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Influence of sulphur and zinc on production of sesame: A review

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Abstract
Sesame (*Sesamum indicum*) is an important oil seed crop cultivated across world for its high -quality and nutritious seed. But the main constraints for production of this crop is soil deficiency of macro and micro nutrients. Sulphur (S) and zinc (Zn) are the elements which play crucial role in sesame crop production. Their impact can be directly seen through growth and development, seed yield, stalk yield, oil content, protein content, carbohydrate content, nutrient uptake and dry matter accumulation. Reduction of resistance against disease and pest, reduction in firmness against drought and frost condition, less chlorophyll formation, lowering in oil and protein content in seed and lowering in nitrogen metabolism are key symptoms of Sulphur deficiency. Symptoms of zinc deficiency mainly include growth and yield reduction, delay in seed maturation, production of low conc. of phytohormones, reduced cell division and production of malformed fruit in severe deficiency condition etc. The strategies behind eradication of S and Zn deficiency and its management may lead to an era of sustainable sesame production and its application in future agricultural production system.

Keywords: Sesame, sulphur, zinc, sustainable

Introduction
Sesame (*Sesamum indicum*) is the 4th most important edible oil seed crop after groundnut, rapeseed and mustard. Sesame or gingelly belongs to family pedaliaceae. It is also known as til or gingelly. This is a both kharif or rabi season, short day and drought resistant oilseed crop in India. In northen India the crop is grown as minor kharif crop. Sesame is basically a crop of the warm regions of the tropics and sub-tropics. It grows in plains as well as up to an elevation of 1250 meters. It requires fairly hot conditions during growth to produce maximum yield. A temperature of 25-27 °C encourages rapid germination and initial flower formation. Low temperature during flowering can result in the production of sterile pollen or pre - flower drop (Singh, *et al*., 2007) [43, 44]. Sesame can be grown on a wide variety of Soil types ranging from sandy loam to heavy black soil, with a pH ranging from 5.5 to 8.2. This short duration crop fits good in intercropping and sequence cropping. Due to being exceptionally nutritional, medicinal and high cooking quality it is regarded as 'queen of oil seeds crop' (Goel and Kumar, 1994) [15]. Sesame contains 46-55% oil, 20-25% protein, 20-25% carbohydrate, 5-6% ash (Salunkhe *et al*., 1992) [37] and 6355 kcal/kg energy. Seeds are rich in nutrients such as potassium (525.9 mg/100 g), phosphorus (516 mg/100 g), magnesium (349.9 mg/100 g), sodium (15.28 mg/100 g), iron (11.39 mg/100 g), zinc (8.87 mg/100 g) and manganese (3.46 mg/100 g) (Elleuch Mohamed *et al*. 2007) [12]. Sometimes it is also called as 'poor man's substitute for ghee'. Sesame is quality food, nutritious edible oil, used in bio-medicine and health care. The seeds are a good source of fat, vitamin-B, fiber and minerals. Its non-culinary application includes use as an ingredient in soap, cosmetics, body lotion, hair oil, perfume and medicines. It has high quality poly-unsaturated atty acid which makes the oil healthy, tasty and flavorful. Certain health issues such as swelling, wound, weak bone, high blood pressure, high blood sugar, cholesterol, weight management, digestive problems and absorption of sugar can be cured by sesame uptake. The oil seed is highly stable and also consumed to prevent coronary heart diseases. Due to the presence of potent antioxidants such as sesamol and sesamolin and the ability to prevent rancidity, sesame seeds are called as 'the seeds of immortality'.

Sesame seed bear anti-aging property. Sesame finally left an edible oil cake high in methionine, cystein, arginine, and tryptophan, mostly used as a cattle feed. It's a vital element that can make up to 5% of a well-formulated chicken feed. It can be used as manure as well (Debnath *et al*, 2022) [9]. Cake has a nitrogen content of 6.0-6.2%, a P_2O_5 content of 2.0-2.2%, and a K2O content of 1.0-1.2% (Gali Haritha, 2022) [13]. The crop has insecticidal property, the antioxidant sesameolin, a constituent of the oil, is used for its synergistic effect in pyrethrumj, which increases the toxicity of insecticides.

