples yielded *H. armigera* larvae, and these were mostly in the northeast of the study area. This is despite the fact that in the laboratory *H. armigera* larvae survive and grow well on some key inland hosts. *H. punctigera* larvae were found on 122 plant species from 18 families. Of these, 120 were new host records. Host suitability was assessed using the matrix of Zalucki *et al.* (1994; *Aust. J. Zool.* **42**, 329), which plots relative incidence against relative abundance. The best hosts were annual daisies and legumes. Annuals from several other families were also commonly recorded as hosts. Perennial species were less suitable. Crops sampled around the margins of the study area supported fewer larvae than the native hosts, indicating the importance of native hosts in the continental population dynamics of *H. punctigera*. This presentation sets the scene for the presentation by Del Socorro et al., which describes the impact of medium-term changes in climate, represented by the Millenium Drought, on Helicoverpa ecology, and the implications for management of these pests.

S4S12:

Overview of Cotton Incorporated's Entomology Research Program and Insect Management in US Cotton

Ryan Kurtz
Cotton Incorporated, USA

Cotton Incorporated is a non-profit organizations whose mission is to increase the demand for and profitability of cotton through research and promotion. Each year, Cotton Incorporated funds more than 300 research projects with universities, the US Department of Agriculture and private cooperators. This presentation will provide an overview of the key areas of emphasis in Cotton Incorporated's entomology research program, as well as an update on the current status of insect management in US cotton with a focus on major pests, resistance issues, and management practices.

S4S13:

Management of emergent pests in GM cotton: refining experimental techniques for valid outcomes

Simone Heimoana, Lewis Wilson and Tanya Smith
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The pest status of green vegetable bug (*Nezara viridula*, GVB) in GM cotton has increased as it is no longer controlled by sprays applied against *Helicoverpa* spp, and is not affected by Bt proteins. Management is problematic as older, cheaper insecticides are effective, but disruptive of beneficial populations, increasing risks from secondary pests like silverleaf whitefly (SLW, *Bemisia tabaci*), aphids (*Aphis gossypii*) or mites (*Tetranychus* spp.). Assessing GVB is difficult as the pest occurs sporadically and is irregularly distributed through the field and the crop canopy. We developed a sound approach to investigate more selective options for GVB control and their effects of SLW and beneficial populations.

The approach ensured pest abundance: SLW infested kale plants were transplanted into cotton plots and between-replicate rows of mung beans were infested from a GVB culture. GVB transferred from the mung beans to the cotton. GVB were also collected and released into marked cotton rows. Insect abundance in plots was assessed before and after spraying using beat sheets for GVB, visual counts for SLW and suction samplers for all other pests and beneficials. Insecticides compared in replicated field experiments were fipronil 1/3 rate + salt, clothianidin ½ rate (3 years), dimethoate and flonicamid (2 years).Three sprays were applied each year.

Clothianidin, dimethoate and fipronil all controlled GVB but flonicamid did not. Plots treated with fipronil (two of three experiments) or flonicamid (one of two experiments) had increased SLW abundance and dimethoate trended that way. All products flared mites, likely reflecting negative effects on key beneficial species. The results suggest clothianidin may be the most suitable option for IPM systems, though still with risks for mites. This approach highlighted differences between compounds and may be suitable in other systems.

S4S14:

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

Kristen Knight
Monsanto

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 2014/15-2016/17 seasons *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.

S4S15:

Abundance of Helicoverpa host plants in inland Australia before and after the Millenium Drought

Alice Del Socoirro, Peter Gregg and Kris Le Mottee
University of New England

A thirty year study of the ecology of Helicoverpa spp. in inland Australia (see abstract for the presentation by Peter Gregg) has provided a comprehensive picture of short and long term changes in host plant abundance in different inland habitats (floodplains, grasslands, acacia shrublands, chenopod shrublands, sandy deserts and stony downs). The presence or absence of known host plants for Helicoverpa spp. was recorded at over 3,300 randomly selected sites in inland Australia. The Millenium Drought in 2001-2009 which severely affected southeast Australia (Van Dijk *et al.* 2013, *Water Resour. Res.*, **49**, 1040-1057) significantly affected host plant abundance in the acacia shrublands and to a lesser extent in the grasslands. Floodplains, sandy deserts, stony downs and chenopod shrublands were not affected. Host plants were recorded in about 61% of the sites surveyed in the acacia shrublands before the drought, and only in about 28% after the drought ($P<0.001$)). In the grasslands, about 49% of these sites supported host plants compared with 35% after the drought ($P=0.018$). The abundance of host plants also declined in many sites, and good hosts (such as the daisy *Rhodanthe floribunda*) were replaced by plants which supported fewer larvae (such as the Malvaceous plant *Sida platycalyx*). The acacia shrublands or mulga lands were thought to be the 'bridge' between the inland sources of *Helicoverpa* spp. and the cropping regions in the south-eastern part of the continent. The impact of the Millenium Drought on the host plants, and how it may have changed the potential for immigration of Helicoverpa spp. to cropping areas will be discussed.

S4S16:

Invasion history and movement of *Nezara viridula* (the Green Vegetable Bug) relative to Australian cotton growing regions

Dean Brookes[1], James Hereward[1], Lewis Wilson[2] and Gimme Walter[1]
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The Green Vegetable Bug, *Nezara viridula*, is a pest of global significance that has become a more significant problem in Australian cotton since Bt cotton became widely used. Pest pressure from the bug is variable - it does not reach numbers that require control in every season or in every growing region. Outside of cotton *N. viridula* has a wide host plant range and feeds on plants from over 40 different families. Investigation of the host plant use and movement of *N. viridula*, relative to the availability of its host plants, was conducted during my PhD to better understand its ecology and to better predict when this bug will be in high abundance.

Nezara viridula was collected from across Australia, from a number of different host plants and from both northern and eastern regions. Phylogenetic and population genetics approaches where used to investigate the genetic relationship between Australian and global populations of *N. viridula*, as well as between bugs collected from different host plants and different growing regions. Samples were collected across two seasons which allowed investigation into the stability of these genetic relationships.

Australian *N. viridula* are derived from two different evolutionary lineages, one Asian and one European. The two lineages have mated in northern Queensland but populations of *N. viridula* across the cotton growing regions in eastern Australia are a single genetic population derived predominantly from the European lineage. Eastern Australian populations of *N. viridula* are more genetically distinct from one another the further they are separated geographically. This pattern of genetic differentiation, found in both seasons, indicates that *N. viridula* populations are relatively localised and are not regularly moving the large distances separating growing regions.

S4S17:

Host plant resistance to silverleaf whitefly in cotton: identification of key traits

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Silverleaf Whitefly (SLW, *Bemisia tabaci*) is a major insect pest for the Australian cotton industry. It contaminates the lint with honeydew and poses a risk for the whole industry in terms of our international reputation for cotton quality. Chemical control is limited due to the development of insecticide-resistant populations to multiple insecticides, therefore the use of host plant resistance is an effective and economical control method in an integrated pest management approach. Our research aims to develop cotton cultivars with improved resistant to this insect, which would require fewer pesticide applications, reducing costs and damage to beneficial invertebrate populations. An understanding of the mechanisms of resistance is important when breeding for host plant resistance as it assists in the development of rapid screening techniques to select the most resistant genotypes within large populations. Artificial infestation and population monitoring protocols in the field have allowed us to confirm okra/glabrous traits conferring resistance in *G. hirsutum*, as well as to identify resistance in *G. arboreum* and other diploid species controlled by unknown traits, although they are likely to be non-morphological. In order to identify those host plant resistance traits in diploid cottons, we have conducted SLW oviposition preference and life history studies under controlled conditions. The results indicate that genotype does not affect SLW immature development and survival, but it could affect SLW adult oviposition preference. However, an accurate method to screen cotton genotypes for resistance to SLW under controlled conditions has not been developed yet. Finally, some backcross breeding lines developed from a *G. arboreum* genotype had a high level of resistance to SLW in field conditions, which suggests that introgression of SLW resistance into commercial cultivars is possible.

S4S18:

Linkage mapping of an indoxacarb resistance gene isolated from a field population of *Helicoverpa armigera* via genotype-by-sequencing

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Traditional approaches to studying the genetic basis of resistance require a large number of recombinant individuals and developing genetic markers along the chromosomes. An alternative can use next generation sequencing in combination with conventional backcrossing and selection.

To generate the makers we used genotype-by-sequencing and produced more than 10,000 distributed in the *Helicoverpa* sp. genome. Firstly, we used the restriction enzyme *PstI* to cut the genome into small DNA fragments, after which a barcode and sequencing adaptor was attached. DNA fragments were sequenced with an Illumina sequencer with 100 bp reads. Raw sequence data were filtered and aligned to a reference genome. To generate the desired recombinant individuals, we set up insect crosses and selected resistant F_1 males back crossed to the susceptible strain sequentially 5 times to generate F_6 progeny.

We generated 22,679 useful sequence tags, and 13,202 were mapped to the *H. armigera* genome. *H. armigera* has 31 chromosome pairs with total genome size about 313 MB. Therefore, we estimate our marker coverage to be about 25-100kb. We then carried out a genome-wide association analysis finding a cluster of markers highly associated with indoxacarb resistance on scaffold NW_018395414, so it is probable the resistance causing allele(s) lie on that region.

Further, we then carried out a full sequence alignment for that scaffold and examined all the markers highly associated with indoxacarb resistance. These markers are located in a narrow 2.6 MB region. Additionally, we examined the genes in this 2.6 MB region finding numerous detoxification genes including the 10 CYP6AE gene cluster (also suggested via a related bioassay study). To pursue this we designed a series of primer pairs along the haploid block. The combination of these PCR amplifications can distinguish between resistant and susceptible genotypes and will form the basis of a molecular diagnostic tool.

S4S21:

Verticillium wilt - rotation crops

Linda Scheikowski, Linda Smith and Tim Shuey
Queensland Department of Agriculture and Fisheries

Verticillium wilt continues to be a major disease problem for cotton production in Australia. Disease incidence is related to the soil population of *Verticillium dahliae*, so management strategies that can lower this population are required. Non-host rotation crops can be beneficial in aiding this reduction compared to continually planting susceptible hosts. A field trial located near North Star in northern NSW investigated the incidence of disease in cotton following a crop of sorghum, corn, cotton or fallow by monitoring flagged plants for external disease symptoms over time. A hot summer resulted in a lack of visible symptoms of Verticillium until a period of cooler, overcast wet weather and reduced temperatures occurred in mid-March. Expression of disease symptoms then became obvious very quickly. When assessed prior to harvest disease incidence was greatest where cotton was planted after cotton, compared to after fallow and lowest disease occurred where cotton followed either one crop of sorghum or corn. Both 2A and 1A strains of the pathogen were confirmed from the field. Additionally, soil plating and DNA quantification will provide further information on the effect different cropping rotations are having on soil populations of *V. dahliae*.

