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Optimizing Indian Mustard productivity through balanced Zinc and Sulphur nutrition

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Introduction

Oilseeds constitute the second most important agricultural commodity in India after cereals and play a significant role in the agricultural economy of the country. India is one of the leading producers of oilseeds in the world and possesses the fourth-largest vegetable oil economy after the United States, China and Brazil. The total production of oilseeds in India is estimated to be about 39.59 million tonnes during 2023–24. Among the different oilseed crops, rapeseed–mustard, soybean, groundnut, sunflower, sesame and safflower contribute majorly towards edible oil production in the country.

Despite substantial domestic production, India still imports a large quantity of edible oils to meet the increasing demand of its growing population. Oilseed crops contribute nearly 13% of the total cultivated area, around 3% of the gross national product and approximately 10% of the total value of agricultural commodities. These crops are important not only for edible oil production but also for nutritional security because edible oils are rich sources of energy and carriers of fat-soluble vitamins such as A, D, E and K.

Among various oilseed crops, rapeseed–mustard occupies an important place in Indian agriculture. Globally, rapeseed–mustard is cultivated over about 43 million hectares with production exceeding 89 million tonnes. India ranks third in both area and production after Canada and China. During 2024–25, rapeseed–mustard was cultivated over approximately 10.60 million hectares with a production of 13.58 million tonnes and productivity of 1281 kg ha^{-1}. However, the average productivity in India remains considerably lower than the global average, indicating the need for improved agronomic and nutrient management practices.

The major mustard-growing states in India are Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana and West Bengal. Haryana records comparatively higher productivity because of better irrigation facilities and improved crop management practices. The development of the oilseed sector in India received momentum during the Yellow Revolution through the establishment of institutions such as the All India Coordinated Research Project on Oilseeds, Directorate of Oilseeds Research and Technology Mission on Oilseeds.

Indian mustard (*Brassica juncea* L.), commonly known as sarson or rai, belongs to the family Brassicaceae and is one of the most important rabi season oilseed crops of northern India. The crop grows well under cool and dry climatic conditions with optimum temperature ranging from 6– 27°C. Mustard can be cultivated under rainfed as well as irrigated conditions and adapts well to marginal and sub-marginal soils.

Mustard seed contains about 35–40% oil rich in essential fatty acids such as linoleic acid and linolenic acid. Besides edible oil extraction, mustard has several medicinal, industrial and nutritional uses. Mustard oil is extensively used in cooking, pickles and traditional medicinal applications. The young leaves are consumed as green vegetables, especially in the traditional

Punjabi dish "Sarson ka Saag". Mustard oil cake obtained after oil extraction serves as a valuable cattle feed and organic manure due to its high nutrient content.

The productivity and quality of mustard largely depend upon balanced nutrient management. Continuous cultivation and intensive use of high-analysis fertilizers supplying mainly nitrogen, phosphorus and potassium have resulted in widespread deficiencies of secondary and micronutrients in Indian soils. Among these nutrients, Sulphur and Zinc are particularly important for mustard because of their direct involvement in oil synthesis, protein formation and metabolic activities.

Role of sulphur in mustard production

Sulphur is considered the fourth essential nutrient after nitrogen, phosphorus and potassium. It is a structural component of Sulphur-containing amino acids such as cysteine, cystine and methionine, which are essential for protein synthesis. Nearly 90% of the total Sulphur present in plants occurs in these amino acids. Sulphur is also an important constituent of glucosides responsible for the pungent flavor and aroma of mustard oil.

Sulphur plays an important role in chlorophyll formation, photosynthesis, enzyme activation, energy transformation and synthesis of oils and proteins. Adequate Sulphur nutrition enhances vegetative growth, flowering, siliqua development and seed formation in mustard.

Deficiency of Sulphur causes chlorosis in young leaves, stunted growth, delayed maturity, poor flowering and reduced seed formation. In severe deficiency conditions, leaves become cupped and stems develop reddish discoloration. Sulphur deficiency has become increasingly common in Indian soils due to continuous use of Sulphur-free fertilizers and low application of organic manures.

