Nutri-Facts

Agronomic fact sheets on crop nutrients

Sulfur

NO. 4

AUSTRALIA AND NEW ZEALAND GRAINS EDITION

NORTON/IPNI IMAGE

Sulfur deficiency in canola.

In crop production, sulfur (S) is considered the fourth most important fertilizer nutrient after nitrogen (N), phosphorus (P) and potassium (K). Sulfur occurs naturally in deposits near 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. Ammonium sulfate is manufactured from sulfuric acid and ammonia, often as a by-product of manufacturing processes.

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. Soil organic matter is a major source of plant S, and low organic matter levels mean less S is able to be mineralised from this source. 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 provided by the soil. Sulfur can also be absorbed through the leaves from the air as sulfur dioxide (SO_2), but this source does not play a significant role in Australian agriculture. Within the plant, S performs many functions, the most important being energy and protein production. Sulfur is a constituent of two of the 21 essential amino acids that form proteins. This function is of particular importance in the grains industry as low grain protein correlates to low grain quality. Sulfur is also essential for N fixation by legumes.

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 and chickpea have relatively low S removal, with an N:S ratio in grain of 17:1 and 12:1 respectively. Canola however has a much high S removal, with a N:S ratio of 8:1 in the seed. While removal ratios do not necessarily determine the nutrient demand, canola and high-yielding forages generally have a higher demand for S than cereal crops.

Table 1. Total removal of sulfur in the harvested portion of selected field crops compared to N, P, and K (kg/ha).

Crop	Yield, t/ha	N, kg/ha	P, kg/ha	K, kg/ha	S, kg/ha	N:S ratio
Chickpea	3	93	11	30	5	17
Wheat	5	100	17	23	9	12
Lucerne	15	390	90	375	41	10
Corn	8	96	50	36	11	9
Canola	3	126	17	20	15	8

Sulfur in Soils

The majority of S in soil is found in organic matter and crop

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IPNI PHOTO-SHARMA AND KUMAR

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

residues and is not immediately available for plant uptake. Before S can be absorbed it needs to be converted to sulfate and this occurs as organic matter mineralises. Native or added elemental sulfur (S^0) is oxidised to sulfate by common soil bacteria (e.g., *Thiobaccilus* species) and this process can take from weeks to months or longer. The rate of oxidation depends on environmental conditions including soil moisture, temperature, aeration, pH, and the size of the S^0 particles being broken down. Sulfate derived from organic matter mineralisation or S^0 oxidation is soluble and readily moves with soil water to roots, or can be subject to leaching below the root zone in areas with high rainfall or with excessive irrigation.

Sulfur Deficiency

Sulfur deficiency symptoms include pale green leaves and the chlorosis of young tissue. Tissue samples for youngest expanded blade/leaf provide the best diagnostic guide because S is relatively immobile in the plant. Once S has been taken up by the plant and assimilated into organic compounds it does not move again. In *brassicas* such as canola, plants may also suffer from thin stems and leaves may develop a reddish colour first apparent on the underside of the leaves. In canola, the flowers may also be visibly affected and they can appear pale in colour and in severe cases, almost grey.

Fertilizing Soils with Sulfur

There are numerous sources of S fertilizer available for use, some containing soluble sulfate that provides immediately plant available S, and others that contain insoluble elemental S that requires oxidation to sulfate before the plant can access the additional nutrients. A blend of both elemental and sulfate sulfur can provide a balance of S supply over time, especially where leaching of S can be a problem. Many growers also use gypsum (calcium sulfate dihydrate) as a soil amendment, and this also provides sulfate-S for crop nutrition.

In Australia, soil tests such as the KCl-40 or MCP extraction have provided guidance, but because S is mobile, samples to 30-cm depth are often a better indicator of the response to additional S containing fertilizer the 0-10 cm samples. Soils testing should not be considered alone, but decisions made in conjunction with visual crop assessments and taking into consideration other factors such as soil organic matter, soil texture, rainfall, and rooting pattern of the crop.

Crop Response to Sulfur

Crops frequently respond well to S fertilization, especially under conditions of low sulfate availability and low organic matter. Responses are generally greater in sandy soil, especially in crops with a high requirement for S such as canola. Applied S often results in both yield (**Table 2**). The study reported in Table 2 also showed significant increases in seed oil content in response to added S. In general, plants are able to recover quite well from early S deficiency so topdressing with a sulfate source can be effective. Attention to S fertilization is becoming more important, especially with the reduced S emissions from industry, the increase in conservation tillage and because higher-yielding crops are taking up and removing more S from soil as harvested products.

Table 2. Effect of timing and rate of sulfate-S application on the yield of canola (Hocking et al. 1996). The nil S yield was 1.03 t/ha, and 80 kg N/ha was supplied. The LSD = 0.43 (p = 0.05).

S applied, kg/ha	Sowing	5-6 Leaf	Buds Visible	Stem Elongation
10	1.73	1.62	1.56	1.41
40	2.15	2.26	2.11	2.19

References

Hocking, P.J. et al. 1996. Aust. J. Exp. Ag., 36:79-85.

Further Reading

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

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Till, R. 2010. Sulphur and Sustainable Agriculture. International Fertilizer Industry Association, Paris. 70 pp.