The remarkable improvements in Australian mixed farming

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Average dryland farm – land area, crop area and livestock number

ABARE data
Australian wheat yields, 1850-2010

Yield (t/ha)

0.0
0.5
1.0
1.5
2.0
2.5

1860 1880 1900 1920 1940 1960 1980 2000

Nutrient exhaustion
Superphosphate
Fallowing
New cultivars
Legume nitrogen
Better rotations
Mechanisation
Semidwarf cultivars
Selective grass herbicides
N fertiliser in Sth. Aust
Break crop (canola) in Sth. Aust
Break crop (lupin) in WA
Millenium drought

Aust. J. Exp. Agric 41, 277-288
Wheat yield gap below the water-limited potential

China Loess Plateau
Mediterranean Basin
North American Great Plains
SE Australia

Aust. J. Agric. Res 57, 847-856
Contributions to increased wheat productivity

**Breeding**
- Timing
- Disease resistance
- Stress tolerance ([www.patentlens.net](http://www.patentlens.net) / search: wheat & drought)
- Stature – semi dwarfs
- Grain quality

**Crop management**
- Timing
- Nutrition – fertilisers and pasture-N
- Crop sequences – rotation
- Tillage and stubble management
- Correcting soil acidity - liming
- Weed control – herbicides
- Disease control - fungicides

**Climate change**

**Adoption - innovation**
<table>
<thead>
<tr>
<th>Reference</th>
<th>Region</th>
<th>Percentage of yield improvement due to management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warren (1971)</td>
<td>Southern NSW</td>
<td>100</td>
</tr>
<tr>
<td>Russell (1973)</td>
<td>South Australia</td>
<td>78</td>
</tr>
<tr>
<td>Greb (1979)</td>
<td>USA</td>
<td>70</td>
</tr>
<tr>
<td>Ridley and Hedlin (1980)</td>
<td>Canada</td>
<td>85</td>
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<td>Schmidt (1984)</td>
<td>USA</td>
<td>47</td>
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<tr>
<td>Perry and D’Antuono (1989)</td>
<td>Western Australia</td>
<td>71</td>
</tr>
<tr>
<td>Bell et al (1994)</td>
<td>Mexico</td>
<td>50</td>
</tr>
<tr>
<td>Anderson and Impiglia (2002)</td>
<td>Western Australia</td>
<td>68</td>
</tr>
<tr>
<td>Horie (2004)</td>
<td>Rice, Japan</td>
<td>100</td>
</tr>
<tr>
<td>Mackay et al (2010)</td>
<td>UK winter wheat ’48 -’82</td>
<td>40</td>
</tr>
<tr>
<td>Mackay et al. (2010)</td>
<td>UK winter wheat ’83 -’07</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>65</td>
</tr>
</tbody>
</table>
Trends of WA wheat yield on farms and in variety trials

Variety yields by year of release (Perry and D'Antuono 1989)

WA wheat yields (5-year running mean)
Western Australian wheat and barley yields, 1876-2010

The graph shows the yield (t/ha) of wheat and barley from 1860 to 2020. The yield ratio (wheat/barley) is also depicted over the same period. The yields have seen an overall increase, with fluctuations in specific years.
Wheat yields on farms and variety trials in the Victorian Wimmera

Yield (t/ha)

Free Gallipoli
Federation
Ghurka
Summit
Pinnacle
Meering
Cocamba
Kewell
Free Gallipoli
Federation
Ghurka
Pinnacle
Meering
Cocamba
Kewell

Breeding

Management

Contributions to grain yield

GRDC R&D investments in 2005-06

- Varieties: $55.1m
- Practices: $36.7m
- New Products: $11.2m
- Communications: $8.9m
- Others: $3.4m
Middle-distance speed of racehorses (selectively bred) and human males (not selectively bred)
Adoption of N fertiliser in Australia is recent

The graph illustrates the adoption of nitrogen fertiliser in Australia and worldwide from 1950 to 2010. The x-axis represents the years, while the y-axes represent the quantity of nitrogen fertiliser used, with one axis showing world nitrogen fertiliser in units of $10^6$ t N and the other showing Australian nitrogen fertiliser in units of $10^3$ t N. The chart highlights the recent increase in the use of nitrogen fertiliser in Australia compared to the world.
Wheat yield response to topdressed nitrogen fertiliser

