

Site-Specific Nutrient Management

For Nutrient Management Planning To Improve Crop Production, Environmental Quality, and Economic Return

Presentation Script: Sulfur - Chapter 5

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Funding provided by the USDA-NRCS and TFI.

... and justice for all

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Sulfur Management

Slide 1.

This module will cover the most important concepts of sulfur management in agricultural systems for profitable crop production. Since it is impossible to go through specific scenarios for all regions of the U.S., general concepts regarding sulfur management will be presented. Even though these principles apply for most regions, viewers are encouraged to review locally developed sulfur use recommendations.

Slide 2.

Sulfur is considered a “secondary” plant essential element, mainly due to a smaller plant requirement but also because it is less frequently applied as a fertilizer and in smaller amounts compared to other nutrients like the macronutrients. However, if deficient, sulfur can have a dramatic effect on plant growth and crop productivity. Sulfur is a constituent of three amino acids which are essential to protein synthesis. Sulfur is also necessary in the formation of chlorophyll and other important compounds. As a constituent of amino acids, sufficient sulfur is essential for high protein content in forages. It plays an important role in crop quality such as wheat grain for making bread and protein content of forages and grains. Breadmaking varieties of wheat have approximately 10% more sulfur in grain than non-breadmaking varieties, although total plant sulfur uptake is similar. Sulfur is also necessary for the biological nitrogen fixation by legumes.

Slide 3.

Sulfur deficiencies are on the rise in the U.S. and throughout the world. Three trends are responsible for increasing sulfur deficiencies. 1) Fertilizer sources are now more concentrated, and more pure products containing little to no sulfur. Historically sulfur was a co-product of the manufacturing fertilizer manufacturing process. 2) There has been a reduction of sulfur dioxide emissions from burning coal and oil, which decreases sulfur additions to the soil from atmospheric deposition. And, 3) There has been a steady increase in crop sulfur uptake and removal due to high-yielding crops and more productive management. Sulfur deficiency looks similar to nitrogen deficiency with yellowing and interveinal chlorosis, but because sulfur is not very mobile in the plant, the younger leaves tend to show the deficiency first versus the older leaves as in nitrogen deficiency. With severe deficiency, the entire plant will have yellowing and

reduced growth or spindly stems. Efficient nitrogen utilization requires adequate sulfur because both are needed to form proteins in the plant. Sulfur is also needed for nitrogen fixation by legume crops. Effective management of sulfur requires an understanding of the processes that determine its availability to crops and the methods to manage soils with inadequate sulfur levels.

Slide 4.

This figure shows a recent U.S. map with sulfate wet deposition mainly due to industrial activity. As can be seen, higher sulfate depositions are located in areas with heavier industrial activity. However, because of improved industrial processes in the U.S. and in other regions of the world, sulfur deposition has significantly decreased over time to levels that are generally insufficient to meet crop needs.

Slide 5.

This table lists the sulfur removal per unit of yield, and can be used for estimating sulfur removal. In general, legumes have higher sulfur requirements in comparison to cereals.

Slide 6.

Sampling soil, plant tissue, and irrigation water are methods for determining potential sulfur fertilization needs. Testing the topsoil for plant-available sulfur has been and continues to be debated because testing for extractable sulfate-sulfur or other sulfur forms has a poor relationship with sulfur sufficiency for crops, and is not reliable in soils of many regions for predicting yield response to applied sulfur. Other suggested soil tests for sulfur include measuring organic sulfur content and estimating mineralization during the growing season. A low testing soil may still supply a crop with adequate sulfur. Ample sulfur may be below the testing depth, for example in a subsoil sulfate or gypsum layer. There may be significant organic sulfur mineralized during the growing season. Or, there may be high sulfur levels in shallow groundwater. The issue is that soil tests by themselves cannot integrate all of the potential sources and variation in supply of plant-available sulfur.

Slide 7.

For example, the figure on this slide is an example from an Iowa study depicts no value of extractable soil sulfate-sulfur at a 0-6 inch depth for predicting corn yield increase from sulfur application. This is a reason that several land-grant universities do not recommend sulfur application based on soil testing.

Slide 8.

Plant tissue testing can also be used to determine sufficiency of plant-available sulfur. Samples are analyzed for total sulfur concentration or for the nitrogen to sulfur ratio. In some crops, these plant tests for sulfur have greater reliability than soil testing in some crops. For example, the figure shows the sulfur concentration in the top six inches of alfalfa plants at the early bud state. In research with corn in the same area of Iowa, plant sulfur concentration of ear leaves at silking did not indicate a specific critical sulfur concentration.

Slide 9.

In some crops and geographic areas, the plant nitrogen to sulfur ratio has been successfully used as an indicator of the plant sulfur status. For example, this figure shows that the critical ratio for wheat is about 16:1, so, assuming adequate nitrogen supply, ratios greater than 16:1 would indicate a sulfur deficiency in the plant. Unfortunately, deficiencies indicated by tissue tests in some crops taken during the growing season cannot easily be corrected until the following year. In other crops with multiple harvests per growing season, like alfalfa, deficiencies can be corrected after any harvest.

Slide 10.

Yield responses to sulfur occur most commonly in crops with higher sulfur requirements such as alfalfa, canola, and corn; when most of the plant material is removed; in sandy or eroded soils; and soils low in organic matter or with low or very low sulfate-sulfur content in the profile. Unlike nitrogen, phosphorus, and potassium, sulfur fertilization guidelines do not exist in many regions of the U.S. The existing sulfur fertilization recommendations are often based on plant testing for specific crops when reliable or on local yield response trials. These recommendations often include consideration of soil properties and other conditions commonly associated with response to sulfur application. Due to the complexity of sulfur cycling and factors affecting plant available sulfur levels no single diagnostic method or recommendation system seems to be appropriate for all crops or regions. Therefore, diverse sulfur management strategies have been implemented in different production areas, supporting the need to use locally developed information.