S4S22:

Managing Black root rot in Southern NSW

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Black root rot is a major threat to profitable cotton production in southern NSW. The disease was identified in 50% of fields in the 2016/17 annual disease survey conducted by CottonInfo in southern NSW. Growers have ranked the disease as a major constraint to profitable cotton production in the past three end of season CottonInfo surveys. A problem BRR field was identified in 2016 with a history of back to back cotton. Soil samples were taken before rice was grown in October 2016 and soil samples were taken in the same location after rice was grown in the field in May 2017. Spore counts dropped from 180 spores/gram of soil to 65 spores/gram of soil using a commercially available test. Cotton seedlings were grown in soil before rice and after rice with seedlings showing reduced severity and incidence of BRR in the soil after rice. The management option to grow rice in the rotation maybe an option for some fields in the future if layouts and soil types are suitable for rice. Water availability and water price needs to be factored in when making this choice. Other options need to be investigated as potential practical options including summer flooding for a minimum of 30 days, biofumigant crop options and how effective the different biofumigant crops are at reducing the impact of Black root rot. Cotton production is expanding rapidly in southern NSW and is moving further south with potential increased risks from seedling disease impacts. This initial investigation needs validation of the testing if it is a reliable predictive tool that can be used and replicated research into practical management options available to growers.

S4S23:

Region-based differences in the diversity and abundance of fungal community in cotton soils

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Fungi are ubiquitous and account for more than 60% of microbial abundance in Australian soils including those under intensive cotton cropping. Plant associated fungal communities not only assist with crop nutrition but can also function as an important line of defence against fungal pathogens e.g. species-rich communities are more resistant to pathogen invasions. Their many roles in ecosystem processes, both beneficial and deleterious, have been identified but the determinants of their diversity and abundance in cotton soils as influenced by the biographical habitat are poorly understood. Surface 0-10 cm soils from farmer fields, monitoring cotton performance and disease incidence in 5 cotton growing regions in Queensland and New South Wales, collected during 2016 cotton season were analysed for the genetic diversity (ITS region sequencing) and abundance (qPCR) of fungi. Samples were also analysed for microbial catabolic diversity, microbial biomass and soil chemical properties.

Briefly, Ascomycota are the most dominant group of fungi in all the soils accounting for 68 to 78% of total fungi followed by Basidiomycota (12 to 19%) and Zygomycota (1-9%). Fungal genera belonging to the Classes Sordariomycetes (43 to 53%), Agaricomycetes (9-21%) and Dothideomycetes (5 to 17%) were the major groups that showed distinct differences between locations. Members of Glomeromycetes fungi (mycorrhizal fungi) accounted for <1% of total fungal community, which is less than that previously found in the remnant bush soils (>2.2%), probably due to the P fertilization in cotton crops. Results also indicated significant differences in the abundance & diversity of fungal community, e.g. Shannon diversity index was lower in the soils from St. George and Emerald regions compared to that in the Darling Downs and Namoi region soils. Overall, these results suggest that soil ecological and environmental factors and management-related filtering processes related to substrate quality and availability play a significant role in shaping fungal communities and their functionality in cotton soils.

S4S24:

Groundwater biota and water chemistry: influences of agricultural practices on ecosystem services

Kathryn Korbel and Grant Hose
Macquarie University

Through biogeochemical cycles, groundwater ecosystems provide a range of services significant for water quality and quantity. Microbes perform a range of metabolic functions that influence the cycling of carbon, hydrogen, sulfur, iron and nitrates. Additionally, larger invertebrates (stygofauna) and protozoans perform a range of functions including grazing and promoting microbial growth, which in turn can impact water chemistry. Thus an understanding of the types and roles of biota within aquifers is vital for industries such as the cotton industry, which in some locations is heavily reliant on irrigation from groundwater.

Previous studies have indicated a diverse and rich biological community within groundwater, however relatively few investigations have been conducted on groundwater microbial communities, mainly due to difficulties in using traditional methods to culture these organisms. With advances in technology, it has now become relatively easy (albeit expensive) to study the potential microbial function and diversity within environmental data though the use of metagenomics and DNA sequencing.

The study utilised DNA community profiling (metabarcoding) of 16S rDNA and 18S rDNA, to characterise and infer functional significance of groundwater biota from the cotton growing regions of the Namoi, Condamine, Gwydir and Macquarie catchments between 2015-2016. A number of differences in the structure of communities under irrigated or non-irrigated lands were demonstrated, including differences in relative abundances of nitrogen cycling microbes. Additionally, a diverse array of methanogenic microbes have been identified. Such findings suggest human activities may impact biogeochemical cycling and, in turn, ecosystem services provided by biota.

S4S25:

Improving disease resistance in cotton using marker assisted breeding

Vanessa Gillespie[1], Bec Edwards[1], Yuman Yuan[1], Philippe Moncuquet[1], Washy Gapare[1], Qian-Hao Zhu[1], Warwick Stiller[2], Danny Llewellyn[1] and Iain Wilson[1]

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Diseases of cotton are responsible for significant and widespread decreases to production globally. Reducing the impact of major pests and diseases therefore represents an effective way to realise the true yield potential of elite varieties, and breeding resistant germplasm is the most effective long term means for minimising these losses. For many important cotton diseases it is difficult or at least very slow to improve varietal resistance due to the genetic complexity of resistance, disruption of performance when bringing in resistance from distant genetic resources or from just the difficulty in assaying for resistance in the field as novel resistances are being incorporated into elite breeding lines. Molecular markers are DNA tags or sequence differences that are physically located on cotton chromosomes near regions carrying important traits like disease resistance, and so can be used as a substitute to screen for the presence of those traits without ever exposing the plant to the disease causing organism. Possessing markers for disease resistance can greatly speed up the selection for resistant plants as it reduces the need to perform disease assays in the field and can target specific genomic regions for introgression. Analysis of populations segregating for Black Root Rot, Fusarium Wilt and Verticillium Wilt have identified regions in exotic germplasm linked to resistance for these diseases. The mapping of these resistance loci and the application of these markers for breeding better CSIRO varieties with increased resistance will be discussed.

S4S26:

Phenotypic variability of yield components, fibre properties and seed characters in a multi-parent population of *Gossypium hirsutum* background

Shiming Liu[1], Rebecca Warnock[1], Louise Zemcevicius[1], Brett Ross[2], Hannah Hartnett[2] and Danny Llewellyn[3]

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Economic and adaption traits in cotton are all quantitative in nature, for example, yield, fibre and seed quality properties, or disease and stress tolerance. Breeding for their enhancement relies on better understanding of their genetic architecture and interrelations. To facilitate such research and to design better breeding strategies in cotton, we have created a structured genetic population consisting of about a thousand recombinant inbred lines (RILs) in a *G. hirsutum* background. Following a description of its development, we will present phenotyping results for yield components, fibre properties and seed characters, based on a replicated field trial of a quarter of the population using randomly selected RILs. It was found that transgressive variability was commonly observed for the traits studied, and that there were no strong inverse pair-wise correlations between the traits. Therefore, it should be possible to improve lint yield by selecting higher lint percentage and without compromising seed weight and vigour. The evidence also supports our assertion that such a population would provide enormous value for molecular marker associated QTL discovery and mapping as well as for developing novel marker-assisted breeding tools in cotton.

S4S27:

Genomic Selection: - an additional toolbox for cotton breeding

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Genomic selection (GS) is a promising new breeding tool that estimates performance of individuals based solely on their marker (genotype) data by using a statistical model built from phenotypic and marker data previously collected from a training population. The training population needs to be relevant to the breeding objectives of the program and cover the founder varieties and/or lines contributing genetic alleles into breeder's populations. A GS model is initially built that best estimates marker effects (positive, negative, or neutral) simultaneously for all markers spread across the genome as random effects contributing towards each of the phenotypes being measured. Once trained, the model can be used to calculate the genomic estimated breeding values (trait performance) of individuals that are related to the training population, but that have only been genotyped and not phenotyped. The model can be refined as more data is collected to increase its prediction accuracy. Thus, GS can potentially eliminate the need to phenotype during a selection cycle and so can greatly increase trait performance/genetic gain per year relative to standard phenotypic selection. It has been used extensively in cattle breeding, but not widely yet in crop plants.

We are currently investigating the use of GS to improve breeding for agronomic traits in CSIRO's cotton breeding program. A training population of 215 upland cotton accessions phenotyped for fibre length and strength was genotyped with approx. 13,500 single nucleotide polymorphic markers. We used these data to investigate the potential for GS as a breeding tool in cotton to predict length and strength and to define the pilot breeding studies that need to be developed to test and transition to genomics-assisted selection methods. The long-term goal of this research is to optimize GS approaches and use it in cotton breeding to fast track the release of improved cotton varieties.

S4S28:

Accelerating cotton functional genomics and improvement by gene-editing

Qian-Hao Zhu, Iain Wilson, Filomena Pettolino and Danny Llewellyn
CSIRO Agriculture and Food, GPO Box 1700, Canberra, ACT 2601

With the completion of the draft sequences of four cotton genomes (*Gossypium raimondii, G. arboreum, G. hirsutum* and *G. barbadense*), cotton has entered a post-genomic era with the major goals to functionally characterise all annotated genetic loci in various biological processes and to use agronomically important genes in cotton improvement through transgenic and/or conventional breeding approaches. Mutants are powerful tools for elucidating functions of genes responsible for the mutant phenotypes, and can be generated by chemical or physical mutagenesis, and by insertion of T-DNA or transposable elements (TE) through *Agrobacterium*-mediated transformation. Generation of mutants using chemical and physical mutagenesis is simple, but characterisation of those mutants and identification of the causative gene(s) is time-consuming. Generation of a T-DNA or TE insertional mutagenesis population is also technically challenging in cotton. Furthermore, these approaches suffer from difficulties in achieving genome-wide saturated mutagenesis.

CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats-associated nuclease 9) has recently emerged as a powerful tool for functional genomics in both plants and animals. The technology provides an effective method of introducing targeted insertions and deletions (indels) at specific sites in the genome that result in loss-of-function alleles, and has become the most popular tool for functional genomics in model organisms. The target specificity of CRISPR/Cas9 is defined by a 20-bp single-guide RNA (sgRNA). Transforming a pool of sgRNAs targeting a set of genes or all annotated genes into cotton could be used to generate a mutagenized population with each individual containing indel mutations that will provide clues on gene function. In addition, CRISPR/Cas9 has been shown to be able to precisely change one target base into another in the gene of interest through base-editing. In this presentation, we will discuss the concept of using gene-editing in the generation of a mutant library for cotton functional genomics and propose that this technology would be the key for future cotton improvement by targeting the genes underlying yield components and fibre quality that are identified by map-based cloning and/or genome-wide association studies.

S51:

Prospects for Improving CO_2 fixation in Cotton

Robert Sharwood
Australian National University, Canberra ACT

Global climate change is posing a serious threat to future cotton productivity through increases in ambient air temperatures and the frequency and prevalence of heat waves. The impact of these events are compounded by unpredictable rainfall patterns associated with increases in the prevalence of drought conditions, which exacerbate the impact of elevated temperatures. These factors together impact the catalytic properties of the central rate-limiting CO_2-fixing enzyme of photosynthesis, Rubisco. Under conditions of elevated temperature and drought, the propensity of Rubisco oxygenation increases to produces significant amounts 2-phosphoglycolate that must be recycled through the photorespiratory pathway. Photorespiration is energetically costly to C3 plants, therefore reducing the propensity of this pathway is a major goal of plant engineers. We have sought to address these problems of Rubisco catalysis by screening terrestrial plants and oceanic algae and bacteria for more efficient forms that would improve cotton CO_2 fixation under future predicted climates. Recently, our screen shifted towards finding more active and thermostable versions of Rubisco activase. Rubisco activase is responsible for maintaining Rubisco activity under certain climates but is often limited by its inherent susceptibility to elevated temperatures. An update of our research into finding better adapted Rubisco and Rubisco activase to future climates will be presented.

S52:

Building climate change resilience through translational physiology

Demi Gamble[1], Michael Bange[2], Warren Conaty[2], David Tissue[3], Spencer Whitney[1] and Robert Sharwood[1]
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In order to sustain and improve cotton yield production during sub-optimal future climates, the resilience of the physiology and biochemistry of cotton to extreme temperatures and water deficit needs to be improved. One such approach that hasn't been exploited in cotton is through enhancing photosynthetic performance through modification to the key photosynthetic enzyme, Rubisco. It has been demonstrated in other crops, such as wheat and rice that improvements in the catalytic activity and content of Rubisco may be a potential solution to overcome the detrimental climatic impacts on crop productivity.

This proposed research aims to elucidate potential diversity in Rubisco catalytic activity and content between species of *Gossypium*, and cultivars of *Gossypium hirsutum*. Through a number of glasshouse and field studies, photosynthetic gas-exchange measurements and a range of biochemical assays will provide information on the photosynthetic performance of selected cotton species and cultivars under specific abiotic conditions. Determining the temperature dependency of photosynthesis for different cotton species and cultivars will aid in understanding the impact of future climate change on cotton. Through the development of models, this data can be used to advise the necessary level of transformation required to build resilience in cotton systems exposed to the impact of variable and future climates. With further research, future cultivars and management practices may be developed to increase cotton productivity under predicted sub-optimal climates. An update on the current progress will be presented.

S53:

Elimination of gossypol in cottonseed will increase the value of cottonseed and help mitigate future protein shortages

Tom Wedegaertner
Cotton Incorporated, USA

Gossypol, a naturally occurring noxious compound that resides in pigment glands located throughout the cotton plant, is an effective insect deterrent and a cumulative toxin in animals. Due to gossypol, almost all of the protein produced by the cotton plant is consumed in ruminant feeds. Ruminant species can tolerate higher levels of gossypol, but they are not efficient converters of plant protein to animal protein, compared to mono-gastric or aquaculture species.

Modern plant biotechnology, utilizing RNAi and a seed specific promoter, has produced a genetically enhanced plant, known as Ultra-Low Gossypol Cottonseed (ULGCS) where gossypol production is silenced in the seed, but all other plant tissues retain normal or increased levels of gossypol, allowing the plant to retain its natural chemical defense mechanism. This biotechnology has the potential to greatly improve the utilization of cottonseed and make a substantial contribution to global food security and cotton sustainability.

Each year about 10-11 million metric tons of cottonseed protein are produced worldwide. Without gossypol, this is enough protein to satisfy the daily, basic protein needs (50 grams/person) of more than 600 million people for one year. Food scientists have created a wide range of food products from cottonseed, including humus, plant-based dairy substitutes, chopped nuts, a peanut butter alternative, protein fortified beverages, protein bars and others. In addition to direct consumption by humans, recent research has demonstrated 75% to 100% replacement of fishmeal in feeds for shrimp, black sea bass, hybrid striped bass and flounder, without a decrease in performance. Using ULGCS to replace fish meal in the diets of aquaculture species, will greatly improve the value and utilization of cottonseed while also facilitating the ongoing expansion of the aquaculture industry.

This biotechnology breakthrough demonstrates that it is possible to produce a gossypol-free cottonseed, in otherwise 'normal' cotton plants.

S54:

Skill Development: An opportunity to transmit the values that make work in the cotton industry a rewarding career option

Nicole McDonald
University of Southern Queensland

This year, Cotton Australia, the GRDC, and NSW Government launched Agskill, which is a $14.7 million investment in training for our industry which includes a focus on skill development on-farm (Cotton Australia, 2017). It is expected that these courses will improve the competence of people who work in the cotton industry and by doing so improve the productivity of the workforce, thereby increasing the potential for better outcomes on farm. Training can improve the confidence of workers on farm but perhaps even more importantly it provides the potential to translate the values that make work in agriculture a rewarding career option for people. The current study demonstrated that identification with the values that underpin business decisions on farm is a critical mediator in increasing work engagement and job satisfaction of farm workers in the Australian agriculture industry.

Farm workers (N = 172) employed in a range of positions from casual seasonal worker through to on-farm agronomists and farm managers were surveyed during the 2015-16 summer crop season. Measures captured Social Cognitive Career Theory constructs linked to job satisfaction, which included: (a) farm worker task self-efficacy, (b) values congruence, (c) work volition, (d) work engagement, and (e) job satisfaction. Structural equation modelling examined the relationships between these variables and found self-efficacy indirectly predicted work engagement through values congruence. The model was able to predict 42.6% of the variance in work engagement scores and 66.3% of the variance in job satisfactions scores. Further research on how training may increase not just skill level but also commitment to the cotton industry through values congruence is required.

This research project was supported through the CRDC.

S61:

Rocky's long term rotation trial - what rotation stands out after 21 years?

Tim Weaver, Ian Rochester, Kellie Gordon and Michael Bange
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In 1996, Dr Ian Rochester established a long term rotation trial in Field 6 at the Australian Cotton Research Institute (ACRI), north-western NSW. The rotations established included a continuous cotton (*Gossypium hirsutum* L.), cotton-vetch (*Vicia* spp.)-cotton, cotton-wheat (*Triticum aestivium* L.)-cotton, cotton-wheat-vetch-cotton and cotton-faba bean (*Vicia faba* L.)-cotton. The cotton varieties sown in the initial years included Sicala V2 and new release of Ingard cotton - Sicala V2i. The initial lint yields for the 1997/98 season for continuous cotton was 1752±147 kg/ha and the cotton-vetch 1634 ±57 kg/ha. However, the following 1999/2000 and 2001/2002 cotton seasons saw a reversal. In the 1999/2000 season the continuous cotton yield had decreased to 655±48 kg/ha and the cotton-vetch treatment was 1067±56 kg/ha. Rotating cotton with a legume from that point in time has continued to produce higher yields up to the most recent 2016/17 season. The lint yield for the continuous cotton rotation in 2016/17 was 2449 kg/ha whereas the cotton-vetch rotation was the highest of all rotations at 3135 kg/ha. Legumes are a valuable asset in cotton farming systems. They have shown over the 21 years to be consistent in contributing to higher lint yields and improving the soil health and soil organic carbon.

S62:

Winter sowing for more reliable boll filling in Central Queensland

Paul Grundy[1], Steve Yeates[2], Jamie Iker[3], Gail Spargo[1], Sharna Holman[1] and Carlo Stangherlin[4]
[1]Queensland Department of Agriculture & Fisheries, [2]CSIRO Agriculture & Food, [3]Spackman Iker Ag Consulting & [4]Cowral Ag

Central Queensland has a unique climate that presents both challenges and farming systems opportunities for cotton production. We have re-examined the Emerald climate to identify opportunities that might enable the production of more consistent cotton yields and quality in what can be a highly variable climate.

This 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 planting time. Our experiments have sort answers to two questions: i) how much earlier can cotton be sown whilst maintaining reliable crop establishment and, ii) how should agronomic management be varied to optimise crop performance when sown early.

Data collected over 4 years has demonstrated that August sowing offers the potential to grow reliably higher yields compared to the traditional spring planting window with an average improvement of 2.2b/ha per annum(23%) over 4 years. Sowing cotton during August still presents wet weather related picking risks however the period of crop exposure is reduced compared to the traditional planting window and the increased yield potential offers a significant buffer against seasons when weather related lint quality downgrades may occur. An aspect of this research is that it has been conducted in partnership with growers and consultants at a commercial scale without forsaking scientific rigour. The experiments have also been fully utilised for extension purposes so that growers could experience research outcomes in real time. The outcome has been rapid adoption by some growers during the 2016/17 who have successfully grown early sown cotton for the first time with excellent results. This talk will present an overview of the key agronomic findings that have been consolidated over this 4 year project.

S63:

An agro-centric analysis of rainfed cotton in the Southern High Plains of Texas

James Mahan and Paxton Payton
USDA/ARS

Cotton is grown in environments that are subject to constant variation across a day, across a month, across a day, across a month, across a season, across years, across decades. In-season environmental variation is inevitable and, from an agricultural perspective, largely unpredictable. In-season rain is a critical determiner of yield and quality in rainfed cotton production and both the amount and distribution over time are important. In this analysis we have analyzed 10-years of rain records in the Lubbock, TX region in an effort to identify patterns in rain that are associated with specific planting periods. Over the 10-year period the amount and timing of rain was determined for each of 7 planting dates. Plant water status was estimated using calculated evapotranspiration as reference and crop ET. The analysis of the patterns of rain and estimates of the effects on the crop provides an assessment of the extent to which planting date might be altered to improve yield and or quality.

