Great Salt Lake Minerals

Alfalfa

Sulfate of Potash (SOP)

April 2011
Main goals

- General potash management
- Potash management in alfalfa
- Potash fertilizer consideration
- Sulfate of potash (SOP) where it might fit
- Sulfur the 4th macro nutrient?
General potash management
Potassium (K) in a Corn / Soybean rotation

- Role of K in crop production
- Crop up take of K
- Soil K and soil testing
- K deficiencies
- Crop response to K
- K fertilizer
Role of K in crop production

- K activates enzyme reactions
- K fosters nitrate-nitrogen (N) uptake and protein synthesis
- K controls water uptake and transpiration
- K influences energy production in photosynthesis and respiration
- K supports photosynthate transport
- K is required for starch synthesis in seeds
Role of K in crop N uptake

Crop grain yield response to fertilizer N rate and soil test K levels

Crosby silt loam soil near Springfiled, OH
Role of K in crop N uptake

The effect of fertilizer N rate and soil test K levels on N uptake efficiency on a corn crop
Role of K in crop water use

- Plants depend on K to regulate the opening and closing of the stomates
  - Stomates are the opening through which gas and water vapor are exchanged
  - When water stress occurs the stomates close preventing water from being loss
  - When K is inadequate the stomates become sluggish and can take hours instead of minutes to close and closure can be incomplete

- K in the roots creates an osmotic pressure gradient which aids in drawing water into the roots
  - Plants deficient in K will be less able to absorb water and thus more susceptible to water stress
Potassium in the soil

Unavailable (90 to 98%)

- Soil Minerals (feldspar, mica)

Slowly available (1 to 10%)

- Soil Colloid
- Trapped K

Readily available (0.1 to 2%)

- Soil water
- Soil Colloid
Crop Uptake

- Absorbed by crop in year 1:
  - 20 to 60% of applied K
  - Highest recovery on low K soils
- Slowly available K (future years):
  - Bulk of remaining K in most soil types
  - Future supply of K
Crop uptake

- Poor soil Aeration
  - Oxygen is need for root uptake
  - Compaction

- Soil Moisture
  - To dry
  - To wet

- Soil Temp
  - Cool soil temp
Aerial partitioning of K in corn

Percent of maximum K uptake vs. Cumulative growing degree days

- Ear and shank
- Stalk and tassel
- Upper leaves
- Lower leaves

Average uptake reported in Extension publications:
1.37 lb K\textsubscript{2}O/bu

Crop uptake

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield/A</th>
<th>K uptake in total crop, lb K₂O/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>250 bu</td>
<td>340 (67.5)</td>
</tr>
<tr>
<td>Soybeans</td>
<td>60 bu</td>
<td>200 (78)</td>
</tr>
<tr>
<td>Wheat</td>
<td>40 bu</td>
<td>80 (19)*</td>
</tr>
<tr>
<td>Canola</td>
<td>35 bu</td>
<td>89 (20)</td>
</tr>
<tr>
<td>Peas</td>
<td>50 bu</td>
<td>150 (39)</td>
</tr>
<tr>
<td>Barley silage</td>
<td>4.5 tons</td>
<td>132</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>3 tons</td>
<td>180</td>
</tr>
</tbody>
</table>

*K removed in grain in parenthesis.
Most soil tests for K are based on either an ammonium acetate extraction or a similar extraction.

In some regions with low CEC soils, K rates are often based on the ratio of K relative to other bases, such as Ca and Mg.

Ion exchange membranes which measure the soil supply rate of K.
Soil test levels

Percent of samples testing below critical levels for K for major crops in 2010.
% Potassium Deficient Soils

- Alfalfa K demand
  - Alfalfa has a high potash removal rate of 60 lb K$_2$O/t
  - Application rates of potash 150-300 lb K$_2$O/a

Percent of samples testing below critical levels for K for major crops in 2010.
Alfalfa Facts
- Perennial
- Legume (fixes N)
- Deep rooted (Taproot system)
- Good drought tolerance
- Optimal growth in 6.8-7.2 pH soils

Alfalfa Forage Facts
- High nutrient content protein, minerals
- Good fiber digestibility
- Rapidly digested
- Supports high DM intakes
- Supports high milk production

