COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY—COLLEGE OF AGRICULTURE

Sulfur Fertilization in Kentucky

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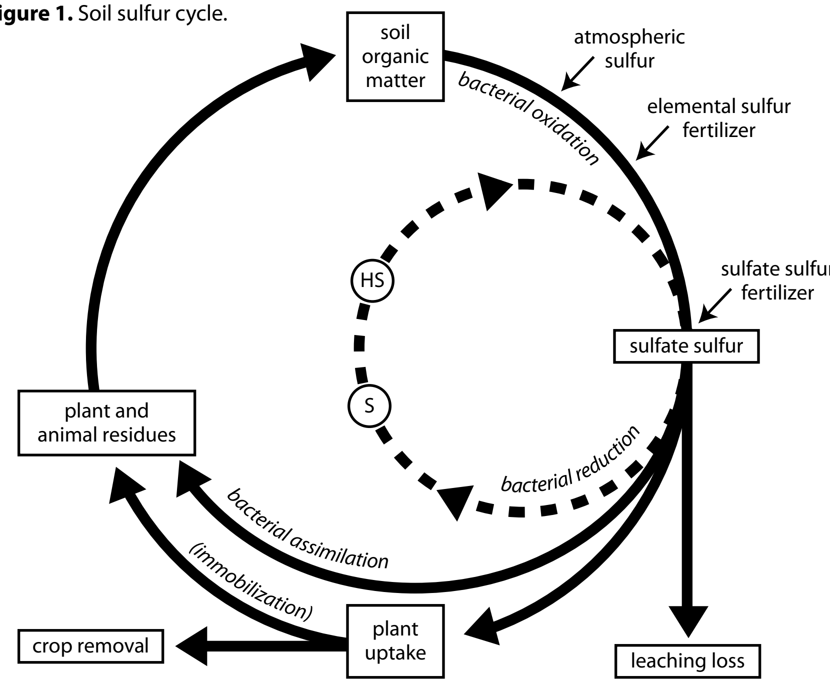
There are a lot of misunderstandings regarding sulfur (S) nutrition for Kentucky crops. Sulfur is considered a secondary plant nutrient because, although the crop requirement for S is relatively large, it is usually found in soil at concentrations adequate for plant growth and yield so that no fertilizer S is needed. For many years, soil S was maintained by atmospheric deposition. However, more stringent clean air standards require greater removal of S during burning of fossil fuels. That fact, along with increasing crop yields, has caused many Kentucky grain producers to begin to question if S fertilization will increase yield.

The Sulfur Cycle

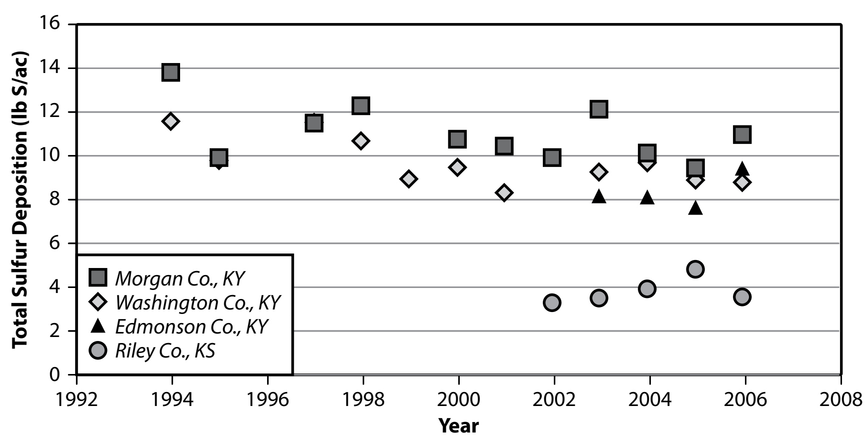
Like nitrogen, most soil S is tied up in organic matter. Organic S must undergo mineralization (biological breakdown) before the S becomes available for plant uptake (Figure 1). Only 1 to 3 percent of the total organic S is mineralized each year, which means there is a large pool of potentially available S in the soil. In addition to the S in organic matter, historically Kentucky and other areas of the eastern United States have had high levels of atmospheric S deposition (last 100 or more years) as a result of burning coal for the generation of electricity and home heating. Recent data shows that there has been some decline in total atmospheric S deposition in Kentucky. However, S deposition is still much higher in Kentucky than in other regions of the country where S deficiencies of crops are more common, as in eastern Kansas (Figure 2).

