2019 is the 350th anniversary of the discovery of phosphorus by Hennig Brandt in 1669
Historical Background: The Red Book

4R Phosphorus Fertilizer Management in the Northern Great Plains: A Review of the Scientific Literature

Draft for Technical Advisory Group
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Don Flaten and Cindy Grant
University of Manitoba

The overall purpose of this review is to assemble and summarize the existing science base for 4R P fertilizer management ("right" source, "right" rate, "right" time and "right" place for fertilizer application) for crop production in the Northern Great Plains region of North America. In addition, this review will identify key gaps in knowledge and priorities for future research on this topic.

Outline of Literature Review

1. Introduction (~1 page, plus references)
   - Reasons behind project … including changes in farming practices

2. Background of 4R Nutrient Stewardship (~5 pages, plus references)
   - History
   - Background and principles
   - Gaps in knowledge

3. Agronomic Value of P for Crop Production (~12 pages, plus references)
   - Functions of P in crops
   - P accumulation in crops
   - Effects of P deficiency
   - Gaps in knowledge

4. P Behaviour in Soil (~22 pages, plus references)
   - The phosphorus cycle
   - What happens when P fertilizer is added to the soil?
   - Residual value of fertilizer P
   - Alternative measurements for assessing P use efficiency
   - Gaps in knowledge

5. Environmental Concerns Related to P Fertilizer (~20 pages, plus references)
   - P loss to surface water and eutrophication
   - P depletion in soils
   - Cadmium loading to soil
   - Gaps in knowledge

6. Phosphorus Fertilizer Sources (~24 pages, plus references)
   - Traditional sources of P fertilizer
   - Fertilizer additives and coatings
   - Reclaimed and by-product sources of phosphorus
   - Microbial products
   - Gaps in knowledge

7. Phosphorus Fertilizer Rates (~34 pages, plus references)
   - Strategies for phosphorus management
   - Use of soil testing as the basis for selecting rates of P
   - Selecting rates of P applications in long-term sustainability strategy
   - Selecting rates of P application in a short-term sufficiency strategy
   - Differences in P response among crops
   - Gaps in knowledge

8. Phosphorus Fertilizer Placement (~16 pages, plus references)
   - Efficiency of band versus broadcast application
   - Effect of band position
   - Seeding toxicity issues related to seed-placed phosphorus
   - Dual banding of N and P fertilizer
   - Gaps in knowledge

9. Phosphorus Fertilizer Timing (~14 pages, plus references)
   - Importance of early season supply
   - Requirement for P supply during grain fill/flowering
   - Factors affecting early-season supply of P to the plant
   - Implications for P fertilizer management
   - Gaps in knowledge

10. Creating a 4R Phosphorus Fertilization Package (~20 pages, plus references)
    - Agronomic drivers for phosphorus management on the Northern Great Plains
      - Tillage system
      - Cropping sequence and intensity
      - Weed competition
      - Effects of other nutrients
      - The 4R package
      - 4R for the environment
      - Gaps in knowledge
✓ Right source
✓ Right rate
✓ Right placement
✓ Right timing

In a coherent combination suited to the crop, economics, and environment
Chapter 3 - Agronomic value of P for Crops

- essential for many plant processes & components, eg. DNA
- taken up only as “ortho-P” (H$_2$PO$_4^-$ or HPO$_4^{2-}$)
- moves to root mainly by diffusion, over v. short distances
- uptake affected by soil, plant & environmental factors
Clayton Harder’s canola field, north of Wpg. with and without 40 lbs $P_2O_5 + 12$ lbs S/acre
Chapter 4 - P Behaviour in Soil

- very small concentrations of P in solution
- most soil P is retained strongly by precipitation and immobilization in soil solids, and adsorption to soil surfaces
- release for crop uptake is affected by soil, plant & environmental factors
Majority of Soils on Northern Great Plains Are Deficient in P
Environment and cropping system drive P management decisions on Northern Great Plains

- Cold soils in spring
- Short growing season
- Often high pH carbonated soils
- Snow-melt runoff

