

SULPHUR NUTRITION AND ITS ROLE IN OILSEED CROPS PRODUCTION: A REVIEW

Comment [x1]: Role of Sulphur Nutrition in Oilseed crops- A Review

Abstract

India is a significant importer of edible oils and an important producer of oilseed. India stands as 4th leading oilseeds producing countries after USA, China and Brazil. Oilseed has become one of the most valuable agricultural commodities. Sulphur is one of the essential micronutrients that is need for higher yield and quality of oilseed crops. With an average concentration of 0.06 percent, it is the 13th most prevalent element in the crust of the earth. It is referred to as the 4th major nutrient after N, P and K because crops need sulphur slightly less than they require P. It plays an important role in formation of plant proteins, amino acids, vitamins, enzymes. It is an integral part of amino acid such as cystine, cysteine and methionine which are essential components of protein. Plant can absorb sulphur in the form of sulphate (SO_4^{2-}) which is decomposes into sulphur. It is a factor for the determination of higher yield seed and quality of seed that content oil in oilseed crops. Since, sulphur is immobile in plants, it must be continuously supplied from crop emergence till maturity. So, reduced yield can come sulphur shortage at any stage of growth. It can be overcome by supplying sulphur containing fertilizers to plant by soil application and foliar application. Among the source of sulphur, elemental sulphur and gypsum are widely utilized in sulphur deficiency.

Keywords: Oilseed, Sulphur, deficiency, quality, nutrient uptake.

Introduction

India is the 4th largest producer country of oilseed crops after USA, China, Brazil; contributing 10% to global production and 20% to the global area. Oilseed self-sufficiency achieved during the “Yellow Revolution” in the early 1990s could only last for a limited time (Roy *et al.*, 2022). India is also one of the major oils importing country in the world. ~~In India, seven edible oilseeds such as groundnut, sunflower, niger and sesame are cultivated. And also, two perennial oilseeds are coconut and palm oil.~~

The largest oilseed production states in India include Andhra Pradesh, Haryana, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. The major producing states are Rajasthan, Gujarat, Madhya Pradesh and

Comment [x2]: India is the world's biggest vegetable oil manufacturer and buyer. Oilseeds play an important role in agricultural economy of India. Oil derived from oilseed crops is considered as essential raw material for many industries. Sulphur (S) plays an important role in determining the quality of oil derived from these crops. Sulphur is required for the formation of proteins, vitamins and chlorophyll. Use of sulphur free fertilizers is one of the main reason for the shortage of sulphur in Indian soils. A balanced fertilization which includes sulphur is necessary for the quality growth of oilseed crops. Range of 30-60 kg S/ha significantly influenced crop growth, yield, nutrient uptake and economics of oilseeds. This review provides an insight about the recent research works carried out on oilseeds in terms of sulphur application

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Maharashtra with respective shares of the total production of about 20%, 20%, 19% and 16%. Oilseeds have a lot of fat in addition to having a lot of protein. Therefore, they are not only good of protein, also concentrated source of energy (Sarwar *et al.*, 2013). Oilseeds are a vital component of our nutrition and the oil extracted from them is used ~~to create many different goods~~, such as paints, varnishes, hydrogenated oil, soaps, perfumes, lubricants and other. ~~Oil cake, the leftover materials after oilseeds have been depleted of their oil, is an essential part of both manure and animal feed. Polyunsaturated fatty acids that are utilized to treat coronary heart problems.~~ Growing oilseeds may significantly alter the diet of human, improving food security and creating income ~~generation~~.00000

Comment [x5]: In number of ways

Comment [x6]: Requirement of Sulphur

~~Sulphur is an essential macronutrient, in accordance with its chemical nature it plays significant role in a number of cellular metabolic process (Hawkesford *et al.*, 2005). It is a nutrient that oilseed crops respond to when applied and they also have the highest sulphur needs when compared to other crops. This is because sulphur plays a role in the biosynthesis oil.~~ Sulphur-containing amino acids are cysteine, cystine and methionine, which makes it an essential factor for plant growth (Parmar *et al.*, 2018). These amino acids contain almost 90% of the sulphur present in plant (Tandon and Messick, 2002). Sulphur is required for the production of co-enzyme A, which is involved in the oxidation of fatty acids, their synthesis and the intermediates of citric acid cycle (Raghuveer M, 2017). Sulphur is utilized as a pesticide, a plant nutrient for increasing yield and quality of oilseed crops, an amendment for amelioration and a chemical agent (Kanwar and Mudahar, 1986). ~~Oilseed crops can only produce high yields and high quality products if they have access to the optimum amount of sulphur.~~ Additionally, it enhances the availability of other nutrients like phosphorus, potassium, zinc and suppress the uptake of sodium and chlorine, which are harmful to plant growth and development. ~~Oil crops need sulphur to produce glucosinolates.~~

