Seasonal Variation in Soil Test Potassium: When do you sample?

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Soil Potassium Basics (aka K, potash)

- Essential macronutrient
  - 200 bu/ac corn = 270 lb/ac K\(_2\)O
  - 50 bu/ac soybean = 110 lb/ac K\(_2\)O
- Exchangeable K\(^+\) on clays/soil OM
- Immobile nutrient
  - Concentrated in topsoil (0-6”)
  - Limited leaching (except sandy soils)
- Fixed/released by clays
  - Fixing clays: Illite, vermiculite
  - Non-fixing clays: Smectite*, kaolinite*

*Stay tuned for more
Today’s goals

1. Recognize the complexity of soil K forms and dynamics
2. Identify interpretive limits of soil test K data
3. Manage those limitations, improve data utilization
Precision Nutrient Management

We are really good at spatial variability:
  • Topography
  • Yield
  • Zone/grid sampling

What about variability in time?
  • Scale: Measurement vs. management
    • Decade (long-term trends, farm succession)
    • Year (soil sampling, crop choice, lease agreements)
    • Month (soil sampling, fertilization)
    • Week (growth stage, tissue sampling, rainfall)
University of Illinois

David W. Franzen
North Dakota State University

Seasonal component in long-term soil test K (Urbana, IL)

The Potassium Cycle

When?

When?

When?

How fast?
Recent soil K studies in North Dakota

2015: 13 sites
2016: 6 sites
Objectives

1. Evaluate corn yield response to K fertilization
2. Identify adequate soil K testing method
   • Determine soil test K critical level
3. Assess seasonal soil test K variation
Soil sampled (0-6”) every two weeks during growing season

Mid-May through late-September
STK range: 49 ppm
STK range: 44 ppm
STK range: 49 ppm
STK range: 36 ppm
STK range: 23 ppm
Leonard S 15

STK range: 90 ppm
What exactly is soil test K?

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

- Clay mineral surface
- Exchangeable K$^+$
- Displaced K$^+$
- NH$_4^+$ ion
- Solution K$^+$ already in solution
Soil Potassium Forms

Soil solution K
- Dissolved $K^+$ ions in soil solution
- Directly available for plant uptake

Exchangeable K
- $K^+$ held by negatively-charged cation exchange sites on clay minerals and soil organic matter
- Readily available to soil solution
Soil Potassium Forms

Nonexchangeable K (interlayer K, fixed K)
- $\text{K}^+$ held between 2:1 clay layers
- Slowly available to soil solution
- Fixation/release dynamic process

Mineral K
- $\text{K}^+$ held within mineral structures
- Slowly available to soil solution
Simplified Potassium Cycle

![Diagram of the simplified potassium cycle](image)

- **Plant-available K**
- **Soil test K**

*Time scale: a cropping season  
Spatial scale: cumulative rhizosphere volume for a crop (rooting zone)*

**Key Boxes:**
- **Soil solution K**
- **Exchangeable K**
- **Primary minerals (feldspars, micas)**
- **Leached K**

**Legend:**
- Erosion
- Runoff
- K loss
- Non-harvested K
- Plant K
- Harvested K
- Added K
- Soil surface
- Interlayer K

**Notes:**
- Dissolution
- Depth of bioavailable K

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Layer structure of 2:1 clay minerals

Not life-sized: Clay minerals only visible with electron microscope.
Illite

Non-expandable, collapsed layers

Smectite

Expandable, shrink-swell layers
What real clay minerals look like using an electron microscope

Exchangeable K
(exchangeable Ca, Mg, Na, etc.)
Nonexchangeable K

Fixed K

Interlayer K

Fixed K
A dynamic equilibrium

Exchangeable K ↔ Nonexchangeable K

Speed? Magnitude?
Clay mineral aKordion
Wet/dry cycles promote K fixation


Conversion of smectite to illite after 100 wet/dry cycles
Those are the nuts and bolts.

What do you do?
Can you predict soil test K?

STK over time across 12 sites in 2015

- Interlayer K release
- Residue K leaching
- Plant K uptake
- Fixation (wet/dry)
Soil test K change is scalable
Soil test K is related to illite content

$R^2 = 0.437$
Soil mineralogy is not static

Exchangeable K ↔ Nonexchangeable K

Soil characterization data from soil survey era?
Age and scale
Difficulties in predicting seasonal soil test K change

**Direction**
- Freeze/thaw
- Fertilizer K
- Rainfall
- Plant K uptake
- Plant senescence

**Magnitude**
- Soil test K level
- Plant K uptake
- Soil water content
- Soil texture
- Soil mineralogy

What is more useful? Absolute or relative change
Lessons from recent soil K studies in North Dakota

<table>
<thead>
<tr>
<th></th>
<th>Maximum STK</th>
<th>Minimum STK</th>
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<tbody>
<tr>
<td><strong>Season</strong></td>
<td>Spring/early summer</td>
<td>Late summer/fall</td>
</tr>
<tr>
<td><strong>Sampling dates</strong></td>
<td>12 May – 13 June</td>
<td>10 August – 30 August</td>
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<tr>
<td><strong>Seasonal range</strong></td>
<td>16 – 90 ppm</td>
<td></td>
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<tr>
<td><strong>Factors</strong></td>
<td>Plant K uptake</td>
<td>Soil water dynamics</td>
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<td></td>
<td></td>
<td>Plant senescence (residue K leaching)</td>
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</table>
What are our tools?

- Soil testing
- Computer models
- Clay mineralogy
What do we know?

- Highest STK in spring/early summer
- Lowest STK in late summer
Thoughts about soil sampling time (agronomically, practically)

<table>
<thead>
<tr>
<th>Spring/early summer</th>
<th>Fall</th>
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<tbody>
<tr>
<td>Highest STK</td>
<td>Lowest STK</td>
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<tr>
<td>Better crop response classification</td>
<td>Weaker crop response classification</td>
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Application within grid/zone sampling

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<tbody>
<tr>
<td>Growing crop</td>
<td>Harvested crop, late?</td>
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<tr>
<td>Uniform soil depth</td>
<td>Tillage, clods?</td>
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<tr>
<td>Calmer soil sampling</td>
<td>Hectic soil sampling</td>
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More thoughts about soil sampling time (spatial variability, K dynamics)

**Spring/early summer**
- Consistent moisture across field
- Before plant K uptake
- Equilibrium between exch K and nonexch K

**Fall**
- Drier fields, variable moisture
- After plant K uptake
- Disequilibrium between exch K and nonexch K
Recognize your goals

- Spatial variability within a field
- Tracking soil test K levels from year to year
- Recommendations for one-year or multi-year fertilizer applications

Working within goals
- Sample at same time of year every time
- Utilize seasonal STK variation in sampling
Concluding Thought

“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
Thank you for your kind attention

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