- Reduced tillage
- Movement towards diversified rotations
- High-yielding cultivars

Photo: Agritruth.ca
Chapter 5 - Environmental Concerns

- Small amounts of P loss cause large problems with water quality
- Most P loss in NGP is dissolved P during snowmelt
- Careful management of P rate, placement and timing is critical for reducing the risk of P loss to surface water
- Cadmium content in P fertilizer is also a concern ... for human health
Rec. Fertilizer Rate = **Crop Requirement - Soil Supply**

Fertilizer Use Efficiency

Therefore, field-specific recommendations require detailed knowledge of:

i) crop's nutrient **requirements**, considering environment, crop species & variety/hybrid, yield potential, quality goals, etc.

ii) soil's power to **supply** nutrients over growing season

iii) fertilizer use efficiency for different sources, placements, & timings
Chapter 6 - Right Source

✔ Right source
✔ Right rate
✔ Right placement
✔ Right timing

In a coherent combination suited to the crop, economics, and environment
Traditional Phosphate Fertilizers

1. Rock phosphate (highly insoluble, but rec. for organic)
2. Monoammonium phosphate or MAP (eg. 11-52-0)
3. Triple super phosphate or TSP (eg. 0-45-0)
4. Ammonium polyphosphate or APP (eg. 10-34-0)
Monoammonium phosphate or MAP (eg. 11-52-0)

- inexpensive to manufacture, easy to handle
- granular form; most popular P fert. in W. Canada (not U.S.)
- low NH$_4$ content & low pH rx zone = low toxicity for seedrow placement (vs DAP, 18-46-0)
- performs better than calcium phosphate (eg. 0-45-0) in W. Canada: NH$_4^+$ enhances P uptake, partly due to acidification of rhizosphere during NH$_4^+$ absorption ("ammonium-ion effect")

https://www.ipni.net/specifics-en
Triple super phosphate (eg. 0-45-0)

- granular form; not popular in W. Canada, but popular in U.S.
- also called monocalcium phosphate
- not as effective as MAP in W. Canada, but a good source of P, especially in research trials where no N is desired as part of P application

https://www.ipni.net/specifics-en
MAP (eg. 11-48-0) was superior to TSP/MCP (0-43-0) in Saskatchewan field trials.

Averages for 12 lb $P_2O_5$/ac drilled with seed over 75 site years (Mitchell 1946 Scientific Agriculture 26:566-577.)
MAP (eg. 11-48-0) was superior to TSP/MCP (0-43-0) in Saskatchewan field trials.
Ammonium polyphosphate or APP (eg. 10-34-0)

- a reasonably popular form of liquid P fertilizer
- poly-P is not immediately available to plants but is quickly split into ortho-P by soil’s phosphatase enzymes
- reactions and effectiveness similar to MAP in NGP

https://www.ipni.net/specifice-en
Products that attempt to improve P use efficiency

- Use of more crop available forms
  - Ammoniated phosphates
  - Dual banding N and P fertilizer together
  - Fluids vs. dry/granular
  - Liquid orthophosphates vs. polyphosphates
- Reduce soil retention
  - Maleic-itaconic acid copolymer additive
- Release P gradually to match plant uptake
  - Polymer coated MAP and struvite
- Fungal inoculants that release P in rhizosphere
  - *Penicillium bilaii*
- Fungal inoculants that improve plant access to P
  - Mycorrhizae
Dual banding N and P fertilizer

- P availability is increased by ammonium in the band
  - Ammoniated P fertilizers (e.g. MAP, APP) outperform other P fertilizers
  - Adding urea or ammonia to MAP bands (dual banding) increases fertilizer P uptake when fertilizer is banded away from seed
- P availability is delayed when banded with high rates of N
  - Typical rates of N will delay P uptake for several weeks due to band toxicity
- Some starter P should be placed in seed row when “dual banding” N & P
  - Enables early season access to P
Fluid vs. Dry Fertilizers

