How Can Factors Influencing Soil K Acquisition by Crop Roots be Used to Improve K Rate Recommendations?

John Kovar
K Fertility Problems on the Rise

Soil test K = Optimum
<table>
<thead>
<tr>
<th>Soil Test Category</th>
<th>1999 K Fertilizer</th>
<th>2002 K Fertilizer</th>
<th>2013 K Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>0-60</td>
<td>120</td>
<td>90</td>
</tr>
<tr>
<td>Low</td>
<td>61-90</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>Optimum</td>
<td>91-130</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>High</td>
<td>131-170</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Very High</td>
<td>171+</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Iowa State University Soil Test K Interpretations and K Fertilizer Recommendations for Corn and Soybean
Improving K Fertility

- Consider basic soil processes
- Consider root growth and function
- Connect soil and plant characteristics to develop better K recommendations
Non-harvested K 

Plant K 

Soil solution K 

Exchangeable K 

Interlayer K 

Primary minerals (feldspars, micas) 

Leached K 

Harvested K 

Added K 

Soil surface 

Erosion 

Runoff 

K loss 

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

http://www.ipni.net/article/IPNI-3396
K fertilizer increases soil solution K

Kovar and Barber, 1990
K fertilizer increases soil exchangeable K
Non-exchangeable K supplies K to roots

Modified from Samal et al. (2010)
What K fertilizer rate is needed in this field?
Why consider the roots?

- Inherent soil physical and chemical properties affect root growth and function.
- Changes in root growth and function can cause changes in crop response to K fertilizer, even when soil supply of K is more than adequate.
Barber, 1995
### Soil Bulk Density and Water Content Affect Maize Root Growth and K Uptake (18 d after planting)

<table>
<thead>
<tr>
<th>Bulk Density (g cm(^{-3}))</th>
<th>Water Content (% (w/w))</th>
<th>Root Growth (10(^{-6}) cm s(^{-1}))</th>
<th>K Influx (10(^{-13}) mol cm(^{-1}) s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>10.7</td>
<td>1.00a†</td>
<td>1.82a</td>
</tr>
<tr>
<td></td>
<td>14.2</td>
<td>1.95cd</td>
<td>2.82b</td>
</tr>
<tr>
<td></td>
<td>19.0</td>
<td>2.43e</td>
<td>3.38c</td>
</tr>
<tr>
<td>1.4</td>
<td>10.7</td>
<td>1.24ab</td>
<td>1.97a</td>
</tr>
<tr>
<td></td>
<td>16.3</td>
<td>1.94cd</td>
<td>3.66c</td>
</tr>
<tr>
<td></td>
<td>19.0</td>
<td>2.24de</td>
<td>4.53d</td>
</tr>
<tr>
<td>1.6</td>
<td>10.7</td>
<td>1.12a</td>
<td>2.17a</td>
</tr>
<tr>
<td></td>
<td>14.2</td>
<td>1.63bc</td>
<td>2.09a</td>
</tr>
<tr>
<td></td>
<td>19.0</td>
<td>2.32de</td>
<td>3.62bc</td>
</tr>
</tbody>
</table>

†Means followed by same letter not significantly different (p<0.05)

Seiffert et al., 1995
Are deep roots active?

- Most soil K test – crop response relationships are based on a 0 to 15 cm sample
- In many environments, and particularly in soils that can store significant plant-available water, roots grow deeper into the soil
- The adoption of reduced tillage or no-till can also result in the 0 to 15 cm layer (especially the top 5 cm) becoming relatively enriched, and the soil layers below becoming depleted (stratification)
Protein channels and carrier proteins transport K+ across root cell membranes.
Autoradiograph of $^{86}\text{Rb}$ depletion from soil and uptake by growing roots

Concentration gradient = diffusion

Walker and Barber, 1962
Measuring rhizosphere nutrient concentrations

Micro-suction Cup

Sample Holders
Changes in rhizosphere soil solution concentrations of P, K, Ca, and Mg with distance from the root surface after 10 days of plant growth

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Solution Concentration (mg L⁻¹)</th>
<th>Maize</th>
<th></th>
<th>Cottonwood</th>
<th></th>
<th>Switchgrass</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;1mm</td>
<td>&gt;8mm</td>
<td>&lt;1mm</td>
<td>&gt;8mm</td>
<td>&lt;1mm</td>
<td>&gt;8mm</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.85b*</td>
<td>1.12a</td>
<td>0.89b</td>
<td>1.05a</td>
<td>1.02a</td>
<td>1.09a</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>4.70b</td>
<td>5.09a</td>
<td>4.85b</td>
<td>5.15a</td>
<td>5.09a</td>
<td>5.11a</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td>23.8a</td>
<td>25.2a</td>
<td>28.3a</td>
<td>25.8a</td>
<td>25.5a</td>
<td>25.5a</td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td>15.0a</td>
<td>13.8a</td>
<td>13.6a</td>
<td>14.8a</td>
<td>15.8a</td>
<td>16.4a</td>
</tr>
</tbody>
</table>

*Values within a species/nutrient combination followed by the same letter are not significantly different at the 0.05 level.
Root K influx increases with increasing solution K concentration

Modified from Britto and Kronzucker (2008)
K uptake rates may differ among root types on the same plant

- Winter wheat grown in solution culture
- K influx 2 to 6 times higher for nodal roots
- Uptake rate per unit root decreased with plant age

Kuhlmann and Barraclough, 1987
Root hairs are more responsive to changes in K influx rates

- Winter wheat grown in low K soil
- 10-fold increase in Imax of root hairs = increased gradient = greater diffusive flux
- K influx 6-fold higher for root hairs

Modified from Samal et al. (2010)
Modelling concepts of nutrient uptake model NST 3.0

1. Influx

\[ \ln = \frac{I_{\text{max}} (C_L - C_{L\text{min}})}{K_m + C_L - C_{L\text{min}}} \]

2. Transport

\[ F_{\text{mass flow}} = C_L v_0 \]

\[ F_{\text{diffusion}} = -D_L \theta f \frac{dC_L}{dx} \]

3. Sorption / Desorption

\[ dC = b dC_L^a + c \]

4. Exudation

Modified from Samal et al. (2009)
Main Points

- Soil test-crop response relationships can be quite site specific.
- Differences in soil K pools, the efficiency of soil K supply processes and soil and climatic factors influencing crop root systems and activity can be major contributors to this site specificity.
- The potential for different soil sampling strategies and combinations of soil analytical tests to account for these differences and provide a more generic understanding of site K fertility should be explored.
- Fertilizers are expensive, so deciding where K inputs are needed, and then how much K is needed, in what form and when and where in space and time are critical decisions for farmers and advisors.
Additional Thoughts...

- Need a better way to evaluate K flux as it relates to K acquisition ➔ may be only way to improve K fertilizer recommendations
- Must consider root traits, and how K requirements differ among crop species and even within species
- Models can help us
- Scale is important