S64:

Plant monitoring for crop termination decisions in US Midsouth cotton

Tina Gray Teague[1], Fred Bourland[2] and Michele Reba[3]

[1]University of Arkansas System Division of Agriculture - Arkansas State University; [2]University of Arkansas Division of Agriculture; [3]USDA-ARS

Process control and other quality auditing principles increasingly are used by progressive agricultural producers and managers to improve farm efficiency and profitability. Process-oriented managers require real-time information to ensure that their production systems are performing as planned and with optimal efficiency. If there is variation, the manager first identifies the root cause (you can't fix something that you don't understand), and then responds appropriately.

In cotton production, farm managers typically are provided in-season plant and pest monitoring information from crop advisers and field scouts. Such information should include whether plant development in a management unit meets, exceeds or deviates from defined specifications. By using plant monitoring, a crop manager can detect early warning signals to avoid hazards before they reach crisis level or to recognize problems that will require corrective actions immediately (e.g. application of a curative pesticide) or in the next cropping season (e.g. use of a cultivar with improved host plant resistance to pests). Perhaps even more importantly, plant monitoring information can inform managers that crop production processes are going well, and no costly protection or production inputs are needed.

In US Midsouth cotton production systems, the most widely-adopted plant monitoring practice is use of NAWF (nodes above white flower) measures to assess crop maturity for end-of-season decision-making for insect control and irrigation termination timing and for defoliation initiation. Decision rules based on NAWF measures can be employed across a field or in site-specific approaches using zone management. For example, managers can apply protectants only to areas of the field still vulnerable to late season insect pest infestations. Adoption of these practices allows producers to offset rising costs as well as reduce environmental impacts of crop production. In this presentation, results from on-farm use of plant monitoring for end-of-season management in Arkansas cotton will be summarized.

S65:

Mechanisms of whole-profile carbon cycling in cotton-based cropping system

Yui Osanai[1], Oliver Knox[1], Gunasekhar Nachimuthu[2] and Brian Wilson[1]
[1]University of New England; [2]NSW Department of Primary Industries

Recent studies in the cotton industry have demonstrated the potential of some systems (e.g. cotton-maize) to increase carbon (C) in the deep soil profile; yet the processes and mechanisms that determine the rate of C cycling in deeper soil layers are relatively unknown. Carbon isotope analysis is a useful tool to quantify C4-derived C (i.e. maize) in C3-cultivated soils (i.e. cotton soil), utilising the difference in $\delta^{13}C$ signatures between C3 and C4 plants. Soil C stock is largely determined by the balance between C input by plants and C losses through microbial respiration, and the $\delta^{13}C$ signature of soil organic C (SOC) often reflects the $\delta^{13}C$ signature of the plant input, although microbial processes can also influence the $\delta^{13}C$ signature. Therefore, examining $\delta^{13}C$ of SOC may give some insights into the mechanisms that control C cycling of the whole soil profile under different systems. We collected soil cores to a meter depth from three historical cropping systems (minimum tillage continuous cotton, maximum tillage continuous cotton and minimum tillage cotton-wheat) with and without inclusion of maize in the rotation (i.e. 6 systems). Field sampling was done periodically to capture changes in C dynamics associated with field management (e.g. cropping, tillage and fallow) over two years. The results from the first year showed that SOC decreased with depth, and became less depleted in ^{13}C with depth. The correlation analyses revealed different relationships between the net changes in SOC and $\delta^{13}C$ signature with depth, suggesting that changes in $\delta^{13}C$ signature is not entirely due to the plant material entering the soil, but also due to other processes (e.g. microbial and physical processes), and that those processes might be more dominant in the deeper soils. Ongoing work will hopefully identify the mechanisms that determine C cycling and soil C storage under these systems.

S66:

Carbon flow in terrestrial hydrological pathways of cotton farming systems of Australia

Gunasekhar Nachimuthu[1], Mark Watkins[1], Nilantha Hulugalle[2], Tim Weaver[3], Lloyd Finlay[1] and Bruce McCorkell[1]
[1]NSW Department of Primary Industries; [2]Australian National University; [3]CSIRO Agriculture & Food

Carbon losses through runoff and deep drainage are one of the loss pathways of carbon in cropping fields. A three year investigation on measuring runoff, deep drainage and associated carbon movement in a furrow irrigated Vertisol was overlaid on a long term experiment near Narrabri, NSW. The irrigation volume, runoff, drainage, total and dissolved organic carbon balance (DOC) during irrigation were monitored during 2014-15, 2015-16 and 2016-17 cotton seasons. The treatments included cotton monoculture and cotton-wheat or maize rotations with maximum (0-0.3m deep) or minimum (0-0.1m deep) tillage. Maize rotation had significant interaction with tillage in generating runoff in subsequent cotton. Irrigation-induced DOC losses in runoff from the cotton field were influenced by tillage and ranged from 21 to 78 kg ha^{-1} $year^{-1}$. Net DOC enrichment of cotton field by irrigation water ranged from 28 to 253 kg DOC ha^{-1}. Overall, the average seasonal net carbon gains in irrigation water were equivalent to mitigating 4 to 20% of long term annual soil organic carbon decline rate in this experiment. Chloride mass balance modelling estimates indicated that seasonal deep drainage at 1.2 m depth ranged from 25 to 32 mm during the 2014-15, and 24 to 88 mm during the 2015-16 seasons. DOC values in soil for the systems with maize rotations were higher (41.1 mg kg^{-1}) than cotton monoculture systems (30.8 mg kg^{-1}). The DOC concentration in drainage water at 1.2 m and 0.6 m depths were 46.6 mg DOC L^{-1} and 38.1 mg DOC L^{-1} respectively. The average deep drainage DOC losses over three years suggest a loss of 11, 17 and 27 kg DOC ha^{-1} per year for minimum tillage and maximum tillage cotton monoculture and minimum tillage cotton wheat system, respectively. The higher DOC at depth suggests that denitrification potential in the deeper depths may be higher than previously believed. Furthermore, research on soil carbon sequestration in irrigated farming systems must account for carbon flow during irrigation because it is a significant factor in the annual carbon balance.

S67:

Tracking sediment, carbon and nutrients using environmental tracers for enhanced cotton production

Sean Brennan[1], Greg Hancock[1] and Gunasekhar Nachimuthu[2]
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Soil and its constituents, such as organic carbon are vital resources to agriculture and in the study here, cotton production. The cotton industry must be both profitable and sustainable both for dryland and irrigated cotton - the focus here. While Australian cotton growers adopt a closed irrigation network with a sustainable practice of recycling the tail drain water, the sediment and nutrient movement from irrigated fields could displace the nutrient rich top soil into tail drains and on farm storage dams. Surprisingly little is known about soil erosion and associated nutrients and organic carbon transport on cotton farms. Here we will present some initial results from an Honours project which examines soil loss and associated carbon and nutrient transport from irrigated cotton. We also assess the movement and or loss of soil throughout the irrigation network in irrigated cotton farms and off-farm sediment and nutrient movement from dryland cotton farms using the ^{137}Cs labelling technique. The rationale for its use is that ^{137}Cs labelled soil (usually the silt and clay fraction), soil organic carbon and other soil chemicals move along the same physical pathways. Future work will use advanced hydrology and sediment transport models numerically track sediment and nutrients. The aim is to understand and quantify soil and associated carbon and nutrient transport across the irrigation network and eliminate its loss from cotton farms via identifying and improving management practices.

S68:

Tracer experiment demonstrates the contaminants moving rapidly through the soil with deep drainage

Anthony Ringrose-Voase, Tony Nadelko and Ben MacDonald
CSIRO Agriculture & Food

A moderate amount of deep drainage is necessary under irrigated agriculture to prevent the buildup of salts in the root zone. However, excessive deep drainage represents a both a waste of a scarce resource and an environmental risk if salt and agrochemicals are transported into groundwater. The lysimeter facility at the Australian Cotton Research Institute allows accurate, high frequency measurement of deep drainage at 2.1 m depth as well as analysis of drainage water for contaminants. Previously reported results showed that deep drainage from a Grey Vertosol under furrow irrigated cotton occurs via two pathways: matrix flow through the matrix of the soil and bypass flow down cracks and macropores. Evidence for the latter is the very rapid increases inflow rate below the root zone and, on occasions, drainage occurring when the gradient of the soil water potential is upwards. A bromide tracer experiment at the lysimeter facility was used to confirm the occurrence of bypass flow.

Potassium bromide was injected into the topsoil over an area of 9 m2 above the lysimeter a day before the second irrigation of the cotton season. Drainage was collected at frequent intervals after irrigation and then less frequently over the rest of the season. The first sample was collected 3 hours after the irrigation front passed over the lysimeter and already had a bromide concentration 50 times greater than the background concentration. This demonstrates conclusively that water and surface applied solutes can move very rapidly below the root zone via by pass flow. The rate of bromide leaching decreased after the irrigation, only to increase again after the next irrigation. Thereafter it decreased over the rest of the season, but was still above the background rate a year after the original application. The two peaks suggest that easily accessible water in the surface layers was completely exchanged in two irrigations, with some draining rapidly via bypass flow. The results illustrate the risk of agrochemicals being lost very rapidly from the root zone.

S71:

The contribution of cellulose crystallites to Upland fibre strength

Stuart Gordon, Jeff Church and Andrea Woodhead
CSIRO Manufacturing

The first structural models for cellulose were proposed over 80 years ago and while models of its structure, in its purest form, have advanced since that time, they still do not wholly relate the contribution of the structural elements, e.g., crystallinity index, fibril size and orientation, to a fibril or fibre's, as is the case in cotton, tensile properties. It is understood the crystallinity index, however it is measured, correlates well with cotton fibre strength, but only if the relationship is examined across an extreme range, e.g., comparing an immature, developing fibre to a fully mature fibre, or comparing fibres from different species. Measuring structural differences between mature, commercial Upland fibres is notably more difficult. One reason for this is that current analytical methods, e.g., XRD or infrared spectroscopy, have not been able to readily measure the structural properties of single, mature, unadulterated fibres because the radiation beam has been too big or, if small enough, without enough flux to return a resolvable pattern or spectra. In this study, the Australian Synchrotron's SAXS/WAXS beamline was used to analyse single cotton fibres from a select set of Upland cotton samples with a wide range of elongation-to-break values but controlled for micronaire and maturity. A range of structural parameters were calculated from the XRD patterns and correlated with single fibre tenacity results. The correlations illustrate the sensitivity of parameters such as Meyer and Misch's cellobiose unit dimensions to mechanical properties such as elongation. Understanding the genetic and environmental signals that influence the biochemistry of cotton cellulose synthesis at this macro-molecular level would help direct development of new fibres with better mechanical properties.

