Back to Phosphorus Basics

Rob Norton, *International Plant Nutrition Institute*

*Better Crops, Better Environment ... through Science*

*Incitec Pivot Fertilizers, March 2011.*
Establishment and Foundation

- Potash Institute and then Potash and Phosphate Institute (PPI) trace back to 1930’s in Canada.

  - Inclusion of N producers
  - Potash & Phosphate Institute (PPI) ceased to exist.
  - PPI’s Board committed its scientific staff to IPNI.

- Not-for-profit international decentralized NGO.

- 30 scientific staff operating in >50 countries.

- Purpose to define strategies for appropriate use and management of plant nutrients.

- Australia & New Zealand program began October, 2009.
Overview of Talk

• Balanced nutrition is important for productive pastures.
• Superphosphate provides available P, available S and Ca to pastures.
• Why is P so tricky?
• Allocate fertilizer dollars to the most responsive areas.
  – Pasture test strips help identify responsive areas
  – Soil tests help identify responsive areas
• Maintain a soil P test near the value that supports the stocking rate.
• Use tools available to help think through the options.
Importance of balanced nutrition

• Macro/Primary Nutrients
  – Nitrogen
  – Phosphorus
  – Potassium

• Minor /Secondary Nutrients
  – Calcium
  – Magnesium
  – Sulphur

• Micro/Trace Nutrients
  – Boron
  – Chloride
  – Copper
  – Iron
  – Manganese
  – Molybdenum
  – Nickle
  – Zinc
  – (Selenium)
P is essential for plant and animal nutrition

• In plants:
  – involved in photosynthesis, energy transfer, cell division & enlargement
  – root formation and growth
  – improves fruit & vegetable quality
  – vital to seed formation
  – improves water use
  – helps hasten maturity

• In animals:
  – major component of bones and teeth
  – important for lactating animals
  – P and calcium are closely associated in animal nutrition
  – essential for energy transfer and utilization
Current Nutrient Management “Benchmarks”

• NSW P use figures show a 50% decline over the past decade
  – Reflection of poor seasons & low commodity prices

• Typical Soil Colwell P Test Values
  – About 20-25% low
  – About 50% very high

• Sulphur
  – About 45-50% low
  – About 20% very high

• What is the status of your paddocks?

NSW Fertilizer Sales
Source: FIFA
Variable P, generally low S

![Graph showing variable P and KCl 40 with percentages 6%, 20%, 40%, and 34%]

Colwell P (<200 PBI & 60 mg/kg)
Phosphate sources

- Phosphate Hill Mine – rock phosphate
- Use S from the Lead/Zinc/Silver deposits at Mount Isa.
- Production capacity of 950 kt MAP/DAP
Primary raw material for P fertilizer is phosphate rock: \([\text{Ca}_3(\text{PO}_4)_2]_3 \cdot \text{CaF}_2\)
# Major P containing fertilizers

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>%P</th>
<th>%S</th>
<th>%N</th>
<th>%Ca</th>
<th>Kg to apply 10 kg Pav</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock Phosphate</td>
<td>11.9</td>
<td>0</td>
<td>2.5</td>
<td>-</td>
<td>400</td>
</tr>
<tr>
<td>Reactive RP</td>
<td>13.0</td>
<td>0</td>
<td>5.0</td>
<td>1</td>
<td>38</td>
</tr>
<tr>
<td>Partially Acidulated RP</td>
<td>14.0</td>
<td>8.1</td>
<td>0.2</td>
<td>varies</td>
<td>120</td>
</tr>
<tr>
<td>Superphosphate</td>
<td>8.8</td>
<td>8.0</td>
<td>0.6</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>TSP</td>
<td>20.7</td>
<td>16.1</td>
<td>4.0</td>
<td>1.0</td>
<td>30</td>
</tr>
<tr>
<td>DAP</td>
<td>20.0</td>
<td>17.8</td>
<td>2.0</td>
<td>1.6</td>
<td>30</td>
</tr>
<tr>
<td>MAP</td>
<td>21.9</td>
<td>18.1</td>
<td>3.7</td>
<td>1.5</td>
<td>30</td>
</tr>
<tr>
<td>Pig Bedding (40% mc)</td>
<td>0.45</td>
<td>?</td>
<td>0.75</td>
<td></td>
<td>2200</td>
</tr>
</tbody>
</table>

