AGRI FACTS™

Sulfate -vs- Elemental Sulfur Part II: Characteristics Of S Oxidation To SO_4

The oxidation of S° to SO_4 in soil is a biological process and is carried out by several kinds of micro-organisms. The rate at which this conversion takes place is determined by three main factors:

- The microbiological population of the soil.
- The physical properties of the Sº source.
- The environmental conditions in the soil.

Microbiological Population In The Soil
Most agricultural soils contain some microorganisms that are able to oxidize Sº. However, the most important organisms in this respect are a group of bacteria belonging to the genus *Thiobacillus*. It is the numbers of these bacteria that generally determines the degree to which Sº is converted to SO_4 in soils, and there can be large differences between soils in the population density of *Thiobacillus*. Under laboratory conditions, the rate of Sº oxidation in some soils can be markedly increased by inoculation with *Thiobacillus*. However, under field conditions, inoculation has not been found very effective.

When a source of Sº is added to a soil, it generally stimulates the growth of S-oxidizing bacteria, and the population of these organisms increases.

Physical Properties Of The Sº Source
The physical property that has by far the greatest effect on the rate of Sº oxidation is particle size. The finer the particle size, the larger the surface area exposed to soil microorganisms and the more rapid the oxidation process. Table 1 clearly shows this effect of particle size.

Table 1. Particle Size Affects Rate Of S Oxidation.

Particle Size (Meshes/Inch)	% S Oxidized 2 Weeks	4 Weeks
5-10	1	2
10-20	2	5
20-40	5	14
40-80	15	36
80-120	36	68
120-170	61	81
230	80	82

A mesh size of 5-15 is about the size range of bulk blended fertilizers and it can be seen that an S particle of this size is oxidized to SO_4 very slowly. In order for Sº to be oxidized to the plant-available SO_4 form at even moderate rates, it must be of a very fine particle size. But finely divided S is very difficult to handle, in addition to posing a fire hazard under some conditions. All this would seem to largely rule out the use of Sº as a fertilizer material. However, fertilizer manufacturers have developed techniques to improve the handling characteristics and agronomic effectiveness of Sº. Elemental sulfur is first ground to a very small particle size range and is then agglomerated to a particle size compatible with granular fertilizer materials. About 10-15% of an expandable clay is added during the agglomeration process. The resulting material is more easily handled than finely divided S. In theory, when such a particle is applied to a soil, it comes in contact with soil moisture. As this moisture is absorbed by the particle, the clay expands, which in effect breaks the particle down into a much finer size range. The rate of oxidation to SO_4 is increased accordingly. Throughout this *Agri-Facts* publication, when discussing Sº fertilizers, it is assumed the material has been manufactured in such a way that it does indeed break down rapidly on contact with soil moisture.

Environmental Conditions In The Soil

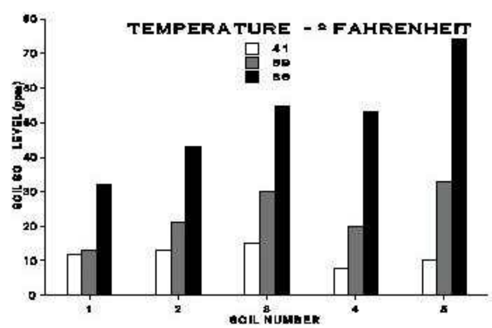
Since the oxidation of S° to SO_4 is a biological process, conditions must be favorable for growth of the organisms in order for oxidation to proceed at optimum rates. The following environmental conditions have been shown to have an influence on the rate of S° oxidation:

- Temperature
- Soil moisture and aeration
- Soil pH
- Fertility status of the soil

Temperature

Like most biological processes, S° oxidation is reduced at both low and high temperatures. Most studies have shown relatively low rates of oxidation below 55-60°F, and steady increases in oxidation rates up to 100°F. At temperatures above 130-140°, oxidizing bacteria are killed. All things considered, the optimum temperature range for oxidation is 75-105°F. Figure 1 shows the marked effect of temperature on oxidation rates of S°.

Figure 1. Effect Of Temperature On Oxidation Of S° After 74 Days Incubation.



Soil Moisture and Aeration

Most S°-oxidizing bacteria require oxygen: any condition that restricts the oxygen supply in a soil will reduce the activity of S°-oxidizing bacteria. Oxidation of S° is most efficient at moisture levels close to field moisture capacity. Both waterlogging and excessively dry conditions greatly reduce the rate of S° oxidation.

Soil pH.

Most *Thiobacillus* organisms thrive best under acid soil conditions. When a fertilizer source of S° is applied to a soil, oxidation occurs most rapidly under acid conditions.

Fertility Status of the Soil

Sulfur-oxidizing bacteria require most — if not all — of the nutrients required by plants. It's not surprising, therefore, that oxidation of S° proceeds more rapidly in fertile soils. There is competition between the bacteria and plant roots for nutrients and this has been found to cause temporary nitrogen deficiencies in plants under high S° oxidation rates. *Thiobacillus* require ammonium rather than nitrate nitrogen. High soil nitrate levels can be toxic to the bacteria.

What does all this mean with respect to the use of these two forms of S° in fertility programs? Since all S absorbed by plants is in the SO_4 form, SO_4 fertilizer sources are immediately available for plant uptake. And since all S° sources must undergo conversion to SO_4 in the soil, there is a certain amount of time lag between application and absorption through the root system. The extent of this time lag is obviously increased by any soil or climatic condition that suppresses the oxidation process. For this reason, when differences are observed between the effectiveness of these two chemical forms of S, the SO_4 forms usually outperform S° forms. The trials with wheat in Arkansas mentioned previously are a case in point. Table 2 compares the effectiveness of SO_4 -vs- S° at various application rates in these trials.

Table 2. Effects Of Sulfate As (K_2SO_4) -Vs- Elemental S On Wheat.

Lb/A S	S Source	Yield bu/A	% S In Tissue
0	--	15.3	0.11
5	K_2SO_4	44.4	0.25
20	K_2SO_4	35.7	0.42
40	K_2SO_4	36.0	0.50
40	S°	29.3	0.11

Treatments were applied to wheat exhibiting S deficiency symptoms in the Spring (May) and plant analysis samples were collected three weeks later. According to the S levels in plant tissue, this was obviously not enough time for S° oxidation under the existing conditions.