S72:

Not all secondary cell walls are the same: how the cotton plant has opened us to new discoveries

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The long strong fibres that grow from cotton seeds are the basis of cotton's use as a global and renewable textile. Each seed fibre is a remarkably long single cell with a thick secondary cell wall which is largely cellulose. On the other hand the cotton stem is woody, containing secondary cell walls that are lignocellulosic. We used these two very different cotton tissues to ask 2 simple questions that have not been asked for other crops. (1) How are the secondary cell walls of these tissues different, at the molecular level? (2) What is different about the genes expressed to make these different secondary cell walls? To answer these questions we used state of the art NMR, cell wall biochemical analyses, micro-imaging for lignin, RNA transcriptomic analyses and qPCR expression validation. Our results from the various cell types in the cotton plant has revealed how remarkably different secondary cell walls can be produced in a single organism. We also share some surprising new discoveries about the composition of various cotton cell walls, as well as the genes expressed in the different cell types. Our findings are a first for a crop plant, and we examine how this new knowledge can be exploited.

S73:

Miniature cotton spinning capability at CSIRO

Robert Long
CSIRO Manufacturing

CSIRO Geelong has recently acquired a new miniature ring spinning line capable of spinning small (10 to 1000g) batches of cotton fibre, which compliments CSIRO's full scale processing which requires a minimum of 50kg of cotton fibre. The new equipment replaces old technology that was manufactured in the 1960's. It enables the spinning and detailed assessment of spun yarn and finished fabric from small sample plots, for research in areas such as physiology and agronomy, or to more easily and quickly assess larger numbers of new variety lines. Uniquely the spinning line includes a miniature combing machine, which allows premium combed yarns to be manufactured from small amounts of cotton fibre. The new equipment is easier to use, more consistent, allows a greater range of different yarn types to be manufactured, and the yarns produced are better than those manufactured by other miniature spinning systems. The new process is now extensively contributing to current research projects.

S74:

Assessing cotton fibre on predicted yarn quality: A new approach to marketing cotton

Stuart Gordon and Shouren Yang
CSIRO Manufacturing

Cottonspec is a yarn quality prediction program that interprets high volume instrument measurements into yarn quality parameters such as yarn evenness and tenacity. In doing this, the program provides an 'integrated' fibre quality value that can be used to determine the real value of a grower's fibre to the spinner. Providing an integrated value means that one fibre property having a positive or negative effect on yarn quality can substituted by another property, or combination of properties, that by themselves would not ordinarily receive a premium, but which collectively contribute to a positive yarn quality effect. For both the grower and merchants, the value of being able to predict yarn quality means that specification of the required fibre quality can be broadened without loss of performance quality to the spinner. The ability to meet and understand the requirements of spinning mills also enhances the transaction between spinner and merchant. For the spinner, Cottonspec can be used as a quality control tool against which fibre and yarn quality can be benchmarked and monitored.

S75:

Pad-Knife-Pad coating of cotton fabric for versatile protection

Xin Wang, Arsheen Moiz and Rajiv Padhye
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Non-fluorine based durable coating technology that brings versatile protections including excellent hydrophobic, oleophobic and stain repellent properties to cotton fabric has been highly demanded. This study focuses on developing a crosslinked network from polyurethane or rubber, polydimethyl siloxane (PDMS) and trimethylated silica (TMS). The conventional padding-knife coating-padding-curing technique has been successfully implemented to conducting the coating. A series of characterizations have been conducted to understand the chemical component, morphology, versatile protection and comfort of the coated fabrics. The coated fabric showed excellent protection against water, oil, chemicals and liquids. The coating was durable against different cycles of washing and crocking. The enhanced durability of the samples has been achieved through the recrystallization of the long chains of the methyl groups of the PDMS and Si-OCH_3 bonding imparted between the substrate and the TPU coating. This developed technology can be further applied in protective clothing and functional textiles in different areas including military, mining and outdoor protection gears.

S76:

RAFT polymers from cottonseed oil

Houlei (Jerry) Gan[1,2], Sally Hutchinson[2], Christopher Hurren[1], Robert Long[2], Xungai Wang[1] and Lu Sun[1]
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The incorporation of biomass resources such as vegetable oil based fatty acids into the polymeric chain were synthesized by using reversible addition fragmentation chain transfer polymerization (RAFT). A series of acrylate and methacrylate monomers with side-chain fatty acids were synthesized by esterification of fatty acids derived from cottonseed oil and 2-hydroxyethyl acrylate or 2-hydroxyethyl methacrylate, respectively. The monomers were subsequently polymerized via RAFT polymerization to form the RAFT homopolymers with controlled structure. The molecular structures of monomers and homopolymers were confirmed by infrared spectroscopy and nuclear magnetic resonance spectroscopy. The effect of length of carbon chain, degree of unsaturation and the introduced groups on the properties of their monomers and homopolymers were studied. The polymerization kinetics of three main fatty acid-based methcarylated monomers (palmitic, linoleic and oleic acid-based methacrylate) were also investigated. The introduction of acrylate and methacrylate into the fatty acid chain, the length of carbon chain, and the degree of unsaturation changed the melting point and crystallization point of their monomers and their finally homopolymers. The saturated fatty acid-based homopolymers displayed crystalline behaviours depending on the length of fatty acids chain, evidenced by differential scanning calorimetry. The polymerization kinetics showed a living polymerization characteristic.

S77:

The removal of plastic wrap during textile processing

Rene van der Sluijs, Mark Freijah and Mauad Guittet
CSIRO Manufacturing

Contamination, even if it is a single foreign fibre, can lead to the downgrading of yarn, fabric or garments to second quality or even the total rejection of an entire consignment and is thus a very important fibre parameter. The release of the new John Deere harvesters that produce round modules covered with a plastic wrap is of concern to the ginning, marketing and textile processing industries because the plastic presents a serious contamination risk. There is evidence that at times not all the plastic is removed in the module feed area resulting in plastic fragments broken up during ginning contaminating bales. Contamination is a serious issue as it creates harm to the reputation of a growth. This study was initiated to investigate the consequence of plastic contamination on textile processing performance and yarn and fabric quality. A trial in which raw cotton was deliberately contaminated with plastic wrap and processed through CSIRO's full scale cotton and textile processing mill was recently conducted. To date, the trial has shown that the mill blow room does not remove large amounts of the plastic, whereas the carding and combing processes removed substantial amounts. Despite the effect of carding and combing, small amounts of plastic wrap were found in the single jersey fabric knitted from the yarn.

S78:

Elimination of acid delinting of cottonseed: evaluation results from a new mechanical delinter

Greg Holt[1] and Tom Wedegaertner[2]
[1]USDA-ARS, USA; [2]Cotton Incorporated, USA

This research reports on data obtained from processing cottonseed through a larger-scale mechanical delinter based on the successful bench-top archetype. Parameters measured include Lint Residue (%), Germination (%), and processing time.

Testing involved processing 4.5 kg lots for 3, 6, or 9 minutes and recording the residual lint (%) and germination. Seed discharge occurred at the fuzzy seed inlet and at the opposite end of the fuzzy seed inlet (air pull side). Results indicate that the seed seemed more polished when discharged from the fuzzy seed inlet than the air pull side. The rationale for cleaner seed from the inlet was due to the air pull drawing the fuzzy cottonseed down the 2.4 m length of the delinter away from the inlet. As the seed became clean, it travelled back towards the inlet due to the wrapped wire scrubbing brushes which acted similar to an augur by conveying the seed against the flow of air. Residual lint was less than 1% for all processing times with the 9 min time having the lowest residual lint regardless of where the seed was discharged. Seed loss in the system ranged between 5 to 15% depending on where the seed was discharged and time of processing.

In addition to the study, updates on the latest developments and future plans will be discussed.

S81:

The value of the POAMA seasonal forecast to cotton systems

Chris Nunn[1], Peter McIntoch[2], Michael Bange[1], Jaci Brown[1]
[1]CSIRO Agriculture & Food; [2]CSIRO Oceans & Atmosphere

Seasonal climate forecasts hold the promise of better farm management in the face of Australia's variable climate. Altering decisions based on the forecast odds of a good or bad season can lead to increased profit or decreased losses and better environmental and resource outcomes. POAMA developed by the Bureau of Meteorology and CSIRO and is a global dynamical model producing forecasts out to 9 months in the future.

To investigate some opportunities with the use of POAMA, three cotton seasonal phases were considered (early, mid and late). Analysis of early season POAMA predictability related to: choice of row configuration in rain-fed systems; timing of phenological stages; and change of sowing time in response to forecasted cool/cold conditions. Mid-season analysis related to decisions that influenced timing of 'Cutout'. While late season issues were predicting climate to influence timing of defoliation (avoiding cold), and harvest (avoiding rainfall).

There was significant opportunity using POAMA temperature forecasts early in the season. At four locations within the industry (Emerald, Dalby, Moree and Griffith) forecasts were able to successfully predict crop stages using day degree models. POAMA coupled with the OZCOT cotton model, forecasts were also successfully able to predict the risk of crop failure with various sowing times potentially helping growers avoid the inconvenience and costs associated with replanting.

Predictions of forecasted climate impacts on mid and late season crop management issues were unsuccessful. This was for two reasons: 1. analyses were seeking for far too detailed weather signals; and 2. from about March onwards the skill of climate models decrease entering a period of reduced predictability. This research has provided a useful platform to investigate use of new seasonal forecasts in cotton systems.

S82:

Field studies of integrated temperature and CO_2 climatic changes on cotton growth and physiology

Katie Broughton[1], Michael Bange[1] and David Tissue[2]
[1]CSIRO Agriculture & Food; [2]Western Sydney University

The combination of changes in air 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 crucial for both (a) developing cropping systems resilient to stresses induced by climate change; and (b) capturing the potential advantages that a changing climate might provide. Field experiments conducted over a number of seasons have explored the growth and physiological responses of cotton to integrated elevated [CO_2] and warmer temperatures. Elevated [CO_2] increases early cotton growth and impacts physiology, although these increases do not necessarily translate to greater yields at the end of the season. Data from these studies provides a basis for improving field-based methods for investigating the potential impact of climate change on cotton production.