- Under arid, highly calcareous conditions in Australia, fluid forms of P are more available than dry
  - water moving toward dissolving granule carries Ca to the fertilizer
  - Ca precipitates P and leads to small reaction zone
  - fluid forms increase reaction zone and allow greater root uptake
- Similar benefit has not shown up in tests in Manitoba and is unlikely in humid areas
No difference between dry MAP & fluid APP in wheat yield over three years at two sites near Brandon

- Similar results in previous studies by Racz and in later studies on canola
- Soils in MB trials were much less calcareous than the 70% calcium carbonate in the Australian trials
Orthophosphates vs. Polyphosphates

- Polyphosphates are chains of orthophosphates
- Most “polyphosphate” fertilizers (e.g., 10-34-0) still have 40-60% of the phosphate in the orthophosphate form
- Polyphosphate converts to orthophosphate in soils rapidly
  - Half usually is converted within a week,
  - Conversion may be slower if soils are cool and dry
- Generally no difference in effectiveness under field conditions

http://www.extension.umn.edu/distribution/cropsystems/DC6288.html
“Wide differences in soluble and bicarbonate-extractable P levels from all four products in all three soils at the onset of incubation became insignificant after 2 to 4 d of incubation, suggesting that there was no difference in P availability among these products soon after their application at the time of seeding.”
Struvite

- Commercial struvite is recovered from wastewater
- Represents a vital step towards sustainable use of recycled P
Struvite and Polymer Coated MAP

- **Greenhouse** trials to measure vegetative growth & P uptake
- **Canola** dry matter response to struvite from pig manure was equal to that for MAP (11-52-0) in the 1st crop and superior to MAP in the 2nd and 3rd crops.
Struvite and Polymer Coated MAP

Canola dry matter response to polymer coated MAP was equal to that for uncoated MAP (11-52-0) in all three crops.
When all crops of wheat and canola were analyzed, overall recovery of P from struvite and coated MAP in wheat and canola was similar to uncoated MAP (11-52-0) in clay loam and sand.
Yield of wheat on the prairies was similar if MAP was applied with or without maleic-itaconic acid copolymer.
What about microbial products?

Two major products sold in western Canada

- *Penicillium bilaii*
- Mycorrhizal inoculants

Low or no P application rates based on claims of enhanced P availability

If application rates are reduced to below crop removal when these products are used, it will increase the P deficit ... the imbalance between crop removal and P applied
Provide is a fungal inoculant

- *Penicillium bilaii* (also classified as *P. bilaji* and *P. bilaiae*) is a fungus that colonizes the rhizosphere
- Effective in solubilizing phosphorus (P) under laboratory conditions
- Under field conditions, results have not been consistent
Penicillium bilaii did not benefit canola yield in recent studies in Manitoba and Saskatchewan.*

P = 0.09

Ramona Mohr
Mycorrhizal fungi inoculants

– very important organisms that help crops such as corn and flax take up nutrients
– inoculants not generally used in field crops
– not for use with canola since canola does not form mycorrhizal associations
– watch for P problems in mycorrhizal-dependent crops such as corn or flax grown after canola
Key Messages for Selecting the Right Source of P

- MAP (eg. 11-52-0) and APP (eg. 10-34-0) are the standard fertilizer sources for the Northern Great Plains; ammonium in formulation enhances efficiency on high pH, calcareous soils
- No evidence of significant agronomic difference between orthophosphate and polyphosphate
- Fluids and dry formulations perform similarly on the Northern Great Plains
- Novel P fertilizer formulations or use of microbial products have generally not shown increased effectiveness over MAP and APP under field conditions on the Northern Great Plains
- Recycled P products such as struvite offer improvements in long term sustainability
Chapter 7 - Right Rate

- Right source
- **Right rate**
- Right placement
- Right timing

**In a coherent combination suited to the crop, economics, and environment**
Soil tests as the basis for recommending P rates