Neal Martin et al., USDA Dairy Forage Research Center
Alfalfa Cultural Practices

- Alfalfa Planting
  - Most common spring planted (April time frame)
  - Some late summer planting (early to mid August)
  - Can be direct seeded (alfalfa only) or with a companion crop like oats

- Alfalfa harvest
  - 3-4 time a year
  - Harvest starting in the first of June and occurring in 30 day intervals after that
  - Harvest as both Hay and Haylage

- Alfalfa stand
  - Can have a life span of 3-5 years
  - Average yields of 3-5 ton/a
Stored carbohydrates in taproots are necessary for rapid regrowth, winter survival, and root-rot resistance. This illustration shows the changes occurring as a result of regrowth after cutting. The darker area of the taproot represents the approximate carbohydrate level.

Source: NCR-184, Alfalfa Diseases in the Midwest
• Potassium Role in alfalfa
  - Optimizes yield
  - forage quality
  - disease resistance
  - overwinter survival

• Importance of managing potassium
  - Alfalfa is a luxury consumer of K (will take up more K than the plant needs)
  - Too much K in transition cow’s (transitioning into lactation) diet is linked to milk fever
  - Too much K will also reduce Ca and Mg availability
2010 Alfalfa plant K and S survey conducted by University of Wisconsin

- 39 samples were collected across 17 counties
- Samples were collected from the top six inches of new growth when the crop was in the bud to first flower stage

Results

- 51 were low in K
- 64% were low in S
- 31% were low in both K and S
### Effect of K fertilization on stand survival

<table>
<thead>
<tr>
<th>K₂O Tmt</th>
<th>Lancaster (3)*</th>
<th>Manitowoc (7)*</th>
<th>Barron (3)*</th>
<th>Arlington (4)*</th>
<th>Madison (6)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb/a/yr</td>
<td>soil K</td>
<td>% stand</td>
<td>soil K</td>
<td>% stand</td>
<td>soil K</td>
</tr>
<tr>
<td>0</td>
<td>55</td>
<td>33</td>
<td>65</td>
<td>35</td>
<td>51</td>
</tr>
<tr>
<td>60</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>120</td>
<td>59</td>
<td>54</td>
<td>74</td>
<td>42</td>
<td>62</td>
</tr>
<tr>
<td>240</td>
<td>68</td>
<td>62</td>
<td>88</td>
<td>48</td>
<td>75</td>
</tr>
<tr>
<td>480</td>
<td>118</td>
<td>71</td>
<td>168</td>
<td>51</td>
<td>119</td>
</tr>
<tr>
<td>720</td>
<td>190</td>
<td>73</td>
<td>275</td>
<td>54</td>
<td>171</td>
</tr>
<tr>
<td>960</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1200</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

K.A. Kelling and R.P. Wolkowski2 1992
Potassium response Alfalfa

Purdue Extension AY-331-W
Alfalfa response to K rate

K.A. Kelling and P.E. Speth, 1998
Potassium response Alfalfa

K balance at 400lbs of K20/a/yr
Pounds of K2O removed to lower soil test by 1ppm

<table>
<thead>
<tr>
<th>Cation Exchange Capacity</th>
<th>Lbs. of K₂O removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>18</td>
<td>13</td>
</tr>
</tbody>
</table>

- CEC = 12
- Yield = 5 tons per acre
- Potassium soil test level is 130 ppm at the beginning of the season.
- 5 tons/acre x 50 lbs. K2O per ton = 250 lbs. of K2O per acre removed by the crop.
- From Table 2, we see that it takes 9 lbs. of K2O of crop removal to change the soil test by 1 ppm. \(250 \div 9 = 27.8\) ppm decrease in the soil test level.
Potassium deficient Alfalfa
Potassium deficient Alfalfa
Potassium deficient Alfalfa

http://landresources.montana.edu/soilfertility/kdeficiency.html
Potash fertilizer consideration
<table>
<thead>
<tr>
<th>Source</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium sulfate, $K_2SO_4$ (SOP)</td>
<td>0-0-50 – 17</td>
</tr>
<tr>
<td>Potassium chloride, KCl (MOP)</td>
<td>0-0-60 (62)</td>
</tr>
<tr>
<td>Potassium-magnesium sulfate, (K-Mag)</td>
<td></td>
</tr>
<tr>
<td>$K_2SO_4 \cdot 2MgSO_4$</td>
<td>0-0-22-22-11</td>
</tr>
<tr>
<td>Potassium nitrate, KNO$_3$</td>
<td>13-0-44</td>
</tr>
<tr>
<td>Potassium thiosulfate, $K_2S_2O_3$ (KTS)</td>
<td>0-0-25-17</td>
</tr>
</tbody>
</table>
Many crops (e.g., almonds and potatoes) are chloride-sensitive.

