Phosphorus Management: Questions of Balance

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AGVISE Soil Fertility Seminars
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P Balance Issues

1. Short term vs. long term P management strategies
2. Crop production vs. environmental protection
3. Environmental challenges for P vs. other environmental challenges
Why is phosphorus balance important?

**Food** - P is a unique element that is essential for almost all life

**Water** - small amounts of excess P cause big problems with water quality
Examples of molecules that are vital for life and that require P DNA genetic coding & control
P Management in Corn & Soybeans in Manitoba
Corn Production in Manitoba

- Grain corn acreage is increasing in MB
- Short growing season and cold soils at planting
- Often planted on land with canola in rotation
- Conservation tillage an important BMP
Corn Rotation Study: Starter P & Zn

Fertilization strategies for corn grown after canola (non-mycorrhizal) vs. soybean

P? Zn?
## Corn Rotation Study: Site Information

<table>
<thead>
<tr>
<th></th>
<th>Planting Date</th>
<th>Harvest Date</th>
<th>Olsen-P (ppm)</th>
<th>DTPA-Zn (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015 Sites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carman, MB</td>
<td>May 25</td>
<td>Oct. 15</td>
<td>19</td>
<td>1.50</td>
</tr>
<tr>
<td>Stephenfield, MB</td>
<td>May 26</td>
<td>Oct. 14</td>
<td>6</td>
<td>0.82</td>
</tr>
<tr>
<td><strong>2016 Site</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carman, MB</td>
<td>May 12</td>
<td>Oct. 05*</td>
<td>9</td>
<td>1.91</td>
</tr>
</tbody>
</table>

* Carman 2016 site was hand harvested due to wind damage and green snap.

**Corn Hybrid: DKC 26-28RIB (2150 CHU)**
Corn Rotation Study Treatments

Crop Treatments - Canola or Soybeans

Fertilizer Treatments (sidebanded 2” by 1” at planting)

<table>
<thead>
<tr>
<th>Control</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>No P Check</td>
</tr>
</tbody>
</table>

MAP (11-52-0) + AS (21-0-0-24)

<table>
<thead>
<tr>
<th>2.</th>
<th>27 P₂O₅</th>
<th>0 Zn</th>
<th>6.8 S lbs/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>54 P₂O₅</td>
<td>0 Zn</td>
<td>13.5 S lbs/ac</td>
</tr>
</tbody>
</table>

MicroEssentials SZ (12-40-0-10S-1Zn)

<table>
<thead>
<tr>
<th>4.</th>
<th>27 P₂O₅</th>
<th>0.68 Zn</th>
<th>6.8 S lbs/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>54 P₂O₅</td>
<td>1.35 Zn</td>
<td>13.5 S lbs/ac</td>
</tr>
</tbody>
</table>
Corn Rotation Study: Early Season Response to Starter

MAP 27 lb P$_2$O$_5$/ac  No P Check  P deficiency symptoms at V3

Corn on Canola Stubble
# Corn Rotation Study

**Corn Early Season Biomass (V4)  
2015 - 2016**

## Canola

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Biomass (lb/ac)</th>
<th>ANOVA Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P Check</td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td></td>
<td>AB</td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>27 lb P2O5/ac MESZn</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>54 lb P2O5/ac MESZn</td>
<td></td>
<td>A</td>
</tr>
</tbody>
</table>

### Range

**85 – 110%**

## Soybean

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Biomass (lb/ac)</th>
<th>ANOVA Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P Check</td>
<td></td>
<td>B</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td></td>
<td>AB</td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>27 lb P2O5/ac MESZn</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>54 lb P2O5/ac MESZn</td>
<td></td>
<td>A</td>
</tr>
</tbody>
</table>

### Range

**30 – 38%**
# Corn Rotation Study

Silking differences as compared to control plots

<table>
<thead>
<tr>
<th>Site-year</th>
<th>Maturity Advance (days)</th>
<th>Fertilizer and Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carman 2015</td>
<td>+2 to 3</td>
<td>All fertilizer treatments, corn on canola</td>
</tr>
<tr>
<td>Stephenfield 2015</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Carman 2016</td>
<td>+2 to 7</td>
<td>All fertilizer treatments, regardless of crop</td>
</tr>
</tbody>
</table>

Earlier tasseling and taller corn plants with spring side-banded 27 lb $P_2O_5$/ac as MAP (L) and 27 lb $P_2O_5$/ac as MESZn (R) vs. control (M) at Carman following canola stubble.
Corn Rotation Study

Grain Moisture at Harvest
(Crop x Fertilizer, $P=0.0002$)

