P and K Fertilization: Effects on Corn and Soybean Yields and Profitability

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Univ. of Minnesota, Southern Research and Outreach Center
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Introduction

• Production Dilemma: Declining commodity prices and production costs which exceed revenue.

• Where can a farmer reduce input costs?
  – Seed, rent, pesticides, equipment, labor, etc.

• Fertilizer: What is the potential cost / benefit of applying less or no fertilizer.
  – Nitrogen: greatest return on investment (high RISK)
  – P and K: depends on soil tests, but greatest potential for input cost reduction.
Outline:

• Utilize research data from long-term P and K studies to answer the following questions.
  – What happens to crop yields when you reduce rates or apply no P and K fertilizer?
    – Yield as affected by soil test P.
    – Soil test critical values and response probability
    – How fast does soil test P decline when no fertilizer P is applied?

• Potassium fertilization of corn and beans.
  – Yield response, critical values, NOT SO EASY

Waseca site:
corn yields = 150 bu./A
beans = 50 bu./A

Planting dates:
Earliest = Apr. 27, 1987
Latest = June 1, 1990
Avg. = May 11
Only 3 of 20 in April

Randall et al., 1997

Fig. 4. Relative corn and soybean grain yield as a function of STP on Webster and Aastad soils.
<table>
<thead>
<tr>
<th>Extractant</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bray-P</td>
<td>0-5</td>
<td>6-11</td>
<td>12-15</td>
<td>16-20</td>
<td>21+</td>
</tr>
<tr>
<td>Olsen-P</td>
<td>0-3</td>
<td>4-7</td>
<td>8-11</td>
<td>12-15</td>
<td>16+</td>
</tr>
</tbody>
</table>
Corn yield response as affected by soil test P (Bray) at Waseca in 2006 (warm spring).

\[ Y = 81 + 17.7x - 0.696x^2 \]

Plateau at 12 ppm Bray

NO FERTILIZER P APPLIED
Corn yield response as affected by soil test P (Bray) at Waseca in 2008 (cool spring).

\[ Y = 108 + 9.0x - 0.207x^2 \]

Plateau at 22 ppm

NO FERTILIZER P APPLIED

MUST APPLY

Response likely

Yield response unlikely
Relative soybean yields as affected by soil test P (Bray) at Waseca (3-yr average).

Yield = 30.6 + 9.99x – 0.391x²
Yield response to soil test P (Bray)

- **Corn:** yield response to P varies
  - In cool years (2008) critical (plateau 100% max yield) value around 22 ppm Bray P
    - 30 bu./A penalty at 10 ppm Bray
  - In warm springs critical value was about 12 ppm
    - only a 10 bu./A penalty at 10 ppm

- **Soybean:** response can vary, not as much as corn
  - Critical value usually around 12 ppm
  - 40% yield reduction at 5 ppm
  - Later planting & slower early growth = warmer soils
What about Olsen P (soils with pH > 7.3)

• On very high pH soils (7.4 to 8.2 pH)
  – Soil chemistry makes building soil test P difficult or impossible and expensive ($ fert.)
  – P can be tied-up in inorganic compounds which are not readily available to plants
  – WISDOM: band fertilizer P and/or apply low to modest rates of broadcast P regularly

• Feed the crop not the soil - sufficiency approach
Minnesota Long-Term Phosphorus Management Trials: The Build Phase.

Albert Sims, Carl Rosen, Dan Kaiser, Jeff Strock, Jeff Vetsch, Karina Fabrizzi

Dept. of Soil, Water and Climate
University of Minnesota

December 7, 2015
Phosphorus management in Minnesota is based on one of two philosophical approaches: Build and Maintain (B&M) and Sufficiency. In recent years, it is argued that higher fertilizer applications associated with the B&M approach are necessary to obtain and maintain greater production levels in today’s agricultural systems.
Experimental sites

1. Becker
2. Crookston
3. Lamberton
4. Morris
5. Rochester
6. Waseca

<table>
<thead>
<tr>
<th>STP Level</th>
<th>$P_2O_5$ Rate lb/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>30</td>
</tr>
<tr>
<td>High</td>
<td>60</td>
</tr>
<tr>
<td>V high</td>
<td>90</td>
</tr>
</tbody>
</table>
When STP < 13 mg kg$^{-1}$

$\text{RY} = 30.3 + 10.5(P) - 0.396(P^2)$

$R^2 = 0.357$ $P < 0.0001$

When STP < 15 mg kg$^{-1}$

$\text{RY} = 49.7 + 6.63(P) - 0.22(P^2)$

$R^2 = 0.492$ $P < 0.0001$
Most of the corn sites were responsive to changes in soil P due to P applications, except Lamberton and Rochester that had little or no response to P applications.
When STP < 14 mg kg\(^{-1}\)

\[ RY_{(QP)} = 24.4 + 10.8(P) - 0.39(P^2) \]

\[ R^2 = 0.737 \quad P < 0.0001 \]