Sources of Sulphur

Sulphur can be supplied through both inorganic and organic sources. Common Sulphur-containing fertilizers include:

Gypsum (18% S)

Single Super Phosphate (SSP) (12% S)

Ammonium sulphate (24% S)

Potassium sulphate (18% S)

Elemental sulphur (85–90% S)

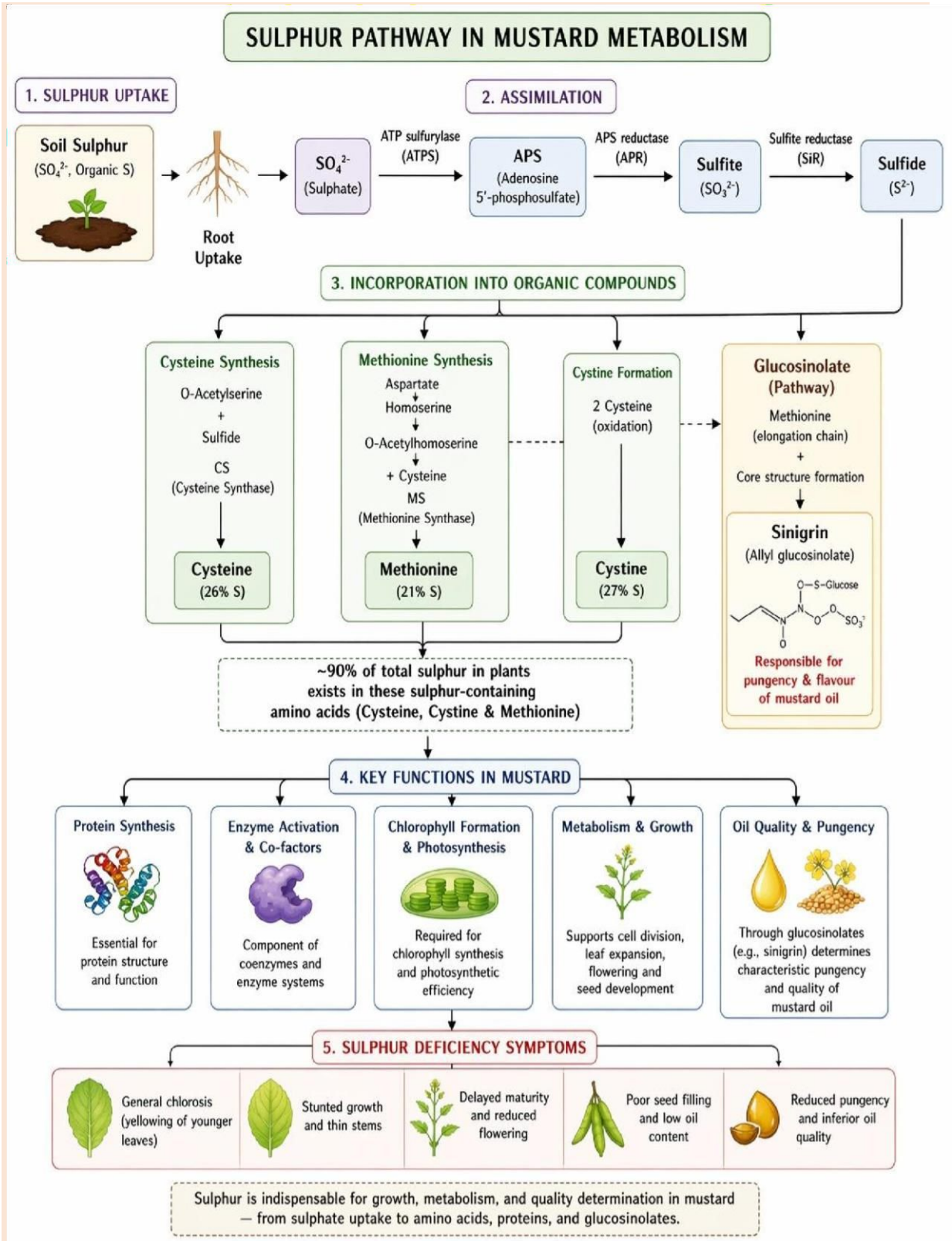
Pyrite (22–24% S)

Bentonite sulphur (around 90% S)

Among these, gypsum, SSP and bentonite sulphur are commonly recommended for mustard cultivation. Bentonite sulphur has gained importance because of its high Sulphur concentration and slow-release behavior. After application, bentonite absorbs moisture and swells, breaking elemental sulphur particles into fine sizes which enhances microbial oxidation and improves Sulphur availability to plants over a longer period. It is especially useful in Sulphur-deficient and light-textured soils.

