Don't Overlook Sulfur In Crop Management

It is a critical nutrient for crops as part of an overall management system.

Drs. Cynthia Grant and John Kovar

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***Summary:** Sulfur (S) is a critical nutrient for crops, particularly canola, pulses, and forage legumes, such as alfalfa. Management of S fertility offers much flexibility, with the availability of several sources. Timing and placement of S can be managed to effectively provide the S needed by the crop. If a deficiency exists and a response is required during the growing season after application, a sulfate source should be used to ensure that S deficiency does not limit yield potential. Elemental sources may have a role in long-term rotational planning. Fertilizer management, however, is only one part of a management system designed to optimize the overall efficiency and profitability of a farming operation. By balancing fertilizer management with the various economic, logistic, and personal considerations in the entire production system, decisions can be made that fit the individual farm.*

Figure 1a: Sulfur fertilizer response in corn.

Sulfur is an essential plant nutrient. It is required by plants in amounts similar to phosphorus (P). Thus, it is grouped with nitrogen (N), potassium (K), and P as the fourth major plant nutrient. Plants lacking essential nutrients have poor growth, low yield, and inferior quality. In plants and animals, S functions like N in that it becomes part of their structure. As a component of amino acids, S is important in protein synthesis, both for protein quality and quantity. It is also involved in N metabolism, photosynthesis, and in the synthesis of oils in oilseed crops, such as canola.

Sulfur deficiencies are becoming more prevalent due to:

- Decreasing aerial deposition of S as a result of clean air legislation
- An increase in the use of high analysis fertilizers with little S
- Decreased use of S-containing pesticides
- Greater S removals with ever-increasing crop yields
- Continued losses through leaching and erosion of topsoil.

Consequently, S has emerged as a major limiting factor in many cropping systems (Figures 1a and b).

Behavior. Sulfur behaves similarly to N in the soil. It is readily mobile and becomes plant available through mineralization of organic matter. Sulfur mineralization rates are highest when soil water content is greater than 60 percent of field capacity, and soil temperature is in the range of 68° to 104°F. Under optimum soil temperature and moisture conditions, a significant amount of sulfate can be mineralized in a short period of time. Sulfate concentrations are usually lowest in the early spring due to leaching and slow mineralization rates.

Sulfur distribution varies with landscape position. Sulfur deficiencies are most often observed on hilltop and side slope positions, especially on eroded, coarse-textured soils. Deficiencies are less common in lower landscape positions with medium- to heavy-textured soils high in organic matter. It is not unusual to find both high soil S concentrations and plant S deficiencies in the same field.

Deficiency symptoms. Sulfur deficiency symptoms include reduced plant growth and chlorosis of the younger leaves, beginning with interveinal yellowing that gradually spreads over the entire leaf area. Sulfur is relatively immobile in the plant, so deficiency symptoms tend to occur first in younger leaves. As the deficiency becomes more severe, leaf cupping and a more erect leaf structure are often observed, especially in canola. Plants are small, grow slowly, and maturity may be delayed. Plants may flower, but have reduced seed set as is the case for canola, lentils, and alfalfa. Under mild to moderate S deficiency, visual symptoms may not always be a reliable indicator. Photos of S deficiency symptoms are available from many sources, including printed works and online sources.

Crop requirements

S content. The S content of plants differs greatly among crop species, among cultivars within a species, and with developmental stage. In general, the oilseed crops (such as canola and sunflower) and legumes (such as alfalfa and soybean) have a much higher requirement for S per unit of production than the small grains and corn. Wheat, barley, and flax have low concentrations of S varying from 0.15 percent to 0.20 percent at flag leaf (shot blade) and flowering, and have high N:S ratios of 15 to 16 at optimum yield. Canola at flowering and alfalfa at full bud generally have similar S concentrations (0.25% to 0.30% S) and N:S ratios of approximately 12 for canola and 14 for alfalfa at optimum yield. The low N:S ratios of the latter crops reflect their greater S requirement and uptake.

S removal. Sulfur requirement is a function of the S taken up in the entire plant, while removal is a function of the S concentration in the tissue or grain that is removed from the field (Table 1). Canola, corn, and oats (among the crops grown for seed) have the highest S requirement and remove the largest quantity of S (15 to 21 lbs S/A) at harvest. The requirements and crop removal of wheat, barley, sunflower, peas, and fababeans are intermediate (9 to 14 lbs S/A). Flax and buckwheat have low requirements for S and remove only a small amount at harvest (7 to 8 lbs S/A). Forage crops remove large quantities of S (9 to 21 lbs S/A), since most of the above-ground biomass is harvested, and there is little return of S to the soil from crop residue. On the other hand, much of the S taken up by grain crops is returned to the soil in the crop residue and can be recycled to subsequent crops.

Managing S fertility

Availability. When the soil is not able to provide enough plant-available S to meet crop demand, S fertilization can be used to optimize crop yield. A wide range of inorganic and organic sources can be used to supply S. Sulfate or thiosulfate materials provide an immediate source of plant-available S for the crop, but the sulfate is highly susceptible to leaching. Following soil application, thiosulfate rapidly reacts to form tetrathionate, which is not plant-available until it converts to sulfate in a process completed within one to two weeks in warm soils. Under cool soil conditions, the reaction may be

Figure 1b: Sulfur deficiency in canola.