- SOP has lowest chloride among potassium fertilizers.
- Our SOP is less than 1% chloride, guaranteed.
- Minimized crop damage due to soil salt buildup.
Potassium Fertilizers

- High salt levels can harm crops:
  - Poor germination
  - Nutritional imbalances
  - Seedling injury
  - “Tip burn”
  - Stunted root and shoot growth
Potassium Fertilizers

- Gives an indication of the relative effect of a fertilizer on the soil solution
- Fertilizers are compared to Sodium Nitrate used as a standard
- Sodium Nitrate’s salt index is 100

<table>
<thead>
<tr>
<th>Salt Index</th>
<th>Potassium Fertilizers</th>
<th>Salt Index</th>
<th>Salt Index/unit of K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOP (Potassium Chloride-60%)</td>
<td>116.2</td>
<td>1.936 (K₂O)</td>
<td></td>
</tr>
<tr>
<td>Sodium Nitrate</td>
<td>100</td>
<td>6.06 (N)</td>
<td></td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>73.6</td>
<td>1.58 (K₂O)</td>
<td></td>
</tr>
<tr>
<td>KTS (Potassium Thiosulfate)</td>
<td>64</td>
<td>2.56 (K₂O)</td>
<td></td>
</tr>
<tr>
<td>SOP (Potassium Sulfate)</td>
<td>46.1</td>
<td>0.88 (K₂O)</td>
<td></td>
</tr>
<tr>
<td>K-MAG (Sulfate of Potash Magnesia)</td>
<td>43.2</td>
<td>1.96 (K₂O)</td>
<td></td>
</tr>
</tbody>
</table>
- **Negative effect of Cl** more evident on light soils than on heavier soils.

- **Potassium Sulfate has the advantage** on low P soils since it improves P availability.

- When the P supply is high, Cl reduces P uptake.

<table>
<thead>
<tr>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Barley</td>
<td>Asparagus</td>
</tr>
<tr>
<td>Apples</td>
<td>Cabbage</td>
<td>Bermudagrass</td>
</tr>
<tr>
<td>Apricots</td>
<td>Carrots</td>
<td>Cotton</td>
</tr>
<tr>
<td>Berries</td>
<td>Cucumbers</td>
<td>Spinach</td>
</tr>
<tr>
<td>Canola</td>
<td>Grapes</td>
<td>Date Palm</td>
</tr>
<tr>
<td>Celery</td>
<td>Melons</td>
<td></td>
</tr>
<tr>
<td>Cherries</td>
<td>Peppers</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>Pumpkins</td>
<td></td>
</tr>
<tr>
<td>Lettuce</td>
<td>Wheat</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peaches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Excess chloride**

- Can accumulate and become toxic in the plant
- Can accumulate in the soil and reduce nutrient uptake of
  - Nitrate
  - Sulfate
  - Phosphorus
  - Boron
Table 2.1. Chloride concentrations in some natural sources.

<table>
<thead>
<tr>
<th>Source</th>
<th>Chloride (g kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth crust</td>
<td>1.50</td>
</tr>
<tr>
<td>Lithosphere</td>
<td>0.48</td>
</tr>
<tr>
<td>Basalt rocks</td>
<td>0.50</td>
</tr>
<tr>
<td>Syenite</td>
<td>0.98</td>
</tr>
<tr>
<td>Igneous rocks</td>
<td>0.23</td>
</tr>
<tr>
<td>Shale</td>
<td>0.16</td>
</tr>
<tr>
<td>Sandstone</td>
<td>0.02</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.37</td>
</tr>
<tr>
<td>Dolomite</td>
<td>0.50</td>
</tr>
<tr>
<td>Soils</td>
<td>0.10</td>
</tr>
<tr>
<td>Ocean</td>
<td>19.0</td>
</tr>
<tr>
<td>Plants</td>
<td>1.0-10.0</td>
</tr>
<tr>
<td>Low to medium saline water</td>
<td>0.10-0.30(^a)</td>
</tr>
<tr>
<td>High to very high saline water</td>
<td>0.30-1.20(^a)</td>
</tr>
<tr>
<td>Table salt (NaCl)</td>
<td>607</td>
</tr>
<tr>
<td>Potassium chloride (KCl)</td>
<td>450-570</td>
</tr>
</tbody>
</table>