Shoots / m²

Yield response to 40 kg N/ha topdressed

- After break crop
- No break crop

Shoots / m²

Yield response to 40 kg N/ha topdressed

- After break crop
- No break crop
Canola triggered the use of lime and nitrogen fertiliser
NSW canola and lime use

Lime ('000 tonnes)

Canola area ('000 ha)
Prime hard wheat experimental sites
Grain quality: screenings of wheat grain in 3 regions

- North
- SE
- West

![Graph showing grain protein and screenings in 3 regions](image)
Rotations
Crop sequences
Break crops
One of 700 assessments of break crops

Wheat after wheat
2 t/ha

Wheat after canola
5 t/ha
Possible mechanisms of the break-crop effect

- Root disease – absence of host or biofumigation?
- Foliar disease
- Residual water
- Residual nutrients
- Biologically fixed N residues
- Hydrogen fertilisation
- Suppression of arbuscular mycorrhizal fungi (AMF)
- Better weed control / earlier sowing
Take-all fungus in wheat roots
Suppression of take-all by brassica and linseed tissue ‘biofumigation’
Hydrolysis of glucosinolates releases isothiocyanates

\[
\begin{align*}
N - OSO_3^- & \quad \text{Glu} \\
\| & \\
\text{Glu - S - C} & \quad \text{R-N=C-S} \\
\downarrow & \\
R & \\
\text{Glucosinolate} & \quad \text{Isothiocyanate}
\end{align*}
\]

R = phenylethyl  (generally present in Brassica roots)
= propenyl  (present in mustard roots)
Hydrogen fertilisation

Nodule

$\text{N}_2 + 6\text{H}^+ + 6\text{e}^- \rightarrow 12\text{ATP} \rightarrow 12\text{ADP} \rightarrow 2\text{NH}_3$

$3\text{H}^+ + 3\text{e}^- \rightarrow 1.5\text{H}_2$

Uptake Hydrogenase (HUP+)
Many symbioses are HUP-
Break crops regulate mycorrhizal colonisation of wheat

Previous crop

\( \Delta \) wheat
- field pea
- canola

Filled symbols  no P
Open symbols  17 kg P/ha

Break-crop effect of oats (0.47 t/ha)

Yield of wheat after oats (t/ha)

Yield of wheat after wheat (t/ha)

Sweden
Australia
Other

Australian Agronomy Society 2008
## Yields benefits of break crops for wheat

<table>
<thead>
<tr>
<th>Break crop</th>
<th>Yield benefit (t/ha)</th>
<th>Wheat yield</th>
<th>No. of obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>+0.19</td>
<td>3.52</td>
<td>60</td>
</tr>
<tr>
<td>Oats</td>
<td>+0.50</td>
<td>3.68</td>
<td>150</td>
</tr>
<tr>
<td>Canola</td>
<td>+0.79</td>
<td>3.45</td>
<td>180</td>
</tr>
<tr>
<td>Mustard</td>
<td>+0.58</td>
<td>3.03</td>
<td>59</td>
</tr>
<tr>
<td>Flax</td>
<td>+0.91</td>
<td>3.20</td>
<td>38</td>
</tr>
<tr>
<td>Field pea</td>
<td>+1.00</td>
<td>2.63</td>
<td>82</td>
</tr>
<tr>
<td>Fababean</td>
<td>+1.10</td>
<td>4.00</td>
<td>41</td>
</tr>
<tr>
<td>Lupin</td>
<td>+1.46</td>
<td>2.24</td>
<td>53</td>
</tr>
<tr>
<td>Chickpea</td>
<td>+0.98</td>
<td>1.73</td>
<td>54</td>
</tr>
<tr>
<td>Lentil</td>
<td>+0.71</td>
<td>2.24</td>
<td>32</td>
</tr>
</tbody>
</table>
Lupins give a greater break-crop benefit than field pea
Effect of 3 different break crops on wheat yield