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>No P Check</th>
<th>27 lb P2O5/ac MAP</th>
<th>54 lb P2O5/ac MAP</th>
<th>27 lb P2O5/ac MESZn</th>
<th>54 lb P2O5/ac MESZn</th>
<th>No P Check</th>
<th>27 lb P2O5/ac MAP</th>
<th>54 lb P2O5/ac MAP</th>
<th>27 lb P2O5/ac MESZn</th>
<th>54 lb P2O5/ac MESZn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 – 3%
Corn Rotation Study
Corn Grain Yield Response to Previous Crop
2015 - 2016

Yield (bu/ac)

Canola Soybean Canola Soybean Canola Soybean

118 bu/ac
8%
Corn Rotation Study

Corn Grain Yield Response to Starter Fertilizer
2015 - 2016

- No P Check: 153 bu/ac
- 27 lb P2O5/ac MAP: AB
- 54 lb P2O5/ac MAP: A
- 27 lb P2O5/ac MESZn: AB
- 54 lb P2O5/ac MESZn: AB

10% increase in yield compared to No P Check.
Corn Strip Till Study – P Timing & Placement

P fertilization strategies for corn planted in strip tillage vs. conventional tillage
## Corn Strip Till Study: Site Information

<table>
<thead>
<tr>
<th></th>
<th>Planting Date</th>
<th>Harvest Date</th>
<th>Olsen-P (ppm)</th>
<th>Residue</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015 Sites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carman, MB</td>
<td>May 25</td>
<td>Oct. 16</td>
<td>8</td>
<td>Wheat</td>
</tr>
<tr>
<td>Portage la Prairie, MB</td>
<td>May 26</td>
<td>Oct. 19</td>
<td>11</td>
<td>Barley</td>
</tr>
<tr>
<td><strong>2016 Sites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carman, MB</td>
<td>May 12</td>
<td>Oct. 5*</td>
<td>5</td>
<td>Wheat</td>
</tr>
<tr>
<td>Portage la Prairie, MB</td>
<td>May 16</td>
<td>Oct. 6*</td>
<td>14</td>
<td>Wheat</td>
</tr>
</tbody>
</table>

*Carman 2016 site was hand harvested due to wind damage and green snap.
*Portage 2016 sites was hand harvested due to hail and black bird damage.

**Corn Hybrid: DKC 26-28RIB (2150 CHU)**
Corn Strip Till Study: 2 Previous Tillage Treatments
Corn Strip Till Study: 5 Fertilizer Treatments (lbs/ac, spring (2" by 1") and fall application (4-5”))

CONTROL

1. No P Check

MAP (11-52-0) Only

2. 27 P₂O₅ SPRING SB
3. 54 P₂O₅ SPRING SB

4. 27 P₂O₅ FALL DB
5. 54 P₂O₅ FALL DB

4-row, Yetter Strip Till Unit 8” (20 cm) wide strips on 30” (76 cm) centers with 4-5” deep band
Corn Strip Till Study
Corn Early Season Biomass (V4) 2015 - 2016

Carman 2015

- No P Check
- 27 lb P2O5/ac MAP
- 54 lb P2O5/ac MAP

Spring Sideband
- B
- A
- AB

Fall Deepband
- B
- B
- AB

Carman 2016

- No P Check
- 27 lb P2O5/ac MAP
- 54 lb P2O5/ac MAP

Spring Sideband
- A
- AB
- ABC

Fall Deepband
- AB
- CD
- BCD

Biomass (% of Conventional)
Carman 2015:
- Spring Sideband: 77%
- Fall Deepband: 76%
Carman 2016:
- Spring Sideband: 76%
- Fall Deepband: 102%
Corn Strip Till Study

Silking differences as compared to control plots

<table>
<thead>
<tr>
<th>Site-year</th>
<th>Maturity Advance (days)</th>
<th>Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carman 2015</td>
<td>+2</td>
<td>All fertilizer treatments</td>
</tr>
<tr>
<td>Portage la Prairie 2015</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Carman 2016</td>
<td>+3 to 4</td>
<td>Both rates of spring side-banded MAP</td>
</tr>
<tr>
<td>Portage la Prairie 2016</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

60 kg $P_2O_5$ ha$^{-1}$ MAP Spring Sideband

CONTROL No P Check

60 kg $P_2O_5$ ha$^{-1}$ MAP Spring Sideband

No P Check
# Corn Strip Till Study

## Kernel Moisture at Harvest

2015 - 2016

<table>
<thead>
<tr>
<th></th>
<th>Spring Sideband</th>
<th>Fall Deepband</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carman 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portage 2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Spring Sideband</th>
<th>Fall Deepband</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carman 2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portage 2016</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Spring Sideband</th>
<th>Fall Deepband</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carman 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portage 2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Moisture (%)

