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Popular Article

Importance of Sulphur and Its Mechanism of Action in Oilseed Crops Nutrition

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Abstract

Sulphur (S) is an essential macronutrient required for optimal growth and productivity of oilseed crops. It plays a pivotal role in protein synthesis, enzymatic activity, and oil quality. This review highlights the importance of sulphur in oilseed crops, its biochemical mechanism of action, and strategies for sulphur nutrition management. Emphasis is placed on the agronomic and economic benefits of sulphur fertilization, as well as future perspectives for sustainable oilseed production.

1. Introduction

Oilseed crops such as mustard, rapeseed, soybean, sunflower, and groundnut are vital contributors to global food security, serving as primary sources of edible oil and protein. Their productivity and quality are highly dependent on balanced nutrient management, with sulphur emerging as a particularly critical secondary nutrient. Sulphur plays a central role in the synthesis of essential amino acids such as cysteine and methionine, as well as vitamins like thiamine and biotin, all of which are indispensable for plant metabolism and oil formation (Gupta & Jain, 2010). Adequate sulphur nutrition not only enhances seed yield and oil recovery but also improves resistance to biotic stresses, making it a cornerstone of sustainable oilseed production (Chatterjee & Dwivedi, 2008).

The importance of sulphur in oilseed crops has grown in recent decades due to declining soil sulphur levels. Historically, atmospheric deposition from industrial activity contributed to soil sulphur reserves, but reductions in emissions have led to widespread



deficiencies (Tandon, 2013). Intensive farming practices, coupled with the removal of crop residues, have further exacerbated this problem, leaving soils increasingly depleted of sulphur. As a result, oilseed crops, which have higher sulphur requirements compared to cereals, are particularly vulnerable to yield and quality losses when sulphur is insufficient (Singh & Singh, 2015). Addressing this challenge requires a deeper understanding of sulphur nutrition and the adoption of integrated management practices to ensure that oilseed crops can meet rising global demands for edible oils and protein.

2. Importance of Sulphur in Oilseed Crops

Sulphur is integral to the synthesis of sulphur-containing amino acids (cysteine, cystine, methionine), vitamins (biotin, thiamine), and coenzymes (Gupta & Jain, 2010). Oilseed crops, compared to cereals, have a higher sulphur requirement due to their protein and oil-rich seeds. Adequate sulphur nutrition enhances seed yield, oil recovery, and resistance to biotic stresses (Chatterjee & Dwivedi, 2008). Sulphur plays a fundamental role in the biochemical processes of oilseed crops, being integral to the synthesis of sulphur-containing amino acids such as cysteine, cystine, and methionine, as well as vitamins like biotin and thiamine (Gupta & Jain, 2010). These compounds are essential for protein formation, enzymatic activity, and metabolic regulation, all of which directly influence the growth and productivity of oilseed plants. Because oilseed crops produce protein- and oil-rich seeds, their demand for sulphur is significantly higher than that of cereals, making sulphur nutrition a critical factor in sustaining crop performance and ensuring high-quality yields (Tandon, 2013).

Adequate sulphur nutrition has been shown to enhance seed yield, improve oil recovery, and strengthen resistance to biotic stresses such as pests and diseases (Chatterjee & Dwivedi, 2008). In addition, sulphur contributes to the synthesis of glucosinolates in Brassica species, compounds that influence both flavor and plant defense mechanisms (Jat & Meena, 2019). Without sufficient sulphur, oilseed crops suffer from reduced protein content, poor seed development, and diminished oil quality, underscoring the nutrient's indispensable role in maintaining both agronomic productivity and economic viability.

3. Mechanism of Sulphur Uptake and Assimilation

Plants absorb sulphur primarily in the form of sulphate (SO_4^{2-}), which enters through specialized root transporters located in the plasma membrane. Once inside the plant system, sulphate is mobilized and transported to chloroplasts, where it undergoes a series of enzymatic reductions. This reduction process converts sulphate into sulphide, a reactive form that can be assimilated into organic compounds. The assimilation pathway is tightly regulated, ensuring



that sulphur is efficiently incorporated into amino acids and other essential biomolecules required for plant growth and development (Zhao, Hawkesford & McGrath, 1993).

