Managing fertiliser inputs on high phosphorus status soils: incorporating soil constraints into decisions

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Background

• Most soils in WA exceed critical levels for soil P
  – 87% soils sampled 09/10 exceeded critical level for P
  – 63% exceeded critical level for P and were below pH 5.5 (CaCl₂)
  – 80% below pH 5.5 (CaCl₂)
  – ~ 90% adoption of minimum tillage (in some cases 20+ years)
• Yield responses to fertiliser P are occurring where soil P > critical level
• Why?
  – Phosphorus is relatively immobile in soil
  – Constraints to root exploration limit soil P availability
Effect of soil pH and rotation on soil P availability

- Aluminium (CaCl$_2$) > 5 mg/kg causes root pruning
  - Reduced access to moisture and nutrients
- Rotation history also can affect soil nutrient availability
  - Root disease
  - Herbicide carry-over

Extractable Al is toxic to root growth at greater than 5 mg/kg.
Trial site history

• Trial established by Barton in 2009 at WHRS
• Lime treatments
  – Lime 2009 - 3.5 t/ha, 2012 – 1t/ha
  – No lime
• Rotation treatments
  – Continuous wheat
  – Lupin wheat (Lupin 2009 only)
• Barton plots split to apply different P rates 2012
## Soil chemical analysis April 2012

Soil surface (0 – 10 cm)

<table>
<thead>
<tr>
<th>Main Treatment 2012</th>
<th>Ammonium Nitrogen</th>
<th>Nitrate Nitrogen</th>
<th>Phosphorus Colwell</th>
<th>PBI</th>
<th>Potassium Colwell</th>
<th>Sulphur</th>
<th>Organic Carbon</th>
<th>pH Level (CaCl₂)</th>
<th>Aluminium CaCl₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lime / Lupin-Wheat</td>
<td>6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>2. Lime / Continuous wheat</td>
<td>6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>3. No lime / Lupin-Wheat</td>
<td>7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.90</td>
</tr>
<tr>
<td>4. No lime / Continuous wheat</td>
<td>8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.30</td>
</tr>
</tbody>
</table>

* No significant difference at any depth

## Soil profile – Extractable Al (CaCl₂) [mg kg⁻¹]

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Lime</th>
<th>No lime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lupin-Wheat</td>
<td>Continuous wheat</td>
</tr>
<tr>
<td>0 to 10</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td>10 to 20</td>
<td>5.7</td>
<td>4.4</td>
</tr>
<tr>
<td>20 to 30</td>
<td>3.0</td>
<td>2.1</td>
</tr>
<tr>
<td>30 to 40</td>
<td>0.4</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* No significant difference at any depth
P uptake at anthesis

- Soil P availability significantly higher where lime was applied (0 P)
- Rotation had no effect where lime was not applied
- For Lupin-Wheat, uptake significantly higher where 10 and 20 kg P applied

L.S.D. ($p < 0.05$) for all treatments: 1.73
Weed biomass at anthesis

- **Lupin-wheat**
  - Lime has less ryegrass
- **Wheat-wheat**
  - Lime has more ryegrass
- **Weed biomass decreases as shoot biomass increases**
  - Competition effect
- **Lime history has not affected herbicide efficacy**
Grain yield

Significant yield responses to fertiliser P

- Trend in yield potential
  - Highest in 1. Lime / Lupin-Wheat
- Trend in P response
  - Greater yield response to 5 and 10P where lime has been applied

L.S.D. (p < 0.05) for all treatments: 577
Determinants of grain yield

- Grain yield had best correlation with:
  - Anthesis biomass
  - P uptake
  - Heads m\(^{-2}\)
- No relationship between grains per head or grain weight
- Grain yield response to treatments occurred early in season
Stored soil moisture at maturity

- Differences ~ 10 mm though not significant
- At WUE of 10 to 20 kg grain / mm is only 100 to 200 kg grain

L.S.D. (p < 0.05) for all treatments: 22
Summary – Soil pH x P

- Lime significantly increased access to background soil P (uptake at 0 kg P ha\(^{-1}\))
- Greater crop biomass in response to lime and P treatments reduced weed biomass
- Significant GY response to fertiliser P in lime treatments only
- Trend of greater GY response to 5 and 10P in lime treatments
Effect of water repellence on soil P availability

- Soil water repellence leads to
  - Preferential flow
  - Incomplete wetting of surface layer (0 to 10 cm)
- Roots can not access nutrients in dry soil
- Actual soil P supply in WR soils may be less than supply estimated by soil testing
Water repellence and soil P - Badgingarra

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MED 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nil</td>
<td>1.5</td>
</tr>
<tr>
<td>2. Banded wetter</td>
<td>1.6</td>
</tr>
<tr>
<td>3. Mouldboard plough</td>
<td>0</td>
</tr>
<tr>
<td>4. Rotary spading</td>
<td>0</td>
</tr>
</tbody>
</table>
Water repellence and soil P - Badgingarra

- 2011
  - ~400 kg ha\(^{-1}\) GY response to 20 P in control and banded wetter
  - No response to 20 P in MP and SP

- 2012
  - GY at 0P similar for Nil and MB
  - Response to 20P greatest in Nil
    - Higher yield potential

- 0 and 20P treatments repeated on same plots
  - 0P: Run-down
  - 20P: Build-up

- Sensitivity of GY response to lower rates (e.g. 5, 10 kg P) not known at this site

* Data for high N, high K treatments only
Water repellence, pH and soil P - Darkan

- Interaction between cultivation, lime and applied P on a water repellent acidic gravelly loam
- 0-10 cm
  - P 75 mg/kg
  - pH 4.4 (CaCl2)
  - MED 3
- 10-20 cm
  - pH 4.8 (CaCl2)
- 20-30 cm
  - pH 5.4 (CaCl2)
Water repellence and soil P - Darkan

- Cultivation had greater impact than lime
- No cultivation, no lime
  - 15 kg P needed to reach max yield
- Cultivation, hylime
  - 7.5 kg P needed to reach max yield

LSD (5%) 388 kg ha$^{-1}$
Root disease

- Affects soil P availability via soil exploration
  - Reduced root length
- Interactions
  - Rhizoctonia worse where
    - Cu and Mn were inadequate
    - Chlorsulfuron reduced zinc uptake

Rhizoctonia bare-patch and root damage

Photo: D. Hüberli
Root disease – current levels

- Focus paddock survey (188 paddocks)
  - Rhizoctonia most common root disease
  - All diseases most prevalent in southern region
Take-all

- Curvature co-efficient (kg grain per kg P) decreased with increasing take-all
  - Fertiliser P used less efficiently as root disease increased
- Lower yield potential
- Less root surface area?

Interactions between herbicides and soil P availability

- Reduced P concentration observed when chlorsulfuron applied in cv. Kulin
  - No affect in cv. Reeves
- No affect on GY for either variety

Source: Osborne et al., AJAR, 1993. 44
Key messages

• Soil P availability reduced at pH < 4.8 (CaCl$_2$)
• Root disease can reduce soil P availability
  – Rhizoctonia most common root disease
  – Rotation history an indicator of disease risk
• Water repellence reduces soil P availability
• Root pruning by herbicides less important
  – Impact likely to depend on other constraints
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  - UMU00035 ‘Improving profit from fertiliser through knowledge-based tools that account for temporal and spatial soil nutrient supply’
  - DAW00213 ‘Putting the Focus on Profitable Crop and Pasture Sequencing’.
  - DAW00201 ‘Identification and characterization of disease suppressive soils in the Western Region’.
Questions?
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