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P Check</td>
<td>21</td>
<td>A</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td>23</td>
<td>A</td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td>21</td>
<td>A</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td>23</td>
<td>A</td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td>22</td>
<td>A</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td>22</td>
<td>A</td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td>21</td>
<td>A</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td>21</td>
<td>A</td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td>22</td>
<td>A</td>
</tr>
</tbody>
</table>

**2%**

**1-2%**
Corn Strip Till Study
Corn Grain Yield Response to P
2015 - 2016

Yield (bu/ac)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spring Sideband</th>
<th>Fall Deepband</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P Check</td>
<td>146 bu/ac</td>
<td>B</td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>27 lb P2O5/ac MAP</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>54 lb P2O5/ac MAP</td>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

5% increase in yield
### Corn Strip Till Study: Summary

<table>
<thead>
<tr>
<th>Early season growth</th>
<th>Silking Date</th>
<th>Grain Moisture</th>
<th>Grain Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>76 - 103%</td>
<td>2 - 4 days</td>
<td>1 - 2 %</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Good News...**

Corn planted in strip till yielded as well as corn planted in conventional till and had similar grain moisture.
Manitoba Soybean P Study #1: Effects of P Fertilizer Rate & Placement on Plant Stand and Seed Yield

Gustavo Bardella
Manitoba Soybean P Study #1: Effects of P Fertilizer Rate & Placement

- Half of the sites tested 10 ppm or less for Olsen P (v. low-low)
- 3 rates of $P_2O_5$ (0, 40, 80) applied as MAP in SR, SB, or B’cast
- Opener type: knife or disc with row spacing from 7 to 12” (low SBU)

<table>
<thead>
<tr>
<th>Site</th>
<th>Olsen P (ppm)</th>
<th>Soil Texture</th>
<th>Row Spacing</th>
<th>Seeder Opener</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
<td>2015</td>
<td>Inches</td>
</tr>
<tr>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseisle</td>
<td>N/A</td>
<td>4 (VL)</td>
<td>4 (VL)</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Melita</td>
<td>3 (VL)</td>
<td>5 (L)</td>
<td>7 (L)</td>
<td>Sandy Clay Loam</td>
</tr>
<tr>
<td>Brandon</td>
<td>5 (L)</td>
<td>6 (L)</td>
<td>5 (L)</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Carman</td>
<td>N/A</td>
<td>15 (H)</td>
<td>7 (L)</td>
<td>Sandy Clay Loam</td>
</tr>
<tr>
<td>Roblin</td>
<td>7 (L)</td>
<td>22 (VH)</td>
<td>8 (L)</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Beausejour</td>
<td>8 (L)</td>
<td>13 (M)</td>
<td>7 (L)</td>
<td>Heavy Clay</td>
</tr>
<tr>
<td>Arborg</td>
<td>14 (M)</td>
<td>22 (VH)</td>
<td>14 (M)</td>
<td>Silty Clay</td>
</tr>
<tr>
<td>St Adolphe</td>
<td>23 (VH)</td>
<td>25 (VH)</td>
<td>71 (VH)</td>
<td>Heavy Clay</td>
</tr>
<tr>
<td>Portage</td>
<td>34 (VH)</td>
<td>18 (H)</td>
<td>10 (L)</td>
<td>Clay Loam</td>
</tr>
<tr>
<td>Carberry</td>
<td>44 (VH)</td>
<td>11 (M)</td>
<td>15 (H)</td>
<td>Clay Loam</td>
</tr>
</tbody>
</table>
Effect of P rate and placement on soybean seed yield for 28 site years in Manitoba

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014</td>
<td>2015</td>
<td></td>
</tr>
<tr>
<td># Sites</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mean Seed Yield (bu/ac)</td>
<td>46</td>
<td>42</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Control Seed Yield (bu/ac)</td>
<td>23 - 66</td>
<td>18 - 60</td>
<td>37 – 65</td>
<td></td>
</tr>
<tr>
<td># Sites with Yield Increase</td>
<td>0</td>
<td>0</td>
<td>1*</td>
<td></td>
</tr>
<tr>
<td># Sites with Yield Decrease</td>
<td>2**</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Change in Yield</td>
<td>-29 to 36%</td>
<td>0</td>
<td>+15%</td>
<td></td>
</tr>
</tbody>
</table>

* Seed yield increased by 40 and 80 lb P$_2$O$_5$/ac at Roseisle 2015
** Seed yield reduced by 80 lb P$_2$O$_5$/ac seed-placed, at Melita and Carberry in 2013
Why only 1 positive response to P in 28 site years? Soybeans are efficient feeders for soil P in Manitoba soils

(Kalra and Soper 1968)
Manitoba Soybean P Study #2:
Soybean response to starter P fertilizer and soil P fertility from historic fertilization practices