Figure 1. Soil sulfur cycle.



Adapted from Lamond, 1997.

Figure 2. Total sulfur deposition at three reporting stations in Kentucky and one in eastern Kansas.



Source: National Atmospheric Deposition Program.

As an anion (negatively charged molecule), sulfate-S (SO_4^{2-}) is mobile within the soil profile and, like nitrate (NO_3^-), is subject to loss via leaching. However, Kentucky soils with red-colored subsoil (due to the presence of iron oxides) have the ability to retain anions. As each sulfate anion has two negative charges and each nitrate only one negative charge, sulfate is held more tightly than nitrate in these soils, located largely in the Pennyroyal region. For this reason, it is unlikely that sulfate will leach through the rooting zone of these soils during the winter months.

In terms of soil testing to determine the level of bioavailable S in the soil, the mobility of sulfate needs to be well understood. Often, private soil test labs recommend S fertilization based on soil samples taken to a depth of only 4 to 6 inches. Usually, information regarding S status at deeper depths is unavailable, which results in much higher S fertilizer recommendations than those that would be made if subsurface S were also measured. In Kansas, soil S status is assessed using a 24-inch-deep sample. The soil test S result, given in parts per million (ppm), is first multiplied by 0.3 and then by the depth (in inches) to determine the amount of plant available S (in lb S/acre). For example, if a producer submits a 4-inch sample and the soil test report indicates that soil test S is 3.0 ppm; then the available S in this layer is 3 x 0.3 x 4 = 3.6 lb S/acre. However, the same soil test value, 3.0 ppm S, for a 24-inch sample would give 3 x 0.3 x 24 = 22 lb S/acre. When testing for a mobile nutrient such as S, it is a mistake to assume that none will be found in the subsoil. In addition, measuring sulfate-S and using this calculation does not indicate anything regarding how much additional S will be mineralized from the organic matter in the next growing season.

Crop Sulfur Requirements

Sulfur is an essential element that is absorbed from the soil as SO_4^{2-}. Sulfur is found in plant proteins and is essential for chlorophyll development and photosynthetic activity. Approximately 1 pound of S is taken up for every 10 pounds of N taken up by plants. However, much of this plant S does not end up in the grain and is, therefore, not removed from the field (Table 1). Sulfur removal is much higher for hay and silage crops where the entire plant is harvested. Sulfur is one of the few nutrients that is relatively immobile within the plant.

Table 1. Sulfur removal for crops commonly grown in Kentucky, at harvest moisture.

Crop	Yield unit	Sulfur removal lb S/acre
Alfalfa	Ton	5
Cool-season Grass	Ton	4
Corn	Bu	0.08
Corn Silage	Ton	1.1
Soybeans	Bu	0.18
Wheat	Bu	0.09
Wheat Straw	Ton	2.8
Wheat Silage	Ton	1.4

Deficiency symptoms, pale light green to white colors, appear on the uppermost leaves; the lower leaves look normal to slightly darker green (Figure 3). In 1999 and 2000 a nutrient survey of wheat tissue (flag leaf samples) was conducted in western and central Kentucky. Of the 20 fields sampled, none tested below the critical tissue S concentration. In addition, more than 3,900 plant samples in the past three years have been submitted to the University of Kentucky Plant Disease Diagnostic Laboratory. None of these samples, nor any submitted previously, were diagnosed as suffering from S deficiency. Currently there is no reason to believe that Kentucky crops would benefit from applications of S fertilizers.

Will There Ever Be A Need for Sulfur Fertilization in Kentucky?

Just because there has not yet been a documented case of S deficiency in Kentucky does not mean that S fertilizer will never be needed. By understanding the S cycle, we can predict which crops and rotations might first show S deficiency and a corresponding yield increase to S fertilization. Since much S comes from organic matter mineralization, the first crops that will exhibit S deficiencies will be those that grow during periods when mineralization rates are low (the winter-annual cereals such as barley and wheat, the cool-season grasses, and first cutting alfalfa). Deficiencies will be further intensified in rotations that have very high S removal. Therefore, wheat grown for forage (either hay or silage) in a double-crop silage rotation with corn will likely be the first cropping system in the state that will exhibit S nutritional need. The University of Kentucky continues to monitor and conduct research in fields with this cropping system. To date, no crop yield response to any form of added S has been measured. Because of continued S deposition and the residual amount of S stored in organic matter, it may be a long time before a fertilizer S source is needed in Kentucky.