Cost/kg P = 0.1*Spread Price per tonne/percentage P content

- factor in the value of other nutrients (eg S from AmS @80c/kg)
- calculate on available P (water soluble + citrate soluble)
Fertilizer responses to P and S

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Mar-Jul</th>
<th>Jan-Mar</th>
<th>Dec-Jan</th>
<th>Aug-Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAP pastille</td>
<td>35%</td>
<td>36%</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>MAP</td>
<td>36%</td>
<td>36%</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>SSP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P Recovery

Source, Flavel, Guppy & Blair, 2010 World Soil Science Congress.
Old Redgrass. Wallaby Grass, Bluegrass, Kangaroo Grass, over sown with sub, white & red clovers. UNE
Phosphorus fertilizer and the soil

• Common commercial P fertilizers are highly (≥90%) water soluble
• Once dissolved in soils orthophosphate ions are available for plant uptake
  – primary orthophosphate ion: $\text{H}_2\text{PO}_4^- \ (\text{pH} < 7.0)$ and secondary orthophosphate ion: $\text{HPO}_4^{2-} \ (\text{pH} > 7.0)$
  – Form most common depends on pH
• P chemistry in soils is complex — P may become sparingly available to plants in some soils due to formation of reversion products
  – High or low pH in particular
• Appreciable organic P is also present – 20% to 70% of total P – mineralised before becoming plant available.
Availability and extractability of soil P pools

For most soils, much of this 75%+ enters the low availability pool ... becomes plant available over time.

Recovery by balance method accounts for fertilizer P that enters the less available pools.

Johnston and Syers, 2009.
Implication 1 - Inputs into soil P pools

Johnston and Syers, 2009.
Implication 2 - P balance

- P applications move from fertility build up to fertility maintenance.
- In build up, input will be more than output
  - Low availability pools build up
- During maintenance, can balance output with input
  - Never perfect due to leaching & erosion losses
  - Component of the applied P still ends up in the low availability P pools
  - It is relatively inefficient to try to maintain a high soil P test value
    - relatively more P ends up in low availability P pools

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P in</th>
<th>P out</th>
<th>P build up</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 dse, nil P</td>
<td>8</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>9 dse, soil test 12</td>
<td>53</td>
<td>7</td>
<td>46</td>
</tr>
<tr>
<td>18 dse, soil test 12</td>
<td>70</td>
<td>11</td>
<td>59</td>
</tr>
<tr>
<td>18 dse, soil test 24</td>
<td>94</td>
<td>13</td>
<td>81</td>
</tr>
</tbody>
</table>

Implication 3 - Movement of N, P, K in the Soil

11 kg P applied:

SSP – 1 granule per 30 cm$^2$
MAP – 1 granule per 60 cm$^2$
### Implication 4 - Predicting soil P availability

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Extractant &amp; conditions</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Olsen P</strong></td>
<td>0.5M sodium bicarbonate (pH 8.5) 0.5 h extraction in 1:20 soil:solution.</td>
<td>Olsen et al. 1954. USDA Circular No.939.</td>
</tr>
<tr>
<td><strong>Bray 1 P</strong></td>
<td>0.03M Ammonium Flouride in 0.025M HCl 1 min. extraction in 1:7 soil:solution</td>
<td>Bray &amp; Kurtz 1945. Soil Sci. 59, 39-45.</td>
</tr>
<tr>
<td><strong>Dilute CaCl₂ P</strong></td>
<td>0.005M Calcium chloride in 18 h extraction for 1:5 soil:solution</td>
<td>Moody et al. 1988. Aust.J.Exp.Agric. 23, 38-42</td>
</tr>
</tbody>
</table>

Comparison of the extractants used, the time for extraction and the ratio of soil to extractant specified by six calibrated soil P tests.
Making money from using P fertilizers

• Identify situations where P is limiting pasture growth
  – Acidity
  – Drainage
  – Species composition
  – Previous P history
• Identify the size of the likely response
  – Pasture test strips
  – Soil tests
  – Plant tests
• Identify the value of the added pasture produced
• Balance against the added cost of the fertilizer
Soil tests and pasture responses

- A soil test aims to give a value that indicates how limiting the nutrient is.

- Law of diminishing returns
  - Higher soil test value gives a lower relative response.