Organic sources such as farmyard manure, compost, crop residues and oil cakes also contribute Sulphur and improve soil biological activity and nutrient availability.

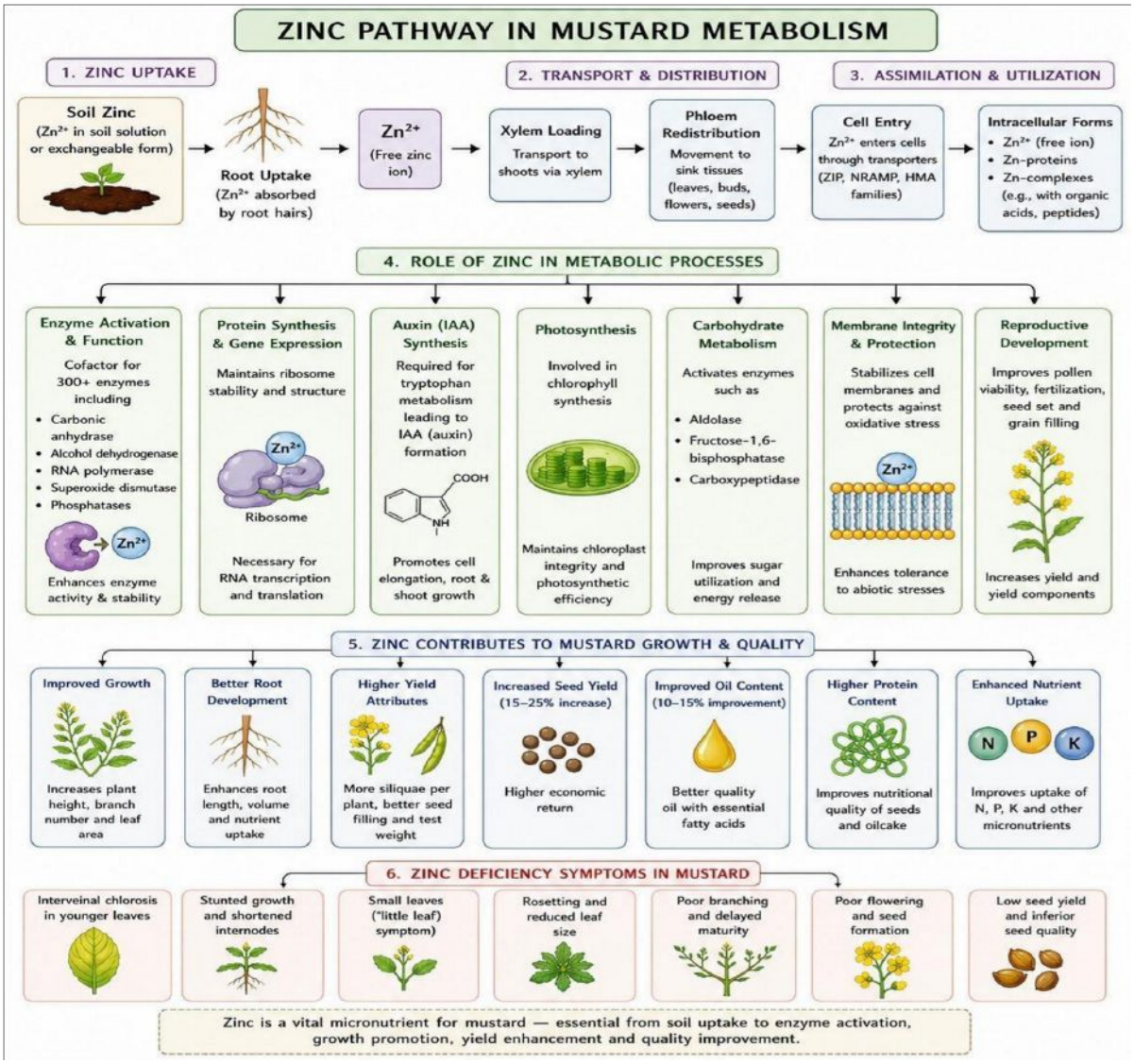
Several studies have reported that application of 30–40 kg S ha^{-1} significantly improves plant height, dry matter accumulation, number of siliquae per plant, seeds per siliqua, test weight and seed yield in mustard. Sulphur application also increases oil content, protein synthesis and nutrient uptake efficiency.



