



Module 5: Sulfur Management

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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



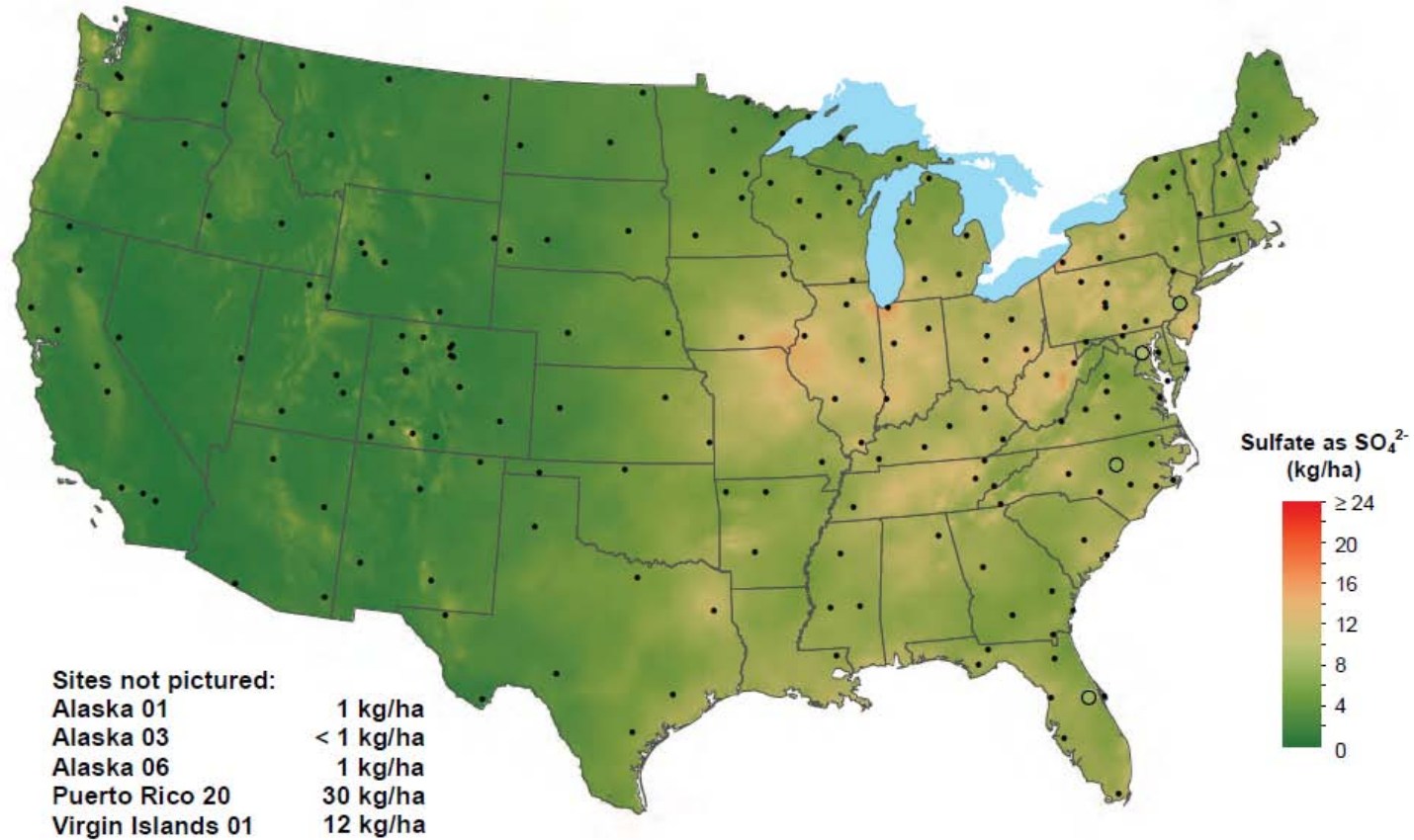
Introduction

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

- Sulfur deficiency symptoms:
 - yellowing and interveinal chlorosis (similar to N deficiency)
 - often more evident in younger leaves (opposite to N)
 - generalized in the entire plant if deficiency is severe

Example of Sulfur deposition with rainfall in the U.S.