<table>
<thead>
<tr>
<th>Soil Phosphorus (sodium bicarbonate or Olsen P test)</th>
<th>Cereal</th>
<th>Corn Sunflower</th>
<th>Canola Mustard Flax</th>
<th>Buckwheat Fababean</th>
<th>Potatoes</th>
<th>Peas Lentils Field beans Soybeans¹</th>
<th>Legume forages</th>
<th>Perennial grass forages</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm</td>
<td>lb/ac</td>
<td>Rating</td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>0</td>
<td>0</td>
<td>VL</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>20</td>
<td>55</td>
<td>110</td>
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<tr>
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<td>5</td>
<td>VL</td>
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<td>110</td>
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<td>40</td>
<td>35</td>
<td>35</td>
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<td>45</td>
<td>90</td>
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<td>15</td>
<td>L</td>
<td>35</td>
<td>35</td>
<td>35</td>
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<td>45</td>
<td>90</td>
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<tr>
<td>20</td>
<td>20</td>
<td>M</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>45</td>
<td>90</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>M</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>15</td>
<td>30</td>
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<td>15</td>
<td>15</td>
<td>0</td>
<td>35</td>
<td>70</td>
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<tr>
<td>35</td>
<td>35</td>
<td>H</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>0</td>
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<tr>
<td>20</td>
<td>40</td>
<td>VH</td>
<td>10</td>
<td>20</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>20+</td>
<td>40+</td>
<td>VH+</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

¹ Field beans and soybeans are the same plants grown together for higher yield.
Critical soil test P thresholds are not exact

- Alberta data show a critical level of 20-25 ppm for average of 10% response
- Above this level, only maintenance (crop removal) application would be required
- ... but the variability is high

Ross McKenzie, Alberta Agric.
Yield Response to P is Highly Variable from Year to Year … and from One Crop Phase to Another

Mean

- Yield on fallow: 251 kg/ha (3.8 bu/A)
- Yield on stubble: 143 kg/ha (2.1 bu/A)

20 kg \( \text{P}_2\text{O}_5/\text{ha} \) applied yearly to a fallow-wheat-wheat rotation near Swift Current, SK

Given the high variability, a probability approach may be more realistic than a "response curve"
### Manitoba P Response Probabilities

<table>
<thead>
<tr>
<th>Available P (ppm Olsen)</th>
<th>Number of Experiments</th>
<th>% Responding to Fertilizer P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 V. Low</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>5-12 Low-Med</td>
<td>50</td>
<td>62</td>
</tr>
<tr>
<td>12-18 Med-High</td>
<td>16</td>
<td>56</td>
</tr>
<tr>
<td>&gt;18 High-VH</td>
<td>14</td>
<td>29</td>
</tr>
<tr>
<td>Overall</td>
<td>95</td>
<td>63</td>
</tr>
</tbody>
</table>

Hedlin, U of M, 1962
<table>
<thead>
<tr>
<th>Soil Test P 0-6 inch (ppm)</th>
<th>Recommended Fertilizer Rate (lb P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;/A)</th>
<th>Probability of Yield Response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>0-10</td>
<td>&gt;75</td>
</tr>
<tr>
<td>5-10</td>
<td>11-20</td>
<td>50-75</td>
</tr>
<tr>
<td>10-15</td>
<td>21-30</td>
<td>50</td>
</tr>
<tr>
<td>15-30</td>
<td>31-60</td>
<td>25-50</td>
</tr>
<tr>
<td>&gt;30</td>
<td>&gt;60</td>
<td>less than 25</td>
</tr>
</tbody>
</table>

Karamanos, 33 site years in AB, SK, MB 1988-1995

Olsen (sodium bicarbonate) extractable P range (mg kg\(^{-1}\))

- <5: 100%
- 6-10: 71%
- 11-15: 50%
- 16-20: 50%
- 21+: 25%
Short-term P sufficiency strategy often depletes long-term P fertility, especially for seedrow placed P.

