Sulfur

Sulfur deficiencies are becoming increasingly more common for several reasons: 1) crop yields continue to increase while the demand for soil-sulfur removal increases, 2) sources of sulfur such as 0-20-0, which contain 12 percent sulfur, are no longer being used, 3) reduced-tillage systems increase soil organic matter, which require extra applications of sulfur, and 4) sulfur contributions from rainfall have been reduced by clean-air regulation. We will discuss sulfur's reaction in the soil and how to correct sulfur deficiencies.

The Role of Sulfur In The Plant

Sulfur is an essential element in forming protein, enzymes, vitamins, and chlorophyll in plants, and nodule development in legumes. There are many forms of sulfur found in the air, soil, and water. However, sulfur is primarily taken up by the plant as sulfate (SO_4^{-2}) from the soil. Crops grown downwind from industrial activity, and within 30 to 60 miles, can take up a significant amount of sulfur through the leaf stomata as sulfur dioxide (SO_2). Generally, sulfur-deficient plants show a pale green color, appearing first on younger leaves. Eventually, the entire plant can take on a pale, green appearance.

Comparison of alfalfa growth with and without sulfur application

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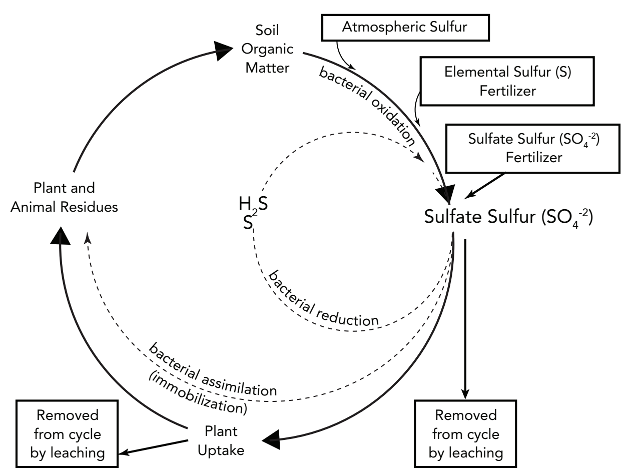
Factors Affecting Sulfur Availability

In many ways, sulfur behaves and reacts in the soil much like nitrogen. Like nitrogen, sulfur has a cycle (see Figure 1). Starting at the top of Figure 1, sulfur is mineralized from organic matter to sulfate. Sulfate is negatively charged (like nitrate) and subject to leaching. Sulfate can be tied-up (immobilized) by soil microbes if the residue contains a low amount of sulfur. Sulfate can also volatilize as hydrogen sulfide (H_2S) under water- logged conditions, which is similar to denitrification in nitrogen. This is why stagnant water often has a rotten-egg smell. Atmospheric sulfur can contribute about 5 to 10 lbs./acre of sulfur per year. Elemental sulfur is unavailable to the plant and must be converted by Thiobacillus bacteria to SO_4, which is an acid-producing process.

Figure 1. The Sulfur Cycle



Diagnosing Deficiencies

There are many factors that affect sulfur nutrition in plants. A suggested checklist to assess the possibility of sulfur deficiencies is listed below. You should think about applying sulfur if your checklist has more than three of these factors:

- **Organic matter –** Soil organic matter releases about 10 parts nitrogen for every part sulfur through mineralization. The release of nitrogen from soil organic matter ranges from 10 to 30 lbs. for every 1 percent organic matter. Therefore, you can expect about 1 to 3 lbs. of sulfur released for every 1 percent organic matter. Soil with less than 1 percent organic matter is prone to sulfur deficiencies. On the other hand, soil with greater than 5 percent organic matter is usually unresponsive to sulfur.

- **Residue –** Soil sulfur is temporarily tied up (immobilized) when soil microbes break down crop residue. Additional soil sulfur must be added to prevent this temporary sulfur deficiency.

- **Soil temperature and moisture –** Soil temperature and moisture control the amount of sulfur released from soil organic matter. Soil that is cold and wet, like many springs in the Midwest, can produce sulfur deficiencies.

- **Soil texture –** Sandy soil is more prone to sulfur deficiencies than medium-to heavy-textured soil for three key reasons: 1) sulfate that is negatively charged, like nitrate, is easily leached out of the root zone of coarse-textured soil, 2) sandy soil is usually low in organic matter, and 3) sandy soil is drier throughout the year, which results in less microbial activity to release soil-organic-matter sulfur.

- **Soil-test extractable sulfur –** Soil-test levels less than 10 ppm are considered deficient, but all the factors listed in this checklist must be included when interpreting this number. Soil-test sulfur levels greater than 15 ppm are very unlikely to respond to sulfur.

- **Crop-sulfur sensitivity –** Crops such as canola, alfalfa, and clover are very responsive to sulfur, while cereal crops such as corn, soybeans, and wheat are less responsive.

- **Plant-sulfur tissue levels –** In general, plant nitrogen-to-sulfur ratios greater than 15:1 would potentially be sulfur deficient.

Recommendations

Since sulfur is leachable, like nitrate, it is safer to apply closer to the time of plant uptake in early spring. This is especially true for sandy soil. Corn-grain removal of S/bu is about 0.07 lbs., and total crop uptake of S/bu during the growing season is about 0.13 lbs. Alfalfa removes about 5 lbs. S/ton. Therefore, application rates of 10 to 20 lbs./acre are recommended for grain crops depending on yield goal, and 20 to 40 lbs./acre for crops like alfalfa, which are sulfur sensitive and have high removal rates. Band application (2x2) is recommended, but broadcast works well if adequate rainfall or irrigation is available to leach the sulfur into the root zone. Sulfur sources such as ammonium sulfate, thiosulfate, gypsum, and K-Mg are all very soluble and are immediately available for plant uptake. On the other hand, elemental sulfur requires microbial conversion to sulfate to make it available to the plant. The speed of this reaction is dependent upon the fineness of grind, soil temperature, and moisture. Elemental sulfur is beneficial because it will be present in the soil for two to three years and provide a slow-release source of sulfur. The bad news is that the first-year response to elemental sulfur could potentially be less than the more water-soluble sulfur sources.

Conclusion

Sulfur behaves like nitrogen in the soil and functions like nitrogen in the plant. The only difference is that the sulfur requirements in the plant are only 6 to 10 percent of the nitrogen requirements. Determining sulfur deficiencies is not simply a "soil test", but a combination approach of integrating several factors such as organic matter, residue, soil temperature and moisture, soil texture, soil-test extractable sulfur, crop-sulfur sensitivity, and plant-sulfur tissue levels into the sulfur deficiency equation. Corrective sulfur application rates of 10 to 20 lbs./acre for most cereal crops and 20 to 40 lbs./acre for forages like alfalfa and clover should be sufficient.