Research achievements in the Australian cotton industry

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March, 2018
Overview

1. Challenges, opportunities and broad outcomes
2. Research areas (and extension)
3. Three examples of success
4. Outcomes and impacts
### Challenges and opportunities for research

<table>
<thead>
<tr>
<th>Issue</th>
<th>1970</th>
<th>1995</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield = $</td>
<td>Low (800 kg/ha)</td>
<td>Moderate (1750 kg/ha)</td>
<td>High (2600 kg/ha)</td>
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<tr>
<td>Pests</td>
<td>Severe</td>
<td>Severe</td>
<td>Respectable</td>
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<tr>
<td>Sustainability</td>
<td>Severe</td>
<td>Problematic</td>
<td>Respectable</td>
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<tr>
<td>Soil health</td>
<td>Severe</td>
<td>Respectable</td>
<td>Respectable</td>
</tr>
<tr>
<td>Diseases</td>
<td>Bacterial blight, Verticillium wilt</td>
<td>Fusarium wilt, Bunchy Top</td>
<td>Verticillium wilt?</td>
</tr>
</tbody>
</table>

More progress, more ★★
RESEARCH AREAS in recent decades

1. Physiology, agronomy, farming systems
   - Water – irrigation, wue
   - Nutrition - fertilizer
   - Soils
   - Tillage

2. Crop protection
   - Pests
   - Diseases
   - Weeds

3. Genetic improvement
   - Breeding
   - Biotechnology

4. Processing
   - Ginning
   - Fibre measurement, Spinning

5. Other, eg Machinery

Note especially:
- IPM – Integrated Pest Management
- IWM – Integrated Weed Management
- IDM – Integrated Disease Management
- IFM – Integrated Fibre Management

Combined = ICM – Integrated Crop Management

GM traits:
- Protein(s) from soil bacteria *Bacillus thuringiensis* (Bt) toxic to *Helicoverpa* and other lepidopterans. Released 1996.
- Regulatory studies too (GMAC, OGTR).
Research bodies

1. Public agencies
   - Federal – CSIRO
   - State – NSW, Qld, WA, NT
   - University – SU, UNSW, UWS, UNE, UQ, USQ, CQU, JCU, Deakin U.
   - Cooperative Research Centre (x3) 1994 to 2012 (~$2m pa).

2. Private/commercial
   - Growers (+ researchers)
   - Chemical companies – Shell, Bayer, Monsanto, etc.
   - Machinery – JD, Case, local
   - Contract research – Kalyx, etc.
Prior to 1987, funding was via tax payer - through research agencies.

In 1972, the Australian Cotton Growers Research Association (ACGRA) supported research focused on their needs, via voluntary 25 c/bale levy, full compliance demonstrated growers commitment.

In 1987 the Cotton Research Council was established to collect grower levy ($2.25/bale) and matching Federal money and distribute research funds. This body was replaced by the Cotton Research and Development Corporation (CRDC) in 1990. $24m in 2016/17.

ACGRA (later CA) play a role by assessing all CRDC research applications.

External research funds are critical in an era of government budget cuts.
Three major research achievements

Soil management

Pest management

Plant breeding
SOIL MANAGEMENT
A typical soil where cotton is grown:
Vertosol
High clay content
High water holding capacity
Cracks when dry
Alkaline
Sodic
Reasonable fertility – N, P, K, Zn
Resilient

So:
Drainage may be slow – waterlogging (N loss, stunting).
The soil is fragile when wet – prone to soil compaction from tillage or traffic.
Appropriate tillage for soil type and moisture content is required.
It is sometimes necessary to consider a rotation crop to dry the profile.
Soil compaction

From Dave Anthony
Soil compaction

From Dave Anthony
Information to help decisions on soil management, particularly tillage

**Outcome:** massive improvement in soil structure (=resilient) which facilitated better crop response to water and fertilizer.
PEST MANAGEMENT
PEST MANAGEMENT

- Large numbers of pests (100) + cotton is attractive to pests.
  - Especially *Helicoverpa* spp.
  - Zero yield with high incidence of uncontrolled *Helicoverpa*.
- Regular control = Pesticide contamination: air, soil, water. +Resistance.
- Large number of beneficial predators and parasites of pests.
- However, insecticides can kill beneficiaals as well as pests.
- **Integrated Pest Management** was required
  - Damage thresholds (eg 2 v. small larvae/m); accurate scouting.
  - Understand insect ecology / movement of different species.
  - Pesticide resistance management. Reactive?
    - Chemistry rotation, defined windows, pupae destruction.
- Prevention of resistance to Bt GM traits. **Preemptive!**
Adoption of Bt cotton varieties in Australia

- Traits from Monsanto and Bayer used under research agreement with CSIRO (breeding) and commercial agreement with CSD (seed sales).
- Grower signs licence agreement with Monsanto to follow resistance management requirements. Compliance is audited.

