The efficiency of fertilizer phosphorus use in cropping systems

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Better Crops, Better Environment ... through Science

#1 You get nothing for nothing…….

If produce is removed, nutrients go with it – if not replaced, then the soil reserves go down.

This is soil not the “magic pudding”.
• Cereals contain about 2.7 to 3.9 kg P/t
  – A 5 t/ha cereal/3 t/ha canola crop removes from the paddock 17kgP/ha
  – **Replacement** rate = 85 kg/ha DAP/MAP
• History tells us the service done by earlier farmers.
• If not replaced soil reserves are depleted

Source, Christy et al. (2014).
Derived from ANRA 2001 Audit
Where are you and your soils?

Soil testing identifies your position

• Take good samples  (0.5g = paddock)
  – Sample as you will manage
    • zones, gridded, random.
  – About same time each year
  – Depth is critical (P is not that mobile)
  – Stock camps, gate ways, etc.

Most soil tests calibrated to 0-10 cm.
#2 Do you know what the problem is?

- It's no good checking to see if the hydraulic fluid is OK........

- What is limiting production – until that is addressed, then no extra response.
So .... reading the coffee grounds

<table>
<thead>
<tr>
<th>Analyte / Assay</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Colour</td>
<td>Grey</td>
<td>Orange/Yellow</td>
</tr>
<tr>
<td>Soil Texture</td>
<td>Clay</td>
<td>Clay</td>
</tr>
<tr>
<td>pH (1:5 Water)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH (1:5 CaCl2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Conductivity (1:5 Water)</td>
<td>dS/m</td>
<td>0.24</td>
</tr>
<tr>
<td>Electrical Conductivity (Saturated</td>
<td>dS/m</td>
<td>1.50</td>
</tr>
<tr>
<td>Extract)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/kg</td>
<td>110.0</td>
</tr>
<tr>
<td>Organic Carbon (OC)</td>
<td>%</td>
<td>1.60</td>
</tr>
<tr>
<td>Nitrate Nitrogen (NO3)</td>
<td>mg/kg</td>
<td>5.6</td>
</tr>
<tr>
<td>Ammonium Nitrogen</td>
<td>mg/kg</td>
<td>0.8</td>
</tr>
<tr>
<td>Phosphorus (Colwell)</td>
<td>mg/kg</td>
<td>43</td>
</tr>
<tr>
<td>Phosphorus Buffer Index (PBI-Col)</td>
<td>mg/kg</td>
<td>100</td>
</tr>
<tr>
<td>Sulphate Sulphur (KCl40)</td>
<td>mol/kg</td>
<td>90.0</td>
</tr>
<tr>
<td>Cation Exchange Capacity</td>
<td>cmol(+) /kg</td>
<td>8.01</td>
</tr>
<tr>
<td>Cation Exchange Capacity</td>
<td>cmol(+) /kg</td>
<td>10.30</td>
</tr>
<tr>
<td>Calcium (Amm-acet.)</td>
<td>%</td>
<td>3.700</td>
</tr>
<tr>
<td>Calcium (Amm-acet.)</td>
<td>cmol(+) /kg</td>
<td>3.700</td>
</tr>
<tr>
<td>Calcium (Amm-acet.)</td>
<td>%</td>
<td>46.000</td>
</tr>
<tr>
<td>Magnesium (Amm-acet.)</td>
<td>%</td>
<td>2.900</td>
</tr>
<tr>
<td>Magnesium (Amm-acet.)</td>
<td>cmol(+) /kg</td>
<td>4.900</td>
</tr>
</tbody>
</table>

- N/S: Not Specified
- Micros
- P/K
- pH
Phosphorus fertilizer and the soil

- Plants take up P from solution as orthophosphate
  - primary orthophosphate ion: $\text{H}_2\text{PO}_4^{-}$ (pH < 7.0)
    - and secondary orthophosphate ion: $\text{HPO}_4^{2-}$ (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

- Applicable organic P is also present — 20% to 70% of total P — mineralised before becoming plant available.
For most soils, much of the applied P enters the lower availability pools. Phosphate Buffering Index can be available over time.
### Soil Tests for P ............

<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>Mehlich 3</strong></td>
<td>“weak” acids – Amm Flouride, Nitric Acid EDTA, AmmNitr.</td>
<td>Mehlich 1984. CSSPA. 15, 1409-1416</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>
What does the soil test value mean?

- Compare to the critical value.
From Better Fertilizer Decisions for Crops

46 P Treatment Series

Soil test calibration:
- 80% Relative Yield: 15.0 (13.0 - 17.0)
- 90% Relative Yield: 19.0 (17.0 - 22.0)
- 95% Relative Yield: 23.0 (20.0 - 27.0)

Correlation R: 0.89
Slope RY(50-80): 4.3 (3.6 - 5.0)
Regression equation: $x = e^{(1.9182(\text{arctan}(\text{sqrt}(y/100))) + 0.56952)}$
70% confidence limit at 90% Relative Yield: 19.0 (18.0 - 21.0)
For wheat in Southeastern Australia