Compiled from Yaalon (1963); Flowers (1988). \(^a\) Unit: kg m\(^3\)
Sulfate of Potash (SOP)

where it might fit
- High K2O analysis 50%
  - Alfalfa has a high potash demand removal rate of 60 lb K₂O/t
  - Application rates of potash 150-300 lb K₂O/a

- High S 17% i
  - Sulfur in the sulfate form, immediate plant available form
  - Alfalfa has a typical response to about 30lb S/a when deficient in the soil

- Low Cl less than 1%
  - Balanced plant nutrition total 67% potassium and sulfur everything you need and nothing you don’t

- Low salt index
  - Flexibility in application and timing
  - Safety for the plant and soil systems

- Lower potential for leaching
  - Less losses in sandy soils
Potassium Response Alfalfa

ALFALFA RESPONSE TO K RATE, SOURCE AND TIME OF APPLICATION^'

K.A. Kelling and P.E. Speth

- **K rate response**
  - 0, 70, 140, 210, 280, 350 lb K2O/a
  - K source K2SO4

- **K source response**
  - K2SO4, KCl, KCl+S
  - 70, 210, 350 lb/a

- **K application timing**
  - Green up, after 1\textsuperscript{st} cut, after 3\textsuperscript{rd} cut, split 1\textsuperscript{st} and 3\textsuperscript{rd} cut
  - 350 lb K2O/a as K2SO4 or KCl
 Alfalfa response to SOP rate

- Results
  - 210 lb K2O/a optimum rate of SOP
  - Increased stand productivity
  - Improved yield
Results

- SOP significantly increased yields 3 of 4 years
- SOP significantly increased yields of KCl+S in 1994, however in subsequent year no difference was seen

<table>
<thead>
<tr>
<th>K source</th>
<th>Alfalfa yields¹</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>K&lt;sub&gt;2&lt;/sub&gt;SO&lt;sub&gt;4&lt;/sub&gt;</td>
<td>4.63</td>
<td>4.21</td>
<td>2.98</td>
<td>2.39</td>
</tr>
<tr>
<td>KCl</td>
<td>4.40</td>
<td>4.16</td>
<td>2.76</td>
<td>1.95</td>
</tr>
<tr>
<td>KCl+S</td>
<td>4.29</td>
<td>4.28</td>
<td>2.99</td>
<td>2.40</td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td>0.23</td>
<td>NS</td>
<td>0.19</td>
<td>0.19</td>
</tr>
</tbody>
</table>

¹Averaged across 3 topdress rates and 2 initial soil test K levels.
Interaction of K Source and Timing

- Results
  - SOP increased yields 3 of 4 application timings
  - SOP applications after the 1st or 3rd cutting resulted in the greatest yield
**GSL is Investing in Research**

- Not a tremendous amount of research has been done with SOP on alfalfa
- Research has plots were established in Wisconsin in spring 2010

**Opportunities**
- Greater yields with SOP
- Enhanced nutrient use efficiency
- Maximizing forage quality
- Improved haylage production
- Improved nodulation
- Enhanced palatability
Return of Using SOP

- How much is $15/a
  - 0.1t/a Alfalfa yield gain from SOP
  - 30 lb N/a gained in the rotation from increased nodulation
  - $15 of increased feed value

<table>
<thead>
<tr>
<th>Alfalfa potassium cost 200 lb K2O/a 30 lb S/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Rate lbs/Acre</td>
</tr>
<tr>
<td>------------------------------</td>
</tr>
<tr>
<td>Cost Using MOP</td>
</tr>
<tr>
<td>Cost Using SOP</td>
</tr>
<tr>
<td>Difference</td>
</tr>
</tbody>
</table>
Sulfur the 4th macro nutrient?
The Sulfur Cycle