- Located on three sites for a previous long term P fertilization trial that received 3 rates of MAP fertilizers applied each year, from 2002 until 2009, with total cumulative applications of 320, 640 and 1280 lbs P$_2$O$_5$/acre over the 8 year period
- No fertilizer P added from 2010-2012
- Soybean planted on the same sites in 2013, 2014, 2015

<table>
<thead>
<tr>
<th>Historical P Applied (lb P/ac) (lb P$_2$O$_5$/ac)</th>
<th>Soil Test Olsen P (ppm)</th>
<th>Brandon</th>
<th>Carman</th>
<th>Forrest</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>11</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>143</td>
<td>320</td>
<td>22</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>285</td>
<td>640</td>
<td>33</td>
<td>53</td>
<td>22</td>
</tr>
<tr>
<td>570</td>
<td>1280</td>
<td>54</td>
<td>91</td>
<td>40</td>
</tr>
</tbody>
</table>
Soybean Seed Yield 2013
- no yield response to starter P or historic P fertility

Brandon 2013

Forrest 2013

With side-banded starter P (18 lb/ac)
Without starter P
Soybean Seed Yield 2014

- no yield response to starter P or historic P fertility

**Brandon 2014**

<table>
<thead>
<tr>
<th>Cumulative Historical P (lb/ac)</th>
<th>Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P</td>
<td>30</td>
</tr>
<tr>
<td>143</td>
<td>35</td>
</tr>
<tr>
<td>285</td>
<td>36</td>
</tr>
<tr>
<td>570</td>
<td>37</td>
</tr>
</tbody>
</table>

**Carman 2014**

<table>
<thead>
<tr>
<th>Cumulative Historical P (lb/ac)</th>
<th>Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No P</td>
<td>40</td>
</tr>
<tr>
<td>143</td>
<td>41</td>
</tr>
<tr>
<td>285</td>
<td>42</td>
</tr>
<tr>
<td>570</td>
<td>43</td>
</tr>
</tbody>
</table>

- With side-banded starter P (18 lb/ac, for 2\textsuperscript{nd} year)
- Without starter P
Soybean Seed Yield 2015

- no yield response to historic P fertility

- Brandon 2015
- Forrest 2015
- Carman 2015

Yield (bu/ac)
Cumulative Historical P (lb/ac)

No P 143 285 570
0 10 20 30 40 50 60

Forrest 2015

Carman 2015

No P 143 285 570
0 10 20 30 40 50 60
Summary and Conclusions for Manitoba Soybean P Study #2

• The soil test threshold for soybean yield responses to long term soil P fertility and/or P fertilizer appears to be very low in Manitoba soils, lower than those in the soils tested so far (7, 11 & 20 ppm Olsen P)

• Observations of higher soybean yields on Manitoba soils with higher P fertility (e.g., manured soils) may be due to other factors
Soybeans may not “care” about P fertilizer, but what about the crop after soybeans?

The phosphorus deficit hangover ...
Balancing P application with crop removal is essential to avoid excessive accumulation or depletion of P in soil.
Effect of legume green manures on long term wheat yields in SK

Figure 1. Yields of stubble wheat crops in fallow-wheat-wheat (F-W-W), fallow-wheat-wheat plus fertilizer (F-W-W (N+P)) and green manure-wheat-wheat (GM-W-W) rotations at Indian Head (Black soil zone) (C.A. Campbell, unpublished data).
Dr. Martin Entz’s long term organic rotation at U of MB demonstrates the importance of P replacement.
Majority of Manitoba Soils Are Deficient in P According to % Less Than Critical Level

Percent of Samples Testing Below Critical Levels for P in 2015

International Plant Nutrition Institute 2016
% Soil Samples with Phosphorus less than 10 ppm

Fall 2017 samples (0-6” samples) (Olsen P test)
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.
Manitoba’s new recommendation for P fertil’n strategy: Phosphorus balance should be managed through the rotation … not just on a single crop basis

- What is the current soil P level?
  - If excess, can draw down by using only starter P
  - If near optimum, can balance input and removal
  - If low, may want to build by applying fertilizer or manure P in excess of crop removal
A fertilization concept to move soil P levels into an optimum range over time

- **Buildup range**
- **Maintenance range**
  - 10-20 ppm Olsen soil test P
- **Drawdown range with starter P**

Adapted from OMAFRA Soil Fertility Handbook
Phosphorus Fertilization Strategies

Did you know? Soybeans remove 0.84 lbs P per bushel, which means a 40 bu/ac soybean crop removes 34 lbs P/ac. Attention must be paid to ensure a proper fertilization strategy is adopted to ensure application rates are meeting removal rates through the entire crop rotation – learn more below.