S83:

Plant sex: How hot is too hot? Reproductive screening for heat tolerance in cotton

Susan (Evy) Jaconis and Warren Conaty
CSIRO Agriculture & Food

Lacking voluntary locomotion, plants are highly susceptible to the stresses of their immediate surroundings. In particular, abiotic factors such as high temperature and low moisture can have adverse effects on cotton (*Gossypium* spp.) including negative effects on plant growth, development, and subsequently yield. There is a general lack of studies focusing on cotton reproductive characteristics as an early indicator of stress tolerance despite the direct impact on boll (fruit) production. Because plant sexual reproduction and especially pollen is highly sensitive to the environment, the aim of this study was to investigate floral pollen tube germination and growth as well as boll development under both temperature and water stress. In this study, we grew cotton cultivar Sicot 746 B3F in both irrigated and non-irrigated (rainfed) systems. To impose a heat stress, open top chambers were used in both irrigation conditions. Open flowers were collected from these treatments for in vivo microscopic analysis to quantify the germination percentage and tube length of successfully deposited pollen on floral stigmas. In addition, open flowers were tagged for boll analysis of seed number and size, lint percentage, and fibre quality at the end of the growing season. We hypothesized that elevated temperature and water stress as individual stressors would decrease the percent germination and tube length of pollen into the floral style of cotton plants and that seed set would be negatively impacted. It was expected that applying both heat and water stress simultaneously would have a cumulative negative effect on these early reproductive traits. This research will be used to understand the physiology and floral biology of cotton under stressful environmental conditions, which will help develop early screening tools in cotton breeding.

S84:

Border cells and Bollgard3

Oliver Knox[1], Gupta Vadakattu[2], Martha Hawes[3] and David Backhouse[1]
[1]University of New England; [2]CSIRO Agriculture & Food; [3]University of Arizona

Border cells are terminally differentiated cells found at the root tips of most plant species. These cells are viable and exist within a layer of mucilage allowing them to be easily removed from the root tip, however, the role of these border cells goes beyond that of simply cushioning root exploration of the soil. Border cells are now recognised as being involved in plant biotic and abiotic monitoring and in providing plant protection from a range of potential pathogens, making border cells true pioneers of the rhizosphere. In 2007 we established that cotton varieties had a variation in their root tip border cell numbers and identified that here was a moderate relationship between border cell number and Fusarium resistance ranking. Most varieties at that time had between 3000 to 5000 border cells, whilst Sicot189 was out on its own at 12000 border cells per root tip, which meant there was a large gap in the data set between these borer cell counts. The introduction of Bollgard3® varieties in 2016/17 offered opportunity to reassess cotton border cells. Assessment of these new varieties produced between 6000 and 16000 border cells per root tip and showed a significant difference between varieties (P<0.001). However, no relationship between border cell number and F and V rank could be established. Attention has now turned to the exogenous DNA associated with the root cap and its mucilage and initial observations from this work will be discussed.

S85:

Leaf sodium content at flowering can be used to screen sodicity tolerance in cotton

Shiming Liu, Greg Constable, Rebecca Warnock, Louise Zemcevicius and Danny Llewellyn
CSIRO Agriculture & Food

Sodic soils are common in the Australian cotton belt. Cotton grown in such soils will take up and accumulate excessive amount of Na, which can interfere with uptake of potassium (K) and phosphorous (P) and cause plant nutrient imbalance. Therefore, soil sodicity can be a limiting factor for high cotton yields so breeding for tolerance to such stress becomes very important for ongoing sustainability and profitability of cotton production.

We examined whether Na content of cotton leaves at flowering can be used for fast phenotyping for sodicity tolerance. In the experiments, five backcross derived sister lines with low or high leaf Na content plus the recurrent parent were grown on sodic soils over two seasons under fully irrigated management. Fully expanded cotton leaves during flowering were sampled and Na content analysed. Although leaf sampling date and season affected leaf Na content, genotype ranking was not affected by sampling date or season. When leaf Na content was measured in a population with 81 recombinant inbred lines grown in the fields at the same location for two seasons, there was also a strong pair-wise correlation for Na content of test lines between two seasons. Average Na was 320 ppm in low Na genotypes and 619 ppm in high Na lines and control cultivar. The low and high Na lines also possessed contrasting profiles of Na content in different plant parts, with the low Na lines exhibiting higher Na in stems and roots, indicating that they sequester Na away from the photosynthetically active tissues. We conclude that leaf Na content at flowering is a reliable indicator for measuring differences in sodicity tolerance in cotton.

PT1:

Increasing Capability in Cotton Science

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One of the main challenges facing the cotton industry 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 10 years CSIRO with support from CRDC successfully worked with the cotton industry to address this issue through a project that used experiential learning to engage students with agribusiness to improve the supply of suitably qualified professional personnel. For instance, we placed secondary school students with agricultural organisations for their work experience program. In a current initiative, students studying agriculture related courses at university are identified and placed into agribusiness service roles by matching their skills with employer needs. The outcomes of this project have been successful however to further add value we propose to increase the diversity of capability and thinking available to agricultural businesses by matching them with students from a greater range of academic backgrounds including digital approaches, data analytics, and robotics. This would benefit the agriculture sector by enhancing standard practices with insights from modern disciplines to drive innovation and impact.

PT2:

Stripping of soil organic nitrogen during initial phases of furrow irrigation

James Latimer
CSIRO Agriculture & Food and Australian National University.

Many farmers add nitrogen to irrigated cotton visualising a simple binary outcome: it either goes straight into the plant or is lost. In doing so, however, they forget that the plant acquires its nutrients from the soil, rather than directly from the applied fertiliser, and that the added nitrogen must first enter the soil nitrogen pool before it can be taken up by the plant. It is therefore important to think of fertiliser addition in terms of managing the soil's nitrogen pools, rather than just as an uninterrupted progression from urea pellets to the cotton plant. The goal of fertiliser application should be to add nitrogen to the soil, replacing that which is taken out by the plant. In practice, this balance is extremely difficult to achieve, and frequently soils are 'mined' of their nutrients.

My research suggests that this mining of soil nitrogen is occurring during the initial stages of furrow irrigation in at least some Australian cotton farms. Samples taken from irrigated cotton operations in the Riverina during the 2016/17 season show that soil organic nitrogen is being stripped during the initial 'wetting up' stages of furrow irrigation and then dumped into the tail drains. In the case of water-run urea fertigation, much of this lost nitrogen is then replaced with synthetic urea, resulting in an inefficient 'strip and replace' practice. For straight irrigations this will be even worse, with net nitrogen removal from the soil. This stripping phenomenon was observed at two scales: along individual furrows as a function of distance, and temporally at a whole-of-field scale.

In a world of increasing fertiliser costs and public scrutiny, further research is needed to understand the scope and drivers of this nitrogen loss, and to identify possible mitigating strategies to improve nitrogen use efficiency.

PT3:

Effect of cotton residues on N_2O emissions and soil nitrogen following incorporation

Stephen Leo, Clemens Scheer, Massimiliano De Antoni Migliorati, and Peter Grace
Queensland University of Technology.

The incorporation of crop residues post-harvest can provide an important source of nitrogen (N) for the subsequent crop but can simultaneously lead to elevated nitrous oxide (N_2O) emissions. The magnitude of N supply and corresponding N_2O emissions strongly depends on the quality of the added crop residues, and soil and climatic conditions. However, little data is available for subtropical cotton systems. The primary aims of this study were to (i) quantify carbon dioxide (CO_2) and N_2O emissions, and corresponding emission factors (EFs) following cotton residue incorporation, and (ii) determine the contribution cotton residues have to soil N content for the subsequent crop. Using a semi-automated sampling system, CO_2 and N_2O emissions were monitored during a cotton fallow period following cotton residue incorporation under varying rainfall conditions compared to residue removal. The high C/N of the incorporated residues, low temperatures and the limited C substrate resulted in low N_2O emissions. EFs were found to be 0.015 and 0.051% for average and high rainfall conditions, respectively which is significantly lower than the IPCC EF of 1%. The majority of decomposed residues were recovered in the soil with the remaining undecomposed and a very minimal amount was lost. There was a net mineralisation or loss/immobilisation observed across sites indicating soil conditions and management practices significantly influence N dynamics. The study suggests that the current IPCC methodology should be re-evaluated and that EFs need to be lowered to reflect the low N_2O emissions from high C/N cotton residue N inputs. It also shows that effect of crop residues on soil N dynamics needs to be considered in N fertiliser management strategies in order to maximise the benefits from crop residue incorporation.

PT4:

Verticillium wilt - The American perspective

Karen Kirkby[1], Jason Woodward[2] and Terry Wheeler[2]
[1]Biosecurity and Food Safety, NSW Department Primary Industries; [2]Texas A&M AgriLife Extension

Dr Karen Kirkby will undertake a travel scholarship to visit international experts in USA in the field of Verticillium wilt research. During the visit Karen will work in laboratories at the Texas A&M AgriLife Research & Extension Center as well as touring the cotton production crops of the High Plains. Karen will also have the opportunity to learn the soil isolation techniques developed and used in the USA to diagnose and quantify Verticillium inoculum in soil. Together, Dr Woodward and Dr Wheeler developed a disease risk matrix based on their research with inoculum levels in cotton soil. A full update on the visit will be presented at the conference.

PT5:

Solenopsis mealybug - the new cotton IPM enforcer

Richard Sequeira, Moazzem Khan, Kristy Byers and David Reid
Queensland Department of Agriculture & Fisheries

The solenopsis mealybug (*Phenacoccus solenopsis*) is widespread throughout QLD and in 2017 was confirmed as being present in the cotton growing areas in the Gwydir and Namoi valleys of northern NSW. Solenopsis mealybug adults are 3-4 mm long and have two characteristic dark longitudinal bare spots across their thorax and abdomen (look like black spots).

Solenopsis is a high priority pest for the cotton industry for several reasons: (i) it causes direct yield loss, plant damage and death, typically in the form of patches or dead plants or 'hot spots' (ii) populations of solenopsis are easily flared by spray practices targeting other pests such as mirids and mites which require frequent control in Bollgard III cotton production systems; (iii) it is very easily dispersed by wind and rain, and through the movement of infested plants, farm machinery, vehicles and on clothing and footwear; (iv) it's population dynamics are highly unpredictable.