Sulfate ion wet deposition, 2010





Sulfur Amount in Harvested Portions of Crops

Crop	Unit of Yield	Pounds of S per unit of yield
Corn	bu	0.07
Corn silage	ton	0.58
Soybean	bu	0.10
Oat and Straw	ton	4.50
Wheat	bu	0.08
Barley	bu	0.08
Alfalfa	ton	5.00
Clover	ton	3.00

Adapted from Modern Corn and Soybean Production.
2000. MCPS Publications.

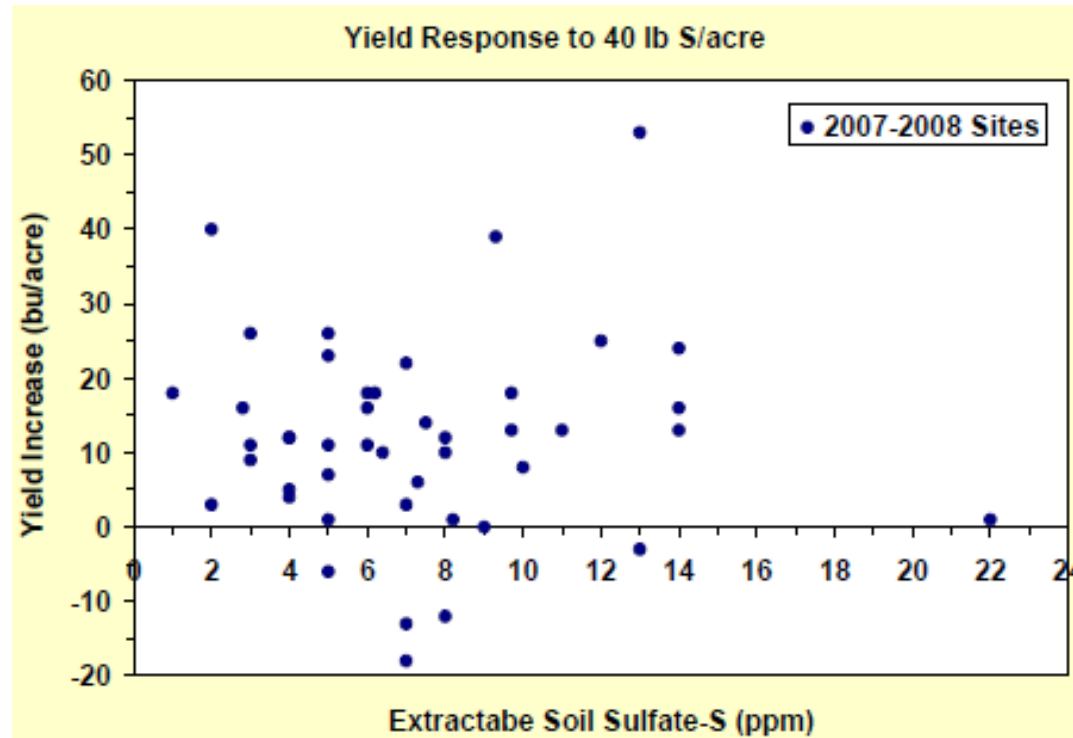


Testing for Sulfur Sufficiency

- Sampling soil, plant tissue, and irrigation water are methods for determining S supply and needs.
- Soil testing for inorganic S ($\text{SO}_4^{2-}\text{-S}$) 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



