Potassium & Potassium Management

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Potassium Cycle

Havlin et al., 2001
K release during mineral weathering

Recolored from Fig. 6.9 in Havlin et al. (1999)
Exchangeable vs. Non-exchangeable K

Exchangeable K
Readily buffers soil solution K

Non-Exchangeable K
Slowly buffers soil solution K

Soil tests measure exchangeable K
Factors Influencing Exchangeable K

- Wetting/drying
- Freeze/thaw
- Oxidation state of Fe
Wetting/Drying

- Exchangeable K can increase or decrease when soil is dried
  - Is dependent upon the clay minerals present

- K fixation can occur
  - Soils with high exchangeable K or recent K fertilizer applications are dried
  - Fixation is a result of K becoming trapped within clay sheets as they dry and collapse

- K release can occur
  - Soils low in exchangeable K are dried
  - The clay sheets roll back and release K
Wetting/Drying

- Net effect depends on whether fixation or release dominates

- Time of soil sampling in relation to field wetting and drying cycles may influence soil test K levels
Freeze/Thaw

- Fixed K released with freeze/thaw
  - Soils with considerable amount of mica

- K release/fixation not impacted by freeze/thaw
  - Soils with smaller amounts of mica & greater amounts of exchangeable K

- STK may be different in spring v. fall
  - Depending on clay minerals present & winter weather conditions
Oxidation State of Fe

- Fe structural component in clay minerals
- Fe has different oxidation states
  - Fe$^{3+}$ - oxidized
  - Fe$^{2+}$ - reduced

- In smectites, as Fe$^{3+}$ $\rightarrow$ Fe$^{2+}$, K is fixed
- In illite, as Fe$^{3+}$ $\rightarrow$ Fe$^{2+}$, K is released

- In soils containing both illite & smectite, net effect of fixation/release depends on which clay mineral dominates
Clay Minerals in WI

- Composition of clay minerals varies

- Environmental impacts on STK may vary differently depending upon region

What does a soil test measure?

- Soil test K measures:
  - K in soil solution
  - Exchangeable K

- Seasonal variation in soil test K is known to exist
  - Sample at about same time each year to minimize this factor
### Interpreting soil test K results

<table>
<thead>
<tr>
<th>Crop</th>
<th>Medium &amp; fine soils</th>
<th>Course textured soils†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimum</td>
<td>No response</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>91 – 120</td>
<td>&gt; 170</td>
</tr>
<tr>
<td>Corn</td>
<td>81 – 100</td>
<td>&gt; 140</td>
</tr>
<tr>
<td>Soybean</td>
<td>81 – 100</td>
<td>&gt; 140</td>
</tr>
</tbody>
</table>

† Not irrigated
Environmental Factors Affecting K Availability to a Plant

- Soil moisture
  - Low soil moisture results in more tortuous path for K diffusion – takes longer to get to root
  - Increasing K levels or soil moisture will increase K diffusion
  - Increase soil moisture from 10 to 28 % can increase total K transport by up to 175 %

- Soil Aeration
  - High moisture results in restricted root growth, low \( \text{O}_2 \) and slowed K absorption by the root
Environmental Factors Affecting K Availability to a Plant

- **Soil temperature**
  - Low temperature restricts plant growth and rate of K uptake
  - Providing high K levels will increase K uptake at low temperatures
    - Reason for positive response to banded starter

- **Soil pH**
  - At low pH, K has more competition for CEC sites
  - As soils are limed, greater amount of K can be held on CEC and K leaching reduced.
Environmental Factors Affecting K Availability to a Plant

- **Leaching**
  - K leaching can occur on course textured or muck soils particularly if irrigated
  - Large fall K applications to sandy or muck soils discouraged
K Sources
# K Sources – Inorganic

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Chemical Formula</th>
<th>Fertilizer Analysis</th>
<th>Salt Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chloride (muriate of potash)</td>
<td>KCl</td>
<td>0-0-60 to 0-0-62</td>
<td>116</td>
</tr>
<tr>
<td>Potassium magnesium sulfate</td>
<td>K₂SO₄•2MgSO₄</td>
<td>0-0-22</td>
<td>43</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>KNO₃</td>
<td>13-0-44</td>
<td>74</td>
</tr>
<tr>
<td>Potassium sulfate</td>
<td>K₂SO₄</td>
<td>0-0-50</td>
<td>46</td>
</tr>
</tbody>
</table>
Red v. White Potash

- Both mined KCl
- Red potash produced by floatation, 0-0-60
- White potash produced by recrystallization, 0-0-62
- Color due to Fe and Mn impurities
- Use white for liquids
- No agronomic difference
K Sources - Organic

