Breeding for Cotton Disease Resistance in Australia

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The CSIRO cotton breeding team objectives:

- Yield
- Fiber quality
- Disease resistance
Cotton Production in Australia

- Between 23°S & 34°S latitude
- Mainly furrow irrigation
- Alkaline clay soils
- 1998/99 – 562,000ha
- 2006/07 – 144,000ha
- High average yields
Annual Disease Surveys

• Since 1984/85 in NSW (23 years)
• Since 2002/03 in Queensland (5 years)
• NSW DPI, QDPI&F and CSD pathologists
• 100 – 150 commercial fields per survey
• In November and February each season
• For each field we record:
  – Cropping history, crop residues, ground preparation, variety, seed rate, sowing date, growth stage, disease incidence and severity
Disease Survey data:

• Illustrates the history and success of the cotton breeding effort

• Quantifies the distribution and importance of each disease

• Indicates the rate of adoption and impact of resistant varieties
Disease Survey data also:

- Gives direction to plant disease research
- Justifies funding of plant disease research
- Shows impact of farming practices on disease incidence and severity
Four disease problems challenge breeders in 23 years

Diseases of Cotton in NSW - 1984-85 to 2006-07

- Bacterial blight (% bolls)
- Black root rot (% plants)
- Verticillium wilt-NSW (% plants)
- Verticillium wilt-Namoi (% plants)
- Fusarium wilt (% farms)

Courtesy NSW DPI
Bacterial blight
Bacterial blight

- *Xanthomonas axonopodis pv malvacearum*
- Race 18 predominant
- Seed borne infection important

- A clean seed scheme reduced seed borne infection to < 0.03% within 5 years
Resistant varieties

- Immunity introduced from US Tamcot germplasm with $B_2$, $B_3$ and $B_7$ genes
- All Australian varieties now immune
- BUT – hypervirulent races found in Africa and used in USA
- Breeding material with resistance to these races imported into Australia
Disease survey results:

Bacterial blight of cotton

![Graph showing the incidence of bacterial blight and resistant varieties over years from 1984/85 to 1998/99.]

- **Boll blight** (%)
- **Resistant Varieties** (%)

- **Boll blight** (red line)
- **Resistant varieties** (black line)


**Courtesy NSW DPI**
Screening for resistance

- All breeding material screened twice as follows:
  - Infected leaves collected, dried and ground to powder (will store for years)
  - Tractor mounted sprayer (up to 8 rows)
  - Inoculum at 2g/L, 100L water/ha, 3 bar
  - ‘Stomate flooding’ surfactant at 0.2mL/L
  - Susceptible breeding lines removed
‘Stomate flooding’ surfactant

Water + 0.2 mL/L organosilicone surfactant

Water
Verticillium wilt
Verticillium dahliae

- **Australia**
  - Mild strains
  - VCG 4 or group 4

- **Elsewhere**
  - Severe defoliating strains
  - VCG 1 or group 1
  - Non-defoliating strains
  - VCG 2 or group 2
Verticillium wilt

- Increasing incidence associated with adoption of permanent bed systems and reduced tillage

- Widespread and common – especially in the Namoi valley where some fields had over 70% of plants infected

- Yield reductions were significant
Breeding for resistance? or Breeding for yield tolerance?

- Selecting for high yield at field sites where the incidence of Verticillium wilt was high

- Only limited effort to quantify disease incidence
Sicala V-1

• Released in 1990
• Not completely resistant to Verticillium
  – Disease incidence in Sicala V-1 was 50 – 80% lower than that in other varieties.

• Resistance is temperature sensitive
  – More susceptible at low temperatures

• Later replaced by Sicala V-2
Disease survey results:

Verticillium wilt of cotton in NSW

Incidence (%)
- Incidence
- Resistant varieties

Courtesy NSW DPI
Verticillium wilt

Susceptible variety

Resistant variety

%
<table>
<thead>
<tr>
<th>Field Number</th>
<th>Incidence (Season)</th>
<th>Number of Cotton Crops</th>
<th>Incidence in 1997/98</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>70% (1988/89)</td>
<td>6 crops in 9 seasons</td>
<td>4.5%</td>
</tr>
<tr>
<td>31</td>
<td>67% (1988/89)</td>
<td>5 crops in 9 seasons</td>
<td>6.5%</td>
</tr>
<tr>
<td>33</td>
<td>74% (1990/91)</td>
<td>5 crops in 7 seasons</td>
<td>7.0%</td>
</tr>
<tr>
<td>21</td>
<td>72% (1993/94)</td>
<td>3 crops in 4 seasons</td>
<td>22.5%</td>
</tr>
</tbody>
</table>
Resistance Ranking

