The Potassium Sandwich: Is It Nutritional?

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The K Sandwich
What is the Potassium Sandwich?

- The “bread” of the sandwich:
  - Phyllosilicate minerals
  - Two basic structural components:
    - Tetrahedral layer
    - Octahedral layer

Phyllosilicates: Layer Structure

“Fixed” K
Mica and Illite examples

“Fixed K”

Soil

Organic input

Output

Transformation

Component

Cycle flow

Legend

Manures
Biosolids
Plant residues
Fertilizers

Plant K

Crop harvest
Runoff and Erosion

Primary minerals
Weathering

Adsorption/exchange
Desorption/exchange

Secondary minerals and compounds

Solution K

Fixation
Release

Leached K

Atmosphere

Complete Cycle
Summary:
The K Sandwich

Interlayer potassium is the “meat” of our discussion
Mineral Transformations
Mica Weathers to Other Minerals

Transmission Electron Micrograph Shows “Feathering” of Mineral Edges

B. Joern, Purdue Univ. (personal communication)
Vermiculites and Smectites
(Swelling minerals)

- Interlayer cations in vermiculites and smectites are hydrated (have water around them) and are exchangeable
- Vermiculite has a higher layer charge than smectite

Illite
(Non-swelling mineral)

- Illite often occurs interlayered with smectite (I-S crystals)
- Percentage of illite in I-S crystals varies

Dehydrated K$^+$ ion

Hydrated K$^+$ ion

Vermiculite (Charge = 0.9)
Illite (Charge = 1.8)
Montmorillonite (Charge = 0.5)
Illite (Charge = 1.8)
Vermiculite (Charge = 0.9)

Mineral Transformations Summary

- Pure mineral phases are not common
- Interstratification is common, and Illite-Smectite (I-S) interstratification exists in many Midwestern agricultural soils

*Note: To see how mineralogy affects K behavior, go to “K Budgets and Soil Test Changes”*
The Moist K Test
Moist vs. Dry Sample Preparation Affects Soil Test Calibration Relationships

Moist vs. Dry Sample Preparation Affects Soil Test Calibration Relationships

Dry/Moist Ratio and Critical Level

- At lower soil test K levels, dried samples produce higher readings than moist samples.
- At or above the critical level, the two methods of preparation produced the same results.

Summary:
Moist K Test

• Critical soil test levels are lower
• Variability appears smaller, but what about relative differences?
• Differences in moist and dry values decrease exponentially as the critical level is approached
Site-Specific Soil Test K Calibration
Soil Test vs. What the Plant “Sees”

• Newly summarized studies are showing that a soil test may not be well related to the fertility the plant “sees” at specific sites.

• Long-term research at Purdue showed that soil testing was a poor indicator of fertility at 3 out of 5 sites where corn was grown in long-term fertility experiments.
Example of a location where lower soil tests are associated with lower soil fertility.
Example of a location where lower soil tests are not associated with lower soil fertility.

![Graph showing relative corn yield vs. K_{exch} (mg kg^{-1}) for Tracy sand. The graph includes a linear-plateau model, 95% confidence band, plateau K_{exch}, critical K_{exch} range, and mean relative yield.]

R.Navarette-Gonchozo. 2013. Personal communication (Purdue University)
Fine Sand Particles Can Have Mineral Inclusions

- Fine Sand (100 – 250 μm)
- Individual quartz grains contained inclusions of
  - Feldspar
  - Mica
- May help explain why some sands seem to have an adequate supply of K

Summary
Site-Specific Soil Test K Calibration

• Different sites may have different critical levels and levels of crop responsiveness
• New studies showing mineral inclusions in sands may indicate why some coarse textured soils may not be as responsive as expected
Obtaining Mineralogical Information from Soil Surveys
Mineralogy Classes (p. 825 – 827)

- Smectitic
  (> 50% smectite by weight)
- Illitic
  (> 50% illite by weight)
- Vermiculitic
  (> 50% vermiculite by weight)
- Mixed
  (other)
https://soilseries.sc.egov.usda.gov/osdname.asp

Official Soil Series Descriptions
USDA-NRCS Soil Survey Division View by Name

DIRECTIONS
The following entry field may be used to retrieve an Official Soil Series Description or a Series Extent Map. If you enter a complete series name, buttons to choose the Official Soil Series Description or Series Extent Map of the series name will be displayed. If you enter an incorrect or incomplete series name, the best-matched series names will be displayed for your selection.