Role of zinc in mustard production

Zinc is an essential micronutrient required for several physiological and biochemical functions in plants. It acts as an activator of many enzymes associated with carbohydrate metabolism, protein synthesis and auxin production. Zinc also plays an important role in chlorophyll synthesis, photosynthesis and maintenance of membrane integrity.

In mustard, Zinc deficiency adversely affects growth and reproductive development. Deficiency symptoms include chlorosis in younger leaves, stunted growth, shortened internodes and poor seed development. Zinc deficiency is more common in alkaline, calcareous and sandy soils with low organic matter content.



Sources of Zinc

The commonly used Zinc fertilizers include:

Zinc sulphate heptahydrate ($ZnSO_4 \cdot 7H_2O$)

Zinc sulphate monohydrate ($ZnSO_4 \cdot H_2O$)

Zinc oxide (ZnO)

Chelated Zinc (Zn-EDTA)

Among these, zinc sulphate is the most widely recommended source because of its higher solubility and better availability to plants. Zinc can be applied through soil application or foliar spray. Foliar spray of 0.5% zinc sulphate during flowering and siliqua formation stages helps in rapid correction of Zinc deficiency.

Application of Zinc significantly improves plant height, branching, siliquae formation, test weight, seed yield and oil content in mustard. Application of 5–10 kg Zn ha^{-1} has been found beneficial for improving productivity and nutrient uptake in mustard crops.

Combined effect of zinc and sulphur

The combined application of Zinc and Sulphur exerts synergistic effects on mustard growth, yield and quality. Sulphur improves oil synthesis and protein formation, whereas Zinc regulates enzymatic activities and metabolic processes. Together, these nutrients improve photosynthetic efficiency, assimilate translocation and nutrient utilization.

Research findings have indicated that combined application of 40 kg S ha^{-1} along with 5–10 kg Zn ha^{-1} significantly increases growth parameters, yield attributes, seed yield, oil content and nutrient uptake in mustard. Integrated application of these nutrients also improves soil fertility and fertilizer use efficiency.

Incorporation of organic manures along with Zinc and Sulphur further enhances soil microbial activity, nutrient availability and long-term soil health. Balanced nutrient management involving secondary and micronutrients is therefore essential for sustaining mustard productivity under intensive cropping systems.

Economic and sustainability aspects

Application of Zinc and Sulphur not only increases crop productivity but also improves profitability. Higher seed yield, improved oil content and better quality produce contribute to higher economic returns for farmers. Balanced fertilization also improves nutrient use efficiency and reduces nutrient losses from soil.

Proper Zinc and Sulphur management enhances soil microbial activity, organic matter decomposition and root growth, thereby improving soil fertility and sustainability. Balanced nutrient application also reduces environmental problems associated with nutrient imbalance and excessive fertilizer use.

Conclusion

Indian mustard is one of the most important oilseed crops contributing significantly towards edible oil production and nutritional security in India. However, productivity of mustard remains below the global average mainly due to nutrient deficiencies and imbalanced fertilizer use. Among the essential nutrients, Sulphur and Zinc play a crucial role in improving growth, yield, oil content and quality of mustard. Application of 30–40 kg Sulphur ha^{-1} along with 5–10 kg Zinc ha^{-1} has been found highly effective for enhancing mustard productivity and nutrient uptake. Proper management of these nutrients through suitable fertilizer sources such as gypsum, SSP, bentonite sulphur and zinc sulphate can help achieve higher yields, improved oil quality and sustainable soil fertility. Therefore, balanced application of Zinc and Sulphur is essential for sustainable mustard production and strengthening India's edible oil security.