Weed and volunteer plant control, farm hygiene practices and the conservation of naturally occurring beneficial insects (lacewings, *Cryptolaemus*, 3-banded ladybird, *Aenasius* wasp) are key elements of successful solenopsis mealybugs control in cotton.

Research done over the last three years by the Queensland Department of Agriculture and Fisheries staff in Toowoomba and Emerald has resulted in the identification of sulfoxaflor, buprofezin and spirotetramat, new generation, IPM-compatible insecticidal compounds with efficacy on solenopsis mealybugs. Spray Oils were also identified as having a significant suppressive effect.

The cotton industry is currently working with registrants towards permit/registrations.

PT6:

Exploring modes of action of novel biopesticides: from model cell line to target insects

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The adoption of *Bt*-cotton has seen a welcome reduction in insecticide applications, although it has been accompanied by increasing development of resistance by the targeted species in the field. The reduced use of broad-spectrum insecticides also creates a niche opportunity for secondary pests to reach damaging levels. This investigation looks at the effects of novel and known biopesticides on a model insect cell line, *Drosophila melanogaster* S2, and target cotton arthropod species using an array of assays. Cell growth assay, electrophysiology, confocal microscopy, and whole organism bioassay have enabled comparisons between fractions of selected, insecticidal plant extracts. Cell assays and whole organism bioassays have identified three novel extracts with insecticidal potential, with cell growth inhibition and insect mortality at low concentrations. Electrophysiology results indicated at least one of these extracts has dual activity involving modulation of both potassium and sodium ion channels, while a second extract may suppress chloride ion movement, and the third extract may affect cell and arthropod mortality via a non-neuronal mode-of-action. Moreover, confocal imaging of H_2O_2 (a key stress-inducible secondary messenger) showed that the extracts cause different signalling responses and patterns in *D. melanogaster* S2 cells. We also found that one novel extract showed high toxicity to both cotton aphids (*Aphis gossypii* Glover) and two-spotted spider mite (*Tetranychus urticae* Koch) without affecting *D. melanogaster* flies or honeybees (*Apis mellifera* L). We propose that combining these physiological and cellular techniques is likely to assist the discovery of new biopesticides, and the identification of new modes of action for insecticidal activity.

PT7:

Potential for a spray-on polymer to conserve soil water

Michael Braunack and Darin Hodgson
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Efficient use of water and other agricultural inputs must underpin agronomic practices to improve crop establishment and increase crop yields. This study explored the potential of a newly developed spray-on biodegradable polymer membrane to reduce soil evaporation to improve crop productivity. A field experiment conducted at ACRI demonstrated a non-significant saving of surface soil water at both application rates (1250 & 625 l/ha) compared with a bare soil after four weeks. Heavy rainfall eight days after application of polymer may have compromised the integrity of the membrane, thereby minimising treatment effects. The rates of application were considerably lower than previously used. There was no significant effect of polymer on cotton establishment.

PT8:
Monsanto’s insect protected pipeline project - sucking pests

Kristen Knight
Monsanto

Monsanto’s built in insect protected Bollgard 3 cotton has provided excellent control of the lepidopteran pests Helicoverpa spp. However, Bollgard technology does not control sucking pests such as green and brown mirids (*Creontiades* spp.). Since the introduction of the Bollgard technology in Australia in 1996, the main insect species targeted for control are mirids. Monsanto has recently begun trialling a new Bt trait/mode of action, Cry51Aa2.834_16 to control *Lygus* spp. and thrips in the USA. The trait has shown efficacy against both groups of pests. Monsanto Australia applied for and received a licence (DIR 147) from the Office of Gene Technology Regulator to conduct a proof of concept trial in Kununurra, Western Australia. The mode of action and the initial trial work will be described.

PT9:

Quantifying seedling vigour: Laboratory based methods to better predict field establishment

Hannah Hartnett and Brett Ross
Cotton Seed Distributors Ltd, Wee Waa NSW

Establishment of an adequate plant stand is important to maximising yield potential and to avoid the costly exercise of replanting. Along with field and climatic conditions, seed quality plays an important role in field establishment. The physiological quality of cotton planting seed supplied to the Australia cotton industry by Cotton Seed Distributors (CSD) is already thoroughly tested using internationally recognised (ISTA, AOSA) standard testing protocols: the standard warm germination test for germination capacity and the cool germination test for seed vigour. In recent years, varieties with a low density seed type have represented the majority of seed planted by Australian growers. It is well recognised that the compromise for the exceptional yield potential of these varieties is lower seedling vigour and while this seed may have excellent germination capacity, it can still have issues with field establishment under less than optimal conditions. The aim of the current study is to identify a reliable, robust and repeatable method for quantifying seedling vigour which would allow growers to better predict field establishment in a range of conditions. Initial trials have been conducted using the current B3F varieties, each of the five varieties were represented by seed from a number of different sources including various production years and a range of physiological seed quality. Numerous laboratory based methods were trialled with correlations being made with establishment assessments from the concurrent replicated field trials.

PT10:

One for you and one for me - Can we share cropping space with insect pests?

Richard Sequeira
Queensland Department of Agriculture & Fisheries

Insect pest management in most crops is underpinned by the philosophy of minimal sharing of the cropping space (paddock or land on which crops are grown); crops grown for commercial food or fibre purposes cannot be freely shared with insects due to the risk of economic loss. Farmers are constantly doing battle with insect pests to limit the amount of crop damage and/or loss of productivity. Battles with insect pests typically involve the use of chemical insecticides.

There are alternative approaches to insect pest management based on the philosophy of sharing the cropping space with insects by growing two or more crops simultaneously - one for the insects and one or more for the farmer. Examples include various forms of companion cropping, trap cropping and strip cropping, to name a few. The ultimate objective of these approaches is to minimise the use of chemical insecticides in managing crops pests. The main problem with most of such sharing approaches is the allocation of cropping space to a sacrificial (non-profitable) activity such as growing food purely for insects.

Insect pests such as whiteflies that can become problematic in high yielding cotton crops at the tail end of the season cannot be effectively controlled using chemical insecticides. This is thought to be partly due to the failure of aerially applied sprays to achieve sufficient penetration of the crop canopy to control the target pest population which is usually lower down in the canopy. Here I ask the question: Can the problem of controlling whiteflies in late season cotton crops be resolved by strategic sharing of the cropping space?

I present a variation on the concept of sharing cropping space and show that soybean planted as an understorey within cotton can effectively displace whiteflies from the former due to an innate, strong preference for the latter.

PT11:

Diversity of Cotton leafroll dwarf virus in Thailand and Timor-Leste

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One of the aims of a current CRDC-funded project is to determine the genetic relatedness of Cotton leafroll dwarf virus (CLRDV) from Thailand and East Timor to the ‘atypical’ strains from South America which are known to overcome CRLDV-resistance. Some recent reports from Brazil and Argentina (da Silva *et al.* 2015; Cascardo *et al.* 2015; Agrofoglio *et al.* 2017) showed that the PO gene is the most variable region of the CLRDV genome and shows the greatest differences between the standard and resistant-breaking strains of CLRDV. The P0 protein is reported to control the ability of the virus to overcome plant resistance. I have now sequenced the partial PO gene from 12 isolates of CLRDV from Thailand, Timor-Leste and Uzbekistan, and compared these to published sequences of standard and resistance-breaking strains from Brazil and Argentina. The standard (typical) and resistance-breaking strains from Brazil and Argentina form their own clades which share about 90-91% nt identity. By contrast, the PO gene sequences from Uzbekistan, Thailand and Timor-Leste show greater diversity. In fact, the diversity between CLRDV samples from two sites in Timor-Leste separated by only 21 km (Lospalos and Luro), share about 86 % nt identity, which represents greater diversity than that between the standard and resistance-breaking CLRDV samples from across vast distances and the two countries of Brazil and Argentina. Further diversity is also present in the CLRDV samples from Thailand and Uzbekistan which both form their own clades.

While the CLRDV strains from Timor-Leste are different to the ‘atypical’ strains from South America, there may be enough diversity in the CLRDV strains present in Timor-Leste to overcome a resistance gene in cotton. The industry should remain vigilant to minimise the risk of incursion or spread of CLRDV.

da Silva et al. (2015). *Archives of Virology*, **160**, 1371-1374.
Cascardo et al. (2015). *Virology Journal*, **12**, 123.
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EP1:

Cotton production in north-west NSW: climate change mitigation options

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High yields associated with Australian cotton production dramatically minimise greenhouse gas emissions intensity. However, the industry as a whole continues to face pressure to demonstrate environmental credentials, especially given market pressure from synthetic fibres and developing nations. To respond to this pressure, we estimated the climate change impact of cotton production in North-West New South Wales, using Life Cycle Assessment and tested the effect of an array of mitigation options.

We conducted the study for the 2011-2014 production years, drawing on published data, survey data, scientific literature; and Australian and international databases. We assumed that 96% of production was from irrigated systems, with 85% of water pumped by diesel-powered irrigation pumps; and assumed a median yield of 10.28 bales/ha. We applied emissions formulae and factors from the Australian National Inventory Report, except where more specific published literature was available, particularly for fertiliser-related N_2O emissions and those from the decomposition of cotton residues.

We calculated the climate change impact on a cradle-to-port basis as 1607 kg CO_2-e per tonne of cotton lint, with 26% of emissions occurring during the pre-farm stage, 47% during the on-farm stage and 27% post-farm. Production and use of nitrogenous fertiliser contributed 45% of the emissions.

Several management scenarios were shown to reduce emissions intensity, including: optimising nitrogen application rate (2.6% - 13.2% reduction, for N=240 and N=180), use of controlled-release and stabilised N fertilisers (5.9%), solar-powered irrigation pumps (8.1%), biofuel-powered farm machinery (3.4%), legume crop rotations (3.9%) and fertigation (2.1% - 12.5%). However, further research is required to consider the full life cycle consequence of biodiesel production, including alternative uses of the biomass and displacement of other land uses; and to better understand a potential reduction in carbon sequestration when legume break crops are introduced, due to a lower volume of biomass production.

EP2:

Cotton surface modification and functionalisation

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This study used visual representation techniques to explore relationships between cotton fibre properties and current approaches for modification and functionalisation of the cotton surface. The literature on relevant topics was reviewed to establish the conceptual framework, and the information was organised thematically and hierarchically. Mapping techniques were then applied to convert the information into a visual form.