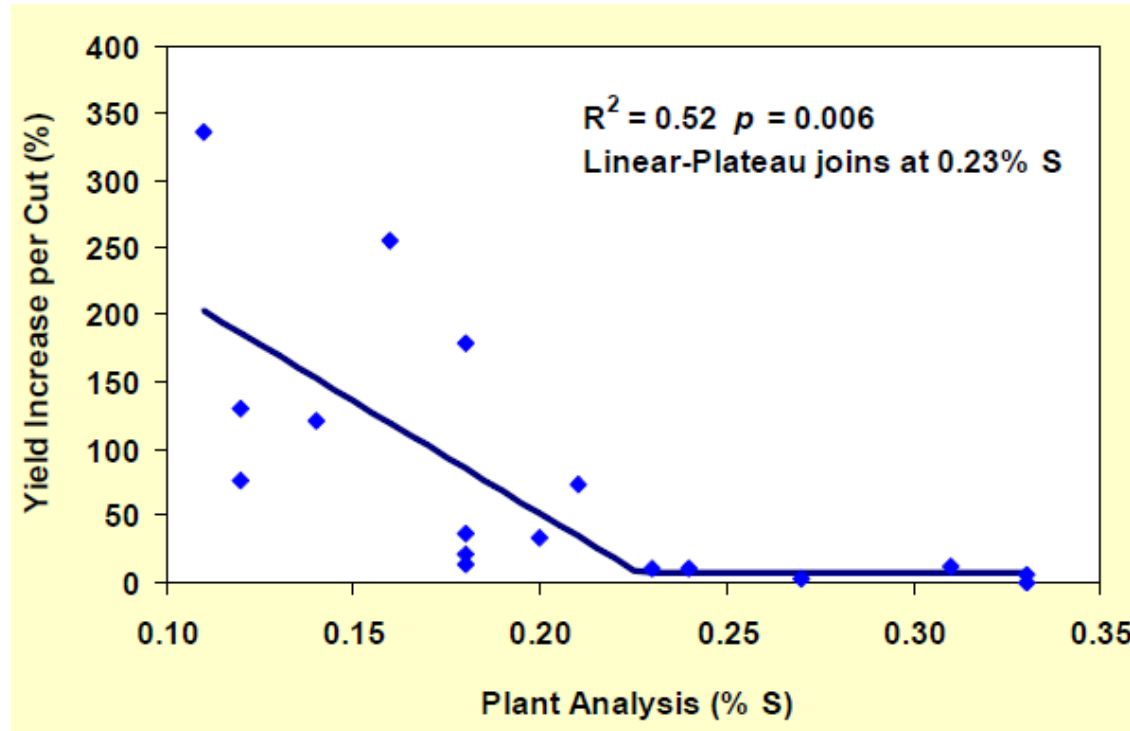
Testing for Sulfur Sufficiency – 0 to 6 inch soil test for extractable soil sulfate-sulfur



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.



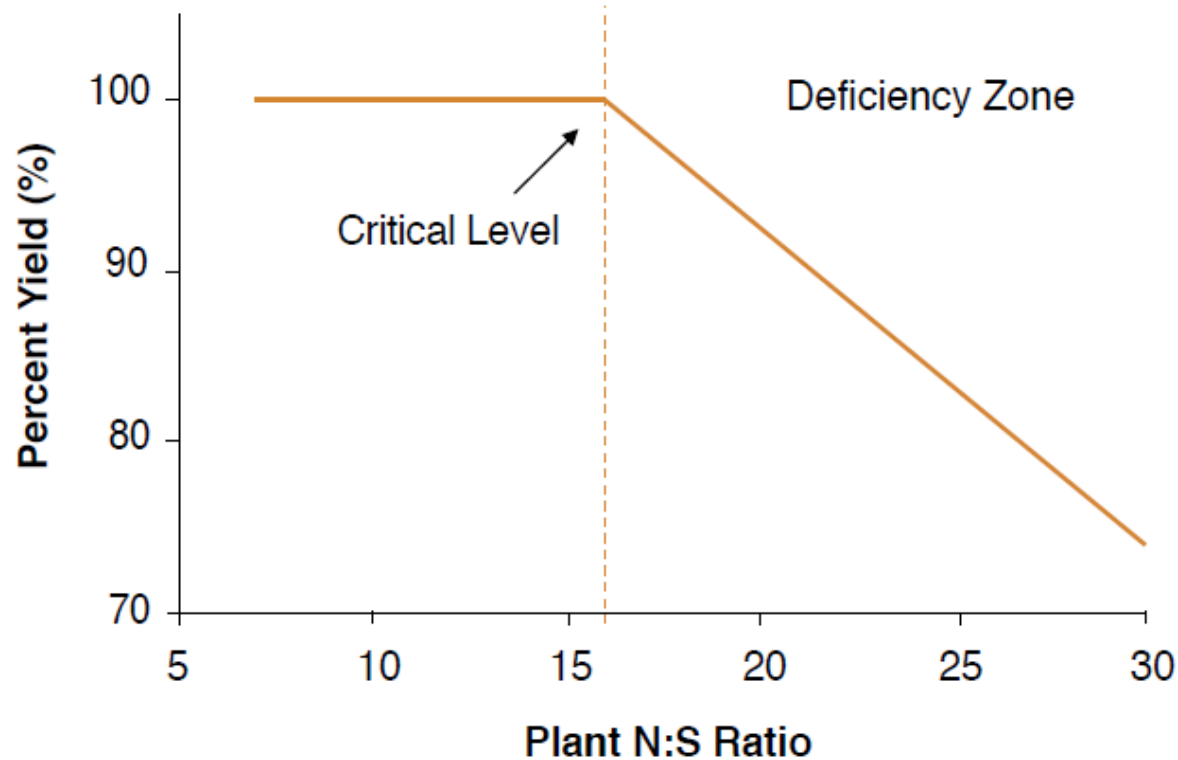
Testing for Sulfur Sufficiency – Plant tissue testing for Sulfur



