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# SULPHUR MANAGEMENT FOR SUSTAINABLE AGRICULTURE

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## Introduction

Sulfur is one of the 16 elements essential to crop production. It is typically considered a secondary macronutrient, but is essential for maximum crop yield and quality. Sulfur is often ranked immediately behind nitrogen, phosphorus, and potassium in terms of importance to crop productivity. It is a component of the amino acids; cysteine and methionine making it essential for protein synthesis in plants. Plants contain a large variety of other organic sulfur compounds, such as glutathione, sulfo-lipids and secondary sulfur compounds which play an important role in physiology and protection against environmental stress and pests. Sulfur fertility has historically not been a major concern for growers on most soils, as soil organic matter, atmospheric deposition; manure application and incidental sulfur contained in fertilizers have typically supplied sufficient sulfur for crop production. However, in recent years reductions in the amount of sulfur contributed by these factors combined with increased sulfur removal with greater crop yields have made sulfur deficiencies more common.

## The importance of Sulfur for plants

- Sulfur is a vital element for all organisms due to its important role in methionine and cysteine biosynthesis. Cysteine is not only an important constituent of proteins, but is also essential to determine the structural conformation of proteins and metal binding, and contributes to the catalysis of enzymatic reactions.
- It is needed for the formation of mustard oils, and the sulphydryl linkages that are the source of pungency in onion, oils, etc. It also takes part in chlorophyll formation and in the activation of enzymes.
- Sulfur is also essential for the synthesis of coenzyme A, which is important for fatty acid biosynthesis and oxidation, amino acid uptake, oxidation of intermediates of the citric acid cycle, and for ferredoxin oxidation, which is vital in photosynthesis and biological N fixation. Furthermore, S is important in vitamin synthesis.
- Without adequate S, crops can't reach their full potential in terms of yield, quality or protein content; nor can they make efficient use of applied N.
- The S concentration in plant tissues varies between 0.1 and 0.5 %, with decreasing concentrations in plants of the orders *Cruciferae*, *Leguminosae* and *Gramineae*, respectively. S is required by crops in amounts comparable with P.

## Sulfur uptake by plants

Following nitrogen, phosphorus, and potassium, sulphur is an essential plant nutrient. It contributes to an increase in crop yields in three different ways: 1) it provides a direct nutritive value; 2) it provides indirect nutritive value as soil amendments, especially for

calcareous and saline alkali soils; and 3) it improves the use efficiency of other essential plant nutrients, particularly nitrogen and phosphorus.
Most crops remove 15 to 30 kg for sulphur per hectare. Oil crops, legumes, forages, and some vegetables require more sulphur than phosphorus for optimal yield and quality. Plants contain as much sulphur as phosphorus, with an average content of approximately 0.25%. Sulphur uptake by plant roots occurs preferentially in the form of sulfate ($SO_4^{2-}$) but it can also be absorbed as thio-sulfate ($S_2O_3^{2-}$). Leaves can additionally absorb small amounts of $SO_2$. Foliar assimilation of $S^0$ in soybean which, regardless of the dose and nature of the source, resulted in increased N and S levels in the leaves as compared to $S^0$ supplied to the soil.

**Sulphur deficiencies in in Indian Soils**

Soil fertility surveys by the ICAR system (analysis of 60,000 soil samples) have shown sulphur deficiencies to be a widespread problem. A soil is considered deficient in S if it tests less than 10 mg S/kg soil extractable with 0.15% $CaCl_2$.

**A = 45% districts having more than 40% soil samples deficient in S**

**B = 40% districts having 20-40% soil samples deficient in S**

**C = 15% districts having less than 20% soil samples deficient in S**

Soil analysis and crop response data generated by the TSI-FAI-IFA project (1997-2006) re-enforced the findings of the ICAR system. Based on reported results, out of over 49,000 soil samples analyzed across 18 states, 46% of samples were deficient in sulphur and another 30% were medium in available sulphur which could be considered as potentially sulphur deficient. Soil sulphur deficiencies were encountered in all parts of the country. These data prove that sulphur deficiencies are a critical problem in 40-45% of districts translating into 57-64 million ha of net sown area.

**Areas affected by deficiency of Sulfur**

•Light textured soils with low organic matter
•Canal irrigated areas
•Areas where S-free fertilizers are used
•Acid soils are more prone to S-deficiency due to stronger adsorption of SO4
•Wheat is more prone to S deficiency than rice
•Cool soil temperatures can restrict root development and reduce S availability

**Factors contributing to increasing sulphur deficiencies in agricultural production**

•More sulphur is removed from the soil as a result of an increase in agricultural production by increasing fertilizer use, intensifying cropping systems, promoting high-yield crop varieties, and improving irrigation

•Less sulphur is added to the soil due to the increasing proportions of high-analysis, sulphur-free fertilizers, such as urea, di-ammonium phosphate (DAP), and potassium chloride; decreasing use of traditional organic manures and sulphur-containing fertilizers, such as single superphosphate and ammonium sulphate, and sulphur-containing pesticides.

•Farming practices (removing stover/straw in addition to grain) increased net depletion of soil sulphur.

•Distinct possibility of sulphur losses through leaching and runoff with the spread of flood irrigation to large areas, and in areas receiving heavy rainfall.

•Reduced soil S reserves from organic matter losses due to mineralization and erosion.

## Sulphur Deficiency Symptoms

•Generally, sulphur-deficient plants have short and/or spindly stems and yellowing of the young (top) leaves. These symptoms are different from N deficiency symptoms (lower leaves first becoming pale green and then yellow).

•Sulphur-deficient canola can also have purpling and upward cupping of young leaves, delayed and prolonged flowering, pale-coloured flowers and fewer, smaller pods.

•Sulphur-deficient alfalfa, pea and other legumes may have reduced nitrogen fixation.