- At a critical level (95% of potential), pasture is not limited by the supply of that nutrient
  - Rainfall, other nutrients, drainage, light
Soil tests and pasture responses

- Olsen P values
- Response is affected by co-limiting factors
- Interpret critical values with soil texture, chemistry.
- For Olsen, critical P = 15 mg/kg (=ppm)
- Range of 14-17
- Better Fertilizer Decisions for Pastures.
Colwell P and pasture responses

• A critical P test value depends on soil chemistry – P buffering capacity

• PBI is a measure of how much applied P is transferred to the low availability pools

• Scale 0 to 1000

• Critical value is 95% of potential

<table>
<thead>
<tr>
<th>PBI Category</th>
<th>Critical Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15</td>
<td>Extremely Low</td>
</tr>
<tr>
<td>15-30</td>
<td>Very very low</td>
</tr>
<tr>
<td>36-70</td>
<td>Very low</td>
</tr>
<tr>
<td>71-140</td>
<td>Low</td>
</tr>
<tr>
<td>141-280</td>
<td>Moderate</td>
</tr>
<tr>
<td>281-840</td>
<td>High</td>
</tr>
</tbody>
</table>
Pasture test strips

- Set up on typical species/soil types.
- March to July – preferably before spreading
- Away from fence lines, drainage lines, stock camps.
- Machine or hand spread
- Monitor growth, height, composition, evenness

From soil test values to investments

1. Use soil testing to assess the P-fertility status of your soil.
2. Determine the stocking rate that is appropriate for your current or projected soil fertility level.
3. Determine how much P needs to be applied given your projected stocking rate and soil P status.
4. Check that the proposed investment in P-fertiliser and/or livestock will generate an acceptable return.
5. Think through any other factors that might modify your decision to apply P.

Apply P and/or adjust livestock numbers.
How much P to apply?

- Maintenance of fertility = keep same DSE and Colwell P

How much is needed to meet the present stocking rate demand?

0.5 kg P/DSE - exported in produce

0.3 to 1.0 kg P/DSE lost through leaching, soil erosion

0.1 kg P/DSE in soil fixation (PBI)

Pasture type/rainfall/grazing system

- Increase in fertility = increase DSE and Colwell P

How much is needed to raise the test value to meet the extra demand?

Soil test response to added P

- eg 100 PBI – 2.7 kg P to raise Colwell 1 unit.
- eg 300 PBI – 3.0 kg P to raise Colwell 1 unit.

For example

- 0.9 kg P/DSE
- 100 wethers = 1 t of SSP
What extra carrying capacity will an increase in soil test value give?

- Derived from stocking rate & P trials
  - unfertilized soil test & stocking rate (#1)
    - 6 DSE & 10 Colwell P
    - **5.4 kg P/ha**
  - What is the current soil test & stocking rate (#2)?
    - 10 DSE & 27 Colwell P
    - **9 kg P/ha**
  - To move to 14 DSE – requires Colwell of 35 (#3)?

*Maintenance of 13 kg P/ha + Fertility of + 24 kg P (8 units @ 3 P/unit)*
Decide if this will make you any money

- Extra fertilizer
- Extra costs & stock
- Extra production

- Use tools to assist with decision making
Importance of taking good soil samples

- In the lab, 0.5 g of soil is tested.
- This sample should represent the paddock or area to be managed.
  - Zone, gridded, random?
- Timing about the same time each year.
- Avoid stock camps, gates, etc.
- Take particular care with depth, especially for P.
- Clear away pasture thatch or dry material
- 20 cores mixed then subsampled into sample bags and dispatched ASAP.
- Garbage in = Garbage out.
New/Old Products

• Does it make sense
  – Mass balances?
  – Magic or special?
  – Laws of physics/chemistry

• Evidence from Trials
  – Where
  – When
  – Controls
  – Replicated

• Test it yourself, be sceptical – its your $.

• “If it is too good to be true ..................”
Summary

• Balanced nutrition is important for productive pastures.
• Superphosphate provides available P, available S and Ca to pastures.
• Soil chemistry makes P tricky – *use it or loose it*.
• Allocate fertilizer dollars to the most responsive areas.
  – Pasture test strips help identify responsive areas
  – Soil tests help identify responsive areas
• Maintain a soil P test near the value that supports the stocking rate.
• Use tools available to help think through the options.
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