eg. MB Soil Fertility Guide recommendations for 10 ppm Olsen P.
Short-term P sufficiency strategy often depletes long-term P fertility, especially for seedrow placed P.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (bu/ac)</th>
<th>P Applied</th>
<th>P Removed* (lb P₂O₅/ac)</th>
<th>Annual Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP spring wheat</td>
<td>60</td>
<td>30</td>
<td>35</td>
<td>-5</td>
</tr>
<tr>
<td>Canola</td>
<td>40</td>
<td>20</td>
<td>40</td>
<td>-20</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>75</td>
<td>30</td>
<td>38</td>
<td>-8</td>
</tr>
<tr>
<td>Soybeans</td>
<td>35</td>
<td>10</td>
<td>30</td>
<td>-20</td>
</tr>
<tr>
<td>4 Year Total</td>
<td>90</td>
<td>143</td>
<td></td>
<td>-53</td>
</tr>
</tbody>
</table>

* Using 0.59, 1.0, 0.51, 0.85 lb P₂O₅/bu respectively for grain only.
P Rate can be Managed for Short-Term Sufficiency or Long-term Sustainability

**Short-term sufficiency**
- Rate chosen based on economic yield response in the year of application
  - Often seed-place a low rate of P
- Suitable for short-term land tenure and when P costs are high relative to crop prices

**Long-term sustainability**
- Target applications to reach and maintain soil test P target range:
  - Build on low-P soils
  - Deplete on high-P soils
- Long-term economics considers residual P value
- Suitable for long-term land tenure and when P costs are low relative to crop prices
Balancing P application with crop removal is essential to avoid excessive accumulation or depletion of P in soil.
Dr. Martin Entz’s long term organic rotation demonstrates the importance of P replacement.
Crops respond to P fertilizer and soil P fertility, so depleted soil P can decrease crop yield potential.

Amount of P b'cast initially (lb P$_{2}$O$_{5}$/ac)

Wheat Grain Yields (bu/ac)

Seed Placed P Applied Yearly (lb P$_{2}$O$_{5}$/ac)

Six year study in SK by Wagar et al. 1986

Yield was higher with moderate rather than very low P fertility at all rates of seed placed fertilizer applied annually.
Crops respond to P fertilizer and soil P fertility, so supplemental P can increase crop yield.

**Faller Spring Wheat Yield Response to High Rates of Supplemental P Fertilizer**

(Adam Gurr, Agritruth Research, Brandon, MB)

* data are for only the first site-year of study (2018)
Crop Removal and Replacement of P in Manitoba (1965-2016)*

*John Heard (Manitoba Agriculture) with data from Statistics Canada data, does not include additions of manure or removal of straw P
P fertility is declining in many Prairie soils

- Short term P sufficiency strategies often deplete P fertility (already discussed)
- Yields of all crops have increased, increasing P removal in grain
- Increased acres of canola, soybeans and corn,
  - high rates of P removal
  - low rates of P can be placed in the seed row, without risk of toxicity
- Decreased barley and wheat acres
  - less opportunity to place high rates of P with seed
Increased crop yields = more P removal

Average Spring Wheat Yields in MB (1970-2016)

average yield of spring wheat in MB has more than doubled since 1970

Statistics Canada - Estimated areas, yield, production, average farm price and total farm value of principal field crops, in imperial units annual
More canola + soybeans = more P removal

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed Yield (bu/acre)</th>
<th>Uptake/Removal (lb P$_2$O$_5$/ac, lb/bu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>60</td>
<td>54 (36), 0.59</td>
</tr>
<tr>
<td>Canola</td>
<td>40</td>
<td>67 (40), 1.0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>35</td>
<td>38 (30), 0.85</td>
</tr>
<tr>
<td>Barley</td>
<td>80</td>
<td>45 (34), 0.43</td>
</tr>
<tr>
<td>Peas</td>
<td>50</td>
<td>43 (34), 0.68</td>
</tr>
<tr>
<td>Oats</td>
<td>100</td>
<td>41 (26), 0.26</td>
</tr>
<tr>
<td>Corn</td>
<td>100</td>
<td>63 (44), 0.44</td>
</tr>
</tbody>
</table>

*Removed in grain
Safe rates of seed-placed P will not replace P removal for many crops ... especially for soybeans and canola