•For cereals and forage grasses, yellowing of the newly-emerging leaves is an indicator of sulphur deficiency.

## Management of S in Agriculture

For sustainable crop yields, S application should form an integral part of the fertilizer program. Usual recommendations for correcting deficiency are 15 to 30 kg S/ha for cereal crops and silage grass; and 25 to 50 kg S/ha for oil crops, legume, sugarcane, and some vegetable crops. On appearance of deficiency symptoms, apply gypsum @ 125-150 kg/ha to soil, followed by mixing and a light irrigation. Use SSP in S-deficient soils**.** Sulphate sources should be preferred to elemental S that takes 12-18 months to get converted in to the sulphate form. Sulphur from ammonium sulphate accelerates emergence and improves resistance to white mould in dry beans; it makes P and micronutrients more available in early planted cold soils. Since S is the protein forming nutrient (90 % of S is found in amino acids the building blocks for protein), protein yield/acre could be significant with S application. Sulphur is also part of the anti fungal proteins and could therefore help in suppressing fungal diseases.

**Table 1.** Important S fertilizers with their chemical composition

| **Material** | **Formula** | **Plant nutrient content (%)** | | | | |
|---|---|---|---|---|---|---|
| | | **N** | **$P_2O_5$** | **$K_2O$** | **S** | **Other** |
| Ammonium polysulfide | $NH_4S$□ | 20 | - | - | 45 | - |
| Ammonium sulphate | $(NH_4)_2SO_4$ | 21 | - | - | 24 | - |
| Ammonium thiosulphate | $(NH_4)_2S_2O_3$ | 12 | - | - | 26 | - |
| Calcium polysulphide | $CaS$□ | - | - | - | 22 | 6 (Ca) |
| Calcium thiosulphate | $CaS_2O_3$ | - | - | - | 10 | 6 (Ca) |
| Ferrous sulphate | $FeSO_4.H_2O$ | - | - | - | 19 | 33 (Fe) |
| Gypsum | $CaSO_4.2H_2O$ | - | - | - | 19 | 24 (Ca) |
| Magnesium sulphate | $MgSO_4.7H_2O$ | - | - | - | 13 | 10 (Mg) |
| Potassium- Magnesium sulphate | $K_2SO_4.MgSO_4$ | - | - | 22 | 22 | 11 (Mg) |
| Potassium polysulphide | $KS$□ | - | - | 22 | 23 | - |
| Potassium sulphate | $K_2SO_4$ | - | - | 50 | 18 | - |
| Potassium thiosulphate | $K_2S_2O_3$ | - | - | 25 | 17 | - |
| Elemental sulphur | $S^o$ | - | - | - | 100 | - |
| Sulphur (granular w/additives) | $S^o$ | 0-7 | - | - | 60-95 | - |
| Sulphuric acid (100%) | $H_2SO_4$ | - | - | - | 33 | - |
| Triple superphosphate | $Ca(H_2PO_4)_2$ $CaSO_4.2H_2O$ | - | 46 | - | 1.5 | - |
| Urea-sulphar | $CO(NH_2)_2 + S$ | 38 | - | - | 10-20 | - |
| Urea-sulphuric acid | $CO(NH_2)_2 + H_2SO_4$ | 10-28 | - | - | 9-18 | - |
| Zinc sulphate | $ZnSO_4.H_2O$ | - | - | - | 18 | 36(Zn) |

**Table 2.** General guidelines for s fertilizer use

| **Materials** | **Guideline** | **Remarks** |
|---|---|---|
| Elemental $S^o$<br>Dispersible, granular $S^o$<br>Ammonium phosphate- $S^o$<br>Urea- $S^o$ | Direct application and bulk blends, apply materials several months before growing season; fall application are encouraged, allow for dispersion before incorporation of broadcast applications | As starter or preplant, $SO_4^{-2}$ should be included; dispersion of water-degradable granular S at soil surface before incorporation improve effectiveness; incorporate 4-5 months preplant; apply preplant or on severely S-deficient soils, $SO_4^{-2}$ should be included |
| Ammonium sulphate | Direct application and bulk blends; Effective anytime | Segregates in bulk blends unless physical properties are improved by granulation; where leaching losses expected, apply shortly before planting |
| Ammonium nitrate sulphate<br>Ammonium phosphate sulphate<br>Potassium sulphate<br>Potassium Magnesium sulphate | Direct application and bulk blends; Effective anytime | Where significant $SO_4^{-2}$ leaching is expected, apply shortly before planting |
| Calcium sulphate (gypsum) | Direct application; effective anytime | Difficulties encountered in application (dust, caking**)** |
| Ammonium thiosulphate<br>Potassium thiosulphate<br>Calcium thiosulphate | Direct application, blending with fluid fertilizers; broadcast preplant or applied in starters; top-dress on certain crops (low rate); add through open-ditch and irrigation systems | Blended with neutral fluid P products, all N solutions, most micronutrient solutions |
| Ammonium polysulphide<br>Potassium polysulphide | Direct application, blending with N solutions; injected into soil; broadcast application with $H_2O$ dilution; single preplant applications; repeated application (low rate) through open-ditch irrigation systems | Ammonium polysulphide not suitable for mixing with P-containing fluids |
| Sulfuric acid | Mixing with ammonium polyphosphate and anhydrous ammonia for clear liquid blends | Applied directly to crops for weed control purposes |
| Suspensions-containing $S^o$ | Direct application, simultaneous application with other fertilizers, suspensions applied 2-3 months before growing season | Starter or preplant; include $SO_4^{-2}$ (15-20% total S applied) |
| Suspensions-containing $SO_4^{-2}$ | Effective anytime | Where leaching losses expected, apply preplant or before beginning of growing season |

## References

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