Soil Testing for K in Relation to Sample Handling and Mineralogy

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Soil Testing Use in Crop Production

- Often there are several tests for a nutrient, some more appropriate than others for soils with "contrasting" soil properties.
- Century old known fact: Need research to select tests for different soils of a region.
- A soil-test result is meaningless without proper field calibration with yield response.
  - Different tests may measure different amounts, and values for a test may have different meanings for different soils, sampling times, and sample handling.
Field Calibration of Soil Test Methods

- Give a meaning to soil-test values in terms of sufficiency for crops and rates needed
- Field Correlation: Relate test values to crop response across many sites/years
  - Determine critical concentrations or ranges, establish interpretation classes
  - Treatments can be just a control and one non-limiting but not excessive nutrient rate
- Field Calibration: Find rates needed for a wide range of soil-test values
  - Need trials with several application rates
Problematic Soil K Testing Issues

- More uncertainty for soil K testing and prediction of crop response than for P
  - Higher temporal and spatial variability
  - Complex exchange between soil K pools
  - Moisture issues in the field and lab
  - K recycling from residues and rainfall
  - Induced K deficiency even with high soil K
    - Dry, wet, compacted, or loose soil
    - Root damage by diseases or insects

- These factors affect in different ways the correlation, calibration, interpretations, and fertilization management
Short Iowa Soil K Testing History

- Extensive basic and applied research in the 1950s to 1970s, in Iowa and regional
- Minor mineralogy & exchangeable/non-exchangeable issues in row-crop areas
- Lower K rates needed for small areas of sandy soil, little applied research on them
- Subsoil properties and K level impacts
  - Need lower critical concentrations or K rates in soil series with high subsoil K
  - Implemented differential interpretations
  - But we dropped this in 2013, major field correlation work could not justify it
Traditional View of Iowa Soil Mineralogy

- Clay minerals in most Iowa soils under row-crop agriculture (Hallberg, 1980)
  - Dominated by smectites, montmorillonite and some beidellite (60 to 70%)
  - The remaining includes mica (illite) and kaolinite, and sometimes very small amounts of vermiculite (0 to 5%)

- However, ongoing work is suggesting a larger mineralogy variation, mainly in the proportion of smectites, mica, and kaolinite (M. Thompson and R. Oltmans)
Regional research on sample drying
- Standardized drying temperature (35-40°C)
- K testing of field-moist samples was a better predictor of yield response
- Didn't affect Ca, Mg, Na, or P

Field-moist testing was the default at the ISU soil testing lab from 1963 to 1988
- Among recommended NCR-13 methods
- Correlated the NH₄OAc with crop response
- But other labs didn't adopt it, the excuse was "complicated handling procedure"
Mid 1990s to 2001 Dry Test Correlations

Mallarino et al., 2002

15-cm Sampling Depth

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Long-Term Trends: Moist & Dry K

Soil-Test K (mg kg\(^{-1}\))

kg K ha\(^{-1}\) yr\(^{-1}\)

- \(= 0\)
- \(= 33\)
- \(= 66\)
- \(= 99\)

Years of Corn-Soybean Rotation

Moist Test

K applications discontinued

Dry Test
Correlated with corn & soybean response, 2001 to 2006, 362 site-years, 32 soil series:
- Dry & moist, NH$_4$OAc & Mehlich-3 tests
- "Quick" NaTB non-exchangeable K test as suggested by Cox, Joern et al (1996, 1999)
- K reversion, pretreating dried soil with water or octanol (Scott & Bates 1967, 1969)

Some was published (Barbagelata and Mallarino, 2012) but much is waiting turn in Theses folders (Barbagelata, 2006; Hill, 2009)
Pretreating Dried Soil: Rewet & Octanol

Adapted from Hill and Mallarino (2009, unpublished thesis)

Moist vs Dry

Moist vs Rewet

Moist vs Octanol

Dry/Moist K Ratio

Rewetted/Moist vs Moist

Octanol/Moist vs Moist

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Soybean: Dry & Moist K Field Correlation

Adapted from Barbagelata & Mallarino 2012 (data 2001 to 2006)

15-cm depth; NH₄OAc test shown; same results with Mehlich-3
Corn: Dry and Moist K Field Correlation

Adapted from Barbagelata & Mallarino 2012 (data 2001 to 2006)

Dried Soil K (mg kg⁻¹)

- VL
- L
- Opt
- H
- VH

Dry Test ISU Classes until 2012

Moist Soil K (mg kg⁻¹)

- VL
- L
- M
- H
- VH

Moist Test ISU Classes 1980s

15-cm depth; NH₄OAc test shown; same results with Mehlich-3
Effects of STK Level & Soil Moisture

Adapted from Barbagelata & Mallarino 2012 (data 2001 to 2006)