- Break down of crop residue
- Manures
  - Majority of K is soluble
    - 80% of total K in manure available the year of application
    - 10% of total K is available 2\textsuperscript{nd} year after application
    - 5% of total K is available 3\textsuperscript{rd} year after application
  - Book values
    - Dairy solid – 9 lb K\textsubscript{2}O/ton
    - Dairy liquid – 20 lb K\textsubscript{2}O/1000 gal
- Biosolids
K Management
K Management in WI

- Many soils deficient
  - Particularly alfalfa rotation
- K important in reduced tillage
- More liquid (low K) starter used
- Topdress K used as insurance
- Excessive K in some forages
- Timing relatively unimportant
Average interactions of soil test K levels and topdressed K\textsubscript{2}O rate on alfalfa yields, Arlington, WI, 1994-1997

![Graph showing the relationship between initial soil test K (ppm) and total yield (ton/acre) for different annual K\textsubscript{2}O rates (lb/acre). The x-axis represents initial soil test K (ppm) levels of 69, 75, 85, 126, and 166, and the y-axis represents total yield (ton/acre) ranging from 2 to 4. The graph includes five bars for each initial soil test K level, each representing different annual K\textsubscript{2}O rate levels: 0, 70, 140, 210, and 280 lb/acre. The graph highlights the interaction between soil test K levels and K\textsubscript{2}O rates on alfalfa yield.]
Response of corn to row-applied K on a silty clay loam soil (3 yr. avg.)

Oshkosh, Wis. (45 lb K₂O/a)
Wolkowski, WI
## Broadcast vs. Band

<table>
<thead>
<tr>
<th>K₂O applied (lb/acre)</th>
<th>Placement</th>
<th>Corn Yield (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>114</td>
</tr>
<tr>
<td>40</td>
<td>Starter (band)</td>
<td>143</td>
</tr>
<tr>
<td>100</td>
<td>Broadcast</td>
<td>136</td>
</tr>
<tr>
<td>200</td>
<td>Broadcast</td>
<td>141</td>
</tr>
</tbody>
</table>

Soil test (0-6") = 85 ppm; considered medium (optimum)
Goodhue County, Minnesota
From Rehm & Schmitt, 1997
Tillage and K Placement
Importance of K in Starter Fertilizers

- Response to deep-banded K at high soil tests
  - Ridge-till and no-till
- More frequent starter response at soil test K < 140 ppm
- Offset soil compaction effects
  - Restricted root volume
  - Poor aeration – limited K uptake
- More consistent starter response
Effect of tillage and soil test K on corn response to starter fertilizer

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Soil test K (ppm)</th>
<th>Response, bu/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50-60</td>
<td>100-145</td>
</tr>
<tr>
<td>Ridge-till</td>
<td>45</td>
<td>12</td>
</tr>
<tr>
<td>Chisel</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Moldbrd.</td>
<td>20</td>
<td>5</td>
</tr>
</tbody>
</table>

Moncrief & Schulte; 8-48-12 starter fert.
Arlington, WI
Corn yield advantage of deep-banded K over broadcast or planter-band K

<table>
<thead>
<tr>
<th>Tillage System</th>
<th>Advantage (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge-till</td>
<td>8</td>
</tr>
<tr>
<td>No-till</td>
<td>4-5</td>
</tr>
<tr>
<td>Chisel-disk</td>
<td>2</td>
</tr>
</tbody>
</table>

Mallarino, Iowa
Initial soil test K was very high in Wolkowski, WI.
Row K Effects on Corn Yield with Increasing Soil Compaction

Initial K Soil test = 102 ppm (Optimum)
Wolkowski, WI
Effect of K Source
Effect of K source on alfalfa yield where fertilizer is applied in split applications

<table>
<thead>
<tr>
<th>K source</th>
<th>Ashland*</th>
<th>Hancock+</th>
<th>Lancaster +</th>
<th>Manitowoc +</th>
<th>Marshfield*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.42</td>
<td>2.79</td>
<td>3.46</td>
<td>3.71</td>
<td>2.81</td>
</tr>
<tr>
<td>KCl</td>
<td>2.57</td>
<td>4.12</td>
<td>3.98</td>
<td>4.33</td>
<td>2.80</td>
</tr>
<tr>
<td>KCl + S</td>
<td>2.69</td>
<td>4.02</td>
<td>4.02</td>
<td>4.40</td>
<td>3.08</td>
</tr>
<tr>
<td>K$_2$SO$_4$</td>
<td>2.44</td>
<td>4.17</td>
<td>4.12</td>
<td>4.36</td>
<td>2.94</td>
</tr>
<tr>
<td>K-MgSO$_4$</td>
<td>2.46</td>
<td>4.05</td>
<td>4.15</td>
<td>4.48</td>
<td>2.89</td>
</tr>
</tbody>
</table>