- Atmospheric sulfur
- Crop harvest
- Volatilization
- Mineral fertilizers
- Runoff and erosion
- Reduced sulfur
- Plant uptake
- Atmospheric deposition
- Plant residues
- Animal manures and biosolids
- Organic sulfur
- Absorbed or mineral sulfur
- Sulfate Sulfur (SO₄²⁻)
- Immobilization
- Mineralization
- Oxidation
- Bacterial oxidation
- Bacterial reduction
- Leaching
Sulfur in the Plant

Sulfur function in the plant

• synthesis of amino acids
  • Amino acids are the building block of proteins
• Sulfur deficient plants
  • Accumulate more non protein N in the leaves increases the N:S ratio
  • It is important to maintain an N:S ration for proper microbial function in rumen animals
• It can also effect food quality in vegetable production
Sulfur Deficiencies

- Soil Properties and Climatic Conditions Aggravating Deficiency Symptoms
  - Coarse textured soils (sandy soils)
  - Low organic matter soils
  - Cold, wet soils
    - Slow release of S from organic matter
  - Low atmospheric deposition

- No application from
  - Manure
  - Other fertilizers
Sulfate ion wet deposition, 1994

Sites not pictured:
AK01  1 kg/ha
AK03  1 kg/ha
PR20  17 kg/ha

SO$_4^{2-}$(kg/ha)

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu
Sulfate ion wet deposition, 2007

Sites not pictured:
AK01  1 kg/ha
AK03  < 1 kg/ha
PR20  19 kg/ha
VI01  9 kg/ha

Sulfate as SO$_4^{2-}$ (kg/ha)

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu
Figure 8. Percent of soils testing less than 3 ppm S in 2010 (for states and provinces with at least 2,000 S tests).
Sulfur deficiency in alfalfa (right): short plants, thin stems, and light green color.
Sulfur deficient Alfalfa

Stunting and yellowing of new growth caused by sulfur deficiency. Photo courtesy of Montana State University
Sulfur Response in Alfalfa

- Results
  - 25 lb S/a optimum rate of sulfate
  - S increased stand productivity
  - Sulfate preformed better that elemental

<table>
<thead>
<tr>
<th>Source</th>
<th>Rate lb S/a</th>
<th>1997 Dry matter yield ton/a</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>0</td>
<td>0.74</td>
<td>4.08</td>
<td>4.33</td>
<td>3.3</td>
</tr>
<tr>
<td>Sulfate-s</td>
<td>25</td>
<td>0.97</td>
<td>4.27</td>
<td>5.09</td>
<td>3.74</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>0.93</td>
<td>4.22</td>
<td>5.04</td>
<td>3.67</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>1.03</td>
<td>4.28</td>
<td>5.25</td>
<td>3.85</td>
</tr>
<tr>
<td>Elemental S</td>
<td>25</td>
<td>0.66</td>
<td>4.4</td>
<td>4.96</td>
<td>3.43</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>0.85</td>
<td>4.04</td>
<td>5.12</td>
<td>3.92</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>0.95</td>
<td>4.37</td>
<td>4.96</td>
<td>3.76</td>
</tr>
</tbody>
</table>

K.A. Kelling, et al, 2002
Carrying Effect of 1x75 lb S/a appl over 4 years

- Results
  - SOP and elemental performed similarly
  - S increased yield and tissue S%

<table>
<thead>
<tr>
<th>Source</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>0.74</td>
<td>4.08</td>
<td>4.33</td>
<td>3.3</td>
</tr>
<tr>
<td>K2SO4</td>
<td>0.87</td>
<td>4.2</td>
<td>5.23</td>
<td>4</td>
</tr>
<tr>
<td>CaSO4</td>
<td>0.87</td>
<td>4.04</td>
<td>5.01</td>
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</table>

K.A. Kelling, et al 2002
GSL is investing in research

- Not a tremendous amount of research has been done with SOP on alfalfa

- Opportunities
  - Greater yields with SOP
  - Enhanced nutrient use efficiency
  - Maximizing forage quality
  - Improved haylage production
  - Improved nodulation
  - Enhanced palatability