<table>
<thead>
<tr>
<th>Soil Order</th>
<th>Critical P</th>
<th>Critical Range</th>
<th>R value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>26</td>
<td>23-29</td>
<td>0.45 (488)</td>
</tr>
<tr>
<td>Chromosol</td>
<td>27</td>
<td>19-38</td>
<td>0.39 (79)</td>
</tr>
<tr>
<td>Sodosol</td>
<td>30</td>
<td>21-45</td>
<td>0.44 (78)</td>
</tr>
<tr>
<td>Vertosol</td>
<td>20</td>
<td>14-27</td>
<td>0.35 (41)</td>
</tr>
</tbody>
</table>
### Critical Colwell P values – BFDC project

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil Type</th>
<th>Critical Value (mg/kg)</th>
<th>Critical Range (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat &amp; Barley</td>
<td>Vertosol</td>
<td>17</td>
<td>12-25</td>
</tr>
<tr>
<td></td>
<td>Chromosol/Sodosol</td>
<td>22</td>
<td>17-28</td>
</tr>
<tr>
<td></td>
<td>Calcarosol</td>
<td>34</td>
<td>26-44</td>
</tr>
<tr>
<td></td>
<td>Brown/Red Chromosols</td>
<td>25</td>
<td>18-35</td>
</tr>
<tr>
<td>Barley</td>
<td>Ferrosol</td>
<td>76</td>
<td>46-130</td>
</tr>
<tr>
<td>Canola</td>
<td>All soils</td>
<td>18</td>
<td>16-19</td>
</tr>
<tr>
<td>Field Pea</td>
<td>All soils</td>
<td>24</td>
<td>21-28</td>
</tr>
</tbody>
</table>

- Canola – less responsive to P than cereals (soil type)
- Wheat –
- Peas – about the same response to P as cereals
- Incomplete data on all crops and soils.
Selecting the Right Rate

• Soil Test & PBI
  – Build up = replacement + (build up + fixation)
  – Maintenance = replacement + a little if PBI is low
  – Maintenance = replacement + soil fixation if PBI is moderate

• Dahlen Long Term Cropping N&P Experiment (est. 1996)
  – Four rates of P (TSP 0/9/18/36) * Five rates of N (Urea 0/20/40/80/160)
  – Each year the site sown to a single crop.
  – Canola, wheat, barley, pulse.
  – Direct drilled, zero cultivation, stubble retained.
  – Soil samples, grain harvest, nutrient content.
Dahlen progressive P balance

Colwell P 24
2.46 t/ha

Colwell P 40
2.31 t/ha
88% P recovery

Colwell P 17
1.81 t/ha

IPNI
Selecting the Right Rate

• Soil Test & PBI
  – Build up = replacement + (build up + fixation)
  – Maintenance = replacement + a little if PBI is low
  – Maintenance = replacement + soil fixation if PBI is moderate

• At Dahlen PBI ~ 100 (low)
  – Maintenance + 40 kg surplus gave 16 Colwell soil test increase.
    • 2 kg P to raise Colwell 1 unit (some loss to soil fixation)

• If PBI higher (eg Chromols)
  • 3-5 kg P to raise Colwell 1 unit (larger loss to fixation)
Selecting the Right Rate

• Soil Test & PBI
  – Build up = replacement + (build up + fixation)
  – Maintenance = replacement + a little if PBI is low
  – Maintenance = replacement + soil fixation if PBI is moderate

• Allocate P to the most responsive situations
  – Wheat on wheat – Critical Colwell = 34 mg/kg
  – Wheat on canola – Critical Colwell = 49 mg/kg (PBI 70)
  – Clean paddocks
  – Following canola – wheat has a somewhat higher P demand.
Right Place/Time for P

- Low mobility
- Placement at seeding
  - Banded
- Potential for seed damage – MAP/DAP
  - Wide rows.
  - High rates
  - Narrow points

### Safe Rate

<table>
<thead>
<tr>
<th>Safe Rate</th>
<th>Soil Type</th>
<th>Point &amp; Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Share Spear Point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15cm 30cm 15cm 30cm</td>
</tr>
<tr>
<td>Canola &amp; DAP</td>
<td>Sandy Moist</td>
<td>100 50 30 15</td>
</tr>
<tr>
<td></td>
<td>Loam Moist</td>
<td>150 70 50 30</td>
</tr>
</tbody>
</table>
http://seed-damage-calculator.herokuapp.com
Options opening up

• Co-granulation (Zn, S)
• Fluid P sources
  – Benefits on calcareous soils
  – Less fixation (Ca, Fe, Al)
• Foliar P
  – Opportunity to “top-up” P, becomes a tactical decision
  – Conceptual and experimental at present – but some interest.

McBeath et al, 2011, CPS

• phosphoric acid +/- Adj
• NP blend +/- adjuvant
#3............there are no silver bullets

“Frankly, I don’t know what to believe. They say if it sounds too good to be true, it usually is.”
Summary

• Get the foundation correct (esp. pH).
• Colwell P is still a reliable test – sampling critical
  – Understand what it is telling you.
• Allocate fertilizer dollars to the most responsive situations.
  – Soil tests help identify responsive areas
  – Yield potentials/replacement
• Maintain a soil P test near the value critical value.
• The development of new products and technologies are promising but not yet mature.