Wheat: breeding, physiology, agronomy

John Passioura
CSIRO, Plant Industry
Water as a limiting resource
Current dryland wheat yields are much less than the water-limited potential

How to improve water-limited yield:

Produce crops that:

• Use more of the rainfall
• Trade water for CO₂ more effectively
• Convert more biomass into grain
Water Supply

Soil water at sowing
Growing-season rain

Losses:
- Net runoff
- Deep drainage
- Soil evaporation

Water used by crop

Water not extracted by crop

Biomass

Trade water for CO₂

Convert biomass into grain

Grain Yield

Passioura and Angus 2010
Water Supply

Soil water at sowing

Losses:
- Net runoff
- Deep drainage
- Soil evaporation

Growing-season rain

Water not extracted by crop

Water used by crop

Trade water for CO₂

55 kg/ha per mm

Biomass

Convert biomass into grain

Harvest index 0.40 → 22 kg/ha per mm (2.2 tonne/ha per 100mm)
Australian Wheat Yield from 1850

Yield (t ha⁻¹)

1860 1880 1900 1920 1940 1960 1980 2000

0.0 0.5 1.0 1.5 2.0 2.5

Nutrient exhaustion
Fallowing & mechanisation
Phosphorus & improved pasture
Break crops & nitrogen
Millenium drought

Courtesy of John Angus
Silver bullets?

• Drought tolerance?
• Salt tolerance?

Marginal improvements at best
Source: Cordell et al, 2009
### Prebreeding

**Traits for improved performance under drought:**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Selection environment</th>
<th>Molecular Markers</th>
<th>Best selection method</th>
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</thead>
<tbody>
<tr>
<td>Seedling establishment</td>
<td>Favourable</td>
<td>Yes</td>
<td>Phenotype and marker</td>
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<tr>
<td>Shoot vigour</td>
<td>Favourable</td>
<td>Yes</td>
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<tr>
<td>Root vigour</td>
<td>Favourable</td>
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<td>Phenotype</td>
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<tr>
<td>Root length</td>
<td>Favourable</td>
<td>No</td>
<td>Phenotype</td>
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<tr>
<td>Transpiration efficiency</td>
<td>Favourable</td>
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<tr>
<td>Stem carbohydrates</td>
<td>Favourable</td>
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</tr>
<tr>
<td>Reduced tillering</td>
<td>Favourable</td>
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<td>Phenotype or marker</td>
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<td>Glaucousness</td>
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<td>Floret sterility</td>
<td>Droughted (?)</td>
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<td>Phenotype</td>
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</tbody>
</table>

Richard Richards 2010
Risk faced by farmers:

• Drought
• Cold, heat, waterlogging….
• Weeds
• Pests
• Diseases
• Prices – inputs, markets
• Legislation
• Domestic…….
Symptoms

- Low harvest index
  - Kernels small
  - Kernels large, filled, but very few

- Low biomass
  - Normal or high plant density
  - Low plant density

Diagnosis

- Kernels pinched
  - Water deficit and/or lodging before anthesis
  - Inhospitable substratum

- Kernels filled but few
  - Root or foliar disease
  - Frost after anthesis

- Water deficit before anthesis
- Frost or water deficit before anthesis

- Late sowing
  - Low soil fertility
  - Water deficit before anthesis

- Early infection
  - Inhospitable substratum

- Poor plant establishment
Agronomic adaptation

Tactical responsiveness
now (but 5-10 years to create flexibility)

Increase range of novel options through R&D
5-30+ years
Grazing vegetative wheat crops defers water use and can increase yield.

Grain yield
2.27 t/ha  2.80 t/ha

John Angus
Timeliness is crucial
Roots in the field

genetics and environment
Wheat root systems doubled in new wheat lines

G. Rebetzke
New lines have deeper roots at grain development in the field

23 cm; 24% deeper

Extra 20 mm of deep water ~ Valuable 0.5 tonnes of grain

Michelle Watt
Wheat root in conventional ploughed soil

Wheat root in conservation farming soil

Wheat root in conservation farming soil

conservation farming soil

pore

slow growth high microorganisms

tip

fast growth low microorganisms

Michelle Watt
New line has faster root growth and fewer inhibitory rhizosphere bacteria

[Image of Vigour line and Conventional cultivar with bar graph showing bacteria count]