Module 5: Sulfur Management

To view the chapter for this topic click here.
Introduction

- Sulfur (S) is often classified as a “secondary” plant essential element.

- Importance of S:
  - constituent of three essential amino acids
  - necessary in the formation of chlorophyll, vitamins, enzymes, and aromatic oils
  - essential for high protein content in forages
  - plays an important role in crop quality such as wheat grain for making bread
  - needed for N fixation by legumes
Module 5: Sulfur Management

Introduction

• Sulfur deficiencies are on the rise due to:
  o the shift to more concentrated fertilizers, containing little to no S
  o reduction of sulfur dioxide (SO₂) emissions
  o higher S removal by more productive crops

• Sulfur deficiency symptoms:
  o yellowing and interveinal chlorosis (similar to N deficiency)
  o often more evident in younger leaves (opposite to N)
  o generalized in the entire plant if deficiency is severe
Example of Sulfur deposition with rainfall in the U.S.

Sulfate ion wet deposition, 2010

Sites not pictured:
- Alaska 01: 1 kg/ha
- Alaska 03: < 1 kg/ha
- Alaska 06: 1 kg/ha
- Puerto Rico 20: 30 kg/ha
- Virgin Islands 01: 12 kg/ha

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu
Sulfur Amount in Harvested Portions of Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Unit of Yield</th>
<th>Pounds of S per unit of yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>bu</td>
<td>0.07</td>
</tr>
<tr>
<td>Corn silage</td>
<td>ton</td>
<td>0.58</td>
</tr>
<tr>
<td>Soybean</td>
<td>bu</td>
<td>0.10</td>
</tr>
<tr>
<td>Oat and Straw</td>
<td>ton</td>
<td>4.50</td>
</tr>
<tr>
<td>Wheat</td>
<td>bu</td>
<td>0.08</td>
</tr>
<tr>
<td>Barley</td>
<td>bu</td>
<td>0.08</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>ton</td>
<td>5.00</td>
</tr>
<tr>
<td>Clover</td>
<td>ton</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Adapted from Modern Corn and Soybean Production. 2000. MCPS Publications.
Testing for Sulfur Sufficiency

- Sampling soil, plant tissue, and irrigation water are methods for determining S supply and needs.

- Soil testing for inorganic S (SO$_4^{-2}$-S) is not as reliable as for other nutrients.

- An alternative is use of an index that incorporates several factors besides a S test only.

- A low testing soil may still supply a crop with adequate S because of:
  - ample plant available S below the testing depth
  - significant organic S mineralized during the growing season
  - high S levels in shallow groundwater
Testing for Sulfur Sufficiency – 0 to 6 inch soil test for extractable soil sulfate-sulfur

Corn grain yield response to S application as related to extractable soil sulfate-S concentration (0-6 inch soil depth) in the no-S control. Data from a multi-year study conducted in Iowa.
Yield increase per cut from S fertilization relative to the alfalfa plant tissue S concentration (6-inch plant top) with no S applied. Data from a multi-year study conducted in Iowa.
Testing for Sulfur Sufficiency – Plant tissue testing for N:S ratio

Basis for Sulfur Fertilizer Recommendations

- Yield responses to S occur most commonly:
  - in crops with higher S requirements such as alfalfa, canola, and corn
  - when most of the plant material is removed
  - in sandy or eroded soils
  - soils low in organic matter
  - soils with low sulfate-S content in the profile

- Unlike N-P-K, S deficiency determination and associated fertilization guidelines do not exist in many regions of the U. S.

- The existing S fertilization recommendations often are based on:
  - plant testing (for specific crops when reliable)
  - local yield response trials
  - soil properties/conditions associated with response to S
Examples of Sulfur Rate Determination

- **University of Wisconsin**
  - S availability index (SAI) = (soil test $\text{SO}_4^{2-}$ x 4) + Subsoil-S + precipitation-S
    
    $$+ \text{ (% OM x 2.8 lb/acre)} + \text{ available manure-S.}$$
  - If SAI > 40 → adequate
  - If SAI > 30 → application of 10-50 lb S/acre
  - If SAI > 30 and < 40 → tissue test recommended

- **Alabama**
  - All crops receive 10 lb S-acre per year. Cotton receives 20 lb S/acre.

- **Great Plains**
  - For canola, if soils have < 5 ppm $\text{SO}_4^{2-}$ → 15 lb S/acre.
  - For wheat, barley, and oats, if soils have < 3 ppm $\text{SO}_4^{2-}$ → 10 - 15 lb S/acre.
Example Crop Response to Sulfur Application Rate

Corn grain yield response to S application rate at responsive sites. Data from a multi-year study conducted in Iowa.
Example Crop Response to Sulfur Application Rate

Cotton lint yields as affected by the rate of S on a Lucy loamy sand. Data from a multi-year study conducted in Alabama.
## Sulfur Sources

<table>
<thead>
<tr>
<th>Fertilizer Source</th>
<th>Formula</th>
<th>Analysis (N-P-K-S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium sulfate</td>
<td>(NH$_4$)$_2$SO$_4$</td>
<td>21-0-0-24</td>
</tr>
<tr>
<td>Ammonium thiosulfate (ATS)</td>
<td>(NH$_4$)$_2$S$_2$O$_3$</td>
<td>12-0-0-26</td>
</tr>
<tr>
<td>Gypsum</td>
<td>CaSO$_4$ • 2H$_2$O</td>
<td>0-0-0.5-17</td>
</tr>
<tr>
<td>Epsom salt</td>
<td>MgSO$_4$ • 7H$_2$O</td>
<td>0-0-0-14</td>
</tr>
<tr>
<td>Granular elemental S</td>
<td>S + bentonite</td>
<td>0-0-0-90</td>
</tr>
<tr>
<td>Potassium magnesium sulfate</td>
<td>K$_4$SO$_4$ • 2MgSO$_4$</td>
<td>0-0-22-23</td>
</tr>
<tr>
<td>Potassium sulfate</td>
<td>K$_4$SO$_4$</td>
<td>0-0-50-18</td>
</tr>
</tbody>
</table>
Sulfur Timing and Placement

- Desired goal: time S fertilizer applications so S is available when the crop needs it.

- Application of a sulfate form well in advance of crop uptake can be subject to leaching losses in soils with high leaching potential.
  - In those soils, application close to or at planting would be desirable. Sidedress applications can be beneficial.

- Sulfate leaching is slow in most soils due to interaction with soil clays.

- Application of elemental S should be in advance of crop need so there can be conversion to sulfate.

- For forages, there are more opportunities for application due to multiple cuttings.

- Applied S must be in the rooting zone for plant uptake: banding or incorporation into the soil is desirable.

- Surface application must be well in advance of crop need and in or converted to the sulfate form so movement into the soil can take place with rainfall.
Module 5: Sulfur Management

Summary

- Sulfur management requires a thorough understanding of how different factors can affect the plant availability of S and potential deficiency:
  - temperature and moisture
  - soil organic matter and texture
  - erosion
  - tillage system
  - landscape position
  - rooting depth
  - subsoil sulfate
  - past S inputs
  - atmospheric deposition
  - cropping system

- The frequency of S deficiencies is increasing and so is the need for supplemental S.

- Therefore, S needs to be considered for developing successful nutrient management plans.