Breeding sustainable milling wheat varieties

AMC May 2016
Dr Steve Jefferies, CEO, AGT
North American cereal yields

- Corn
- Barley
- Wheat
- Wheat (Canada)

Introduction of hybrid corn
Corn is displacing wheat in the US

Change in wheat acres (10 years)

Change in corn acres (10 years)
What has driven the success of hybrid corn in the US?

• Increased feed and fuel (ethanol) demand
• Improved agronomy
• Breeding
  • Growers must buy hybrid seed every year
What has driven the success of corn in the US?

Seed Royalties

Grower buys new Seed every year

Investment in Corn breeding
Hybrid seed creates an excellent value ($) capture system for corn breeders
What about Australia?

- Wheat is by far the dominant crop in Australia
- Corn is a summer crop, Australia too dry in summer
- Very small trade in wheat seed - 95% farmer saved seed
- Hybrid wheat seed not practical
- Little or no means for breeder to capture return from seed royalties
What did Australia do about this?

• Plant Breeders Rights legislation amended in 1994 to;
  • create incentive for greater private investment
  • allow breeder to capture a return on investment at ANY single point in the use of the variety

• Still no impact due to farmer saved seed provisions

• Grower led development and introduction of End Point Royalty (EPR) system in 1998
EPRs drive change to Australian wheat breeding

• 98% wheat breeding in Australia prior to 2000 was in the public sector
  • Approximately $18 million/year invested
• 15 years later (2015)
  • 100% of wheat breeding in the private sector
  • 100% funded by EPR
  • >$45 million/year invested in wheat breeding and still increasing
• $$$ invested in Australian wheat breeding has more than doubled over the past 10 years
• What has been the impact???
• A bit early to draw a graph like corn in the US
• AGT - an example of the impact of >$ investment in wheat breeding in Australia
Background to AGT

Australian Wheat Breeding
Began 1880’s, publicly funded until 2002

AGT established
2002

Shareholders
GRDC, UA, SARDI, Limagrain (Vilmorin & Cie)
AGT’s investment in wheat breeding now exceeds all of Australian public and private combined in 2000.
How it all starts – the cross
Breeding is a numbers game

Parent 1

<table>
<thead>
<tr>
<th>Trait</th>
<th>Genes</th>
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<tbody>
<tr>
<td>Flour yield</td>
<td>3</td>
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<tr>
<td>Flour colour</td>
<td>2</td>
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<tr>
<td>Water absorption</td>
<td>3</td>
</tr>
<tr>
<td>Rmax</td>
<td>3</td>
</tr>
<tr>
<td>Baking</td>
<td>4</td>
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Parent 2

<table>
<thead>
<tr>
<th>Trait</th>
<th>Genes</th>
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</thead>
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<tr>
<td>Extensibility</td>
<td>4</td>
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<tr>
<td>Development time</td>
<td>3</td>
</tr>
<tr>
<td>Mixing tolerance</td>
<td>3</td>
</tr>
<tr>
<td>Noodle colour stability</td>
<td>3</td>
</tr>
<tr>
<td>Noodle texture</td>
<td>2</td>
</tr>
</tbody>
</table>

New variety

Combine all 30 genes

Frequency of “target variety” = \( \left( \frac{1}{2} \right)^{30} = \frac{1}{1,073,741,824} \)
The AGT wheat breeding funnel

Year 1: 1,000 parent combinations
Year 2-4: 200,000
Year 5: 20,000
Year 6: 2,000
Year 7: 200
Year 8: 20
Year 9: 2
Breeding is a numbers game

One of AGT’s 50 breeding sites
80 hectares
60,000 yield plots
40t of pure breeder’s seed
The fundamentals of successful Breeding

Maximise rate of genetic gain for every $ invested

Population size
- it’s a numbers game

Cycling time
- time from cross to elite progeny as parent
The population size chance of success

AGT
250,000 yield plots

Canada
80,000 yield plots

UK
100,000 yield plots

France
120,000 yield plots
Cycling time

Time from cross to elite progeny becoming a parent - in 2 ways

1. More generations in 1 year
2. Identify elite parents earlier
AGT has produced more DNA data in the past 12 months than all Australian wheat breeding in the past 100 years.
High throughput field technologies

Robotics, GPS technology, and more
Sophisticated experimental design and analysis
AGT from 2002 to 2015

Released 51 varieties since 2002

11 Australian Prime Hard (APH)
18 Australian Hard (AH)
10 Australian Premium White (APW)
 2 Australian Soft (AS)
 3 Durum (AD)
 3 Feed/Dual Purpose
 4 Triticale
Mace is the most successful wheat variety in the history of Australian wheat breeding (% of Australian production)