Manitoba fertilizer phosphorus (P) guidelines have not been updated since 1992 and some troubling trends have been identified:

- In several of the past years the crop removal of P has surpassed the application rate of fertilizer P
- More soil test values are declining into the LOW range in some areas of Manitoba

This decline in soil test P levels (STP) may arise for a number of reasons:

- Changing crop acreages – from relatively low P removal crops of cereals and flax to canola, soybeans and corn
- Move to low disturbance seeders and planters with narrow openers and wide row spacings (low seedbed utilization) which limit the safe rate of seed row applied fertilizer, especially with sensitive crops such as canola and soybeans
- Promotion and adoption of low P rate starter fertilizers that do not replace P that is removed by crops
- Increase in grain yields since development of original MAFRD recommendations in the early 1990s due to breeding (ie introduction of hybrid canola, general purpose spring wheats etc.) and technology (ie fungicide use)
- Provincial recommendation tables do not include yield adjustment factors, so rates have been inadequate to meet current yield levels, let alone match rates of P removal

Thinking about your cropping system, or that your client, does P applied equal P removed? Or are crop removal rates exceeding P applied, leading to a negative soil P balance? Use the interactive Phosphorus Balance Calculator to determine your annual P balance:

Interactive Phosphorus Fertilization Calculator

Phosphorus Recommendation Strategies for Manitoba

Manitoba Soil Fertility experts have collaborated to develop “Phosphorus Fertilization Strategies for Long Term Agronomic and Environmental Sustainability” which outlines
## Phosphorus Balance Calculation for a Rotation (Version 4 - October 1, 2014)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Typical Yield</th>
<th>Yield Units</th>
<th>P Applied per unit</th>
<th>P Removed* per acre</th>
<th>Annual Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR Spring wheat</td>
<td>60</td>
<td>bu/ac</td>
<td>30</td>
<td>0.59</td>
<td>35</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>75</td>
<td>bu/ac</td>
<td>30</td>
<td>0.51</td>
<td>38</td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td>bu/ac</td>
<td></td>
<td>0.42</td>
<td>0</td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td>bu/ac</td>
<td></td>
<td>0.26</td>
<td>0</td>
</tr>
<tr>
<td>Canola</td>
<td>40</td>
<td>bu/ac</td>
<td>20</td>
<td>1.04</td>
<td>42</td>
</tr>
<tr>
<td>Soybeans</td>
<td>40</td>
<td>bu/ac</td>
<td>10</td>
<td>0.84</td>
<td>34</td>
</tr>
<tr>
<td>Peas</td>
<td></td>
<td>bu/ac</td>
<td></td>
<td>0.69</td>
<td>0</td>
</tr>
<tr>
<td>Flax</td>
<td></td>
<td>bu/ac</td>
<td></td>
<td>0.65</td>
<td>0</td>
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<tr>
<td>Corn (grain)</td>
<td></td>
<td>bu/ac</td>
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<td>0.44</td>
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<tr>
<td>Other**</td>
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<td></td>
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<td>0.00</td>
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</tr>
</tbody>
</table>

**Total for Rotation**

|               |               |             | 90               | 149               | -59            |

Fill in any of the blue cells for typical rotation, yields, and P appl'n

*P removal figures are estimates from the Manitoba Soil Fertility Guide.

**For nutrient removal in other crops see table in next worksheet.
Almost all fertilizer P in the Canadian Prairies is banded under soil surface, in or near seed, at planting

**Agronomically beneficial**, especially in cold soils in areas with short growing season

**Environmentally beneficial** because P placed under soil surface after spring snowmelt runoff
P sufficiency strategy for short term (fertilizing for optimum economic responses in first year after application) often decreases P fertility for long term.

### Appendix Table 17. Phosphorus recommendations for field crops based on soil test levels and placement™.

<table>
<thead>
<tr>
<th>Soil Phosphorus (sodium bicarbonate or Olsen P test) ppm</th>
<th>Fertilizer Phosphate (P₂O₅) Recommended (lb/ac)</th>
<th>Cereal</th>
<th>Corn</th>
<th>Sunflower</th>
<th>Canola</th>
<th>Mustard</th>
<th>Flax</th>
<th>Buckwheat</th>
<th>Faba Beans</th>
<th>Potatoes</th>
<th>Peas</th>
<th>Lentils</th>
<th>Field Beans</th>
<th>Soybeans¹</th>
<th>Legume forages</th>
<th>Perennial grass forages</th>
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<tr>
<td>0</td>
<td></td>
<td>S¹</td>
<td>S²</td>
<td>B³</td>
<td>B¹</td>
<td>B³</td>
<td>S¹</td>
<td>B³</td>
<td>PPI³</td>
<td>B²</td>
<td>S¹</td>
<td>B²</td>
<td>PPI³</td>
<td>S¹</td>
<td>Seeding PPI³</td>
<td>Est. stand BT⁶</td>
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<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

