Value of French serradella (*Ornithopus sativus* Brot.) pastures for the control of annual ryegrass (*Lolium rigidum* Gaud.) in the Central Wheatbelt of Western Australia

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Traditional crop-pasture rotations

- Ley farming system developed in 1930s
- Successful during 1950s and 1960s
- Drivers of adoption:
  - High livestock profitability
  - Hard-seeded annual legumes
  - Superphosphate
  - Cultivation and grazing kill crop weeds
Extended crop rotations

- Extended crop sequences used 1970s onwards
- Drivers of adoption:
  - High relative profitability of cropping
  - Reduced tillage systems
  - Introduction of selective herbicides
  - Widespread uptake of N fertiliser and grain legumes
- Barriers exist:
  - Development of herbicide resistance in weeds
  - Soil fertility decline
  - High recharge to saline water tables
Annual ryegrass (*Lolium rigidum* Gaud.)

- Development of resistance promoted by heavy reliance on efficient selective herbicides
- Survey in WA wheatbelt:
  - 68% resistant to diclofop, 61% to sethoxydim
  - 88% resistant to sulfometuron
  - Development of resistance to Group C and D chemicals
- Most herbicide-resistant weed in global agriculture (Pannell et al., 2004)
- Strategies for in-crop integrated weed management expensive

Source: Professor Stephen Powles, WAHRI
“Phase farming” (Reeves and Ewing, 1993)

- Extended crop sequences (3-8 years) prevent regeneration of pasture
- Re-sow pasture species in each phase
- Opportunity to control weeds, improve soil fertility and dry profile
- Use annual or perennial pastures (differ in establishment costs)

Source: Dr Lindsay Bell, CSIRO
First seed of cv. Cadiz released in 1996

Bred specifically for phase farming

Most popular sown pasture in WA (Nichols et al., 2006)

Producers can harvest own seed as plant is upright and aerial-seeded

Highly-productive annual legume

Source: Dr Clinton Revell, DAFWA
Economic value of French serradella

- Limited economic analysis of serradella
- Monjardino et al. (2004) studied a three-year phase
- One- and two-year phases are relevant due to perception of lower opportunity cost by farmers

Objective: improve understanding of the circumstances in which serradella is a profitable break pasture in WA mixed-farming systems
RIM model

- Evaluates NPV \( (NPV = \sum_{r=1}^{20} (1+r)^{-t} \pi_t) \) of alternative IWM strategies for ryegrass control
- Fixed rotations
- Good sandplain soil in CWB
- 50 treatments available (cultural, biological, chemical)
- RIM extended to involve wild radish, lucerne, and eastern star clover
- Large number of decisions makes search difficult \( (2^{395} \) solutions in one rotation!)
Compressed annealing (CA)

- First practical application of CA (Ohlmann et al., 2004)
- Random search technique for constrained, combinatorial problems
- Reduce probability of taking infeasible or unprofitable steps as no. of iterations grows
- Near-optimal solution, take best of 10 runs

Source: MATLAB
Rotations

- C: a continuous-cropping rotation
- 7C+S: 7 years crop, 1 year serradella
- 7C+2S: 7 years crop, 2 years serradella
- 7C+3S: 7 years crop, 3 years serradella
- 7C+V: 7 years crop, 1 year unsown pasture
- 7C+2V: 7 years crop, 2 years unsown pasture
## Profit and initial seed burden

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Initial ryegrass seed density (seeds m(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>693</td>
</tr>
<tr>
<td>7C+S</td>
<td>685</td>
</tr>
<tr>
<td>7C+2S</td>
<td>624</td>
</tr>
<tr>
<td>7C+3S</td>
<td>671</td>
</tr>
<tr>
<td>7C+V</td>
<td>590</td>
</tr>
<tr>
<td>7C+2V</td>
<td>513</td>
</tr>
</tbody>
</table>
### Profit and initial herbicide resistance

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Herbicide groups to which annual ryegrass is resistant in Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>C</td>
<td>695</td>
</tr>
<tr>
<td>7C+S</td>
<td>681</td>
</tr>
<tr>
<td>7C+2S</td>
<td>635</td>
</tr>
<tr>
<td>7C+3S</td>
<td>661</td>
</tr>
<tr>
<td>7C+V</td>
<td>579</td>
</tr>
<tr>
<td>7C+2V</td>
<td>490</td>
</tr>
</tbody>
</table>
Severe resistance constrains in-crop weed mgmt.