When STP < 19 mg kg\(^{-1}\)

\[ RY_{(QP)} = 73.9 + 2.68(P) - 0.07(P^2) \]

\[ R^2 = 0.282 \quad P < 0.0001 \]

When STP < 11 mg kg\(^{-1}\)

\[ RY_{(QP)} = 32.2 + 12.4(P) - 0.57(P^2) \]

\[ R^2 = 0.529 \quad P < 0.0001 \]
Soybean in 2014 was very responsive to P at all sites except Rochester.
ALPS Yield Data Summary

• In 15 of 20 site-years (individual years not shown), yields were optimized with STP in the medium soil test level (11-15 ppm Bray P), which received 30 lb P$_2$O$_5$/ac annually during the study.

• Data from recent response trials showed critical values were similar to data from 30+ years ago.
On-farm Assessment of Critical Soil Test Phosphorus and Potassium Values in Minnesota

Dr. Daniel Kaiser
Univ. of Minnesota
Dept. of Soil Water and Climate
St. Paul, MN
Corn Relative Yield Data – P
Critical Level = 95% max. yield

Critical Level = 12

Critical Level = 8

- Bray test is being influenced by high pH soils
## Corn Probability of Response Data – CY 2014

<table>
<thead>
<tr>
<th>Class</th>
<th>n</th>
<th>Bray-P1 Test</th>
<th>Olsen-P Test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Probability of Response</td>
<td>Magnitude of Response†</td>
<td>Probability of Response</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig.</td>
<td>All</td>
<td>Sig.</td>
</tr>
<tr>
<td>VL</td>
<td>16</td>
<td>100</td>
<td>13.0</td>
<td>13.0</td>
</tr>
<tr>
<td>L</td>
<td>133</td>
<td>72</td>
<td>12.7</td>
<td>9.2</td>
</tr>
<tr>
<td>M</td>
<td>59</td>
<td>25</td>
<td>7.9</td>
<td>2.0</td>
</tr>
<tr>
<td>H</td>
<td>59</td>
<td>10</td>
<td>2.2</td>
<td>0.2</td>
</tr>
<tr>
<td>VH</td>
<td>133</td>
<td>5</td>
<td>11.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>

†Percent increase in yield considering (Sig.) only field areas where P significantly increased yield and (All) all zones for the given soil test classification
Summary of Kaiser data

• Corn:
  – At 95% of maximum yield, STP critical level 12 ppm Bray and 8 ppm Olsen.
  – A small yield penalty (2.2%) for not applying fertilizer P when Bray P is 16-20 ppm (high level), but little or no economic penalty with $3-4 corn.
  – No yield penalty when Bray P > 21 ppm (very high).
Incline / Decline Rates for Soil Test P
Decline rates for STP in zero P plots during a 20-yr period at Waseca and Morris (1973-1993).

Waseca site:
6-yr period ('73–'78)
Started at 20 ppm
declined about 2.2 ppm/yr

14-yr period ('79–'93)
Started around 10 ppm
declined only 0.4 ppm/yr

Morris site:
6-yr period ('73–'78)
Started at 10 ppm
declined about 0.9 ppm/yr

Randall et al., 1997

Waseca site:
8-yr period (‘85–‘93)
Starting at 40 ppm declined about 2.5 ppm/yr
8-yr period (‘85–‘93)
Starting at 22 ppm declined about 1.9 ppm/yr

Morris site:
8-yr period (‘85–‘93)
Starting at 40 ppm declined about 2.7 ppm/yr
8-yr period (‘85–‘93)
Starting at 22 ppm declined about 1.6 ppm/yr

Fig. 3. Decline rates of STP in an 8-yr period when no fertilizer P was added to very high testing soils built up by 50- and 100-lb P₂O₅ rates.
Minnesota Long-Term Phosphorus Management Trials:

Albert Sims, Carl Rosen, Dan Kaiser, Jeff Strock, Jeff Vetsch, Karina Fabrizzi

Dept. of Soil, Water and Climate
University of Minnesota

December 7, 2015
P rates were 0, 30, 60 and 90 lb P$_2$O$_5$/ac/year.

Soil test P (STP) declined with 0-lb P$_2$O$_5$/ac at all sites except Lamberton.

30-lb of P$_2$O$_5$/ac maintained STP except at Morris.

60-lb P$_2$O$_5$/ac increased STP at all sites except Morris.