$Y = 0.82e^{88.0/(X+27.7)}$

$R^2 = 0.77, P < 0.01$

$Y = 1.72 + 0.024X$

$r^2 = 0.02, P < 0.01$

15-cm depth; NH$_4$OAc test shown; same results with Mehlich-3
Big Change: New Tech Implemented in 2012

Courtesy of Solum Inc.
The Moist Test for K is Back to Life

- More field correlations 2011 to 2013
- New soil sample handling chapter in the NCERA-13 methods publication
  - Gelderman and Mallarino (2012)
- Four laboratories operating in the Midwest offer it as the default test or optional
- Moist K test interpretations in Iowa State University recommendations since 2013
  - Mallarino, Sawyer, and Barnhart (2013)
- Also updated the interpretations for the common dry test (higher sufficiency level)
Drying Effects for Different Iowa Soils

Yes, series mean STK varied but only from 100 to 200 mg kg\(^{-1}\) dry

Adapted from Barbagelata and Mallarino, 2003
Drying x Soil Series x Mineralogy

Extracted K Increase Over Field-Moist Test (%)

Drying temperature
- Air dried
- 40 °C
- 50 °C

Marshall SCL
- Verm
- Smec
- Mica
- Kaol

Clarion Loam
- Verm
- Smec
- Mica
- Kaol

Kenyon Loam
- Verm
- Smec
- Mica
- Kaol

Mahaska SCL
- Verm
- Smec
- Mica
- Kaol

Galva SCL
- Verm
- Smec
- Mica
- Kaol

Adapted from Barbagelata and Mallarino, 2003

A.P. Mallarino, Iowa State University
Drying x Soil Series x Internal Drainage

Extracted K Increase Over Field-Moist Test (%)

<table>
<thead>
<tr>
<th>Drying temperature</th>
<th>Air dried</th>
<th>40 °C</th>
<th>50 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall SCL</td>
<td>Well Drained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarion Loam</td>
<td>Moder. Well</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mahaska SCL</td>
<td>Somewhat Poor</td>
<td>Moder. Well</td>
<td></td>
</tr>
<tr>
<td>Galva SCL</td>
<td>Poor</td>
<td>Moder. Well</td>
<td></td>
</tr>
<tr>
<td>Webster Canisteo SCL</td>
<td>Poor</td>
<td></td>
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</tr>
</tbody>
</table>

Adapted from Barbagelata and Mallarino, 2003

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K Rate, Removal, Post-harvest STK

Galva Silty-Clay-Loam, Loess

Initial STK 180 mg kg\(^{-1}\)

Webster Silty-Clay-Loam, Glacial Till

Initial STK 110 mg kg\(^{-1}\)
Mineralogy and Drainage

- **Pre-plant K Applied (kg K ha\(^{-1}\))**
  - 0
  - 28
  - 56
  - 112
  - 168

- **Soil-Test K Increase (%)**
  - 90
  - 95
  - 100
  - 105
  - 110
  - 115

- **Increase of K Removed with Grain (%)**
  - 90
  - 95
  - 100
  - 105
  - 110
  - 115

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- **STK Post-harvest**
- **Pre-plant K Applied (kg K ha\(^{-1}\))**
  - 0
  - 28
  - 56
  - 112
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- **Webster Silty-Clay-Loam, Glacial Till**
- **Galva Silty-Clay-Loam, Loess**

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- **Smec**
- **Verm**
- **Mica**
- **Kaol**

- **Moderately to Well Drained**
- **Poorly Drained**

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K Rate, Post-harvest STK, TBK

Galva Silty-Clay-Loam, Loess

Initial STK 180 mg kg\(^{-1}\)

Webster Silty-Clay-Loam, Glacial Till

Initial STK 110 mg kg\(^{-1}\)
Mineralogy and Drainage

Galva Silty-Clay-Loam, Loess

Pre-plant K Applied (kg K ha\(^{-1}\))

Soil-Test K Increase (%)

Non-exchangeable K Increase (%)

Webster Silty-Clay-Loam, Glacial Till

Pre-plant K Applied (kg K ha\(^{-1}\))

Soil-Test K Increase (%)

Non-exchangeable K Increase (%)

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Ongoing Work for Better Understanding

- Oltmans & Stephen dissertations, while Mallarino & Thompson relax & drink beer
- New field crop response trials in Iowa
  - Dry & moist testing, sampling time, moisture, mineralogy of clay and fine silt fractions, slowly exchangeable K, short-term retention & release, recycling from crop residue to the soil
- Incubations
  - Contrasting soils (IA, IL, MN, WI) and K levels, dry and moist testing, mineralogy of clay and fine silt, K retention and release over time, redox and moisture regimes