Soil Phosphorus, Soil Test Recommendations and Phosphate Fertilizer Management

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Acknowledgements

- Dr Ross McKenzie
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- International Plant Nutrition Institute (IPNI)
- Pulse Canada and Stratus Ag Research
Phosphorus Overview

- Second most widely deficient nutrient - Why?
  - Soils low in P minerals in the parent material
  - Very low solubility in the soil of phosphate
- 2 anionic forms available for plant uptake;
  - pH dependent
  - primary orthophosphate (\(H_2PO_4^-\))
  - secondary orthophosphate (\(HPO_4^{2-}\))
- Compared to N & K, plant content is smaller
  - Plants contain 0.1 - 0.5% P
- P forms organic compounds in the plant
- P is mobile in plants
Function in Plants

- Photosynthesis and respiration
- Energy storage and transfer
- Cell division and enlargement
- Critical for early vigorous growth
- Stimulates root and tiller development
- Disease resistance
- Promotes reproduction (maturity & seed formation)
- P accumulates in the seed transfer of heredity traits
- Winter hardiness
Soil Phosphorus
A Good Nutrient Soil Test

- Needs extensive field and laboratory research.
- Needs to provide a measure of the nutrient proportional to what a plant utilizes.
- Able to identify responsive vs non-responsive soils based on soil test critical level and/or other related properties.
- Able to predict nutrient application rate for responsive soil.
- Able to identify excessive nutrient levels.
Limits of a Nutrient Soil Test

- One time snapshot of nutrient levels that must be able to take the entire crop growing season into account
- Misconception – nutrient measure equals availability; Soil analysis is an inventory of nutrient levels in the soil
- Requires continuous verification, evaluation and updates
- Field research related to management changes crops, varieties, nutrient sources, rates, time of application, placement, tillage, etc.
- Laboratory improvements: procedures, detection limits, multiple nutrient extraction
Soil Test Calibration:
- Process by which a soil test provides a means to measure soil nutrient levels.

Soil Test Interpretation:
- Guidelines to identify nutrient levels: deficient, marginal, adequate or excessive.

Soil Test Nutrient Recommendation:
- Process by which soil test calibration curve provides the basic nutrient requirement.
- Any factor that enhances or limits crop growth will increase or decrease crop nutrient requirements.
Soil Test Calibration

- Gain information about a soil and provide a fertilizer recommendation that is economically and environmentally sound.
- Nutrient soil test must be calibrated with crop yield response across many different soil types.
- May use crop nutrient removal.
- Often regionally specific.
- Costly and time consuming.
- Soil test methods will vary between laboratories.
Soil Test Calibration Research

Field trials - Variables:
- Crops, varieties, fertilizer products, time of application, fertilizer placement, tillage
- Regions - soil types, climate, soil moisture, irrigation
- Soil samples

Laboratory soil test methods - Chemistry:
- Chemical extraction solutions
  - Acids, bases, neutral salts
  - Anion and cation displacement

Correlation - How good is the relationship:
- Crop response - Fertilizer rate relationship
- Soil test - Crop response relationship
- Soil test - Fertilizer rate relationship
- Linear, Non-linear, Spline, etc
- As the soil test increases, the recommended fertilizer rate decreases
Soil Test Interpretation

Interpretation directly related to philosophy and recommendation

Philosophies

- Sufficiency - Deficiency Correction: Deficient, Marginal, Adequate, Excessive, Toxic
- Replacement - Crop Removal
- Build and Maintenance: Application of nutrients in excess of crop removal
Soil Test Phosphorus

Five Year Running Averages - Stubble

YEAR

Soil P lb/ac (0-6 in)

BROWN & DARK BROWN
THIN BLACK & BLACK
IRRIGATED
GRAY WOODED
PEACE RIVER REGION

Alberta
Soil Test Phosphorus

Five Year Running Averages - Fallow

YEAR

Soil P lb/ac (0-6 in)

BROWN & DARK BROWN
THIN BLACK & BLACK
GRAY WOODED
PEACE RIVER REGION

Alberta
P Fertilizer Trials in Alberta

1969-73 (J. Robertson, UofA)
- 38 sites
- Evaluate response of spring wheat
- Calibration of P soil tests

1971-75 Risk Adjusted Yield Potential (RAYP)
- 125 sites
- Evaluate response of barley and canola
- Calibration of P soil tests

1990-93 (R. McKenzie, AARD)
- 427 sites
- Evaluate response of wheat, barley and canola
- Calibration response to different soil P tests
## P Trials in Alberta (1990-93)