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (bu/ac)</th>
<th>P Removal</th>
<th>Seed Limit</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>60</td>
<td>36</td>
<td>50</td>
<td>+14</td>
</tr>
<tr>
<td>Canola</td>
<td>40</td>
<td>40</td>
<td>20</td>
<td>-20</td>
</tr>
<tr>
<td>Soybeans</td>
<td>35</td>
<td>28</td>
<td>10</td>
<td>-18</td>
</tr>
<tr>
<td>Barley</td>
<td>80</td>
<td>38</td>
<td>50</td>
<td>+12</td>
</tr>
<tr>
<td>Flax</td>
<td>32</td>
<td>20</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Peas</td>
<td>50</td>
<td>38</td>
<td>20</td>
<td>-18</td>
</tr>
<tr>
<td>Oats</td>
<td>100</td>
<td>29</td>
<td>50</td>
<td>+21</td>
</tr>
</tbody>
</table>

*Rates are based on solid seeding with disk or knife openers with a 1 in. spread, 6 to 7 in. row spacing and good to excellent soil moisture*
A fertilization concept to move soil P levels into an optimum range over time.

- **Buildup range**
  - If low, may want to build by applying fertilizer or manure P in excess of crop removal.

- **Maintenance range**
  - 10-20 ppm Olsen soil test P
  - If near optimum, can balance input and removal.

- **Drawdown range with starter P only**
  - If excess, can draw down by using only starter P.

Adapted from OMAFRA Soil Fertility Handbook.
Effect of P balance on soil test P buildup and drawdown varies with soil type

eg. 8 year study in AB & MB in a durum-flax rotation

- Olsen P increased with high P rates
- Olsen P declined when no P applied
- At 40 lb phosphate/acre/year, Olsen P was maintained at most sites
- Surplus P to raise Olsen P by 1 ppm:
  - 16-23 lb P$_2$O$_5$/ac at Carman
  - 29-32 lb P$_2$O$_5$/ac at Carstairs
  - 27-35 lb P$_2$O$_5$/ac at Brandon
  - 21-25 lb P$_2$O$_5$/ac at Ft. Sask.
  - 32-41 lb P$_2$O$_5$/ac at Phillips
- Most rapid change in light-textured, poorly buffered soils

Grant et al. unpublished
Recommended Strategies for Maintaining P Fertility

- Apply sufficient P in side- or midrow bands to match crop removal on annual basis
- Use a rotational fertilization strategy over several years:
  - Add extra P to crops in rotation that tolerate high rates of seed-placed P (e.g. cereals)
  - Periodically band P fertilizer into soil during fall tillage ... eg. MAP with AS prior to canola, which responds to fert. P, N and S
- Apply manure periodically to meet crop N requirements
Avoid excess P depletion or accumulation

• Deficits can reduce P fertility & long term productivity

• Surpluses can increase risk of P loss and eutrophication

• Target Olsen P levels of around 15 ppm
  – build levels in cereal years, with side- or mid-row band applications, or with manure
  – Consider a maintenance strategy when target soil levels are attained

Key Messages for Selecting the Right Rate of P
 ✓ Right source
 ✓ Right rate
 ✓ Right placement
 ✓ Right timing

In a coherent combination suited to the crop, economics, and environment
Principles of Phosphorus Nutrition that Affect P Placement and Timing

• P is needed early in growth
  – Plants must have adequate supply in first 3-6 weeks
• Phosphorus will not move far through the soil
  – Movement is limited to a few mm
• Adequate P needs to be near the seed-row so the plants can access it early in the season ... especially in cold soils where P movement and root growth are slow
Banding P near seed is most important with

- Low soil P levels
- Restricted rooting
  - Compaction
  - Tillage pans
- Cool soil conditions
  - Solubility, mobility, rooting
  - Early seeding

Factors that impede the ability of the crop to access P early in the season will increase the need for starter P.
Wheat yield is higher with banded than broadcast P fertilizer.
Starter P may increase yield with cold soils and early seeding even on relatively high P soils.

