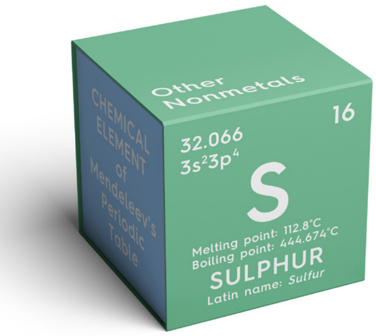
Sulphur



Fundamentals:

- Elemental Form: Sulphur (S)
- Plant Nutrient Form: elemental Sulphur (S)
- Plant Uptake Form: sulphate (SO_4^{2-})

Importance and Roles in Plants:

Sulphur is a component of amino acids, which are built into plant proteins. It promotes the formation of nodules on the roots of legumes by nitrogen-fixing bacteria. And, like so many other nutrients, it is vital to enzymes and the metabolic processes they are involved in.

Deficiency Symptoms:

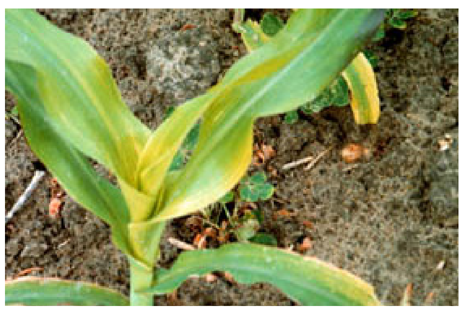


Diagram 1: Sulphur deficient corn plant.

Diagram 2: Sulphur deficiency in cucumber leaves

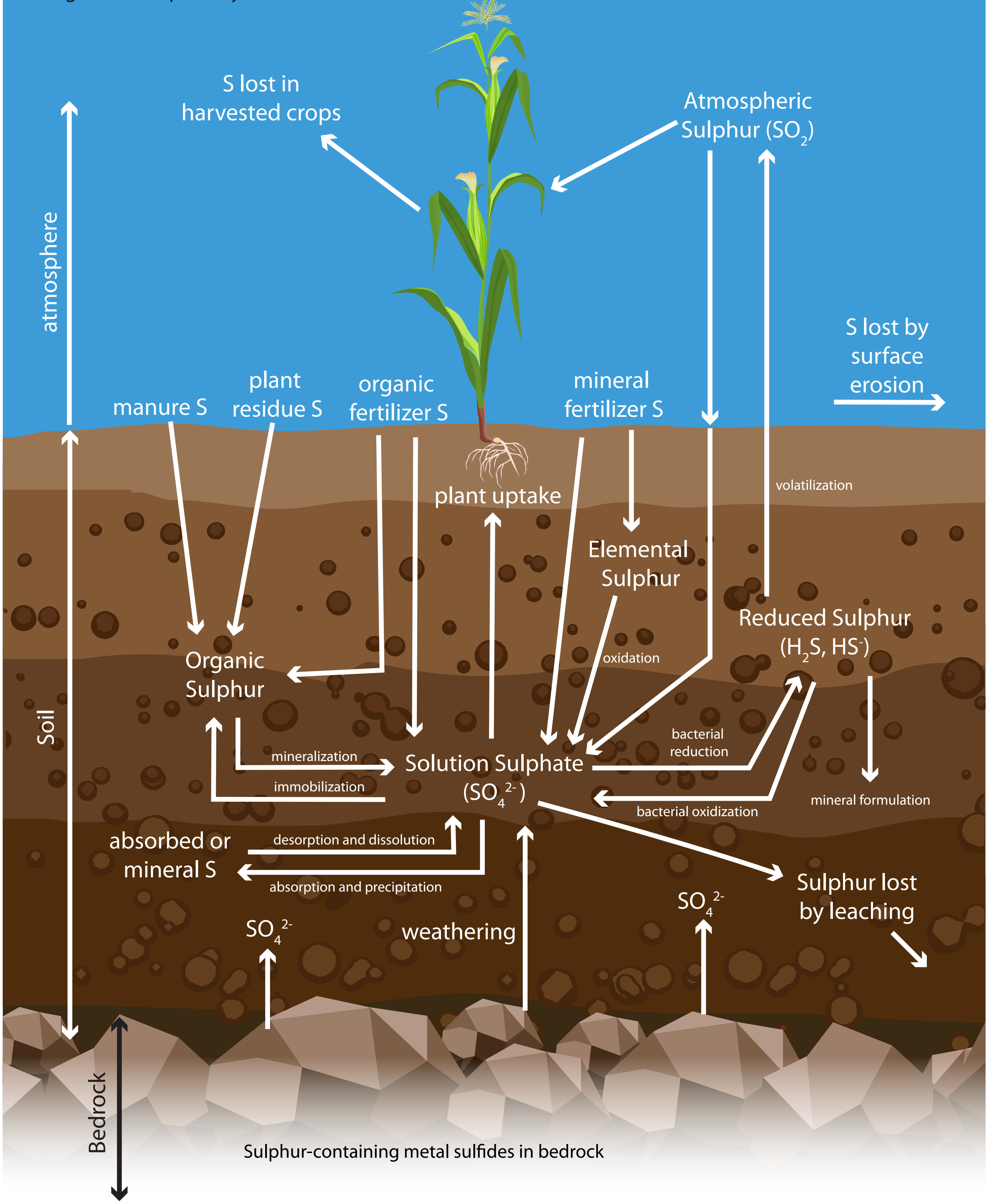
Sulphur deficiency typically appears as very light green leaves in no particular pattern. Unlike nitrogen deficiency that exhibits on older leaves because it is mobile within the plant, sulphur is immobile in the plant, and so deficiency shows first on the youngest foliage. (See diagrams 1 and 2).