<table>
<thead>
<tr>
<th>Year</th>
<th>Wheat (%)</th>
<th>Barley (%)</th>
<th>Canola (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>78 (48)*</td>
<td>89 (47)</td>
<td>82 (38)</td>
</tr>
<tr>
<td>1992</td>
<td>89 (51)</td>
<td>96 (54)</td>
<td>77 (43)</td>
</tr>
<tr>
<td>1993</td>
<td>82 (49)</td>
<td>89 (46)</td>
<td>89 (36)</td>
</tr>
</tbody>
</table>

* total sites

(McKenzie et al. 1993)
# 91-93 Soil test P calibration trials

## Table 5. Summary of responsive and non-responsive sites by soil zone based on yield differences

<table>
<thead>
<tr>
<th>Crop</th>
<th>Type of response</th>
<th>Brown</th>
<th>Dark Brown</th>
<th>Thin Black</th>
<th>Black</th>
<th>Gray Wooded (Central)</th>
<th>Gray Wooded (Peace River)</th>
<th>Total sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Response</td>
<td>9</td>
<td>10</td>
<td>14</td>
<td>21</td>
<td>10</td>
<td>10</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>Marginal response</td>
<td>1</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>9</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>6</td>
<td>8</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Barley</td>
<td>Response</td>
<td>9</td>
<td>14</td>
<td>19</td>
<td>32</td>
<td>14</td>
<td>13</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>Marginal response</td>
<td>5</td>
<td>12</td>
<td>14</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Canola</td>
<td>Response</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Marginal response</td>
<td>8</td>
<td>14</td>
<td>11</td>
<td>12</td>
<td>8</td>
<td>7</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>5</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>34</td>
</tr>
</tbody>
</table>

*Response: yield increase greater than 5 bu/ac. Marginal response: yield increase between 2 and 5 bu/ac. No response: less than 2 bu/ac yield increase.*
# Soil test P methods evaluated in P calibration trials in Alberta

<table>
<thead>
<tr>
<th>Method</th>
<th>Extractant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miller and Axley</td>
<td>ammonium fluoride and sulfuric acid (0.03N NH₄F + 0.03N H₂SO₄)</td>
</tr>
<tr>
<td>Olsen</td>
<td>sodium bicarbonate (0.5M NaHCO₃)</td>
</tr>
<tr>
<td>Kelowna</td>
<td>acetic acid and ammonium fluoride (0.25N HOAc + 0.015N NH₄F)</td>
</tr>
<tr>
<td>Modified Kelowna (Exova)</td>
<td>acetic acid, ammonium fluoride and ammonium acetate (0.5N HOAc + 0.015N NH₄F + 1.0N NH₄Oac)</td>
</tr>
<tr>
<td>Modified Kelowna (ALS)</td>
<td>acetic acid, ammonium fluoride and ammonium acetate (0.25N HOAc + 0.015N NH₄F + 0.25N NH₄Oac)</td>
</tr>
</tbody>
</table>
Soil test P calibration trials in Alberta

Frequency of wheat response to fertilizer, %

Soil test P, lb/A

- Kelowna
- Modified Kelowna (ALS)
- Modified Kelowna (Exova)
- Miller & Axley
- Olsen
Calibration curve indicates which soil test levels tend to limit yields.

The results of this calibration data set from Alberta show a critical level (sufficiency) of 20 to 25 ppm (40 to 50 lb/A) P.

This is the level of soil test P above which minimal response to applied P can be expected.
P Soil Tests Calibrated in Western Canadian Field Studies

- Miller Axley
- Olsen (bicarbonate)
- Kelowna
- Modified Kelowna (Exova, ALS)

P Soil Tests Not Calibrated in Western Canadian Field Studies

- Bray I (weak), Bray II (strong)
- Mehlich-1, Mehlich-3
- Morgan
- Many others
IPNI Soil Test Summary

Phosphorus sample distribution: Alberta, Saskatchewan, Manitoba

- 2001; 77,063
- 2005; 93,835
- 2010; 93,699
- 2015; 119,089

Relative Frequency, %

Bray and Kurtz P1 equivalent soil test level, ppm

Alberta
IPNI Soil Test Summary

Phosphorus sample distribution: Alberta

- 2001; 37,437
- 2005; 36,967
- 2010; 26,877
- 2015; 39,096

Bray and Kurtz P1 equivalent soil test level, ppm
IPNI Soil Test Summary

Phosphorus sample distribution: Manitoba

2001; 14,999  2005; 36,155  2010; 42,392  2015; 43,286

Relative Frequency, %

Bray and Kurtz P1 equivalent soil test level, ppm
IPNI Soil Test Summary

Phosphorus sample distribution: Saskatchewan

<table>
<thead>
<tr>
<th>Year</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>24,627</td>
</tr>
<tr>
<td>2005</td>
<td>20,713</td>
</tr>
<tr>
<td>2010</td>
<td>24,430</td>
</tr>
<tr>
<td>2015</td>
<td>36,707</td>
</tr>
</tbody>
</table>

Relative Frequency, %

Bray and Kurtz P1 equivalent soil test level, ppm

Alberta
Soil Sampling & Soil Testing

Diagram showing different sampling methods based on sampling intensity and field variability.