¹ Soybeans can be used as a nitrogen source and do not require additional N, unless specified by the specific crop's needs.
Following short term “P sufficiency” strategy for seed-row P from MB Soil Fertility Guide leads to P deficits

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (bu/ac)</th>
<th>Applied P (lb P₂O₅/ac)</th>
<th>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>
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<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
Olsen P also followed P balance in Alberta and Manitoba soils after 8 years of P applications in a durum-flax rotation

- Large increases in Olsen P occurred with high P rates
- Olsen P declined when no P applied
- At 40 lb phosphate/acre/year, Olsen P was maintained at most sites (but flax P removal is low)
- 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

Grant et al. unpublished
Recommended Strategies for Maintaining P Fertility in Soybean Fields

- Apply sufficient P in sidebands 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
  - Periodically band P into soil during fall tillage ... eg. MAP with AS prior to canola, which responds to fert. P & N
  - Build soil P to target level, but avoid excess accumulation, eg. manure applied at rate to meet crop N requirements will provide P benefit for several years
### Rotational Fertilization Strategies for P Balance

#### Annual & Overall P Balance for P Strategies in 4 Year Rotation

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (bu/ac)</th>
<th>MB</th>
<th>SFG</th>
<th>Seed</th>
<th>Manure in 1st yr</th>
<th>P Maint. with Sideband</th>
<th>N-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP spring wheat</td>
<td>60</td>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Canola</td>
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<td>-20</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Winter wheat</td>
<td>75</td>
<td>-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>35</td>
<td>-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Year Total</td>
<td>-53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Using values of 0.59, 1.0, 0.51, 0.85 lb P$_2$O$_5$/bu respectively for grain only
Why not simply broadcast P?
Broadcasting P fertilizer, especially in conservation tillage systems leaves water soluble P on the soil surface ... prone to runoff ... especially if applied in fall

An invitation to regulation ...
Why is phosphorus balance important?

**Food** - P is a unique element that is essential for almost all life

**Water** - small amounts of excess P cause big problems with water quality

Source: Christiansen/Scientific American

Photo: MB Conservation
Main Problem: Excess P and “Algae”

“Eutrophication” occurs at very low conc’ns of P (20-50 ppb):

- Blue-green “algae” (cyanobacteria)
- Oxygen Depletion
  - Fish kills
- Nerve and Liver Toxins
  - Livestock & wildlife mainly at risk

Photo: Fisheries & Oceans Canada
“The control of phosphorus in agricultural operations must focus on changes in agricultural practices that have been implemented in recent decades, such as increased prevalence of fall application of nutrients, applying two years’ worth of fertilizer in a single application, and broadcast application.”

Excess P & toxic blue-green algae in Lake Erie shuts down water supply to Toledo, Ohio – August 2014
Ohio Regulators Aim to Help Water Problem With Fertilizer Licenses

Farmers in Ohio to Be Required to Get New Certification to Use Fertilizers

By MARK PETERS and MATTHEW DOLAN

Updated Aug. 5, 2014 7:47 p.m. ET

Algae floats in Lake Erie on Monday at Maumee Bay State Park in Oregon, Ohio. Getty Images

The drinking-water crisis in one of Ohio’s largest cities is drawing attention to a new requirement for farmers in the state: a license to fertilize.
Public Concern About Agricultural Nutrients and Water Quality is Increasing

Lake Winnipeg pollution blamed on farm runoff

By Helen Fallding

FARM runoff may be the biggest source of pollution in Lake Winnipeg and the province’s southern rivers, according to a new study by Manitoba Conservation.

About three-quarters of the phosphorus added to the Assiniboine and Red rivers as they passed through Manitoba from 1994 to 2001 had washed off the land. The figures are almost as bad for nitrogen, which combines with phosphorus to promote the growth of algae blooms.

The blooms are bad for fish and wildlife and can produce dangerous toxins.

University of Winnipeg biologist Eva Pip, who has read the report, said many people assumed municipal sewage was the biggest culprit behind the deteriorating health of Lake Winnipeg.

“There’s always been finger-pointing... but now that we have some actual numbers, this gives us a starting point which we can use to start addressing the problem.”

In a previous study completed last year, Manitoba Conservation staff concluded that nitrogen and phosphorus loads in Lake Winnipeg increased 13 and 10 per cent respectively over the last three decades as a result of changes in the Red River basin.

Those are very significant values in a short time,” Pip said.

A Lake Winnipeg sail recently declared endangered is an early warning sign that the lake is in trouble, she said.