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



Relationship between relative yield of wheat and plant tissue N:S ratio.
Adapted from K. Spencer and J.R. Freney (1980). *Agron. J.* 72:469-472.



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 $\text{SO}_4^{-2}\text{-S}$ x 4) + Subsoil-S + precipitation-S
+ (% OM x 2.8 lb/acre) + 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

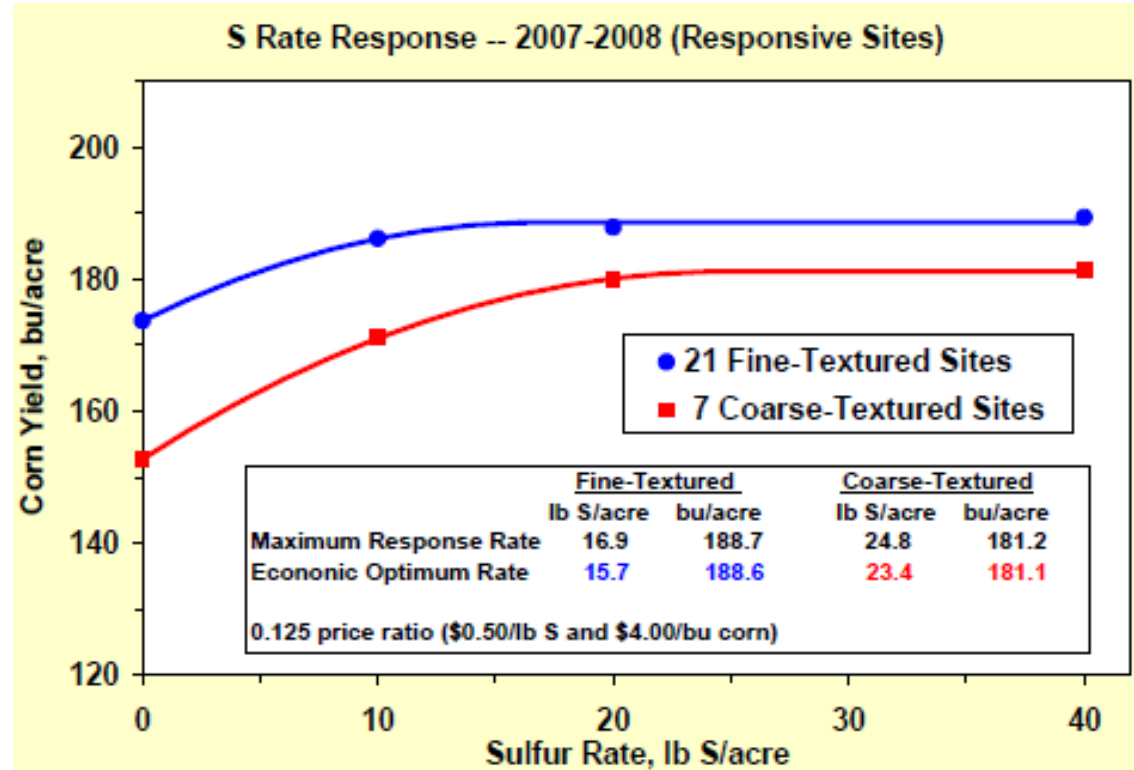
- All crops receive 10 lb S/acre per year. Cotton receives 20 lb S/acre.