Mace 29% 2014
Gamenya 22% 1973
Janz 19% 1998
Halberd 15% 1984
Spear 13% 1992

* On average WA growers $39.84/ha better off from adopting Mace
First 2-gene Clearfield wheat variety released in the world

Kord Cl Plus
Justica CL Plus
Elmore CL Plus
Grenade CL Plus
Hatchett CL Plus

Intervix® herbicide
Application rate: 750 mL/ha + adjuvant @ crop growth stage GS13
Breeding milling quality wheat

- Australian breeders primarily target the Australian wheat quality classes
  - APH
  - AH
  - APW
  - ANW
  - AS
- Major focus on export markets
# EPR compliance in Australia

## WHEAT EPR

<table>
<thead>
<tr>
<th>STATES</th>
<th>2012/13 Compliance %</th>
<th>2013/14 Compliance %</th>
<th>2014/15 Compliance %</th>
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</thead>
<tbody>
<tr>
<td>QLD / NT</td>
<td>44.3</td>
<td>56.4</td>
<td>64.0</td>
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<tr>
<td>NSW</td>
<td>63.9</td>
<td>72.8</td>
<td>71.1</td>
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<tr>
<td>VIC / TAS</td>
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<td>71.0</td>
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<tr>
<td>SA</td>
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<td>WA</td>
<td>86.6</td>
<td>91.7</td>
<td>96.7</td>
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<tr>
<td>Totals</td>
<td>77.1</td>
<td>82.5</td>
<td>87.8</td>
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</table>

## BARLEY EPR

<table>
<thead>
<tr>
<th>STATES</th>
<th>2012/13 EPR Compliance %</th>
<th>EPR Compliance %</th>
<th>2014/15 Compliance %</th>
</tr>
</thead>
<tbody>
<tr>
<td>QLD / NT</td>
<td>38.2</td>
<td>54.1</td>
<td>60.5</td>
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<tr>
<td>NSW</td>
<td>33.8</td>
<td>61.2</td>
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<td>WA</td>
<td>68.7</td>
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</tr>
<tr>
<td>Totals</td>
<td>71.0</td>
<td>76.3</td>
<td>81.2</td>
</tr>
</tbody>
</table>
Breeding quality milling wheats
Quality Traits Breeders Need to Manipulate in hard wheat

**Grain, Milling and Dough Quality**
- Screenings
- Test weight
- Hardness
- Milling yield
- Bran content
- Flour brightness
- Flour yellowness
- Water absorption
- Dough Development time
- Dough Mixing stability
- Dough Strength
- Dough Extensibility
- Peak Viscosity

**Baking Quality**
- 3 different baking methods
- Loaf volume
- Crumb colour
- Appearance
- Texture

**YAN/Ramen Quality**
- Noodle sheet brightness
- Noodle sheet yellowness
- Change of brightness
- Change of yellowness
- Yield
- Texture, bite and mouth feel
Selection for Quality at AGT

- Two fully equipped in-house labs
- Junior milling and Buhler milling
- Dough rheology
  - mixograph
  - farinograph
  - extensograph
  - SDS
  - RVA
- HMW and LMW glutenins
- Whole grain NIR
- DNA technology
- End product testing

2,000 potential new varieties assessed each year
The AGT wheat breeding funnel

Year 1: 1000 parent combinations

Year 2-4: 200,000
- Grain Size and Confirmation
  + DNA, SDS, Glutenin, Jn Mill/Mixo

Year 5: 20,000
- + Buhler Mill, Dough Rheology

Year 6: 2,000
- + End Products

Year 7: 200
- + End Products

Year 8: 20

Year 9: 2
- Final Classification and Variety Release
Breeding quality wheat

• Breeding for the commodity (APH, AH) market will remain our primary target
• Will focus more on differentiation
• Eg we can produce a better baking wheat than CWRS or DNS from North America
• Needs different supply chain solutions
• Hybrid seed in US has created and excellent $ value capture system for breeders
• $ invested in breeding has driven yield increases in corn
• EPR system is a $ value capture system unique to Australia – wheat, barley etc
• EPRs have facilitated major change to Australian wheat breeding (eg AGT)
• The level of investment in Australian wheat breeding has more than doubled in past 10 years and still increasing
• We now have unprecedented rates of genetic gain and will continue to increase
• We have had some success in the past (Mace, Suntop etc) but we are going much bigger, harder, faster, now than ever before
• We have a lot to look forward to from Australian wheat and plant breeding
• Australian wheat breeders focus on export markets
• We need to improve EPR compliance in domestic markets
Nobel Peace Prize Winner, 1970

Norman Borloug

Father of the green revolution

Wheat Breeder