Following reduction, sulphide is incorporated into cysteine, which serves as the primary building block for other sulphur-containing compounds. Cysteine acts as a precursor for methionine, glutathione, and various coenzymes, all of which are vital for protein synthesis, oil biosynthesis, and stress tolerance in oilseed crops. This biochemical pathway directly influences crop productivity and quality, as sulphur availability determines the efficiency of protein formation and oil accumulation in seeds. Thus, the mechanism of sulphur uptake and assimilation is central to the metabolic processes that sustain high yields and superior oil quality in oilseed crops (Gupta & Jain, 2010).

4. Physiological Role of Sulphur

Sulphur plays a crucial physiological role (Figure 1) in plants by contributing to fundamental processes such as chlorophyll formation, enzymatic activity, and nodulation in legumes (Havlin et al., 2014). These functions are essential for maintaining photosynthetic efficiency, metabolic regulation, and symbiotic nitrogen fixation, all of which directly impact crop growth and productivity. By facilitating protein synthesis, sulphur enhances nitrogen use efficiency, ensuring that plants can effectively convert absorbed nitrogen into amino acids and proteins, thereby improving overall nutrient utilization and crop performance (Gupta & Jain, 2010).

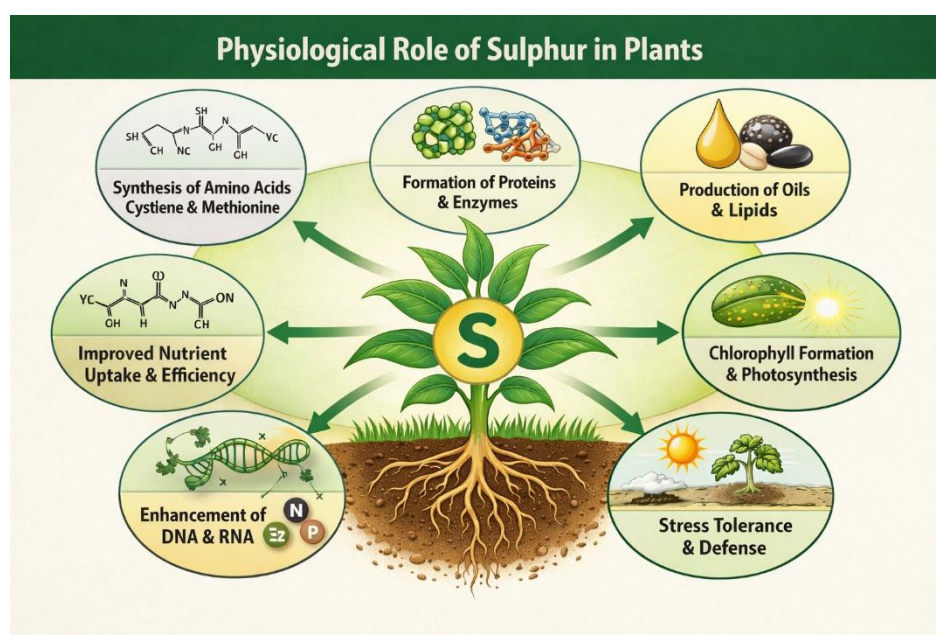


Figure 1: Physiological Role of Sulphur in oilseed crops

In oilseed crops, sulphur assumes an even more specialized role by supporting the synthesis of glucosinolates in Brassica species. These compounds are not only important for determining the characteristic flavor of crops like mustard and rapeseed but also act as natural defence molecules against pests and diseases (Jat & Meena, 2019). Adequate sulphur nutrition therefore strengthens both the agronomic and economic value of oilseed crops, as it improves yield, oil quality, and resilience to biotic stresses. This dual role supporting core metabolic functions and enhancing crop-specific secondary metabolites underscores sulphur's indispensable contribution to the physiology of oilseed crops.

5. Sulphur deficiency in oilseed crops

Sulphur deficiency in oilseed crops is characterized by distinct physiological symptoms that can significantly reduce productivity. One of the most common signs is chlorosis, or yellowing of younger leaves, which occurs because sulphur is relatively immobile within the plant system. Unlike nitrogen, which can be translocated from older to newer tissues, sulphur remains fixed, leading to visible deficiency symptoms in newly developing leaves (Singh & Singh, 2015). This immobility makes continuous sulphur availability throughout the crop cycle essential, as any interruption in supply directly affects the plant's metabolic processes. In addition to chlorosis, sulphur deficiency often results in stunted growth and delayed maturity, both of which compromise the overall yield potential of oilseed crops (Gupta & Jain, 2010).