Sulphur Fertilizers:

There is only one sulphur "simple" or standalone sulphur fertilizer, and that is granular elemental sulphur (90% S). However, elemental sulphur by itself does not provide plant-available sulphur without going through a conversion. As it is, elemental sulphur is relatively insoluble and must be converted to sulphate sulphur (SO_4^{2-}) before it can be taken up by plants. Once applied to soil, under warm, moist conditions, elemental sulphur becomes oxidized by bacterial species of the genus *Thiobacillus*, resulting in the production of sulphuric acid (H_2SO_4). The acid gives up its hydrogen to become sulphate (SO_4^{2-}) which is now plant-available. It is thought by some that this process is slow compared to applying sulphates directly. Nevertheless, TerraLink stocks elemental sulphur, for use either as a sulphur nutrient or for acidifying soil where necessary.

Sulphur is found in very many fertilizer mixes offered by TerraLink. Some of these have quite high sulphur content and will be useful in situations where soil sulphur is low and needs correction. Amongst others, these include the granular fertilizer simples 21-0-0+24(S) (ammonium sulphate), 0-0-50+17(S) (potassium sulphate) and 0-0-22+22(S)+11Mg (sulphate of potash magnesia), general granular mixes 40-0-0+5.5(S) and 34-0-0+11(S), and the liquids 0-0-0+10(S)+6Ca (calcium thiosulphate) and 0-0-25+17(S) (potassium thiosulphate). Many other standard stocked blends contain small

Diagram 3: Sulphur Cycle



amounts of sulphur, typically 3% to 5% S. Gypsum (calcium sulphate) is also a source of sulphur, and unlike limestone, will add not only sulphur but also calcium, without affecting pH of the soil.

Behaviour in the Soil:

Plants take up sulphur as a negative ion called sulphate (SO_4^{2-}) which exists in soil moisture. Negative ions are called anions (positive ions are called cations). As soil typically carries a net negative charge, anions such as sulphate (SO_4^{2-}) tend to be very mobile within the soil, whereas cations are much less mobile, electrostatically clinging to cation exchange sites on clay or organic matter. Thus, sulphate, being so mobile, can easily be leached away and lost. That means that sulphate from fertilizer applied above the root zone will have the ability to be driven down towards the roots by rain or irrigation. Immobile nutrients such as P and K must be fertilized as well as possible directly into the root zone.

Sulphur is relatively unaffected by soil pH, and is easily plant-available from about pH 5.5 or 6 and upwards (towards the basic end of the pH scale). Only two other nutrients are so plant-available in such a wide pH range: potassium and molybdenum.

Interaction with other Nutrients:

Sulphur requirement by plants is linked to the amount of plant-available nitrogen in the soil. Sulphur and nitrogen act together in a couple of ways. First, both sulphur and nitrogen are components of plant proteins. Both are linked to the formation of chlorophyll. Second, both are linked to the action of the enzyme Nitrate Reductase (nitrate reductase is an enzyme that helps convert nitrate to amino acids, and thence to plant proteins). When sulphur is deficient, it can reduce the activity of Nitrate Reductase, resulting in higher than normal nitrate levels in plant tissue.

Sulphur Cycling:

Ultimately, sulphur would have originated in metal sulfides in the rocky crust of the Earth. Today, much of the world's sulphur resides in the atmosphere as sulphur dioxide and other sulphur-containing gases. Most of the balance is in organic matter in the soil, and as a component within living plants and animals in amino acids, the building blocks of proteins. Our sulphur cycle (diagram 3) is focused on soil and plants.

Like other plant nutrients that originated in the Earth's crust, sulphur would have been released by weathering over extremely long geologic time. In the soil, sulphur is plant-available in the anionic form sulphate (SO_4^{2-}). It can enter the soil via mineral or organic fertilizer, manure, plant material such as cover crops, post-harvest plant residues such as corn stalks, or prunings from fruit crops such as highbush blueberries. Sulphur can also be deposited into the soil from the atmosphere in polluted areas via "acid rain", in which sulphur dioxide can add to the soil up to 20 pounds of sulphur per acre per year.

Sulphur can be lost from the soil-plant system via crop harvests, surface erosion, leaching, volatilization back into the atmosphere, or re-forming into mineral form.

Sulphate sulphur (SO_4^{2-}) is mobile within soil water, or soil solution. Besides being taken up by plants in this form, it can also be lost via leaching. From the soil solution, it can undergo a chemical process called immobilization to convert it to organic form. The reverse of this process is called mineralization. Alternately, it can undergo reduction to convert into inorganic form; the reverse being oxidization. Further, sulphate sulphur (SO_4^{2-}) can move from the soil solution onto secondary minerals in a process called adsorption, and back into solution form again via desorption. Finally, sulphate sulphur (SO_4^{2-}) can instead precipitate into secondary mineral form, or undergo dissolution to re-enter the soil solution from secondary minerals.

References:

Blueberry Nutrition Management. Strik, Bernadine. Oregon State University. 2011.

Soil Fertility Manual. International Plant Nutrition Institute, 2006.

Soil Fertility and Fertilizers, Third Edition. Tisdale, S. L, and Nelson, W. L. 1975.

Fertilizing Blueberries, Spectrum Analysis. 2006

Developing Sulphur Recommendations. McKenzie, Ross H. Top Crop Manager West, March 2016.

Image Credit:

http://aesl.ces.uga.edu/DiagnosticsII/Symptoms_/Corn/Images-Corn/images-corn.html#Mn%20Def%20Corn; Haifa Group: Crop Guide – Nutrients for Cucumber. 2017.