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The role of sulphur in agriculture: Enhancing crop yield and quality

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Abstract
Sulphur plays a vital role in agriculture by contributing to plant growth, protein synthesis, and efficient nitrogen metabolism. It is a secondary macronutrient that helps in the formation of essential compounds within plants. Sulphur also enhances the quality and flavor of certain agricultural products. Soil testing helps determine if sulphur supplementation is necessary, which can be achieved through fertilizers or organic amendments. Sulphur is crucial for optimal plant health, crop productivity and sustainable farming practices.

Keywords: Gypsum, iron pyrite, epsomite and sphalerite

Introduction
Sulphur plays a vital role in agriculture as an essential nutrient for plant growth and development. It is an important constituent of amino acids, enzymes, vitamins, and proteins. Sulphur is considered a secondary macronutrient, which means it is required by plants in relatively smaller quantities compared to primary nutrients like nitrogen, phosphorus, and potassium. However, its importance should not be underestimated, as sulphur deficiency can significantly affect crop yields and plant health (Halvin *et al*., 2005) [8].

In agricultural systems, sulphur is primarily obtained from the atmosphere through deposition of sulphur compounds, such as sulphur dioxide (SO_2), during rainfall or through direct uptake by plant leaves. However, with the reduction of sulphur emissions from industrial activities, sulphur deficiencies have become more prevalent in many regions (Wainwright *et al*., 1978) [17].

Sulphur deficiency symptoms vary among crops but commonly include yellowing of younger leaves (chlorosis) due to reduced chlorophyll production. This can lead to stunted growth, decreased seed production, and lower crop quality. Additionally, sulphur deficiency can affect nitrogen utilization by plants, leading to inefficient nitrogen uptake and utilization, further influencing overall plant health (Tandon *et al*., 2007) [16].

Supplementing sulphur in agriculture is crucial to maintain optimal crop nutrition and maximize yields. Several sources of sulphur are used to address deficiencies, including elemental sulphur, sulphate fertilizers, gypsum, and organic amendments. The choice of sulphur source depends on factors such as soil characteristics, crop requirements, and application methods (Prasad *et al*., 1997) [13].

Elemental sulphur is a common sulphur fertilizer that must be oxidized by soil bacteria before it becomes available to plants. This slow-release form of sulphur ensures a sustained supply to crops over time. However, its effectiveness depends on soil pH, moisture, and temperature conditions (Lee *et al*., 1987) [9].

Sulphate fertilizers, such as ammonium sulphate or potassium sulphate, provide readily available sulphur for rapid plant uptake. These fertilizers are water-soluble, making them suitable for both soil and foliar applications. They are particularly beneficial in soils with low pH, as the availability of sulphate becomes limited when soil pH is too high or alkaline (Lipman *et al*., 1916) [10].

Gypsum, a calcium sulphate compound, is not only used to correct soil calcium deficiencies but also serves as a source of sulphur. Gypsum improves soil structure, increases water infiltration, and enhances root growth while supplying sulphur to plants (Ghaudhry *et al*., 2001) [7].

Organic amendments, such as manures, composts, or cover crops, can also contribute to sulphur availability in agriculture. These organic sources contain sulphur in organic forms that undergo microbial mineralization, releasing sulphur for plant uptake. Farmers can use sulphur-containing fertilizers or organic amendments to provide plants with adequate sulphur levels (Eriksen *et al*., 1984) [6].

Overall, sulphur is an essential nutrient in agriculture, impacting plant growth, protein synthesis, nitrogen metabolism, and crop productivity. Its role in optimizing nutrient utilization and enhancing product quality makes it a critical consideration for sustainable farming practices (Singh *et al*., 2001) [15].

Sulphur's importance in plant physiology

Sulfur is an essential element for plants, playing a crucial role in their overall physiology. It is a constituent of various biologically active compounds and proteins, contributing to their structure and function. Sulfur is a vital component of amino acids, including cysteine and methionine, which are building blocks of proteins. These proteins are involved in a wide range of critical processes, such as enzyme activity, nutrient uptake, and defense mechanisms. Sulfur also assists in the synthesis of vitamins, such as thiamine and biotin, which are necessary for various metabolic reactions. Additionally, sulfur compounds, such as glucosinolates and phytochemicals, contribute to plant defense against pests and diseases. Thus, sulfur is essential for maintaining the overall health, growth, and protection of plants (Brunold *et al*., 1993) [2].

Sources of sulphur

Gypsum

Gypsum, a naturally occurring mineral, is a widely used source of sulphur in agriculture. It contains approximately 20% sulphur and is commonly applied to soil as a fertilizer or soil amendment. Gypsum improves soil structure, enhances water infiltration and retention, and reduces soil erosion. It also helps balance the pH level and facilitates nutrient absorption in plants. Furthermore, gypsum can effectively mitigate certain soil-borne diseases and reduce aluminum toxicity (Allison *et al*., 1965) [1].