Beyond visible symptoms, sulphur deficiency also impacts seed development and quality. Reduced seed size and poor oil accumulation are common outcomes when sulphur levels are inadequate, as the nutrient is vital for protein synthesis and oil biosynthesis pathways (Chatterjee & Dwivedi, 2008). In Brassica species, insufficient sulphur further disrupts glucosinolate formation, weakening natural pest resistance and diminishing crop flavor quality (Jat & Meena, 2019). These combined effects highlight the critical role of sulphur in maintaining both the agronomic performance and economic value of oilseed crops. Addressing sulphur deficiency through timely fertilization and integrated nutrient management is therefore essential to safeguard yield, oil quality, and farmer profitability.

6. Sulphur Requirement in Oilseed Crops

Oilseed crops generally require sulphur inputs ranging from 20–60 kg S/ha, with the exact demand varying according to soil type, crop species, and environmental conditions (Tripathi & Sharma, 2017). Among these crops, rapeseed and mustard are particularly sulphur-demanding due to their high protein and oil content, as well as their reliance on sulphur for glucosinolate synthesis. Soybean and groundnut also respond positively to sulphur



fertilization, though their requirements are comparatively moderate. The application of sulphur ensures that crops can meet their metabolic needs for amino acid and enzyme synthesis, which directly translates into improved growth and yield performance (Malhi et al., 2007).

Balanced sulphur nutrition is not only essential for maximizing yield but also for enhancing seed quality parameters such as oil content and protein concentration. Adequate sulphur supply improves nitrogen use efficiency, thereby supporting protein synthesis and contributing to better nutritional value of oilseed crops (Gupta & Jain, 2010). Furthermore, sulphur fertilization has been shown to improve oil recovery and fatty acid composition, making it a key determinant of both agronomic success and economic profitability (Chatterjee & Dwivedi, 2008). Thus, maintaining optimal sulphur levels in oilseed cropping systems is critical for sustaining productivity, ensuring high-quality outputs, and meeting the growing global demand for edible oils.

7. Sources of Sulphur Fertilizers

Gypsum, elemental sulphur, ammonium sulphate, and single superphosphate (SSP) are among the most common sources of sulphur fertilizers used in oilseed cropping systems (Table 1) (Tandon, 2013). Gypsum is particularly valued for its cost-effectiveness and ease of application, making it a widely adopted option for farmers. Elemental sulphur, on the other hand, provides long-term benefits because it undergoes gradual oxidation in the soil, ensuring a sustained release of sulphur over time. Ammonium sulphate not only supplies sulphur but also contributes nitrogen, making it a dual-purpose fertilizer that supports both protein synthesis and oil formation in oilseed crops (Gupta & Jain, 2010). SSP is another important source, offering both phosphorus and sulphur, which are critical for seed development and oil biosynthesis.

In addition to soil-applied fertilizers, foliar sprays of sulphur are increasingly recognized as effective interventions for correcting deficiencies during critical growth stages (Singh & Singh, 2020). Foliar application ensures rapid uptake and immediate correction of sulphur shortages, particularly when crops exhibit visible deficiency symptoms such as chlorosis in younger leaves. This method is especially useful in situations where soil sulphur availability is limited or where rapid nutrient supplementation is required to sustain crop productivity. Integrated nutrient management practices that combine organic amendments with inorganic sulphur sources are also recommended to enhance soil fertility and ensure long-term sustainability of oilseed production systems (Chatterjee & Dwivedi, 2008).

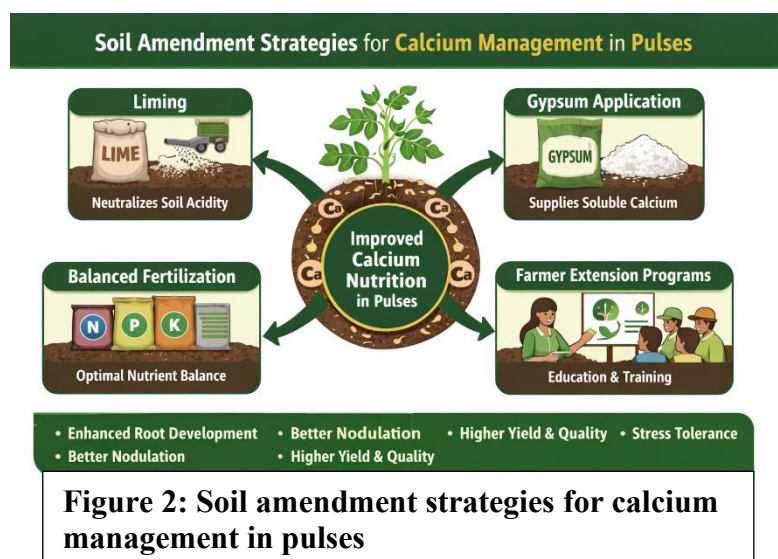


Table 1: Sources, Dosages, and Application Methods of Sulphur Fertilizers in Oilseed crops