Bollgard 3 start 2015. Also stacked with RRF.
Insecticide (ai) use on cotton in Australia

![Graph showing insecticide use on cotton in Australia from 1995/6 to 2009/10. The graph compares Conventional, Ingard, and Bollgard II treatments. Over the years, there is a >80% reduction in insecticide kg ai/ha.](image-url)
**Pest management outcomes**

- **Comprehensive recommendations on pest control options.**
- The experience with insecticide resistance research enabled the development of *pre-emptive* resistance management for GM Bt technology before its widespread use:
  - Refuge crop (eg. pigeon pea, u/s cotton)
  - Planting windows x region ~
  - Pupae destruction (autumn, winter)
  - Different proteins stacked (Ingard ➔ Bollgard II ➔ Bollgard 3)
- With low levels of background resistance in *Helicoverpa* populations to Bt; it is still necessary to be vigilant in compliance with resistance management.
- IPM for all pests is facilitated by GM Bt use.
COTTON BREEDING

• Long history in Australia, particularly in Qld.
• Long term projects >>10 year breeding cycle.
• At the start of the modern cotton industry ~1960s, there were breeding and selection programs in Qld, NSW (2) and WA.
• Key event – 1972. Centralisation of CSIRO breeding program in main production area at Narrabri and staffed by experienced scientists. Other programs closed eventually.
CSIRO breeding activities and objectives

2018: Team >20: 3 breeders; 3 PDF; ~15 technical staff. Return On Investment is > 80: 1. NPV is $5b - $10b.

- **Yield** / local adaptation (soil, pests, climate, etc)
  - Irrigated and rainfed; heat and stress tolerance; tropical and temperate

- **Disease** resistance
  - Bacterial Blight, Verticillium Wilt, Fusarium Wilt, Cotton Bunchy Top

- **Fibre quality**
  - Especially length, strength, fineness - dictated by market preference

- **Introgression of GM traits since 1991**
  - Btx4, RRx3, LL and combinations; plant type = turnover.
  - Involves CSIRO biotechnology group in Canberra.
Yield gain due to Variety, Management & their interaction.
325 CSIRO experiments over 30 years.

Over the period 1980 to 2010, AUS yields increased by ~1000 kg lint/ha (from 1200 to 2200). That is 480 kg/ha for variety (~$1,000/ha); 280 for management; and 240 kg/ha for VxM.

Liu et al FCR 2013
Varieties developed

CSIRO released the first varieties through CSD: Sicot 1 and 3 in 1983 (replaced imported US varieties)

Then Siokra, Sicala and on .... *(green or red are redundant)*

In 35 years, there have been ~110 varieties released (trait turnover).

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Transgenic Bt/RR/LL</th>
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<tr>
<td>Sicot 1</td>
<td>Sicot V-15i</td>
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<tr>
<td>Sicot 3</td>
<td>Sicot V-16i</td>
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<tr>
<td>Siokra 1-1</td>
<td>Sicot V-17i</td>
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<tr>
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<td>Sicot 11B</td>
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<td>Sicot 13B</td>
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<td>Sicot 15B</td>
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<td>Sicot 16B</td>
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Closing comments to sum up
Australian cotton research outcomes: Better yield, better quality, more efficient.

Note: theoretical yield ~ 5,000

Rainfed:
- Dry seasons recently
- Grown in drier locations to west
- Yield increasing if corrected for rain
How does Australian cotton fibre compare with USA?

Data from ACSA and USDA (whole crop)
Water use efficiency

Nutrient use efficiency

- For cotton varieties released 1973 to 2006, nutrient use efficiency increased by >20% (kg lint yield/kg nutrient uptake).

- Current efficiencies, eg:
  - 15 kg/kg N
  - 70 kg/kg P
  - 12 kg/kg K

*ie*, more yield with same water use.  

*(Rochester and Constable 2015)*
Future – vision for cotton research

• Opportunities for improved production and efficiency.
• New technology – eg molecular tools.
• Will production areas change? (Ord, NQ, Vic)
• Change in fibre quality preferences (eg, El).
• Problems/challenges:
  ➢ Drought – direct and indirect politically.
  ➢ Disease – Verticillium strain, new viral.
  ➢ Pests and Weeds will remain/new.
  ➢ Price – competition x2.
  ➢ Research funding ... lean and keen.
  ➢ Researchers balance research v extension; basic v applied
Thanks to all researchers.

My personal thanks to all CSIRO cotton teams,

*especially Norm Thomson, Peter Reid, Warwick Stiller and Shiming Liu*