Cotton breeding and physiology research in Australia

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Overview

1. Introduction and background
2. Yield-physiology
3. Plant breeding
4. Vision

Physiology, agronomy, systems activities

1970-1991

- Plant spacing – including UNR
- Carbon budget
- Temperature
- Nutrition – nutrient budget, especially N
- Irrigation
- Rotation, tillage
- x variety
- Team of 2 people; one RS and one TO

"Yield physiology"

Breeding activities

1991-2015

- Fibre quality – especially strength, fineness.
- Full season environments
- Host plant resistance – okra leaf, nectariless, frego, glabrous
- GM traits - Bt, RR, LL and combinations (x plant type)
- Heat tolerance
- Stress tolerance
- Team of 20: 3 breeders; 3 PDF; ~15 technical staff
- Return On Investment is 80: 1. NPV is $5b - $10b.

Yield-physiology

Theoretical yield

In order to understand where more yield can be achieved (if at all), we have completed an analysis of theoretical and potential yield of cotton (*Constable and Bange 2015 - c.f. Baker and Hesketh, 1969*).

Three methods of integrating potential net photosynthesis showed theoretical yield was ~ **5,034 kg lint/ha.**

Potential yield: in irrigated systems: **3,500 kg lint/ha**.

The analysis highlighted some important constraints in high yields, particularly the uptake, distribution and redistribution of nutrients (N,P,K). In particular there is a need to focus on nutrient use efficiency in future cotton agronomy and plant breeding.

Examples of high cotton yield reported

Location	Yield reported	Yield kg lint/ha	Field/plot size	Harvest	Source
Xinjiang, China, 2013	838.31 kg/mu (0.067 ha)	5,005[a]	na	Hand?	www.nzweek.com/business/xinjiang-setsworld-record-for-cotton-production-13259/
Texas, USA, 2014	6.88 bales/ac	3,866	na	mechanical	Horton (2014).
NSW, Australia, 2015	15.97 bales/ha	3,625	1.5 ha	mechanical	www.csd.net.au/
NSW, Australia, 2013	15.57 bales/ha	3,534	1.5 ha	mechanical	www.csd.net.au/
NSW, Australia, 2010	14.60 bales/ha	3,314	1.7 ha	mechanical	www.csd.net.au/
Arizona, USA, 1982	5.41 bales/ac	3,041	na	mechanical	Pennington (1983).

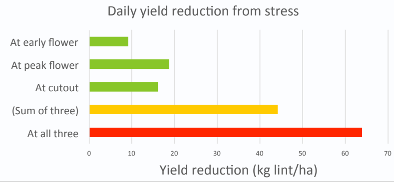
a – assumed lint was 40% of seed cotton
na – not available

Interaction between stresses

Interaction between stress at different stages can be substantial.

In this example, one day of water stress at all three growth stages caused ~50% greater loss in yield than the sum of one day of stress at each stage.

This is because early stress reduces plant size and number of fruiting positions, and later stress prevents compensation as well as growth of surviving fruit.



Combinations of stresses can accumulate to result in low yields

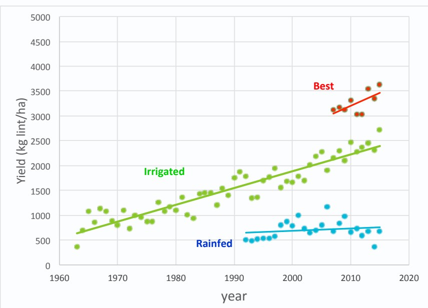
Breeding

- Overall thoughts – breeding strategy and integration.
- Interaction between variety and management.
- Generic diversity (~ germplasm exchange).
- Breeding in a molecular future.
- Fibre quality.

Overall thoughts on breeding approach

- There is nothing wrong with traditional pedigree breeding systems.
- Breeding needs to address the whole production system with knowledge of the factors contributing to yield and to be especially aware of factors interacting. There is little point in having a variety with high yield potential if it is susceptible to a common disease in that production system.
- Thus effective plant breeding needs to combine all desirable traits. That takes time, but for a start, at least prioritise the traits in order of importance, either individually, then how they interact.
- If the climate or management constrain production, it is possible that breeding will have little impact until the conditions are improved.
- Coordination between disciplines needs to be balanced. An isolated breeding program might struggle for impact. The reverse is true too: there is little point is having good biotechnology but poor breeding.