Comment [x7]: Sulphur is an essential nutrient for the production of oilseeds. It is the 13th most abundant element in the earth's crust with an average concentration of 0.06 percent. Sulphur is increasingly recognized as the fourth major plant nutrient after nitrogen, phosphorus, and potassium

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Comment [x11]: Sulphur fertilization in oilseed crops help to increase the productivity of oilseed crops

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Oilseed productivity is low ~~for a various factor~~, due to inadequate and unbalanced fertilization is the most important one. One of the main causes of imbalanced ~~fertilization~~ is sulphur deficiency. Sulphur deficiency causes by decreasing the supply of sulphate, which delays the crop maturity and reduces the plant height and quality (Hawkesford, 2000; Dobermann, 2000). And also reduces oil content and quality of oilseeds (Scherer, 2001). Sulphur deficiency in coarse texture soils is due to low availability of organic matter (Takkar, 1988).

Comment [x13]: fertilization

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Requirement of Sulphur

Several researchers have determined the S need for oilseed crops in the field (Banu *et al.*, 2017; Tandon 1991a, 1991b; Aulakh and Pasricha, 1988; Pasricha *et al.*, 1988 and Kanwar *et al.*, 1983). The Sulphur requirement of oilseeds can be satisfied by using a number a S-containing substances including phosphogypsum, elemental S, gypsum and pyrite. In general, applying 30-40 kg S/ha to groundnut was more beneficial (Singh *et al.*, 1991b; Kale, 1993; Patra *et al.*, 1995). Gypsum added in the pegging zone at flowering at a rate of 250 kg/ha improved pod yield by 20.5% in the demonstration plots (Singh *et al.*, 1991). In general, the ratio (P:S) of the S needs of crops in comparison to P is 1.3 for cereals, 0.8 for legume forages and 0.6 for crucifers. It appears that S uptake in oilseeds is almost two times as high as phosphorus uptake (Tiwari *et al.*, 2006).

Role of sulphur in oilseeds

Sulphur is mostly absorbed by plant roots as sulphate (SO_4^{2-}), but it can also be taken up as thiosulphate ($\text{S}_2\text{O}_3^{2-}$). In addition, leaves can absorb a little amount of SO_2 (Havlin *et al.*, 2005). The amount of sulphur present in oilseed crops is (1.1-1.7). ~~Less~~ sulphur is applied to oilseed crops, which results in the production of low-quality seed (Haneklaus *et al.*, 2016). In rapeseed-mustard, sulphur is necessary to enhance the quantity of glucosides, glucosinolate and protein (Chandel *et al.*, 2003). ~~According to the experiment's finding, applying sulphur at a rate of 60 kg/ha significantly affected the amount of glucosinolate present and oil percentage increased by 44.6%.~~

~~Oilseed crops responded better to specific nutrient and irrigation during the grain filling stage in order to reduce derivatives of oil components. Sulphur must be added to oil to ensure the components that gives it flavour (Nepali and Bhandari, 2019).~~ When sulphur fertilizer levels increased from 0 to 60 kg S kg⁻¹, the content of allyl isothiocyanate in mustard seeds increased (Chandele *et al.*, 2003). Sulphur has a crucial function in the production of protein, vital enzymes and redox processes, which makes it essential for the formation of chloroplasts and chlorophyll. Sulphur is also associated with nodulation, flowering and the quality of oilseeds, particularly groundnut (Rao *et al.*, 2013).