Enter the Official Soil Series Description name you would like to view. Capitalization does not matter.

Fargo

Find Series  Clear Form
FARGO SERIES

The Fargo series consists of very deep, poorly drained and very poorly drained, slowly permeable soils that formed in calcareous, clayey lacustrine sediments. These soils are on glacial lake plains, floodplains, and gently sloping side slopes of streams within glacial lake plains. Slopes range from 0 to 6 percent. Mean annual air temperature is 42 degrees F, and mean annual precipitation is 19 inches.

TAXONOMIC CLASS: Fine, smectitic, frigid Typic Epiaquerts

family level designation: smectitic
BEARDEN SERIES

The Bearden series consists of very deep, somewhat poorly drained, moderately to slowly permeable soils that formed in calcareous silt loam and silty clay loam lacustrine sediments. These soils are on glacial lake plains and have slopes of 0 to 3 percent. Mean annual air temperature is 39 degrees F, and mean annual precipitation is 18 inches.

TAXONOMIC CLASS: Fine-silty, mixed, superactive, frigid Aeric Calciaquolls

family level designation: mixed
Variability in Soil Test K Response to K Budgets
Year-to-Year Variability Impacts Soil Test Response to Nutrient Budgets

Villavicencio and Mallarino, 2011. Personal communication
Possible Cause: Soil Moisture

Soil test K

Soil moisture

Soil test values are ammonium acetate extractable.
## Effect of Iron Reduction on K Fixation

<table>
<thead>
<tr>
<th>Sample</th>
<th>Treatment</th>
<th>Fe(^{2+}) as a percent of total Fe (%)</th>
<th>Fixed K (cmol(+) kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smectite SWa-1</td>
<td>Unreduced</td>
<td>0.16</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Reduced</td>
<td>74.0</td>
<td>31.5</td>
</tr>
<tr>
<td>Smectite API 25</td>
<td>Unreduced</td>
<td>5.8</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Reduced</td>
<td>66.8</td>
<td>25.3</td>
</tr>
<tr>
<td>Fithian Illite</td>
<td>Unreduced</td>
<td>25.4</td>
<td>135.7</td>
</tr>
<tr>
<td></td>
<td>Reduced</td>
<td>60.8</td>
<td>89.8</td>
</tr>
</tbody>
</table>

Under reducing conditions:
- smectites “fixed” K
- illite released K

Interaction of Soil Moisture and K Addition


Eden Soil Series: Ap horizon

Soil test K (ppm)

Soil moisture (%)

Greater reduction

Pre-leached with K\textsubscript{2}SO\textsubscript{4}
Behaves like illite

No K added
Behaves like smectite

Greater reduction
Possible Cause: Nutrient “Uplift”

- Nutrient uplift: Plants take up K from lower in the soil profile. This K is then deposited at the soil surface after maturity as K is leached from the residue.
- Even though soil fertility declines with crop removal, uplift may keep such changes from being detected.
Possible Influences of K Fixation and Release on Soil Test K Response to K Budgets

Fixation

Budget + \( \Delta STK - \)

Budget - \( \Delta STK - \)

Draw down

Buildup

Budget + \( \Delta STK + \)

Budget - \( \Delta STK + \)

Release and/or Uplift

\( \Delta STK \)
Buildup and Drawdown Buffer Capacities May Not Be the Same

4.0 lb K$_2$O/acre to build the soil test 1 ppm

K budget and K uplift move soil test K in same direction

7.7 lb K$_2$O/acre to draw the soil test down 1 ppm

K budget and K uplift move soil test K in opposite directions

R.Navarette-Gonchozo. 2013. Personal communication (Purdue University)
Summary:
Soil Test Response to K Budgets

• There can be large variability in soil test K levels between sampling times
• Given a high enough frequency of sampling over time, soil tests do reflect K budgets
• Major factors contributing to variability:
  – The effect of soil moisture on K fixation and release
  – Nutrient uplift over time
Augmenting Soil Test K Information
Visual Indications of K Deficiency
“You can observe a lot by watching.”