Lake Winnipeg has had very bad algae blooms for the last five years, including some this summer at Victoria Beach and on the western shore as far north as the Jackhead reserve, Pip said.

She is calling for more regulation of the nutrients farmers apply to their land.

The latest Manitoba Conservation study, led by Alex Bourne, did not separate the impacts of chemicals from manure or natural sources.

Manitoba’s livestock farmers are required to monitor the amount of nitrogen they apply in manure, but phosphorus is regulated only in Quebec.

Livestock farmers have long complained they are subject to much greater scrutiny than the majority of their neighbours who use chemical fertilizer — soon to be regulated in Ontario after the Walkerton contaminated water scandal.

Keystone Agricultural Producers vice-president David Rolfe said quality assurance programs that require farmers to better manage their fertilizer if they want to be certified might be a better approach than more regulation.

Manitoba’s water quality manager Dwight Williamson said a discussion paper should be out within six months on setting water quality objectives in the Assiniboine, Souris and Qu’Appelle rivers.

Manitoba Agriculture staff already have extension programs encouraging farmers to invest in soil testing so they don’t waste fertilizer and to use low-till agriculture to keep water on the land.

“We do this all the time,” John Heard said.

When fertilizer prices are high, farmers have more incentive to keep their fertilizer use to a minimum, he said.

Pip said the move to drain more farmland — supported by increased government dollars — is also contributing to runoff problems.

Manitoba has no control over pollutants in the rivers before they cross the U.S. and Saskatchewan borders.

Winnipeg’s wastewater treatment plants and sewers added more than 4,000 tonnes of nitrogen to the Red River a year, according to the Manitoba Conservation study — 11 per cent of the total load in the river at Selkirk.

Pip said the nutrient load will be worse now that the city has added orthophosphate to drinking water to deal with elevated lead levels from old pipes.

helen.fallding@freepress.mb.ca

Over-fertilizing polluting province’s water bodies

By Helen Fallding

FARMERS in livestock-intensive areas of Manitoba are over-fertilizing their land, potentially contributing to water pollution as far away as Lake Winnipeg.

In an $81,000 study for the Manitoba Livestock Manure Management Initiative, DGH Engineering found the nutrients nitrogen and phosphorus building up in soils in the municipalities of Hanover and La Broquerie near Steinbach.

In two other municipalities where there is less livestock production — Roland, south of Carman, and Sifton in western Manitoba — there was less buildup.

Excess nutrients not taken up by crops wash off fields into streams and rivers, with Red River nutrients eventually working their way to Lake Winnipeg.

The lake has been plagued with bad algae blooms in recent years that are toxic to fish and wildlife and interfere with the enjoyment of summer beaches.

DGH senior engineer Doug Small said farmers applying manure on their fields from livestock barns are also applying some chemical fertilizer.

In Roland, fertilizer inputs average 85 kilograms per hectare of nitrogen and 14 kilograms per hectare of phosphorus, but the numbers in Hanover are 98 for nitrogen and 32 for phosphorus.

“We’re not saying it’s an immediate serious crisis,” Small said.

“There’s an issue here that needs to be addressed for long-term sustainability.”

Only about five per cent of Manitoba farmland receives animal manure.

Small said the obvious solution is for farmers using manure to cut back on expensive chemical fertilizers — something that would save them money and conserve the natural gas used to make fertilizer.

The owners of large livestock operations are required by the province to test the soil where their manure is applied to monitor levels of nitrogen, but phosphorus is not yet regulated.
The Red River winds through a sweeping landscape of farms, carrying chemicals downriver that are poisoning Lake Winnipeg—a fate that Minnesota’s other rivers could face.
Lake Winnipeg Basin

- 2nd largest watershed in Canada (380,000 square miles)
- over 50% of the watershed is used for agriculture
- relatively dry climate, where runoff dominated by snow-melt over relatively level landscape
- home to 6.6 million people in 4 provinces and 4 states
Lake Winnipeg’s P comes from many relatively small sources

Sources of P that originate in Manitoba

- Upstream jurisdictions: 53%
- Manitoba cities, towns, industries: 9%
- Estimated natural background: 17%
- Present day agriculture: 15%
- Atmospheric Deposition: 6%

Sources of P that originate in Alberta, Saskatchewan, Ontario, Montana, North Dakota, South Dakota and Minnesota

Managing P loss with traditional soil and water conservation BMPs

- Conservation Tillage
- Perennial Forages
- Vegetated Buffers
Effects of conservation tillage on water quality in South Tobacco Creek watershed:

- ✔ decreased total nitrogen export by 68%
- ✔ decreased sediment export by 65%
- ✗ but P was a different story ...
South Tobacco Creek twin watershed study: P loss from conservation tillage was greater than from conventional tillage ... because erosion of soil particles was a minor contributor to P loss in both systems.