Intrinsic properties of cotton make it one of the most used textile fibres. This popularity is greatly driven by consumers' demand for comfortable, easy care and safe products. Extensive research work has been done to develop approaches that add desired functionalities and improve aesthetics of cotton textiles. Finishes that provide functionalisation such as wrinkle resistance, flame retardancy, improve colour fastness and dimensional stability, impart soil, water and oil repellency, and reduce mechanical, bio and light degradation are common. However, the benefits provided by these approaches are often limited by their undesirable effects on cotton fibre. Manufacturing, use and recycling of cotton products have also raised some environmental concerns. These concerns led to legislative changes, requiring sustainable, more integrated processes capable of delivering high added-value textile and apparel products.

Additionally, the emerging technologies and continuous progress in new advanced textile materials present strong competition. Increased publics awareness and preferences for performance textiles are contributing to the growth of the clothing sectors like outdoor and sports, protective and work wear. For cotton to retain its place in global textile and apparel markets, technological advancement and further innovation in cotton modification and functionalisation methods are needed. Such new approaches would provide critical differentiation of the product, adding desired properties and value.

EP3:

How to manage glyphosate-resistant weeds in genetically modified cotton?

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Weed cost $ 3.5 billion to Australian agriculture including on-farm expenses and lost production. In cotton, yield loss can range from 10-90%, leading to an economic impact of around $173 million. Weeds can badly affect the growth, development, and yield of cotton crop by competing for space, light, water, and nutrients. Genetic modifications in crops have brought a significant revolution in the cotton industry and completely changed the weed management program to sole reliance on glyphosate. Such overuse of glyphosate has resulted in the evolution and development of glyphosate-resistant (GR) weed populations. Presently, 37 weed species are resistant to glyphosate globally and this number is increasing daily. To find an alternative way, a field study was conducted at the Gatton farm of the University of Queensland to evaluate the performance of different herbicides on weed control in glyphosate-tolerant cotton. The experiment was laid out in a randomized complete block design with three replications. Different herbicide treatments were weedy (control), glyphosate applied once, glyphosate applied twice, metolachlor, glyphosate + metolachlor, pendimethalin, glyphosate + pendimethalin, and glyphosate + haloxyfop. Pre-emergence application of pendimethalin and metolachlor proved very effective in controlling all types of weeds and provided total weed biomass reduction of 97 and 96%, respectively, over control whereas glyphosate applied once and twice recorded weed biomass reduction of 58% and 71%, respectively and did not show any significant effect on the reduction of Chloris virgata. Seed cotton yield was also observed higher for pendimethalin and metolachlor. Pendimethalin and metolachlor treatments recorded an increase in seed cotton yield of 353 and 311%, respectively over the weedy control as compared to glyphosate applied once and twice (136 and 186%, respectively). Findings of this study will decrease the pressure on the excessive application of glyphosate and drop off future GR weeds.

EP4:

Effect of cotton residues on N_2O emissions and soil nitrogen following incorporation

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The incorporation of crop residues post-harvest can provide an important source of nitrogen (N) for the subsequent crop but can simultaneously lead to elevated nitrous oxide (N_2O) emissions. The magnitude of N supply and corresponding N_2O emissions strongly depends on the quality of the added crop residues, and soil and climatic conditions. However, little data is available for subtropical cotton systems. The primary aims of this study were to (i) quantify carbon dioxide (CO_2) and N_2O emissions, and corresponding emission factors (EFs) following cotton residue incorporation, and (ii) determine the contribution cotton residues have to soil N content for the subsequent crop. Using a semi-automated sampling system, CO_2 and N_2O emissions were monitored during a cotton fallow period following cotton residue incorporation under varying rainfall conditions compared to residue removal. The high C/N of the incorporated residues, low temperatures and the limited C substrate resulted in low N_2O emissions. EFs were found to be 0.015 and 0.051% for average and high rainfall conditions, respectively which is significantly lower than the IPCC EF of 1%. The majority of decomposed residues were recovered in the soil with the remaining undecomposed and a very minimal amount was lost. There was a net mineralisation or loss/immobilisation observed across sites indicating soil conditions and management practices significantly influence N dynamics. The study suggests that the current IPCC methodology should be re-evaluated and that EFs need to be lowered to reflect the low N2O emissions from high C/N cotton residue N inputs. It also shows that effect of crop residues on soil N dynamics needs to be considered in N fertiliser management strategies in order to maximise the benefits from crop residue incorporation.

EP5:

Exploring modes of action of novel biopesticides: from model cell line to target insects

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The adoption of *Bt*-cotton has seen a welcome reduction in insecticide applications, although it has been accompanied by increasing development of resistance by the targeted species in the field. The reduced use of broad-spectrum insecticides also creates a niche opportunity for secondary pests to reach damaging levels. This investigation looks at the effects of novel and known biopesticides on a model insect cell line, *Drosophila melanogaster* S2, and target cotton arthropod species using an array of assays. Cell growth assay, electrophysiology, confocal microscopy, and whole organism bioassay have enabled comparisons between fractions of selected, insecticidal plant extracts. Cell assays and whole organism bioassays have identified three novel extracts with insecticidal potential, with cell growth inhibition and insect mortality at low concentrations. Electrophysiology results indicated at least one of these extracts has dual activity involving modulation of both potassium and sodium ion channels, while a second extract may suppress chloride ion movement, and the third extract may affect cell and arthropod mortality via a non-neuronal mode-of-action. Moreover, confocal imaging of H_2O_2 (a key stress-inducible secondary messenger) showed that the extracts cause different signalling responses and patterns in *D. melanogaster* S2 cells. We also found that one novel extract showed high toxicity to both cotton aphids (*Aphis gossypii* Glover) and two-spotted spider mite (*Tetranychus urticae* Koch) without affecting *D. melanogaster* flies or honeybees (*Apis mellifera* L). We propose that combining these physiological and cellular techniques is likely to assist the discovery of new biopesticides, and the identification of new modes of action for insecticidal activity.

EP6:

Optimising poultry litter management in cotton production

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Duplex texture contrast soils in southern NSW used for irrigated cropping are prone to surface crusting, waterlogging and compaction. Litter produced from poultry farms in the region may offer growers a way of improving soil physical properties, which may translate to greater crop productivity and yield. A field trial in Griffith NSW, examined the rate and placement strategy (banded or incorporated) of poultry litter and inorganic fertiliser at equivalent N rates on cotton plant N uptake, lint yield and quality, soil biology and soil available N.

The control (Zero), farmer practice (T0), and low litter broadcast (T1) treatments had the lowest values of petiole NO_3-N, crop N uptake (at first flower, cut out and defoliation), and NDRE values from first flower until defoliation. The banded (T2) and high rate litter broadcast (T3) treatments consistently remained at the upper end of each of these parameters, achieving greater plant N uptake. However, the crop N uptake did not correspond well with lint results. The highest lint yield and quality (as determined by micronaire, maturity, strength and elongation) was achieved by T3 and T1 (although T1 recorded the second lowest value in elongation). The influence of treatments on soil biology was also unclear. There was less microbial activity in broadcast litter treatments (T1 and T3) compared with other treatments, however T2 and T3 recorded the greatest microbial biomass.

Conclusions from this first-year study were that the soil was relatively non-responsive to inorganic fertiliser in the form of poultry litter due to initial high nutrient soil concentration and possibly different N leaching in treatments due to the free draining loam nature of the soil. Repeating the research in subsequent years is required to further examine treatment effects on yield, lint quality, soil biology and nutrient use efficiency.

EP7:

Swelling of cotton fibers by amino acid treatment

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In the cotton industry, the swelling of cotton fibres has captured attention because of its importance in textile processes such as dyeing, cross-linking and, most importantly, mercerisation.

Swelling of the cotton fibers by mercerisation treatment is well known. However, this treatment requires highly concentrated sodium hydroxide solutions which are corrosive. A similar improvement by a noncorrosive chemical treatment is therefore important for the cotton industry in this 'green-era'. In this view, the present work focuses on developing a user-friendly, nonhazardous, biocompatible method to swell the cotton fibers in order to modify some properties. Amino acid was used as a swelling agent and the change in morphology of cotton was analyzed by different advanced characterization techniques.

Results obtained from this study suggested that a simple amino acid, glycine in solutions under suitable conditions could remove natural convolutions in cotton and change the fibre cross-sectional shape from bean-shaped to more circular like forms. At the same time, the moisture regain of cotton has increased. The swelling action of glycine also resulted in increases in cross sectional area by 53%. These results reveal a potential new pathway for cotton processing that improves many desired properties.

EP8:

Utilising plant growth regulators to develop resilient future cotton systems

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Seasonal water availability and the physiological impact of periodic water deficit stress have a significant influence on the yield, lint quality and resource use efficiency outcomes from Australian rainfed cotton production systems. Opportunities exist to leverage novel applications of plant growth regulators (PGRs) to create innovative agronomic approaches for rainfed cotton crop management, facilitating greater system resilience to limited water contexts. The research presented are initial screening studies aimed at quantifying short term plant growth responses to exogenous applications of specific PGRs, applied during early vegetative growth to an Australian cotton cultivar (Sicot 746B3F). Two glasshouse experiments (exp.) attempted to manipulate early vegetative growth and development, and utilised plant morphology as a measure of underlying physiological responses to PGR treatments. Agronomic strategies investigated included the manipulation of floral induction (FI), and the promotion of root growth.

Screening exp. (I) investigated applications of cytokinin, gibberellin, auxin, fatty alcohol and phenolic acid to promote root growth. Exp. (I) showed significant increases at harvest, due to PGR treatment effects, on plant height, stem dry weight, total dry weight, and root dry weight, in addition to root:shoot and root:total dry weight ratios.

Screening exp. (II) evaluated gibberellin biosynthesis inhibiting hormones to induce stasis or physiological stunting in early vegetative growth, with the aim of delaying FI. Exp. (II) demonstrated significant PGR treatment impacts in delaying time to 50% first square, slowing the vegetative growth rate at both 10 days post treatment (DAT) and harvest, and decreasing node development both at 10 DAT and harvest.

Exp. (I) & (II) demonstrated the utility of specific PGR applications to improve root growth, being advantageous in improving plant exploration for and access to water, as well as being able to delay crop development, which may have advantages in matching crop water use to prevailing climatic conditions.