Importance of Sulfur for Soybeans

Introduction
Sulfur (S) plays a critical role in nitrogen (N) fixation, the process where rhizobia bacteria in soybean roots fix atmospheric N. Because S deposition from the air has decreased in the past decades, active management of S nutrition is increasingly important. This factsheet provides information on S relating to soybean growth, yield, quality, profitability, uptake, fertilizer sources, tissue and soil tests, and factors that affect soil S supply.

Role of Sulfur in Plant Growth
Sulfur is a vital macronutrient that plants use to build protein and enzymes. The two critical amino acids (building blocks of proteins) that contain S are cysteine and methionine. An S deficiency (Figure 1) reduces production of both of these amino acids and can result in yield loss and lower protein content of soybeans.

Figure 1: Sulfur deficiency in soybeans. Source: https://media.ipni.net.

Crop Removal and Uptake of Sulfur
Soybean yields in New York have averaged 45 bushels per acre since 2013, ranging from less than 40 to greater than 70 bushels for individual fields. Sulfur content averages 0.16 pounds of S per bushel (at 87% dry matter) so S removal can range from less than 7 pounds of S per acre for a 40 bushel per acre crop to just over 11 pounds of S per acre for a 70 bushel yield. Total S uptake is typically twice the amount of S in the seed alone so a good crop of soybeans takes up about 20 pounds of S per acre.

Sulfur Deposition
Sulfur is deposited through dry and wet deposition. Dry deposition occurs from the settling of small particles and gases from the air without rain or snow. Wet deposition occurs when S is deposited by rain, snow, or fog. Deposition rates have declined over time in New York from about 9 pounds of S per acre in 1991 to just above 1 pound of S per acre in 2016, according to records of the United States Environmental Protection Agency (USEPA).

Sulfur Supplied by Soils
Sulfate is the plant available form of S in the soil. Soil microbes are instrumental in turning soil organic matter (SOM) and crop residues into available nutrients, including sulfate, through a process called mineralization. Mineralization rates are impacted by temperature (mineralization occurs between 68 and 104°F); moisture and oxygen (optimal when the soil is just below field capacity); and microbial activity (a higher and more active microbial population results in faster breakdown of organic matter and thus greater S release). The C:S ratio of SOM can be used to estimate S release but S content is not typically reported on soil test reports. In general, 1-3 pounds of S are released for every 1% SOM in the soil.

Crop Residue
Crop residues contain S. For example, corn and wheat have about 3 pounds of S per ton of stover/straw versus 6 pounds of S per ton of stover for soybeans. Soil microorganisms can break down crop residues and release some of this S to the soil. Crop residue type, placement and level of incorporation, soil temperature, moisture and oxygen level affect microbial activity and thus S release from crop residues.

Soil texture and pH affect S Availability
Sandy soils are more prone to S deficiencies than medium- to heavy-textured soil because (1) negatively charged sulfate can leach out of

the root zone of course-textured soil, and (2) sandy soil is typically lower in SOM and drier, resulting in reduced microbial activity. In addition, soil pH regulates nutrient availability. A pH between 6.8 and 7.0 is optimal.

Tests to Determine S Levels

Seed analysis. Normal S levels in soybean seeds range from 0.19-0.31% S on a dry matter basis (Dairy One Feed Composition Library). Lower levels (below 0.19% S) suggest an S deficiency.

Plant tissue analysis. Tissue analyses of the newest fully developed trifoliate at pre-bloom, early bloom, or before pod set can be used to determine if the soybean plant is S deficient. It is recommended to collect 25 trifoliate leaves per field or sampling area. Interpretations depend on stage of sampling (Table 1).

Table 1: Sufficiency ranges for fully developed trifoliate soybean leaves.

Growth stage	Sulfur (%)
Before flower	0.20-0.50
Early bloom	0.20-0.40
Before pod set	0.20-0.40

Soil testing. Soil samples should be taken just before or at planting (0-8 inches depth). Soil should be analyzed for 0.01 *M* $CaCl_2$ or $SrCl_2$ extraction to best reflect plant available S. A critical value of 8 ppm S was established for alfalfa in New York (Factsheet #66) and a similar value is expected for soybeans.

Sulfur Fertilizer

If seed, plant, and/or soil testing suggest that an S deficiency is likely, S addition is recommended. Possible S-containing fertilizers (listed with N, P_2O_5, K_2O + S content) include:

- Elemental sulfur (0-0-0+99.5 S)
- Ammonium thiosulfate (12-0-0+26S)
- Ammonium sulfate (21-0-0+24S)
- Potassium sulfate (0-0-50+18S)
- Calcium sulfate (0-0-0 +15-18S)

Similar to S from crop residues and SOM, elemental S needs to convert to plant-available sulfate first through a biological process carried out by several types of microorganisms. The rate of conversion is determined by physical properties (particle size) of the elemental S source, microbial population, and environmental conditions. The other four S sources listed are highly soluble (contain sulfate) so S from these sources is directly available for plant uptake. There is little or no carryover of sulfate applied from one year to the next.

Manure as Sulfur Source

Sulfur availability from manure differs between solid and liquid manure sources (Table 2). For most accurate information about the S content of a specific manure source, it should be tested for S by an analytical laboratory.

Table 2: Estimated sulfur (S) content of different types of manure.

Animal	Solid (lbs/ton) total S	Solid (lbs/ton) available S	Liquid (lbs/1000 gallons) total S	Liquid (lbs/1000 gallons) available S
Dairy	1.5	0.8	4.2	2.6
Beef	1.7	0.9	4.8	2.3
Poultry	3.2	1.8	9.0	5.0
Swine	2.7	1.5	7.6	4.2

http://corn.agronomy.wisc.edu/Management/pdfs/a2525.pdf

Summary and Next Steps

Soybeans need S for optimal growth, yield, and quality (protein content). Soil organic matter content, residue type and biomass, soil temperature, moisture, and oxygen, and soil texture all impact S supply. If seed, tissue, or soil testing suggest S deficiency, S can be added as fertilizer or by applying manure. A preliminary economic analysis for New York suggests a yield increase of 2 bushels per acre is needed to cover S application costs (break-even yield). Sulfur response trials for soybean are currently being conducted in New York to determine S status and S fertilizer needs.

Additional Resources

- Nutrient Management Spear Program Fact Sheet Series: http://nmsp.cals.cornell.edu/guidelines/factsheets.html.

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For more information

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