90-lb P$_2$O$_5$/ac increased STP at all sites
Potassium Fertilization of Corn and Soybeans

Jeffrey Vetsch and Daniel Kaiser
Univ. of Minnesota, SROC and Dept. of Soil Water and Climate
Potassium

• K in plants
  – Taken up in large quantities like nitrogen
    • 5.2 lb K₂O/ac/day from V10–V14 (Bender et al., 2013)
  – Critical for cell wall thickness and stalk strength
  – In inorganic (K⁺) state, not organic

• K in soil
  – STK is an index of exchangeable K
  – Influenced by: wetting/drying, freezing/thawing, release from crop residues and clay mineralogy (release vs fixation)
Potassium in crop residues

- Plant stover contains a large amount of K that is potentially available
  - > 100 lbs of K$_2$O is typical for corn stover
- Since K is not structural (organic), it washes out of residue as breakdown occurs
- May also leach out of standing corn after black layer prior to harvest
- Soybeans – significant portion in leaves
Long-term potassium fertilization study

• Three different soil types / parent materials
  – Waseca – glacial till (clay loam)
  – Rochester – loess (silt loam)
  – Becker – outwash (loamy sand), irrigated

• Corn–Corn–Soybean rotation

• Treatments: main plot 0, 60, 120 lb K$_2$O/A, (0, 40 and 80 at Rochester) applied in fall.

• Measurements
  – Soil test K in April and October
  – Silage and grain yield
  – Whole plant K uptake and removal in grain

Vetsch and Kaiser, 2015
Parent Materials of MN Soils
Corn and soybean yields as affected by fertilizer K rate across years at Waseca.

Initial STK=100 ppm

Grain yield, bu ac$^{-1}$

- 0-lb K$_2$O
- 60
- 120

2012 2013 2014 2015

Soybean
Corn and soybean yields as affected by fertilizer K rate across years at Rochester.

Soybean
Initial STK=130 ppm

Grain yield, bu ac⁻¹
0-lb K₂O
40
80

2012 2013 2014 2015
Grain yield, bu ac⁻¹
0
50
100
150
200
250
0-lb K₂O
40
80

Initial STK=130 ppm
Corn and soybean yields as affected by fertilizer K rate across years at Becker.

Initial STK=70 ppm
Yield Summary:

- **Waseca**
  - Visible K deficiency in all corn and soybean plots
  - Variability in yields (drought) in 2012
  - Large response to fertilizer K in 2013 – 2015
    - 58 to 73 bu/ac response in 2014
    - 60 lb K$_2$O statistically equal to 120 in 2014 and 2015

- **Rochester**
  - Significant yield response in all years; however, responses less than at other locations
    - 14 to 36 bu/ac response in 2014
Yield Summary Continued:

- Becker
  - Significant yield response in all years
  - No differences between 60 and 120 lb K$_2$O/ac in any year.
  - 90 bu/ac responses in 2014 and 2015
### Minnesota soil test K (ammonium acetate) interpretation classes

<table>
<thead>
<tr>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg K kg(^{-1})</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>0 – 40</td>
<td>41 – 80</td>
<td>81 – 120</td>
<td>121 – 160</td>
<td>&gt;161</td>
</tr>
</tbody>
</table>

Vetsch, Dec. 2015
Soil test K (dry) as affected by K\(_2\)O fertilizer rate and sampling time at Waseca.

![Graph showing soil test K as affected by K\(_2\)O fertilizer rate and sampling time at Waseca.](image-url)
Soil test K (dry) as affected by K$_2$O fertilizer rate and sampling time at Rochester.
Soil test K (dry) as affected by K₂O fertilizer rate and sampling time at Becker.
Soil Test Summary: Incline – Decline

• STK in 0-K control plots declined at all sites, STK declined fastest at Becker (loamy sand)
• 60-lb K$_2$O/ac/year maintained STK at Waseca and Becker; whereas, 120-lb K$_2$O/ac/year increased STK
• 80-lb K$_2$O/ac/year increased STK at Rochester
Soil Test Summary: Sampling Time

- Change in STK over time was affected by K in crop residues and soil moisture; generally, STK assumed to be lower in fall
  - STK > in fall on glacial till soil at Waseca, varied among years at Rochester (silt loam soil), fall STK < at Becker (sand)
  - Spring sampling (early June) appears best on glacial till soils
Where can you reduce fertilizer input costs?

- Phosphorus has the greatest potential in the short-term.
  - If soil test P (STP) is Low or Very Low (<12 Bray or <8 Olsen), **APPLY FERTILIZER P**.
  - If Bray is 11-15 ppm (Olsen 8-11), a response is likely but may not give an economic return. If Bray is 16-20 (Olsen 12-15) response unlikely.
  - If Bray > 21 ppm (Olsen > 16). No fertilizer P needed.

- Potassium: data inconsistent, some data show potential for yield response on High STK (121–160 ppm) soils, especially glacial till soils.
Questions

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