- **Random composite**
- **Benchmark**
- **Directed random**
- **Directed benchmark**
- **Grid**
Nutrient Recommendations

Factors Influencing Recommendations

- Soil Nutrient Level
- Crop
- Agro-Climatic Zone
- Growing Season Precipitation
- Soil Texture
- Soil Moisture
- Soil Organic Matter
- Soil pH
- Soil Salinity
Soil pH

- Affects the dominate form of soil phosphorus
- Crops have variable tolerance that will effect yield potential
- Affects the soil test extraction effectiveness
Phosphate Recommendation

Soil Test P (lb/ac) 0-6 in

P₂O₅ Recommendation (lb/ac)

- Responsive Zone
- Maintenance Zone

Recommendation Curves
- Crop, Soil Zone, Moisture

Alberta
Agro-Climatic Zones

Zones reflect differences

- Soils
- Climate (pptn, temp, growing season)
- Crop management
- Yield potential
- Nutrient availability
- Nutrient requirements
FERTILIZER MANAGEMENT SURVEY

2014 CROP YEAR
2015 CROP YEAR
Phosphorus Fertilizer Use Survey

Phosphorus fertilizers were applied on 87% of Spring Wheat acres.
- MAP represents 86% of total phosphorus volume applied in spring wheat.
- 94% of Phosphorus volumes were applied at planting.
- At planting, the main placements were: 47% seed placed; 26% side banded.
- Average rate (including untreated) = 26.1 lbs./ac; average rate when used at planting = 26 lbs./ac.

Phosphorus fertilizers were applied on 88% of barley acres.
- MAP represents 84% of total phosphorus volume applied in barley.
- 96% of Phosphorus volumes were applied at planting.
- At planting, the main placements were: 51% seed placed; 32% side banded.
- Average rate (including untreated) = 27.8 lbs./ac; average rate when used at planting = 30 lbs./ac.

Phosphorus fertilizers were applied on 86% of canola acres.
- MAP represents 73% of total phosphorus volume applied in canola.
- 92% of Phosphorus volumes were applied at planting.
- At planting, the main placements were: 51% seed placed; 36% side banded.
- Average rate (including untreated) = 31 lbs./ac; average rate when used at planting = 31 lbs./ac.

Phosphorus fertilizers were applied on 44% of peas acres.
- MAP represents 88% of total phosphorus volume applied in peas.
- 94% of Phosphorus volumes were applied at planting.
- At planting, the main placements were: 43% (27 AB) seed placed; 26% side banded.
- Average rate (including untreated) = 12 (20 AB) lbs./ac ; average rate when used at planting = 27 lbs./ac.
Alberta Farm Fertilizer Information and Recommendation Manager (AFFIRM)

- Fertilizer recommendations based soil test calibrations from Alberta research.
- Able to utilize soil test results from several different laboratories.
- Access to current nutrient management knowledge based on Alberta research.
- Nitrogen fertilizer-crop response model that incorporates soil test and fertilizer nitrogen with spring moisture conditions and growing season precipitation.
- Balanced nutrient economic analysis model.
- Nitrogen mineralization estimates to improve fertilizer nitrogen recommendations for crop production.
- Field and whole farm optimization for nutrient management.
AFFIRM Enhancements

- Update Laboratories and Soil Test Calibrations
- New fertilizer products research
  - Enhanced Efficiency Fertilizers
    - ESN (coated urea) and other fertilizer products
- 4R Nutrient Stewardship
  - Product, Rate, Time, Place
- Incorporate nutrients from manure sources
- Linkage to AB Climate Information Services and AB Soil Information Viewer
Key Messages

- P fertilizer is essential for optimum crop production.

- There is a need for P fertilizer in Alberta; 50 to 80% of provincial soils are severely to marginally deficient.

- Soil test P methods vary greatly among laboratories and in their ability to measure crop available soil P.

- Calibration of soil test P methods can be influenced by soil pH, texture and seedbed moisture.

- MAP, seed placed, spring application represents the majority of P fertilizer management; Average application rates range from 12 to 31 lb/ac.

- AFFIRM will provide access to 4R Nutrient Stewardship for a range of laboratory soil test P methods.
Thank You

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