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Sulfur

Sulfur (S) is widely distributed throughout the world in many forms. In some soils, there is insufficient S to meet crop needs. There are many excellent S-containing fertilizer products that can be used to address deficiencies where they occur.

Production

Sulfur is a relatively abundant element in the earth's crust. It has been extracted as pure elemental S from volcanic deposits and salt domes. It is now more commonly obtained as a co-product from processing fossil fuels. Coal, crude oil, and natural gas typically contain between 0.1% and 4% S which is removed during refining or scrubbing of combustion gases. A variety of common earth minerals are used as S sources for agriculture.

Elemental S has a fairly low melting temperature (115 °C; 240 °F), so it is often transported and handled in a hot liquid state until it is transformed into final products. The majority of global S production is converted to sulfuric acid (H_2SO_4) for further processing. A major use of sulfuric acid is in production of phosphate fertilizers.

Common Sulfur Sources

Non-Soluble	Elemental S
Semi-Soluble	Gypsum (15 to 17% S)
Soluble	Ammonium sulfate (24% S); Epsom salt (13%); Kieserite (23% S); Langbeinite (22% S); Potassium sulfate (18% S); Thiosulfate (10 to 26% S)

Elemental sulfur

Sulfur pastilles, containing small amounts of clay to enhance dispersion and oxidation

Agricultural Use

Elemental S is not water soluble and must be oxidized by soil bacteria (such as *Thiobacillus*) to sulfate (SO_4^{2-}) before it can be taken up by plant roots. The general reaction in soil is: $2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4$. The speed of this microbial process is governed by environmental factors such as soil temperature and moisture, as well as the physical properties of the S.

Plants almost exclusively use sulfate as their primary source of nutrition, where it is converted to many essential constituents, such as proteins and enzymes. Various approaches have been used to enhance the conversion of elemental S to plant-available sulfate. The speed of elemental S oxidation is directly related to the particle size, where smaller particles have a greater surface area for the soil bacteria to act on. Therefore, large particles of S may require months or years of biological action before oxidizing significant amounts of sulfate. Fine, dust-sized particles are oxidized quickly, but are not easy to apply.

One approach to enhance the rate of S oxidation is to add a small amount of clay to the molten S prior to cooling and forming small pellets ("pastilles"). When added to soil, the clay swells with water and the pastille disintegrates into fine particles that are rapidly oxidized.

Very thin layers of elemental S can be incorporated during fertilizer granule manufacturing. This S is quick to oxidize and become available for plant uptake. This reaction can have a positive impact on the plant availability of some micronutrients, such as zinc (Zn) and iron (Fe), that become more soluble as the pH declines. Finely ground elemental S is sometimes added to fertilizer suspensions. Elemental S is widely used as a fungicide for crop protection, where toxic hydrogen sulfide is evolved from the interaction of elemental S and the living fungal tissue.

Elemental S and sulfuric acid are commonly used in the reclamation of soils that contain excessive sodium and in the treatment of some irrigation water.

Management Practices

Sulfur is available in many forms to meet specific cropping requirements. Elemental S is generally applied well in advance of crop demand, since a lag period of bacterial oxidation and conversion to sulfate is involved. Since sulfate is an anion, it may be subject to leaching loss, similar to nitrate. However, there are no adverse environmental impacts associated with typical concentrations of sulfate in water.

Non Agricultural Uses

Sulfur is widely used in many consumer products and industrial applications. It is commonly converted to sulfate prior to use in textiles, rubber, detergents, and paper, as examples.

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