Based on field experiments and
Comparison with a standard

Standard = Sicala V2 = 100
(most resistant variety in 2000)

0-100 = more susceptible than standard
100-200 = more resistant than standard
200 = immunity/complete resistance

(Color coordinated to seed technology)

200 = immunity!
# Resistance ranking

<table>
<thead>
<tr>
<th>Season</th>
<th>Location</th>
<th>Trial type</th>
<th>Incidence in Std. (%)</th>
<th>Survival in Std (%)</th>
<th>Survival in Test (%)</th>
<th>V.rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/02</td>
<td>Narrabri</td>
<td>CSD small plot</td>
<td>36.1</td>
<td>63.9</td>
<td>67.1</td>
<td>109</td>
</tr>
<tr>
<td>01/02</td>
<td>Narrabri</td>
<td>CSIRO small plot</td>
<td>25.5</td>
<td>74.5</td>
<td>76.0</td>
<td>106</td>
</tr>
<tr>
<td>02/03</td>
<td>ACRI</td>
<td>CSIRO small plot</td>
<td>63.4</td>
<td>36.6</td>
<td>46.8</td>
<td>116</td>
</tr>
<tr>
<td>02/03</td>
<td>Narrabri</td>
<td>CSIRO small plot</td>
<td>11.5</td>
<td>88.5</td>
<td>88.5</td>
<td>100</td>
</tr>
<tr>
<td>04/05</td>
<td>ACRI-Old 2</td>
<td>CSIRO small plot - N0501</td>
<td>78.1</td>
<td>21.9</td>
<td>25.2</td>
<td>104</td>
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<tr>
<td>04/05</td>
<td>ACRI-B3</td>
<td>CSIRO small plot - N0502</td>
<td>31.0</td>
<td>69.0</td>
<td>70.4</td>
<td>104</td>
</tr>
<tr>
<td>05/06</td>
<td>ACRI-Old 2</td>
<td>CSIRO small plot - N0601</td>
<td>60.6</td>
<td>39.4</td>
<td>48.1</td>
<td>114</td>
</tr>
</tbody>
</table>

**V.rank = 108(7)**

<table>
<thead>
<tr>
<th>inc</th>
<th>Std</th>
<th>Test</th>
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</thead>
<tbody>
<tr>
<td>63.9</td>
<td>67.1</td>
<td>87.5</td>
</tr>
</tbody>
</table>

**Mean** 108

**S.E.** 6
2007 Verticillium wilt - Resistance ranking

V.rank

200 = immunity
IDM for Verticillium wilt

- Use varieties with V.ranks > 100
- Manage for earliness
- Avoid late season irrigations
- Incorporate residues soon after harvest
- Rotate with non-hosts (cereals, sorghum)
- Control alternative weed hosts
- Minimise your tailwater
- Always practice good farm hygiene
Black Root Rot
Black root rot
(*Thielaviopsis basicola*)
Disease survey results:

Black root rot of cotton in NSW

Incidence (farms)
Incidence (plants)

Courtesy NSW DPI
Sources of resistance

• No resistance in *G. hirsutum*
• Some resistance in *G. arboreum*

• Transferring resistance from a diploid *arboreum* to a tetraploid *hirsutum* is difficult (It has been done before!)

• Several research groups are trying!!
Resistance to black root rot?

• *G. hirsutum*
• A tetraploid cotton

• *G. arboreum*
• A diploid cotton
Screening for resistance – in a growth chamber

- Naturally infested soil
- Up to 5 seedlings per 10cm pot
- 12hour/12hour light and 18°C/24°C
- After 3 weeks wash soil from roots
- Assess tap root using a ‘0’ to ’10’ scale
  - 0 = no disease
  - 10 = 100% of tap root blackened
IDM for black root rot

- Use varieties that can ‘catch up’
- Use Bion seed treatment
- Prepare beds well
- Pre-irrigate and/or plant into moisture
- Delay planting if possible
- Rotate with non-hosts for up to 3 years
- Avoid legumes and control weeds
- Effective biofumigation
- Minimise tailwater
- Summer flooding if possible
- Always practice good farm hygiene!
Fusarium Wilt
Fusarium Wilt
Fusarium wilt in Australia

- 92/93 - First record in Queensland
- 94/95 – First record in NSW
- 99/00 – Widespread in 2 production areas
- 06/07 – Widespread in 7 production areas
- Now recorded on 80 farms in NSW

- BUT - Incidence is generally low
Fusarium oxysporum fsp vasinfectum in Australia