Slide 11.

Here are examples that represent some of the various approaches that universities and other research institutions are recommending to manage sulfur fertilization. The University of

Wisconsin recommends the use of a sulfur availability index to determine relative plant available sulfur. This index is comprised of: soil test sulfate-sulfur, subsoil-sulfur, precipitation-sulfur, organic matter mineralization, and available manure-sulfur. For the sulfur availability index, values greater than 40 are considered adequate with no sulfur application needed. Values less than 30 are considered low with application of 10-50 lb sulfur/acre recommended depending of the fertilizer placement method and crop. If the sulfur availability index is between 30 and 40, a tissue test is recommended to determine if additional sulfur is needed. In other states, such as Alabama, sulfur recommendations are more conservative in terms of preventing sulfur deficiencies and suggest that all crops receive 10 lb sulfur/acre per year except cotton which would receive 20 lb sulfur/acre. In the Great Plains, a soil test critical value has been determined for canola. Soils with less than 5 ppm sulfate-sulfur should be fertilized with 15 lb sulfur/ac in an optimal N-P-K blend. In the same region, the critical soil test level for wheat and other small grains such as barley and oats is only 3 ppm sulfate-sulfur and fertilizer recommendations for deficient areas range between 10 and 15 lb sulfur/acre.

Slide 12.

Sulfur fertilizer application rates should be based on expected optimal economic return. Those rates vary among regions, crops, and years, so local research is important for determining economic response. For example, the figure shows a set of sulfur rate trials with corn in Iowa, where the maximum response rate for 21 fine-textured soil sites was 17 lb sulfur/acre, with an economic optimum rate at 16 lb sulfur/acre. However, for 7 coarse-textured soil sites, the maximum response rate was higher at 25 lb sulfur/acre, with an economic optimum rate at 23 lb sulfur/acre. The economic optimum sulfur rate is near the maximum response because the fertilizer cost calculated as application rate times price is low compared to the yield return determined as yield increase times the commodities' price.

Slide 13.

Another example of crop response to increasing rates of sulfur application is presented in this figure for research in Alabama with cotton. In this case, cotton yield reached maximum values with sulfur applications of 20-35 lb sulfur/acre.

Slide 14.

There are several forms of sulfur fertilizers available to producers. The sulfur solubility and plant-availability characteristics of each form can vary. The most common sulfur fertilizers used

in the U.S. are listed in the table. The major factors in choosing a sulfur fertilizer are the analysis, availability to plants, acidifying effect of the material, fertilizer compatibility, and cost.

Ammonium sulfate, ammonium thiosulfate, gypsum, potassium sulfate, and epsom salt are commonly used sulfur sources because they quickly release sulfate for plant use. Therefore, these fertilizers can be applied before, at, or after planting. Elemental sulfur must be microbially oxidized to sulfate before plants can utilize it. Dispersible, granular elemental sulfur can be broadcast to increase surface area and exposure of sulfur, and thereby accelerate oxidation. This form of sulfur must be applied well before the growing season if it is expected to supply the crop with available sulfur; otherwise some readily available sulfur should be included. Manures are a good source of sulfur, and can eliminate the need for sulfur fertilizer application. Also, many locally produced byproducts contain sulfur, and can be an effective source of plant-available sulfur.

Slide 15.

The demand for sulfur by a growing crop is not constant through the growing season. The highest uptake is associated with the periods of rapid growth. Timing sulfur fertilizer applications to provide a plant-available supply when the crop needs it is the desired goal. Plants subject to deficiency during a high demand period may not recover to achieve full yield potential. Yields can be affected when high sulfur rates are applied too late or when a form such as elemental sulfur is not applied far enough ahead of crop need. Conversely, application of a containing plant available sulfate, or of a product that changes quickly to sulfate such as thiosulfate too far in advance of crop uptake can be subject to losses in soils with high leaching potential. An example of high leaching potential is a coarse textured soil that receives high rainfall. In those soils, application close to or at planting is desirable. Sidedress applications can be beneficial for correcting deficiencies, but the source should be in a readily plant available form such as sulfate or thiosulfate, and it should be applied before large plant uptake. For crops with multiple harvests, like forages, there are multiple opportunities for application. Applied sulfur must be in the rooting zone for plant uptake, therefore banding or incorporation into the soil is desirable. Surface applications must be in a sulfate form so movement into the soil can take place with rainfall. Some sulfur fertilizers such as thiosulfate may cause seedling injury and should not be placed in furrow.

Slide 16.

Effective sulfur management requires not only a thorough understanding of sulfur transformations in soil, but also an awareness of how several factors can affect the plant availability of sulfur and potential deficiency. These include temperature, moisture, soil organic matter, erosion, tillage system, landscape position, soil texture, rooting depth, subsoil sulfate, past sulfur inputs, atmospheric deposition, and cropping system. Although sulfur deficiencies have been relatively infrequent in the past, the frequency of deficiencies is increasing and the need for sulfur fertilization is increasing. Sustained high crop yields, with few if any sulfur inputs, have resulted in greater chance of deficiency. Sulfur plays a major role in crop growth, yield, and quality, and improves the effectiveness of other nutrient inputs. Therefore, sulfur needs to be considered for developing successful nutrient management plans.