Australian cotton yields

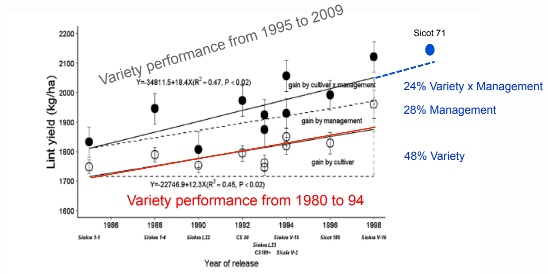


Interaction between variety (V) and crop management (M)

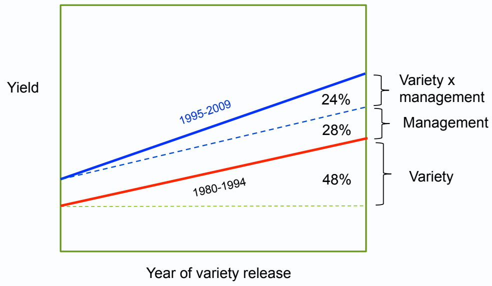
- We used a large dataset of over 325 irrigated sites from 1980 to 2009 to evaluate genetic gain from cotton breeding (Liu *et al* 2013) [*Thomson, Reid, et al*].
- The data showed progress in yield due to Variety and Management as well as a significant V x M interaction, where modern varieties responded more to modern management than older varieties did.

Yield gain due to variety, management & their interaction
325 CSIRO experiments over 30 years.

Liu et al FCR 2013

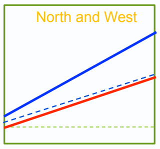


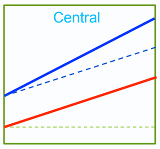
VxM

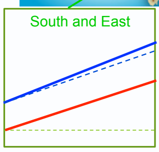


Over the period 1980 to 2010, AUS yields increased by ~1000 kg lint/ha (from 1200 to 2200). That is 480 kg/ha for variety; 280 for management; and 240 kg/ha for VxM.

VxM in different regions;
= VxMxEnvironment







Year of variety release

Large V
Very little M
Large VxM
Sub tropical season

Large V
M = VxM

Large V
Large M
Very little VxM
Shorter season

Some Variety parameters changed indirectly as a result of selection for yield of cotton

- Reduced sodium uptake *(Rochester and Constable 2003)*
- Increased tolerance of waterlogging (Conaty et al 2009)
- Increased nutrient use efficiency (*Rochester and Constable 2015*)
- Increased water use efficiency (*Constable and Bange 2015*)
- Increased leaf photosynthesis (*Conaty, unpub*)

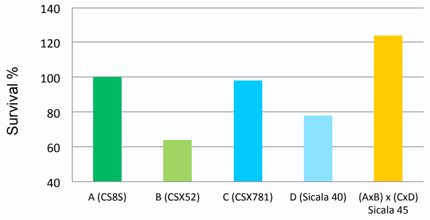
Conclusions from VxMxE

- CO_2 increase is likely a small part of the management improvement. The rest is better overall cropping system (*timing of operations: irrigation, fertilizer, pest management, tillage, etc*).
- Some of the variety and variety x management components can be explained by improved Verticillium resistance. Clearly a variety susceptible to disease cannot respond to improved management.
- We need to know more about VxM to exploit it.
- Lessons for breeding: candidate varieties need to be tested in all environments, and for at least three years before decisions on variety release are made.
- The more reliable sites for evaluation were identified and are now used in preference.

Genetic diversity is essential for breeding progress

- **Diversity bottlenecks in cotton:**
  - a) 1.5 million years ago – chance tetraploids.
  - b) Last 7,000 years – domestication.
  - c) Last ~100 years – breeding.
- **Diversity of opinions on genetic diversity in cotton**
  - DNA polymorphism is low - how measured?
  - but Phenotypes are diverse with wide range of agronomic performance.
  - Both views are right and everyone agrees diversity is essential.
- Breeders should **generate diversity** for <u>their own system</u>.
  - **access** germplasm (by exchange) or **create** diversity.
- **Beware**: **diverse material might <u>not</u> create elite yield (cf disease res).**

Diversity: Expectations and uncertainty with Fusarium resistance

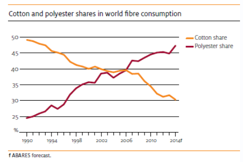


Relative survival in Fusarium wilt nursery for the parents of two F1 used in development of Sicala 45, a line selected from that four way cross.
All four parents were closely related *(B and D were sisters)*.

Additive genetic mechanisms – even with 'no' diversity

Fibre quality

- Continual need to improve
  - More rapid ginning and spinning means fibres have to be stronger to survive the processing.
  - Shift to lightweight fabrics requires longer, stronger and finer fibres.
  - Competition with synthetic fibres.
  - Competition between producing countries = price, volume.
- Breeding challenge: yield.
  - We have improved length and fineness in AUS varieties but strength is difficult.
- Future
  - A better product creates demand for cotton and not expect a better price?



Breeding in a molecular future

- The same breeding procedures are required with GM traits, not just backcross. Our experience is that there is diversity in yield performance within backcross-generated populations, so careful evaluation of elite lines is required.
- Molecular markers are complex because most important traits are multigenic, but future molecular tools will eventually be at least as important as GM traits.

Future - vision

Understand and better exploit VxMxE.

More GM traits – and continued company rationalisation.

Will someone engineer photosynthesis? What plant growth habit?

Breeding with multiple GM traits is slower.

Molecular tools for yield?

Will production areas change?

Problems/challenges:

- Drought – direct and indirect politically.
- Disease – especially viral.
- Pests and Weeds will remain.
- Price – competition.

Finish

Thank you

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