![Graph showing P loss from different tillage systems](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Dissolved P</th>
<th>Particulate P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment 1993-1996</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Post-treatment 2004-2007</td>
<td>1.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Conservation tillage started in fall 1996

P loss/ac up 12%
P conc'n up 42%

(Tiessen et al. JEQ 2010)
In Oklahoma, conservation tillage increased losses of dissolved P, but reduced total P loss from wheat by 95% ... where most of the P loss was by erosion.

El Reno, OK - Sharpley and Smith, 1994
“Our findings suggest that changes in agricultural practices, including some conservation practices designed to reduce erosion and particulate P transport, may have had unintended, cumulative, and converging impacts contributing to the increased SRP loads, reaching a critical threshold around 2002.”
Fresh frozen green plant residues at greatest risk for simulated snowmelt runoff P losses

Freezing, thawing increases P loss from cover crops on manured soil: USDA research in PA

Bechmann et al. 2006
JEQ 34:2301-2309
Perennial alfalfa forage loses 2.6 x as much P in snowmelt runoff as conventionally tilled annual crops (8 site years).

<table>
<thead>
<tr>
<th>Load of TP (kg ha(^{-1}))</th>
<th>0.0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
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<tbody>
<tr>
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</tr>
<tr>
<td>Perennial forage</td>
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</tr>
</tbody>
</table>

TP loss/ac up 160%
TP conc'n up 52%

“Actual P losses likely depend on the timing and extent of plant freezing and drying and of precipitation events after freezing.”

WI studies show that P losses from frozen or dried alfalfa under laboratory conditions did not match losses under field conditions.
Vegetated buffer strips in Manitoba not as effective as expected

Sheppard et al. CJSS 2006 (SE MB)
• VBS reduced runoff [TP] in 50% of cases,
• increased P in 18%, had no effect in 32%
• overall average ... only 4% reduction in runoff [TP]

Sheppard et al. 2011 & Habibiandehkordi et al. 2017
• No significant reduction in P with VBS in 45 of 54 seasonal measurements in Eastern-Interlake CD, Pembina Valley CD, and Little Sask. CD trials
In-stream and near-stream processes (e.g., vegetated buffers and biological uptake) are minimal during snowmelt.
Flow is often concentrated in only a small area of the buffer, overwhelming the nutrient retention system.
Barnyard vegetative filter strips:
Ineffective outside growing season in Vermont

Schellinger & Clausen JEQ 1992
BMP effectiveness for reducing losses of dissolved P (Sharpley, adapted from Gitau et al. JSWC, 2005)

- Manure mgt. system (14): -28%
- Nutrient mgt. plan (14): -40%
- Riparian / strip buffers (34): -20%
- Conservation tillage (13): +5%

Effect on dissolved P loss, %

-100 Decreased loss 0 Increased loss 100

Effect on dissolved P loss, %
Balancing Benefits, Co-Benefits, and Trade-Offs

- Also, remember that P loss is only one of many objectives that agricultural practices must address to be sustainable
Balancing Benefits, Co-Benefits, and Trade-Offs

- No BMP, including conservation tillage, perennial forage or vegetated buffers is a cure-all, for all environmental issues and situations

- BMPs have different effects on different issues (eg. N vs P) in different environments (eg. rainfall on sloping land vs. snowmelt runoff on plains)

- Co-benefits are variable, but trade-offs are inevitable … let’s use knowledge to maximize co-benefits & minimize trade-offs
Balancing Benefits, Co-Benefits, and Trade-Offs

• Perhaps it’s time to treat environmental health like human health ... with more effort to aim for improved overall health:

  • Diagnose the correct cause
    • assess each case individually and comprehensively
    • identify the real cause of the most important problem(s)
  
  • Prescribe the right cure
    • make sure the “cure” works
    • treat with precision
    • consider all the benefits
    • consider all the “side effects”
    • continuously monitor, adapt & fine tune the treatment
1. Starter P improves early season growth, advances maturity, and increases yield in corn, but has little benefit for soybean. However, we need to add enough P to balance removal to maintain long term productivity for the whole crop rotation.
2. Careful management of P rate, placement & timing is critical for reducing the risk of P loss to surface water ...

especially considering that very small concentrations of P cause big problems with water quality ...

and some traditional soil and water conservation practices that reduce water erosion may increase the loss of dissolved P in Northern Great Plains watersheds.
3. We should be make sure that “beneficial management practices” are truly beneficial under local conditions ...

and aim for improving overall environmental health, being careful to consider all the co-benefits and trade-offs of beneficial management practices.
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