<table>
<thead>
<tr>
<th>Barley</th>
<th>Oats</th>
<th>Canola</th>
<th>Mustard</th>
<th>Flax</th>
<th>Field pea</th>
<th>Lupin</th>
<th>Wheat</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.21</td>
<td>+0.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.59</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>+0.60</td>
<td>+0.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.12</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>+1.08</td>
<td>+1.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.54</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+1.55</td>
<td>+1.82</td>
<td>3.25</td>
<td>31</td>
</tr>
</tbody>
</table>
Sources of the break-crop effect and estimates of their contribution to additional yield for a 4 t/ha wheat crop

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<thead>
<tr>
<th>Mechanism</th>
<th>Additional yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-all suppression</td>
<td>0.5</td>
</tr>
<tr>
<td>Suppression of other root diseases</td>
<td>0.3</td>
</tr>
<tr>
<td>Net N benefit of canola</td>
<td>0.1</td>
</tr>
<tr>
<td>Hydrogen fertilisation by legumes</td>
<td>0.4</td>
</tr>
<tr>
<td>Suppression of AMF by non-hosts</td>
<td>0-0.1?</td>
</tr>
<tr>
<td>Net N benefit of legumes</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Adoption of break crops (particularly canola) triggered:

Liming
Increased yield of following cereals
More extraction of soil water and N by wheat
More reliable cereal response to N fertiliser
Lime helped the return of lucerne and barley
Twenty-years of conservation cropping at Harden
Yield response to direct drilling in relation to seasonal rainfall

Growing season rainfall (mm)

Yield diff (RDD-BC) (t/ha)

-1.5
-1.0
-0.5
0.0
0.5
1.0

Yield gain

Yield loss

Growing season rainfall (mm)

Longterm Average
Wheat response to conservation cropping at Harden

DC30 Biomass (g/m²)

- Burn/Cult
- Retain/DD

Yield (t/ha)

- * indicates significant difference
Yield (t/ha) of wheat grown every second year, Harden 1990-2008

<table>
<thead>
<tr>
<th></th>
<th>Burn</th>
<th>No burn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Till</td>
<td>4.8</td>
<td>4.4</td>
</tr>
<tr>
<td>No till</td>
<td>4.6</td>
<td>4.3</td>
</tr>
</tbody>
</table>
Grazing vegetative crops
Effects of grazing vegetative crops with sheep (~20 dse /ha for 30-50 days) 
delayed maturity (1 day's flowering delay per ~4 grazing days)
deferred water use
poor nitrogen uptake after grazing?
reduced lodging of early-sown crops
yield response - 4 ± 25%
Wheat yield increased by grazing because water use is deferred until after flowering.

2.27 t/ha  2.80 t/ha
Reintegrating livestock with cropping

Opportunities

- Perennial pastures
- Grazed crops
- Failed crops as a feed source
- Wool-shedding sheep (Dorper & Wiltipolls)
  - Fewer pests (flies, worms, PETA)
- Transporting northern cattle south?

Problems

- Breeding stock on grazed crops
- Excess paddock size
- Less shade
Innovation and adoption

‘The County Agent’, Norman Rockwell, 1948
Adoption: Delay of ~30 years between research and adoption on farms. Alston et al. 2010.

Innovation: users of products and services—both firms and individual consumers—are increasingly able to innovate for themselves. von Hippel 2005
## Acknowledgements

<table>
<thead>
<tr>
<th>Wal Anderson</th>
<th>John Passioura</th>
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<tbody>
<tr>
<td>Bill Bowden</td>
<td>Mark Peoples</td>
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<tr>
<td>Tony Fischer</td>
<td>Megan Ryan</td>
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<td>Tony Good</td>
<td>Victor Sadras</td>
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<tr>
<td>John Kirkegaard</td>
<td>Anthony van Herwaarden</td>
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<tr>
<td>Lars Ohlander</td>
<td>Jim Virgona</td>
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<td>John Oliver</td>
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</tbody>
</table>
Nitrogen supply and demand by a wheat crop

N supply and demand (kg ha$^{-1}$ day$^{-1}$)

Demand

Supply
Grain quality: test weight of wheat grain in 3 regions

- North
- SE
- West