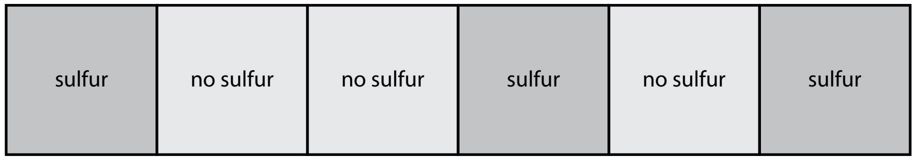
Figure 3. Sulfur deficiency in wheat (left) and corn (right). Classic symptoms consist of pale green upper leaves and darker green lower leaves.

Conducting On-farm Sulfur Evaluations

Although no yield response to S has been observed in Kentucky, some producers with high S-removing cropping systems may want to begin experimenting with S fertilization of their cool-season crops. The first step would be to collect tissue samples from prospective fields. UK Extension publication *Sampling Plant Tissue for Nutrient Analysis* (AGR-92) outlines the sampling process and gives critical tissue nutrient concentrations for crops grown in Kentucky. Fields with plants that are near or below their critical tissue S concentration are good candidates for future trials. The following year, randomly establish strips with and without S fertilizer throughout the field (Figure 4). Be sure to keep all other management practices the same. If you use ammonium sulfate (21-0-0-23S), remember to add an equal amount of extra N to the strips not receiving this S source. For example, if 20 lb S/acre is applied to the S treatments as ammonium sulfate, then an additional 17.5 lb N/acre should be applied to the plots not receiving S. If this N fertilizer is not added, it will be impossible to determine if any yield response is due to added S or to the extra N added with the S.

Throughout the growing season, it is a good idea to collect tissue samples to determine if S fertilization increased tissue S concentrations. Harvest the strips using a well calibrated yield monitor, or weigh each strip to determine the yield response to S fertilization. Statistical analysis can then be done to determine the probability of an actual yield response.

Figure 4. An example of a field plot plan for determining the S responsiveness of field crops.



Note: *It is important to randomly place strips so that soil and other gradients do not unduly influence results.*

Sulfur Fertilizer Sources

There are several different sources of S fertilizer (Table 2). Use the table to help you calculate the least expensive per pound of S. Some sources, such as ammonium sulfate and elemental S, are "acid forming". This means that additional limestone will be needed periodically to neutralize that acidity. A flue gas desulfurization by-product, another S source, results from S removal during electricity generation by coal-burning power plants. Other industrial by-products containing S are also available and are often much cheaper S sources than the S-containing fertilizers. Animal wastes also contain significant amounts of S, so crop response to S fertilization is unlikely for fields where poultry litter or another manure source has been recently applied.

Summary

Currently, there is no reason to believe that Kentucky grain or forage crops are suffering an S deficiency. Atmospheric deposition still accounts for more than 50 percent of required S. However, as atmospheric S levels decline and crop yields increase, S fertilization may become necessary. University of Kentucky research and Extension specialists will continue to look for evidence of S deficiency and will continue to evaluate S fertilization in high S-removing cropping systems. This publication will be revised when or if valid research indicates a yield response to S fertilization can be measured, and S fertilizer recommendations for Kentucky have been established.

Table 2. Common sulfur-containing materials and their corresponding acidity.

		Analysis (%)				
Material	**Form**	**N**	**P_2O_5**	**K_2O**	**S**	**Acidity[1]**
Ammonium Sulfate	Solid	21	0	0	24	4.7
Ammonium thiosulfate	Liquid	12	0	0	26	2.4
Flue gas desulfurization by-product	Solid	0	0	0	6-18	Usually basic
Gypsum	Solid	0	0	0	18	Neutral
Magnesium sulfate	Solid	0	0	0	13	Neutral
Potassium thiosulfate	Liquid	0	0	25	17	1.7
Potassium magnesium sulfate	Solid	0	0	22	22	Neutral
Potassium sulfate	Solid	0	0	50	18	Neutral
Sulfur, elemental	Solid	0	0	0	30-99	3.5
Super phosphate, ordinary	Solid	0	18	0	10-40	Neutral
Super phosphate, triple	Solid	0	45	0	1-2	Neutral

[1] Acidity = lb of 100 percent limestone required to neutralize the acidity resulting from the application of each lb of S.

Adapted from Mortvedt et al., 1999; and Obreza et al., 2003.

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