* Average of 2 years
+ Average of 3 years

Adapted from Kelling, Erickson, and Schulte (unpublished). All plots received 50 lbs P and 400 lbs K/A/yr
K Source Conclusions

- If difference observed, likely due to associated ions
- No difference observed for most uses
- Salt or Cl ion problems avoided by splitting applications of rate more than 400-500 lbs/A
- Price, availability, & need for associated ion should determine which used
Timing Questions

- Preplant versus topdress?
- Frequency of topdress?
- Time of year to topdress?
Effect of rate and time of K topdress on alfalfa or alfalfa/orchardgrass yields, Maryland

<table>
<thead>
<tr>
<th>K Timing</th>
<th>0</th>
<th>100</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>3.63</td>
<td>--</td>
<td>4.13</td>
</tr>
<tr>
<td>Fall/1st cut</td>
<td></td>
<td>--</td>
<td>4.13</td>
</tr>
<tr>
<td>Early spring</td>
<td>3.73</td>
<td>4.23</td>
<td></td>
</tr>
<tr>
<td>1st cut</td>
<td>3.90</td>
<td>4.23</td>
<td></td>
</tr>
<tr>
<td>Early spring/1st cut</td>
<td>4.10</td>
<td>4.27</td>
<td></td>
</tr>
<tr>
<td>Early spring/each cut</td>
<td>3.80</td>
<td>4.13</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Kresge and Younts, 1962.
Alfalfa response to time of topdress application

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenup</td>
<td>4.33</td>
<td>4.16</td>
<td>3.06</td>
<td>2.53</td>
</tr>
<tr>
<td>1st cut</td>
<td>4.46</td>
<td>4.35</td>
<td>3.17</td>
<td>2.65</td>
</tr>
<tr>
<td>3rd cut</td>
<td>4.48</td>
<td>4.27</td>
<td>3.06</td>
<td>2.47</td>
</tr>
<tr>
<td>1st &amp; 3rd</td>
<td>4.44</td>
<td>4.35</td>
<td>3.08</td>
<td>2.61</td>
</tr>
</tbody>
</table>

*Pr>F*  

*Interaction between time and source significant at Pr≥0.10*  
Arlington, averaged across 2 soil test K levels and 2 K sources
Interaction between K source and application time, responsive years only

<table>
<thead>
<tr>
<th>Application</th>
<th>KCl + S</th>
<th>K$_2$SO$_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenup</td>
<td>4.10</td>
<td>4.34</td>
</tr>
<tr>
<td>1st cut</td>
<td>4.31</td>
<td>4.48</td>
</tr>
<tr>
<td>3rd cut</td>
<td>4.27</td>
<td>4.48</td>
</tr>
<tr>
<td>1st &amp; 3rd</td>
<td>4.44</td>
<td>4.34</td>
</tr>
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Average 1994-1995 across 2 soil K levels, Arlington
Consider the cow

Forage K levels > 3% can cause milk fever and other anion balance problems particularly for early-lactation cows
The average effect of soil test K and topdressed K$_2$O on third cutting forage cation concentrations, Arlington, WI 1994-1997

Forage K Conc. (%)

Forage Ca Conc. (%)

Forage Mg Conc. (%)

Initial soil test K level (ppm)

Annual K$_2$O rate (lb/a)

Kelling, WI
Rominger et al., 1975

Graph showing the herbage K% of stems and leaves, with data for fertilized and unfertilized conditions. The graph plots the sample distance above stubble (cm) against herbage K%.
Baker and Reid, 1977

Graph showing changes in K% (potassium percentage) during different stages of maturity for Alfalfa, White Clover, and Red Clover. The x-axis represents stages of maturity: Veg., Bud, 1/4 Bloom, Full Bloom, Seed. The y-axis represents K% ranging from 1.5 to 3.0.
Ways to reduce tissue K

- Soil test
  - Apply K only where needed
  - Credit manure K
- Clip low – retain leaves
- Cut later
- Allow K to drop on some fields
- Segregate low K forages for dry cows/heifers
Potassium BMP’s

- Use soil test to guide K need
- Wisconsin recommendations call for 15 to 25 lb K$_2$O with high K soil
- Consider complete starter
- Avoid excessive build-up; distribute manure
- Avoid fall applications on sands and mucks
- Topdress as needed