Potassium for Corn: Soil Testing and Yield Response in the Northern Plains

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Our Potassium Journey

• Potassium nutrition for corn
• Revising the recommendations
• Potassium rate study: 2015-2016
  – Soil test comparison
  – Yield response to fertilization
  – Sampling time for soil potassium
Potassium nutrition for corn

Deficiency symptoms

- Chlorosis, necrosis of outer leaf margin

- Mobile nutrient in plant
  - Expressed in lower leaves
Potassium nutrition for corn

Near Lisbon, ND (Aug. 2016)
Soil K: 47 ppm

Plot 106
0 K₂O/ac
174 bu/ac

Plot 107
150 K₂O/ac
226 bu/ac

John S. Breker, NDSU
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• Potassium mineralogy
Increase in ND corn/soybean acres

Acreage changes

Yield increase

Data source: USDA-NASS
Typical K removal in grain for principal crops at various yields

Change to corn/soybean production removing K at twice the rate
Soil samples with less than 150 ppm K

Fall 2016 samples (0-6” samples)

Data provided courtesy of AGVISE Laboratories, Northwood, ND.

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Revisiting potassium in North Dakota

• Increase in corn/soybean acreage
  – Higher yields, higher K export
• More soil tests below critical level
  – 1980: 3% of samples (Nelson, 1980)
  – 2010: 17% of samples (Fixen et al., 2010)
  – 2015: 16% of samples (IPNI, 2015)
• Potash price spike
  ~$150/ton (1980-early 2000s)
  $853/ton (2009)
Developing a recommendation: Find the soil test critical level

Image from https://courses.cit.cornell.edu/css412/mod3/ext_m3_pg3.htm

Yield related to amount of plant-available nutrient in soil
Soil testing for potassium

Standard method in North Central region:
1.0 M NH₄OAC (pH 7) extraction on dry soil

- Exchangeable K⁺
- Displaced K⁺
- NH₄⁺ ion
- Clay mineral surface
Scrutiny of soil K test method

Standard method in North Central region:
1.0 M NH$_4$OAC (pH 7) extraction on dry soil

• Effect of sample drying on extractable K
• Inconsistent yield responses to K fertilization
• Plant availability of nonexchangeable K
  – The K sandwich (a packed lunch)
• Seasonal soil test K variation
Study objectives

1. Evaluate corn yield response to K fertilization
2. Identify adequate soil K test method
   • Determine critical level
3. Assess seasonal soil K variation
Potassium rate trials

2015: 13 sites
2016: 6 sites
Study Timeline

Spring

- RCBD with four reps
  - Expt. Unit: 10 ft x 30 ft
- Urea, MAP, gypsum broadcast
- Six KCl (0-0-60) rates
  - 0, 30, 60, 90, 120, 150 lb K$_2$O/acre
  - Shallow incorporation (2-3 inches)
Study Timeline

Summer
- Soil samples
  - Biweekly: 0-6 inch
- Plant samples (2016)
  - V5: Whole plant
  - VT: Ear leaf

Fall
- Harvest one 30-foot corn row
- Yield, grain moisture, test weight
Soil test methods evaluated

- 1.0 M NH₄OAC (pH 7) extraction, 5 minute
  - Air-dried soil, ground
  - Field-moist soil, sieved
- Ion-exchange resin capsule, 168 hour incubation (UNIBEST, Inc.)
- Sodium tetraphenylboron extraction (Cox et al., 1999)
  - 5 minute, most reactive nonexchangeable K
  - 168 hour, total nonexchangeable K
- Soil mineralogy (ACT Labs, Ontario)
What K pools does a soil test target?

From McLean and Watson, 1985

**Exchangeable K**
K ions adsorbed onto clay surfaces

**Nonexchangeable K**
K ions trapped in wedge sites or interlayer spaces

The K sandwich

**Tetraphenylboron**: Releases interlayer-K

**Resin**: Equilibrate with exchangeable/interlayer-K

**NH₄OAc**
Dry soil: layers warp/collapse
Moist soil: field condition

From McLean and Watson, 1985
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# Correlations among K extraction methods

<table>
<thead>
<tr>
<th>r</th>
<th>Dry K</th>
<th>Moist K</th>
<th>TBK 5min</th>
<th>TBK 168hr</th>
<th>Resin K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry K</td>
<td>1.00</td>
<td>0.96</td>
<td>0.94</td>
<td>0.75</td>
<td>0.67</td>
</tr>
<tr>
<td>Moist K</td>
<td></td>
<td>1.00</td>
<td>0.89</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>TBK 5min</td>
<td>Good correlation between NH$_4$OAC and 5-min TBK</td>
<td>1.00</td>
<td>0.88</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>TBK 168hr</td>
<td>TBK and resin methods not related, different mechanisms</td>
<td>1.00</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resin K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