Figure 1: Plant trajectory in C rotation with and without HR.
Long pasture phase allows intensive weed mgmt.

Figure 2: Plant trajectory in 7C+3S rotation with resistance to Group A-C herbicides.
Optimal strategies for no initial HR in the C rotation

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV=$663</td>
<td>NPV=$674</td>
<td>NPV=$685</td>
</tr>
<tr>
<td>15 applications of knockdown herbicide.</td>
<td>15 applications of knockdown herbicide.</td>
<td>15 applications of knockdown herbicide.</td>
</tr>
<tr>
<td>3 applications of Trifluralin. 1 post-emergent application of Glean®. 1 post-emergent application of Simazine. 2 applications of Hoegrass®. 2 applications of Select®.</td>
<td>2 applications of Trifluralin. 2 pre-emergent applications of Glean®. 1 post-emergent application of Simazine. 2 applications of Hoegrass®. 2 applications of Select®.</td>
<td>1 application of Trifluralin. 2 pre-emergent applications of Glean®. 2 post-emergent applications of Simazine. 2 applications of Hoegrass®. 2 applications of Select®.</td>
</tr>
<tr>
<td>Swathe barley twice.</td>
<td>Swathe barley twice.</td>
<td>Swathe barley twice.</td>
</tr>
<tr>
<td>Use seed catching 7 times and windrowing 7 times.</td>
<td>Use seed catching 4 times and windrowing 9 times.</td>
<td>Use seed catching 5 times and windrowing 8 times.</td>
</tr>
</tbody>
</table>
Optimal strategies for full initial HR in C rotation

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV=$177</td>
<td>NPV=$182</td>
<td>NPV=$234</td>
</tr>
</tbody>
</table>
| 15 applications of knockdown herbicide.  
5 applications of Gramoxone for crop-topping of lupins.  
Green-manure wheat once.  
Cut wheat for hay twice.  
Swathe lupins 4 times and barley 4 times. | 15 applications of knockdown herbicide.  
Brown-manure lupins once.  
2 applications of Gramoxone for crop-topping of lupins.  
Green-manure wheat twice.  
Cut wheat for hay once.  
Cut lupins for silage once.  
Swathe lupins once and barley 4 times. | 15 applications of knockdown herbicide.  
Brown-manure lupins once.  
2 applications of Gramoxone for crop-topping of lupins.  
Green-manure wheat twice.  
Cut wheat for hay once.  
Cut lupins for silage 3 times.  
Swathe lupins twice and barley 4 times. |
| Use seed catching 9 times and windrowing 7 times. | Use seed catching 5 times and windrowing 8 times. | Use seed catching 9 times and windrowing 6 times |
Key findings: computational technique

- Compressed annealing automates search in large, constrained decision space
- Identifies array of near-optimal solutions for each problem instance
- Related work identifies better than use of fixed penalty factor
- Solutions contain (a) core components and (b) tactical strategies
- Role for extension and field trials
Key findings: weed management

- Selective herbicides allow efficient in-crop weed control
- Minimise ryegrass population, loss of profit driven by increased control cost
- A higher weed burden or herbicide resistance increases relative value of pasture
- Single year of serradella sufficient where only Group A herbicides are ineffective
- Three consecutive years warranted with more severe resistance
Limitations

- Limited varieties of pasture considered in fixed rotations
- No inclusion of uncertainty in yield, prices, or treatment efficacy
- Tactical management?
- One soil type in one agro-ecological region
- Annual plants promote recharge to saline water tables; value of lucerne?
Further research

- Some producers have no sheep: lifestyle, low profitability, labour supply, preferences, age
- Grain legumes (e.g. lupins) becoming less profitable, esp. with herbicide resistance
- Value of pasture with no sheep?
- Particularly:
  - hard-seeded medics for a “ley fallow”? or
  - undersowing with pasture seed in crop year?
I would like to thank:

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