India ranks 3rd in sesame production with 0.78 million tonnes after, ranks 2nd in area after Sudan with 1.56 million ha areas and productivity of 502kg/ha (ICAR- AICRP on sesame and niger). India accounts 6.1% land area and 2.8% production of sesame among all total oilseed production. Uttar Pradesh covers large area for sesame production in India (33%) followed by Uttar Pradesh (28%). Madhya Pradesh, Rajasthan, Uttar Pradesh, Gujarat collectively produce more than 85% of total sesame production in country (IOPEPC, 2023 *kharif* survey). Being one of the oldest oil seed crop archaeologies suggest domestication of the crop occurred at least 5500 years ago in Indian subcontinent (Bedigian and Vander 2003) [4]. In India, sesamum seeds are used for oil extraction (78%), edible purposes (20%) and seed purpose (2%). Sesame oil cake is used as bovine feed as it contains considerable amount of protein, P and K. It can also be used as concentrated organic manure. In India the main reason to get less production and productivity in sesame are poor rainfall, cultivation of crop on marginal and sub-marginal land with poor fertility under agronomic practices and inadequate or even no use of fertilizers (Praveen Kumar, 2022) [31]. Application of recommended dose of NPK result in beneficial yield of sesame under both rainfed and irrigated condition but additional application of nutrients such as S, Ca, Cu, Zn, B increase yield along with quality of oilseed (Ghosh *et al*., 2002) [9].

Among all available nutrients present Sulphur is regarded as the fourth major plant nutrient after nitrogen, phosphorus and potassium. Sulphur deficiency is considered as limiting factor across all over India and common in oil seeds. Oil seed crops require more amount of sulphur as compared to rice as their storage organs are mostly proteins, rich in sulphur. Gypsum is proved to be significantly superior to other sources of sulphur for growth and development of sesame reported by Singh and Singh (2007) [43, 44]. Sulphur helps in chlorophyll formation (Ajai Singh *et al.*, 2000) [1] and increases firmness against drought and cold (Patel and Shelke, 1995) [29]. Sulphur is helpful in reduction in soil pH level which results in increase of availability and mobility of nutrients such as P, Fe, Mn and Zn (Mondal *et al*, 2023) [45]. It also helps in the synthesis of glucosides in sesame oil and increases the oil quality. Deficiency of sulphur affect nitrogen metabolism as well as synthesis of amino acids containing sulphur such as cystine, cysteine, methionine in plants which adversely affect both seed and oil yield. Sulphur deficiency also affect production vitamins (biotin and thiamine), co-enzyme-A and metabolism of carbohydrate, protein and fat. Sulphur promotes root development in drought and cold condition. Additional functions of sulphur in soil includes decomposition of residues along with pest and disease resistance (R.I. Shelke, 2014) [41, 42]. S deficiency induces chlorosis in young leaves and decrease seed yield by 45% (BARI, 2004) [3].

Zn deficiency is frequently found in Indian soil. The movement of Zn to plant roots is dependent on concentration. Foliar application of zinc to crops is an effective way to increase the grain concentration of zinc. It plays an important role in protein synthesis, enzyme combination, nucleic acid structure, seed maturation, synthesis of plant growth hormone such as auxin, water absorption. Zinc is an essential element for crop growth, as it is a component of carbonic anhydrase and a stimulant of aldolase, a carbon metabolism enzyme (Muhammad Chattha *et al*, 2017) [7]. Zn is also an essential component of various biomolecules, including lipids, proteins, and auxin cofactors, and hence plays a significant part in plant nucleic acid metabolism. Zn application has been shown to improve agricultural yield and quality (Tsonko Tsonev *et al*, 2012) [48], but Zn deficiency diminishes yield and degrades crop quality. Furthermore, higher Zn concentrations are hazardous to plants and decrease cell division and elongation, decreasing biomass output. Reduced growth hormone production in Zn deficient plants causes shortening of internodes and short leaves resulting in malformation of fruit with little or no yield (Shubham Dwivedi, 2020) [46].