Good correlation between NH$_4$OAC and 5-min TBK and resin methods not related, different mechanisms.
Sample drying increased NH$_4$OAc-extractable K

- Average: 1.26 times higher
- Range: 0.8-2.4
- Increase higher for low K soils

\[ y = 0.94 + 24.2x^{-0.972} \]
\[ R^2 = 0.37, \ P < 0.01 \]
Smectitic soils released more K

\[ y = 1.01 + 0.0562x \]

\[ r^2 = 0.45, \ P < 0.01 \]
And *then* drying got complicated…

Figure 1.—K extracted with neutral 1N NH₄Ac from soils that had been dried to various moisture levels after increments of KCl had been added.

From Scott et al., 1957
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Yield response prediction by soil test class

<table>
<thead>
<tr>
<th>Soil K test class (mg kg(^{-1}))</th>
<th>VL (0-40)</th>
<th>L (41-80)</th>
<th>M (81-120)</th>
<th>H (121-160)</th>
<th>VH (161+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sites in soil test class</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of sites with significant yield response</td>
<td>---</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Probability of significant yield response</td>
<td>---</td>
<td>67%</td>
<td>33%</td>
<td>40%</td>
<td>20%</td>
</tr>
</tbody>
</table>

- Six of 14 sites below 150 ppm critical level responded (less than half)
Soil test K and yield response: NH$_4$OAc K on dry and moist soil

- Dry method still superior to moist method
Soil test K and yield response: Tetraphenylboron K, 5-min and 168-hr

• Not better than NH$_4$OAc methods
Soil test K and yield response: Resin K & %K saturation

- Resin method not significant, linear relationship
- K saturation not better than sufficiency level
Correlation between Soil Test K and Tissue K

Leaf stage V5 (whole plant)

\[ Y = 3.4(1-3.56e^{-0.0327x}) \]

\[ r^2 = 0.59, P < 0.01 \]

\[ Y = 3.5(1-1.63e^{-0.0243x}) \]

\[ r^2 = 0.59, P < 0.01 \]
Correlation between Soil Test K and Tissue K

Leaf stage VT (ear leaf)

Y = 0.0065x + 0.57
$r^2 = 0.83, P < 0.01$

Y = 0.0074x + 0.47
$r^2 = 0.83, P < 0.01$
Does tissue K help predict yield?

![Graph showing the relationship between tissue K and grain yield. The graph includes a scatter plot with data points and two regression lines. The R^2 values for the V5 and VT stages are 0.02 and 0.21, respectively.](image)
Does tissue K help predict relative yield response?
What good is tissue K analysis?

In-field comparison for deficiency diagnosis

From http://xkcd.com/1725/
Potassium Mineralogy: An Unexpected Journey

Primary minerals
- K-feldspar
- Mica
  - Biotite
  - Muscovite

Clays
- Illite (K supplier)
- Vermiculite (K fixer)
- Smectite (K fixer when dry)
Site analysis: K-bearing mineral content

Minerals

K-feldspar
Muscovite

5 %
Site analysis: Clay mineralogy
Does mineralogy help explain yield response?

Factor analysis:
Common factors between variables
• Mineralogy
• Relative Yield
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Sampling time: Sinusoidal pattern

Soil K trend
- Highest in spring
- Lowest late summer

2015: 12 of 13 sites followed sinusoidal pattern over time
Sampling time: Sinusoidal pattern

2016: Rainfall variability, not able to combine (Dry K, 5/6 sites)
Sampling time and soil K levels

- Soil K trends
  - Highest in late May or early June
  - Lowest in late summer
  - Begin to increase after physiological maturity

- Crop K uptake, soil water use, tissue leaching

- Sinusoidal pattern within year
  - Long-term sampling needed to establish year-to-year pattern
Summary

- Sample drying increased NH$_4$OAc K
  - Variable between soils, mineralogy
- Dry K test failed to predict half of responses
  - Dry K test best predictor of yield response
- Mineralogy and yield response not clear
- Soil K levels follow a sinusoidal pattern over time
Conclusions

• Dry K soil test not sufficient for predicting yield responses to fertilization
  – Moist K, TBK may not be any better

• Take soil samples at same time every year
  – Spring or fall sampling?

• Potassium is far from simple
Thank you!

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Kevin Horsager
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Austin Kraklau
Conner Swanson
Makenzie Ries

“Tartan” twinning of K-feldspar
“There is a lot that we know [about potassium]. I don’t know if it is all useful for making a recommendation.”

-Dr. Sylvie Brouder (Purdue Univ.), 2014 SSSA Meeting