- 3 Australian strains – based on VCG
- Originated from local native strains
- Classified as race 6
- Races 1, 2 and 6 now called ‘Group A’

- There is no association with nematodes
Screening for resistance

• Glasshouse screening
  – Inconsistent results initially
  – Only limited numbers could be screened

• Field screening
  – Disease nurseries identified
  – 6000 – 9000 plots each year since 96/97
  – Large population sizes used

• Markers
  – Proving difficult to find in cotton
Field screening

• Initial stand count – soon after emergence
• Final count of survivors (0 or 1) – stem x-section at ground level following harvest

• Survival = (final count/initial count) × 100
Screening for resistance!
Sources of resistance

– Over 130 lines were introduced from overseas and screened
– Other species of *Gossypium* were screened
– Numerous Australian breeding lines and existing varieties were screened

• Some good sources of resistance were found:
  – In some Indian and Chinese lines
  – In some varieties of *G. barbadense*
  – In some existing Australian varieties
Sicot F-1

- Resistance from MCU-5 out of India

- When disease is present
  - Sicot F1 yields 32% more than Sicot 189

- When disease is absent
  - Sicot F1 yields 8% less than Sicot 189

- New varieties overcome this yield drag
Resistance to Fusarium?

![Graph showing relative survival of genotypes]

- **Sicot 189**
- **China**
- **China x Sicot 189**

Relative survival can be observed across different genotypes.
Resistance to Fusarium - Sicala 45

![Bar Chart]

- Relative survival

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>(AxB)(CxD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>150</td>
<td>70</td>
<td>105</td>
<td>80</td>
<td>140</td>
</tr>
</tbody>
</table>
Resistance Ranking

Based on field experiments and Comparison with a standard

Standard = Sicot 189 = 100

0-100 = more susceptible than standard
100-200 = more resistant than standard
200 = immunity/complete resistance

Sicot 189 was the most resistant variety available in 1996.
## Resistance ranking

**Sicot F-1B**

### F.rank = 149(7)

<table>
<thead>
<tr>
<th>Season</th>
<th>Location</th>
<th>Trial type</th>
<th>VCG</th>
<th>Survival in Std (%)</th>
<th>Survival in Test (%)</th>
<th>F.rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>04/05</td>
<td>Pampas</td>
<td>CSIRO small plot - Q506</td>
<td>11</td>
<td>25.1</td>
<td>47.0</td>
<td>129</td>
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<tr>
<td>05/06</td>
<td>Pampas</td>
<td>CSIRO small plot - Q062</td>
<td>11</td>
<td>16.8</td>
<td>57.7</td>
<td>149</td>
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<tr>
<td>05/06</td>
<td>Pampas</td>
<td>CSIRO small plot - Q063</td>
<td>11</td>
<td>7.8</td>
<td>50.0</td>
<td>146</td>
</tr>
<tr>
<td>05/06</td>
<td>Norwin</td>
<td>CSIRO small plot - Q064</td>
<td>11</td>
<td>8.4</td>
<td>38.0</td>
<td>132</td>
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<tr>
<td>06/07</td>
<td>Pampas</td>
<td>CSD small plot - Q0701</td>
<td>11</td>
<td>67.15</td>
<td>89.1</td>
<td>167</td>
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<tr>
<td>06/07</td>
<td>Brookstead</td>
<td>CSD small plot - Q0702</td>
<td>11</td>
<td>46.97</td>
<td>74.9</td>
<td>153</td>
</tr>
<tr>
<td>06/07</td>
<td>Brookstead</td>
<td>CSD box trial - Q0703</td>
<td>11</td>
<td>24.87</td>
<td>76.5</td>
<td>169</td>
</tr>
</tbody>
</table>

*QDPI planted, stem cut and counted*

Mean: 149

S.E.: 15
Disease survey results:

Fusarium wilt of cotton in NSW

- Incidence (farms)
- Resistant varieties (%)

Courtesy NSW DPI
IDM for Fusarium wilt

• Plant a high F.rank variety
• Use Bion seed treatment
• Delay planting to the end of October
• Avoid cultivating with knives
• Retain cotton residues on the surface
• Bare fallow rotation is best
• Burn, bury or bale cereal residues ASAP
• Minimise your tailwater
• Summer flooding if possible
• Always practice good farm hygiene
Some conclusions

• Disease surveys provide useful data
• CSIRO cotton breeding
  – All material is screened for immunity to bacterial blight
  – All material is screened for resistance to Fusarium wilt
  – Resistance to black root rot is needed
• Resistance ranking is good for growers and assists with marketing
• IDM supports use of resistant varieties