Influence of S and Zn on sesame production

1. Growth

The rate of increase in growth characters is more with higher rate of S application due to better nutritional environment for plant growth at active vegetative stages. This results in improvement of root growth, multiplication and elongation of cell and cell expression in the plant body through higher apical growth and expansion of photosynthetic surface which ultimately increased growth (Kumar *et al*, 2011 & Puste, 2015) [22, 33]. Supply of sulphur in adequate amount also helps in the development of floral primordial i.e. reproductive parts, which results in the development of capsules and seeds in plant. These results have been reported by Sarkar and Benik (2002) [35] and Raja *et al*. (2007) [36] in sesame. sulphur plays a vital role photosynthetic process of plant which has a direct bearing on plant growth and development (Khan *et al*, 2021 & Yadav *et al*., 2008) [19, 51]. This phenomenon occurs due to synthesis of more amino acids, increase in chlorophyll synthesis in growing region and ultimately enhancing cell division and thereby increased the crop growth rate (Dubey and Khan 1993) [11]. The higher content of sulphur in plants plays an important role in better development and thickening of xylem and collenchyma tissues. Such favourable effects might have resulted in stronger stem thereby increasing the number of primary branches per plant. Higher dry matter production and translocation is seen with the application of recommended dose of SSP or in combination with FYM (Singh *et al* 2000) [1]. The role of S along with N promotes the vegetative growth (Kalyani *et al*, 2020) [34]. It has been shown that metabolic utilization of sulphur in plants promote mitotic activity, resulting in higher apical growth and increased photosynthetic surface area. The increase in plant height may be due to the involvement of zinc in various physiological processes, such as enzyme activation, electron transport, chlorophyll formation, and stomatal regulation (Pravalika and Dawson, 2023) [20]. Zinc helps in plant hormone IAA biosynthesis in plant. Similar findings were also reported by Sharma and Jain (2003) [40] in mustard, Choudhary *et al*. (2010) [8] in sunflower and Murthy *et al*. (2011) [26] in sesame. During early growth stage Zn promotes profuse vegetative growth and during reproductive growth higher capsule/plant have been recorded. Similar result was reported by Shekh *et al*. (2014) [41, 42].

2. Seed yield

Application of sulphur resulted in improved growth and increased seed yield. Among all sulphur fertilizer source,

gypsum is considered superior for seed yield (Chaurasia S K *et al*, 2009) [6]. Increase in yield attributes and yield of sesame due to sulphur fertilization has also been reported by Saren *et al*. (2004) [38] and Tripathi *et al*. (2007) [49] in sesame. Zn is helpful for seed formation. The application of Zn and Fe both show increment in seed yield by 34% shown by Moola Ram in 2021 [25]. There was a significant increase in number of capsules per plant, recorded with higher dose of sulphur at this growth stage while, minimum number of capsules per plant (37.35) was recorded with Sulphur application @ 15 kg/ha. Jhansi *et al*., 2023 showed that application of S 20 kg/ha increased the seed yield of sesame by 10.08%.

3. Quality content

Quality of sesame seed is determined in terms of oil content, protein content, carbohydrate content.

a. Oil content

The oil content increases with level of sulphur application. Sulphur leads to rapid conservation of nitrogen to crude protein and finally to oil. As sulphur is an integral part of oil, the more amount of sulphur applied result more amount of oil and seed production. Sulphur in the form of sulphate is involved in various metabolic and enzymatic activities of plants (Lida, 2013) [23]. It is also a constituent of glutathione, a compound supposed to play part in plant respiration and synthesis of oils. A sulphur-based enzyme, acetic thiolinase in the presence of S convert acetyl C0-A to melonyl Co-A, rapidly resulting in higher oil content in oil seeds (Krishnamurthy and Mathan, 1996) [21]. Application of sulphur, irrespective of sources and levels significantly increased the oil content in seed by 45.57%, where gypsum increases oil content by 48.39%. The oil content of sesame (44.88%) was recorded from application of 2.5 % ZnO (Jahan *et al*., 2019) [28].

b. Protein content

Application of zinc accelerate RNA and protein synthesis as it plays a significant role in nitrogen metabolism and photosynthesis. Suresh *et al*., (2013) [47] reported that fertilization of Zn through foliar spray shown higher protein content in sesame seeds compared to soil application. Application of 45kg/ha level of sulphur exhibit the highest protein content (21.5%) observed. Among all sulphur fertilizer, it is shown that gypsum increased 22.04% protein content in seed (Basu Devi Yadav, 2019) [5]. Increase in protein content by 18.38% due to sulphur application through Ammonium sulphate was observed by N.N. Parmar, 2019 [a].

c. Carbohydrate content

Gypsum significantly increases the carbohydrate content in seed (24.45 g/100 gm) was observed by Basu Devi Yadav, 2019 [5].

Conclusion

In conclusion, the effect of Sulphur and zinc in sesame production emphasizes on growth, development and yield. Effect of application of Sulphur and zinc depends upon source of nutrient, method of application, soil type, environmental condition and cultivation practices. It is shown that Sulphur plays an important role in enhancing germination of seed, chlorophyll synthesis, root development, higher nutrient uptake, increasing resistance against disease, pest and stress where zinc plays a crucial role in seedling establishment, flowering, improving seed quality. The relation between application of Sulphur and zinc on sesame production proves via crop productivity, sustainable sesame farming systems and resilience to environmental stresses.

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