Fertilizer Source	Chemical Composition / Form	Recommended Dosage (kg S ha ⁻¹)	Application Method	Remarks
Gypsum (CaSO ₄ ·2H ₂ O)	18–20% S	20–40	Basal soil application	Improves soil structure; suitable for acidic and neutral soils.
Elemental Sulphur (S ⁰)	100% S	10–20	Basal or split; incorporated into soil	Slow-release; requires microbial oxidation; effective in alkaline soils.
Ammonium Sulphate [(NH ₄) ₂ SO ₄]	24% S	20–30	Basal or top dressing	Provides N and S; acidifying effect; suitable for cereals and oilseeds.
Single Superphosphate (SSP)	12% S	30–40	Basal soil application	Dual source of P and S; widely used in oilseed and pulse crops.
Potassium Sulphate (K ₂ SO ₄)	18% S	20–25	Basal or fertigation	Supplies K and S; preferred for chloride-sensitive crops.
Magnesium Sulphate (MgSO ₄ ·7H ₂ O)	13% S	10–15	Foliar spray or soil application	Corrects Mg and S deficiency; suitable for horticultural crops.
Zinc Sulphate (ZnSO ₄ ·7H ₂ O)	17–18% S	10–15	Basal or foliar	Provides Zn and S; enhances enzyme activity and seed quality.
Ferrous Sulphate (FeSO ₄ ·7H ₂ O)	19% S	10–20	Basal or foliar	Improves Fe and S nutrition; useful in calcareous soils.
Nano-Sulphur Formulations	Variable (nano-scale S)	5–10	Foliar spray	High efficiency; emerging technology for precision nutrient management.

8. Methods of Application

Sulphur can be applied through soil incorporation, foliar sprays, or fertigation. Soil application ensures sustained availability, while foliar sprays provide rapid correction of deficiencies. Integrated nutrient management practices combining organic and inorganic



sources are recommended for sustainable sulphur nutrition (Figure 2) (Gupta & Jain, 2010).

9. Economic Importance

Sulphur fertilization has significant economic importance in oilseed cropping systems because it directly enhances yield, oil recovery, and overall farmer profitability. Adequate sulphur supply improves nutrient uptake efficiency, particularly nitrogen, by facilitating protein synthesis and metabolic activity (Malhi et al., 2007). This synergy between sulphur and nitrogen not only boosts crop productivity but also reduces the need for excessive nitrogen fertilization, thereby lowering input costs. By improving seed quality parameters such as oil content and protein concentration, sulphur application ensures that farmers achieve higher returns from both yield and market value (Gupta & Jain, 2010).

Beyond immediate yield benefits, sulphur management contributes to long-term agronomic sustainability and economic viability. Balanced sulphur nutrition enhances soil fertility, supports crop resilience against biotic stresses, and improves oil quality, which is critical for consumer acceptance and industrial processing (Chatterjee & Dwivedi, 2008). Farmers who adopt sulphur fertilization practices often experience improved profitability due to better nutrient efficiency and reduced dependency on costly nitrogen inputs. Thus, sulphur management is not only an agronomic necessity but also a strategic economic investment that sustains productivity and profitability in oilseed-based farming systems (Tripathi & Sharma, 2017).

10. Future Perspectives

Declining soil sulphur levels due to reduced atmospheric deposition and intensive cropping systems highlight the need for integrated sulphur management. Future strategies should include soil testing, crop-specific recommendations, and use of sulphur-enriched fertilizers (Jat & Meena, 2019). Research on nano-sulphur formulations and precision agriculture techniques may further enhance sulphur use efficiency in oilseed crops (Singh & Singh, 2020).

Conclusion

Sulphur is a vital nutrient for oilseed crops, influencing yield, oil quality, and economic returns. Its role in amino acid synthesis, enzymatic activity, and oil biosynthesis underscores the necessity of balanced sulphur nutrition. Sustainable sulphur management practices are essential to meet the growing demand for edible oils and ensure food security.



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