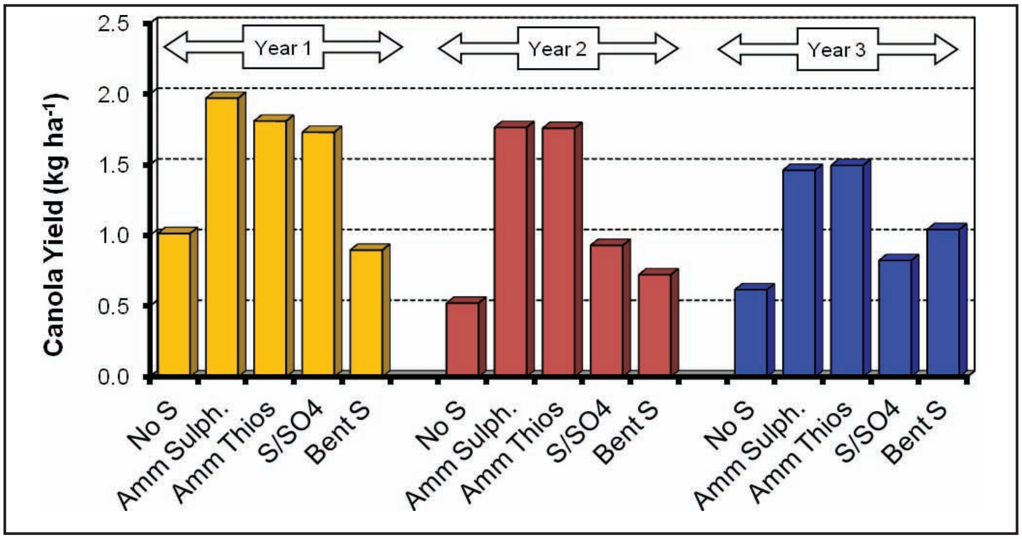

Figure 2: Canola yield as affected by S source.

Table 1. Sulfur removals of various crops at the given yield levels.

Crop	Plant component	Yield	S content
		ton acre-1	lb acre-1
Alfalfa	biomass	5.8	30
Canola/rapeseed	grain	0.98	12
Cool-season grass	biomass	4	16
Corn	grain	5.1	13
	stover	3.1	9
Cotton	lint	0.76	40
Flax	seed	0.83	7
Grain sorghum	grain	4.2	22
	residue	-†	16
Lentil	seed	0.9	5
Orange	fruit	27	28
Peanut	tuber	2	21
Potato	tuber	25	22
Rice	grain	3.5	12
Soybean	grain	1.8	12
	residue	-†	13
Sugar Beet	tuber	30	45
Sunflower	seed	1.7	6
	residue	-†	10
Tomato	fruit	30	41
Wheat	grain	2.4	7
	straw	-†	15

† Sulfur removals in stover, straw, and crop residues are estimates based on typical values of a harvest index (i.e., the ratio of harvested grain to total plant biomass). In most cases, the crop residues are not harvested and the S would not be removed from the field.

somewhat slower. Elemental S materials provide a more gradual release of sulfate into the soil because the S must first be oxidized to the sulfate form. This reduces the immediate risk of leaching losses, but S availability to the crop is delayed, and crop growth will not be affected until oxidation occurs. Cool, dry soils and the relatively short growing season that occurs in northern climates may restrict the oxidation process, so that availability of elemental forms can be delayed for one to several years. However, a residual benefit may occur for subsequent crops.

Timing and placement. The timing of S fertilizer applications, placement of the S sources, and fertilizer rates for specific crops are all management decisions that require careful consideration. The growth and development of cereal grains, oilseed crops, and various legumes are quite different, so the demand for S varies considerably with growth stage. In general, a sufficient S supply is needed during the early growth stages of cereal grains to ensure proper tiller development. In contrast, the greatest demand for S by canola occurs during flowering and seed set. Sulfate sources should be applied at or near the time of planting to provide sufficient S for early growth. In soils with low organic matter content, sandy texture, or rapid water movement through the profile, fall applications of sulfate materials should be avoided to reduce the risk of leaching losses. Soil or foliar applications of sulfate sources can also be used to correct S deficiencies during the growing season. To be effective, in-season soil (top-dress) applications depend on rainfall or irrigation to move the S into the root zone. Fall application of elemental S allows fertilizer granules to break down with freezing-thawing and wetting-drying cycles, thus aiding oxidation of elemental S during the growing season. However, even with fall application, conversion of elemental S to sulfate may be too slow in the northern Great Plains to optimize yield of a spring crop (Figure 2).

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Effective fertilizer placement options for S also depend on the fertilizer source and the soil characteristics. Sulfate will move readily through the soil in the soil water. Therefore, sulfate sources that are broadcast with or without incorporation can provide readily available S to the crops, although stranding of the fertilizer at the soil surface can occur under dry conditions. Row or band applications at the time of planting are also effective, if only small amounts of fertilizer S are required. Care must be taken to avoid damage from excessive sulfate in contact with the growing seedling.

Since elemental S must be converted to sulfate prior to crop uptake, placement of elemental S should encourage oxidation. Elemental S sources should generally not be applied in bands because banding reduces the contact between S and the oxidizing microorganisms in the soil. Elemental sources may be left on the soil surface to allow weathering, but should subsequently be tilled into the soil to blend the fertilizer with soil in the rooting zone to encourage oxidation. Under reduced tillage, the combination of lower soil temperatures during the spring and early summer period and the removal of the mixing action of cultivation may slow the conversion of elemental S to sulfate, reducing the rate at which it becomes available for crop growth. On the other hand, a more active microbial population near the soil surface under reduced tillage and the maintenance of higher soil temperatures through the fall period may enhance oxidation of elemental S.

Dr. Grant is Research Soil Scientist, Agriculture and Agri-Food Canada, Brandon, Canada, and Dr. Kovar is Research Soil Scientist, USDA-ARS, Ames, IA.