+10 kg/ha Seed row P$_2$O$_5$

No starter P

Fall band 70-30-10-10 on whole field

Photo: Aaron Baldwin, Cargill
Effect of “Seed Row” Fertilizer Placement on Wheat Varies with Implement and SBU

- Press Drill - Fertilizer P
- Discer - Fertilizer P
- Broadcast - Fertilizer P

Days After Seeding

P Uptake (mg/sample)

3 Leaf Stage
Shot Blade
Heading
Soft Dough
Mature

Press Drill Fert P
B'cast Discer Fert P

J.B. Bole. 1966. MSc Thesis
Crops differ in response to fertilizer P

- Cereals moderate in their ability to use soil and fertilizer P
- Canola effective at feeding from both fertilizer and soil P
  - Modification of rhizosphere
  - Proliferation of roots in fertilizer reaction zone
- Flax has poor ability to take up fertilizer P
  - Relies more strongly on soil P
  - Poor response to fertilizer P
- Sensitivity to seed-placed P is also important
Seed-placed P fertilizer cannot fully compensate for very low P fertility in the soil.

Yield was higher with moderate rather than very low P fertility at all rates of seed placed fertilizer applied annually.

Amount of P broadcast initially (lb P$_2$O$_5$/ac)

Yield was higher with moderate rather than very low P fertility at all rates of seed placed fertilizer applied annually.

Six year study in SK by Wagar et al. 1986
Seed-placed MAP can lead to seedling damage in sensitive crops

J. Schoenau
Seed-placed MAP can lead to seedling damage in sensitive crops

20 lbs $P_2O_5$/ac as MAP (11-52-0) with disc openers at 12 inch spacing

No seedrow P applied
Seedling damage will be affected by other nutrients in band

- Stand density decreased with increasing rates of seed-placed MAP
- Most damage occurred with highest rates of MAP and ammonium sulphate

Quebec 2010

Thunder Bay 2011
Seedling damage was reduced by use of controlled release phosphate.

The graph shows the percentage emergence of Canola and Flax as a function of phosphate application rate. The legend indicates that:

- Red squares represent Canola - MAP
- Red triangles represent Canola - CRP
- Blue squares represent Flax - MAP
- Blue triangles represent Flax - CRP

The x-axis represents kg of phosphate per hectare, ranging from 0 to 40, while the y-axis represents % emergence, ranging from 40 to 110.
Struvite and coated MAP reduce the risk of seedling toxicity

Seedling damage was reduced by use of struvite and controlled release phosphate

Katanda et al. 2019
Agron. J. 111:390–396
Broadcasting P decreases agronomic efficiency and increases environmental risk

- Broadcasting P fertilizer, especially in conservation tillage systems, is agronomically inefficient and leaves water soluble P on the soil surface ... prone to runoff ... especially if applied in fall
Runoff losses for banded vs. broadcast P applied at 100 lbs MAP (11-52-0) per acre in laboratory studies were 50 times greater for broadcast P than for P banded 1 cm below the soil surface

(Smith et al. 2016)
Key Messages for Selecting the Right Placement and Timing for P Fertilizer

• Plants need P from their earliest growth stages
  – P fertilizer should be applied when and where the crop can access it early in the season.
• Cold soils in the early spring can restrict root growth and P availability, limiting early season P supply to crops
• Band application near the seed-row can improve P efficiency
  – Banding slows soil reactions that reduce P availability
  – Place P bands where plant roots will intercept them in early growth
• Broadcast P at the soil surface is agronomically less efficient than in-soil bands and increases the risk of P runoff
• In-soil banding is agronomically and environmentally beneficial for P applications on the Northern Great Plains
Key Overall Messages for 4R P Fertilization in the Northern Great Plains

• Employing the science-based principles of 4R P fertilizer stewardship is vital for sustainable crop production

• The most efficient sources of P fertilizer for this region are ammonium phosphates

• Long term sustainable crop production requires P fertilizer rates that match crop removal

• Banding P fertilizer in or near the seed-row is agronomically and environmentally beneficial

✔ Right source
✔ Right rate
✔ Right placement
✔ Right timing
Thank you for your attention
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