- Great Plains

- For canola, if soils have < 5 ppm $\text{SO}_4^{-2}\text{-S}$ —————> 15 lb S/ac.
- For wheat, barley, and oats, if soils have < 3 ppm $\text{SO}_4^{-2}\text{-S}$ —————> 10 -15 lb S/acre.



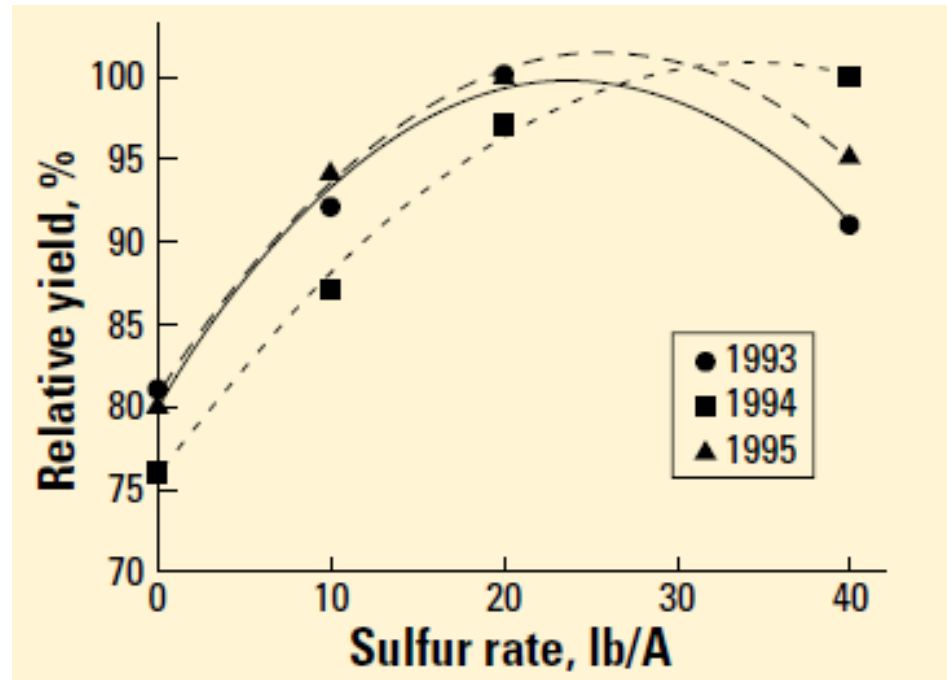
Example Crop Response to Sulfur Application Rate



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

Fertilizer Source	Formula	Analysis (N-P-K-S)
Ammonium sulfate	$(\text{NH}_4)_2\text{SO}_4$	21-0-0-24
Ammonium thiosulfate (ATS)	$(\text{NH}_4)_2\text{S}_2\text{O}_3$	12-0-0-26
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	0-0-0.5-17
Epsom salt	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	0-0-0-14
Granular elemental S	S + bentonite	0-0-0-90
Potassium magnesium sulfate	$\text{K}_4\text{SO}_4 \cdot 2\text{MgSO}_4$	0-0-22-23
Potassium sulfate	K_2SO_4	0-0-50-18



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.



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.