Nutri-Facts

Agronomic fact sheets on crop nutrients

Sulfur

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Sulfur deficiency in corn.

In crop production, sulfur (S) is used by plants in sufficient quantities that it is considered the fourth most needed fertilizer nutrient after the three macronutrients nitrogen (N), phosphorus (P) and potassium (K). Sulfur occurs naturally in deposits nears volcanoes and in various sulfide ore deposits around the world. The main industrial source comes from removal of hydrogen sulfide gas (H_2S) from fossil fuel during its processing.

Sulfur fertilization is increasingly common because higher yielding crops are taking up and removing more S from soil as harvested products. Due to a decrease in S emissions from industrial and transportation sources, S deposition from the atmosphere is much lower than a few decades ago. Maintaining an adequate supply of S is essential for sustaining high-yielding crops, as well as for animal and human nutrition.

Sulfur in Plants

Soluble sulfate (SO_4^{2-}) is the primary source of S nutrition for plants. Within the plant, S is required for protein synthesis. It aids in seed production and producing the chlorophyll necessary for plants to carry out photosynthesis. It is a necessary component of three amino acids (cysteine, methionine, and cystine) needed for protein synthesis. It is also required for nodule formation on root hairs of legume crops. Wheat grown in soils with low levels of available S result in lower quality of grain protein, making the flour less suitable for bread making.

Since both S and N are needed for protein formation, these two nutrients are closely linked. Crops have varied requirements for S compared with N, and have a wide N:S ratio in the harvested product (**Table 1**). For example wheat has a relatively low requirement of S, with N:S ratio in grain of 16:1. Canola has a high S requirement, with a N:S ratio of 6:1 in the seed.

Sulfur is involved in a number of secondary plant compounds. For example, the characteristic flavor and smell of onions and garlic is associated with volatile S compounds.

Table 1. Total removal of sulfur in the harvested portion of selected field crops compared to N, P_2O_5 and K_2O (lb/A).

Crop	Yield/A	N	P_2O_5	K_2O	S	N:S ratio
Corn	200 bu	134	70	50	16	8:1
Soybeans	60 bu	195*	44	72	11	18:1
Wheat	60 bu	89	34	20	6	16:1
Alfalfa	5 ton	255*	60	245	27	9:1
Bermudagrass	5 ton	230	60	250	20	12:1
Bromegrass	3 ton	96	30	138	15	6:1
Canola	50 bu	80	40	20	12.5	6:1

*Primarily, symbiotically fixed N by *Rhizobia* bacteria in root nodules.

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This Nutri-Fact is one of a series of fact sheets written by scientific staff of the International Plant Nutrition Institute (IPNI) that is focused on essential plant nutrients and their use. This series is available as PDF files at www.ipni.net/nutrifacts.

Sulfur-deficient wheat. Inset image shows deficient leaf on left; normal leaf on right.

plant roots take it up. Common soil bacteria (e.g. *Thiobaccilus* species) are responsible for converting elemental S to sulfate, but this process can take from weeks to years. Favorable conditions of soil temperature, moisture, pH, and aeration will speed this conversion to sulfate. Similarly, a small particle size of elemental S will enhance the rate of conversion.

Sulfur Deficiency Symptoms

Plants do not mobilize S from older tissues to supply the S needs of younger growing points. Once sulfate is assimilated into organic compounds, it does not move again within the plant. For this reason, S deficiency symptoms of chlorosis (yellowing) are first observed in the young tissues of leaves, stocks, and flower buds.

Sulfur in Soils

The majority of S in soil is usually found in organic matter and crop residues. It is present in a variety of organic compounds that are not available for plant uptake until they are converted to soluble sulfate. The speed at which soil microorganisms convert these organic S compounds is governed by temperature, moisture, and other environmental factors.

Only a small fraction of the total S in soil is found as sulfate. Sulfate is generally soluble and readily moves with soil water to roots, or it can move below the root zone in high rainfall areas or with excessive irrigation.

Fertilizing Soils with Sulfur

There are numerous sources of S fertilizer available for use. Fertilizers containing soluble sulfate provide an immediately available source of plant nutrition. Fertilizers that contain insoluble elemental S require a conversion to sulfate before plant roots take it up.

Crop Response to Sulfur

Crops frequently respond well to S fertilization, especially under conditions of low sulfate availability in soil. Applied S often results in both yield and crop quality improvements (**Table 2**). This is especially important for crops with a high S requirement such as oil seeds (soybean and canola) and forage crops. It is possible to prevent yield losses if S deficiency is diagnosed early in a growing season and is promptly topdressed with a sulfate form of fertilizer. Attention to S fertilization is becoming more important in many areas around the world.

References

1. Sawyer, J., B. Lang, and D. Barker. 2011. Better Crops 95(2):6-7.

Further Reading

Norton, R., R. Mikkelsen, and T. Jensen. 2013. Better Crops 97(2):10-12.

Mikkelsen, R., and R. Norton. 2013. Better Crops 97(2):7-9

Table 2. Sulfur fertilization increases the yield and the S tissue concentration of alfalfa[1].

Location		Wadena, Iowa		Waucoma, Iowa	
		Yield, ton/A	Alfalfa Hay before 2nd Cut, % S	Yield, ton/A	Alfalfa Hay before 2nd Cut, % S
S application rate, lb S/A	0	1.32	0.14	1.85	0.21
	15	2.59*	0.20	3.06*	0.30
	30	3.14*	0.30	3.14*	0.43
Soil test SO_4^{2-}–S, ppm		7		3	
Soil Organic Matter, %		3.1		2.1	
Soil Type		Fayette Silt Loam		Wapsie Loam	

*Significant difference at p = 0.10 from 0 S rate.