-- Yogi Berra
What K Does In Plants

Potassium is involved in:

- Regulating water pressure in plant cells, affecting cell extension, gas exchange, and movement of leaves in response to light
- Activating enzymes that help chemical reactions take place
- Synthesizing proteins
- Adjusting pH within plant cells
- Increasing carbon dioxide fixation during photosynthesis
- Transporting chemical compounds within the plant
- Balancing electrical charges in various parts of plant cells
K Deficiency in Corn

- Marginal yellowing, leading to necrosis
- Reduces amount of leaf area that is photosynthetically active
- Reduces the quantity of carbohydrates manufactured

Photo: L. Murrell, Lance Murrell Consulting

K Deficiency in Corn

- Delays rate of growth
  - stunted plants
  - delayed pollination and maturity

K Deficiency in Corn: Reduced Ear Diameter and Poor Grain Fill

©Purdue University
K Deficiency in Corn

- Reduces cell extension
  - shorter internodes
  - ears lower to the ground
  - greater harvest losses

K Deficiency in Corn

Without K  
With K

Photo: T.S. Murrell, IPNI
K Deficiency: Volunteer Corn in Soybean Resulting from Corn Harvest Losses the Previous Season

Photo: T.S. Murrell, IPNI
K Deficiency in Corn

- Iron compounds accumulate in the joints of corn plants
- Potassium thiocyanate, applied to plant tissue, makes the iron visible
- Accumulated iron disrupts translocation of photosynthate from leaves to roots

K Deficiency in Corn

- Increased susceptibility to stalk rot
- Increased chances for lodging
  - Smaller brace root system and cellular disintegration in brace roots
  - Cellular disintegration in lower part of the stalk

Photo: P. He, IPNI

K Enrichment Impacts
Mineralogy
“Center of Gravity” Concept:
Area-Weighted Average of Peak Positions

- Smectite-rich mixed layer minerals (1.46 nm)
- Illite-rich mixed layer minerals (1.16 nm)
- Hydroxy-interlayered phases (1.42 nm)
- Poorly crystallized illite (1.02 nm)
- Well crystallized illite (1.00 nm)

### Cumulative K Budgets Used for Evaluating Changes in Mineralogy

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total K applied (kg K ha(^{-1}))</th>
<th>Total K removed (kg K ha(^{-1}))</th>
<th>K budget (kg K ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>580</td>
<td>4088</td>
<td>-3508</td>
</tr>
<tr>
<td>P</td>
<td>580</td>
<td>4771</td>
<td>-4191</td>
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<tr>
<td>K</td>
<td>5980</td>
<td>4478</td>
<td>1502</td>
</tr>
<tr>
<td>PK</td>
<td>5980</td>
<td>5030</td>
<td>950</td>
</tr>
<tr>
<td>0 init</td>
<td>0</td>
<td>3824</td>
<td>-3824</td>
</tr>
<tr>
<td>PK init</td>
<td>8090</td>
<td>4597</td>
<td>3493</td>
</tr>
</tbody>
</table>

Experiment started in 1959 and lasted for 40+ years.
Potassium Budgets Impact Mineralogy

K removal ≈ K application
K depletion
K enrichment

More "smectite-like"

More "illite-like"

\[ \hat{y} = 1.30 - 4.20 \times 10^{-6} x \]

Summary: K Enrichment Impacts Mineralogy

• K enrichment can cause interstratified illite-smectite (I-S) minerals to behave more like illite

• Enrichment can occur by:
  – K fertilization
  – Redistribution of K by the plant: moving K from lower in the soil profile to the soil surface, where it becomes more concentrated

• As soils dry, K is more likely to be “fixed,” lowering soil test K levels