Iron Pyrite

Iron pyrite, also known as fool's gold, is a naturally abundant sulphur-containing mineral. Although it is not typically used directly as a sulphur fertilizer due to its low solubility, it can indirectly contribute sulphur to plants. Over time, iron pyrite undergoes oxidation, producing sulphuric acid, which aids in the release of sulphur from organic matter and rock minerals. This released sulphur subsequently becomes available for plant uptake (Dubey *et al*., 2016) [4].

Epsomite

Epsomite or magnesium sulphate heptahydrate, is another source of sulphur commonly used in agriculture. It contains approximately 13% sulphur and is valuable for supplying sulphur and magnesium to plants. Epsomite is ideally applied as a foliar spray or soil amendment to correct magnesium deficiencies and promote overall plant health. Additionally, it helps improve nutrient uptake, enhances metabolic activities, and increases crop quality and yield (Elbossaty *et al*., 2018) [5].

Sphalerite

Sphalerite, a zinc sulphide mineral, is primarily valued for its zinc content but also contains sulphur. By providing sulphur, sphalerite contributes to the sulphur requirements of crops. Zinc is an essential micronutrient that plays a significant role in various plant physiological processes. Applying sphalerite to the soil can address zinc deficiencies while simultaneously providing sulphur to meet plant needs (Cook *et al*., 2009) [3].

Sulphur deficiency in crops

Sulphur deficiency in crops can have significant impacts on their growth and productivity. It can lead to reduced protein synthesis, impaired chlorophyll formation, and compromised enzyme activation. This deficiency can result in stunted growth, yellowing of leaves, and decreased photosynthetic efficiency. Furthermore, nutrient uptake and transport can be affected, leading to imbalances and reduced plant health. Plants deficient in sulphur are more susceptible to pest and disease attacks, and their ability to withstand environmental stresses is compromised. To prevent sulphur deficiency, it is important to ensure an adequate supply of sulphur through proper soil management and fertilization practices (Mcgrath *et al*., 1996) [11].

Sulphur fertilization

Sulphur fertilization is the application of sulphur-containing fertilizers to the soil or plants to ensure optimal plant growth and health. Sulphur is an essential nutrient for plants, playing a crucial role in various physiological processes. It replenishes sulphur levels in deficient soils, promotes plant growth during key stages, and improves soil health. Different types of sulphur fertilizers are available, including elemental sulphur, sulphate forms, and liquid sulphur. The application rate and timing depend on factors like soil type and crop type. Proper sulphur fertilization practices help maximize crop productivity and promote sustainable agriculture (Meng *et al*., 2004) [12].

Sustainable sulphur management

Sustainable sulphur management is crucial for maintaining soil health and crop productivity while minimizing negative environmental impacts. It involves optimizing sulphur application rates to meet plant requirements without excess applications that can lead to nutrient imbalances or potential pollution of water bodies. Practices such as soil testing, crop-specific sulphur recommendations, and nutrient management planning can help ensure efficient sulphur utilization. Additionally, adopting organic residue management and promoting beneficial microbial activity can enhance sulphur mineralization and availability in the soil. Utilizing sulphur-containing fertilizers that have minimal environmental impact, such as elemental sulphur or sulphur-coated urea, can also contribute to sustainable sulphur management. By balancing the needs of crops with environmental considerations, sustainable sulphur management can support long-term agricultural productivity while safeguarding the ecosystem (Rathore *et al*., 2015) [14].

Conclusion

Sulphur is a vital nutrient in agriculture that should not be overlooked. Although it is classified as a secondary macronutrient, its role in plant growth and development is significant. Sulphur is essential for the synthesis of amino

acids, enzymes, proteins, and vitamins in plants, making it crucial for their overall health and productivity. Sulphur deficiencies can have detrimental effects on crop yields and quality, leading to stunted growth, decreased seed production, and reduced nutrient utilization. With the reduction in sulphur emissions from industrial activities, sulphur deficiencies have become more common in certain regions, necessitating effective sulphur management practices. Various sources of sulphur, such as elemental sulphur, sulphate fertilizers, gypsum, and organic amendments, can be used to address sulphur deficiencies. The choice of source depends on factors like soil characteristics, crop requirements, and application methods. Proper sulphur management involves understanding crop needs, monitoring soil and plant tissue, and applying sulphur sources at the right time and in the right amounts. By addressing sulphur deficiencies and ensuring optimal sulphur nutrition, farmers can enhance crop yields, improve crop quality, and promote sustainable farming practices. Implementing effective sulphur management strategies not only improves plant health but also contributes to the overall sustainability and productivity of agricultural systems. In a world where agricultural productivity is crucial to feed a growing population, paying attention to the role of sulphur in crop nutrition is essential. By recognizing the significance of sulphur and incorporating it into agricultural practices, we can work towards achieving a more sustainable and productive agriculture system.

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