Sulphur and quality of crop

Sulphur is involved in oil synthesis and oil storage organs which are rich in sulphur. Despite the composition of plant protein and oil, variations in the supply of S for plant growth change

Comment [x15]: Instead of requirement write down sulphur deficient oilseeds growing soils of India, Availability of indigenous sulphur sources and physiology of sulphur nutrition in oilseeds

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Comment [x19]: In oilseeds crops like groundnut, rapeseed-mustard, etc. Applications of sulphur along with other nutrients significantly increased the oil content

Comment [x20]: Rapeseed –mustard is an important oilseed crop, has a high demand for sulphur. Due to its high sulphur requirements, application of 60 kg/ha sulphur fertilization has been recommended for maximum yield

the quantity of various kind of chemicals and the composition overall. Sulphur improves the forage's digestibility for ruminants (Rendig, 1986). ~~In recent study, Zhao *et al.*, (1997) found that S enhanced the glucosinolate content of rapeseed, which was decreased by fertilizer and they recommended using N and S fertilizers in balance as a result.~~ Lesserucic acid and linolenic and higher oleic acid were found in the seed ~~form S deficient rapeseed crop~~ (Beaton and Fox, 1971). The increase in protein content as a result of S application have been reported to be 14% in soybeans (Aulakh *et al.*, 1990), 6% in lentils (Tiwari, 1989), 19% in sunflower (Gangadhara *et al.*, 1990), 28-34% in rapeseed and mustard (Pasricha *et al.*, 1987). ~~The S is a component of oil compounds and applying it~~ raises the oil content of the majority of oilseeds. With S fertilization, an average 5% increase in oil content has been observed (Pasricha *et al.*, 1987). However according to research, S application increased oil percentage on average by 11.3% in groundnut, 9.6% in rapeseed-mustard, 6% in linseed and 2-3.8% in safflower, sunflower and sesame (Tandon 1991a). Singh and Singh (1983a) in a study examined different sources of S for seed and oil yields, sulphur and oil contents and S uptake by mustard and ~~discovered~~ that all of these increased with each source of S, but element S was the best. Sunflower seed weight and head diameter increased after S application (Gangwar and Parmeswaran, 1996a). In rapeseed-mustard, the S application increased oil yield by 16% and oil content by 3.4% (Sachdeva and Dev, 1990).

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Comment [x22]: S deficient rapeseed crop

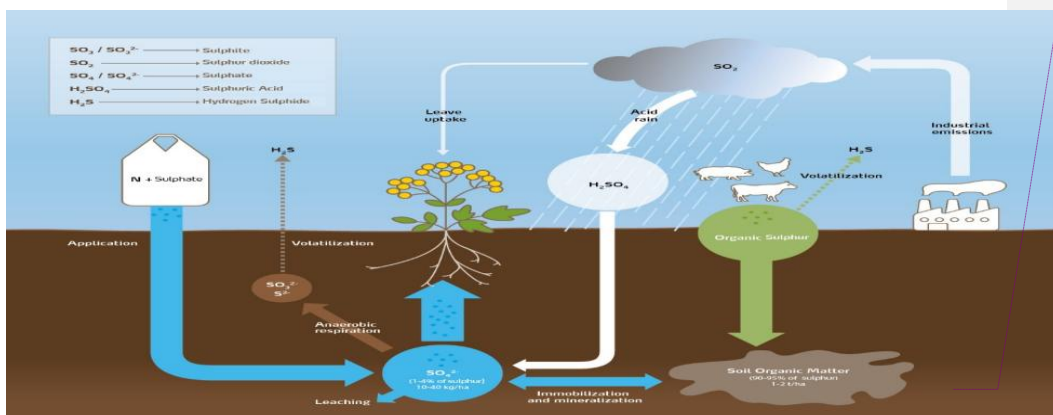
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Source of sulphur for various oilseed crops

Ammonium sulphate (24% S), single super phosphate (12% S), gypsum (13% S), pyrite (22-30% S) and element S (85- 100% S) are the most widely used S fertilizers. The other sources of S are potassium sulphate (18% S), magnesium sulphate (13% S), phosphogypsum (16% S), sulphur sludge (10-16% S), press mud (2-3% S). For most of the oilseed crops, the S fertilizers containing SO_4^{-2} ~~S~~ were effective (Tandon, 1991a). Applying pyrites and elemental sulphur 20-25 days before planting is recommended since elemental sulphur requires oxidation, pyrites is a slow-release fertilizer (Tiwari *et al.*, 1984). Gypsum and phosphogypsum are suitable for both alkaline and acidic soils, however they are more suited for crops that need a lot of Calcium, such as groundnut (Rao *et al.*, 2013). The ammonium sulphate corrects both the N and S deficiency and is the best suited for oilseed crops that do not fix nitrogen. The single super phosphate is a good source of S and P necessary for integrated P and S application in most oilseeds.

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Fig 1: Sulphur Cycle

Source: RaghuveerMunigela, Effect of sulphur on oilseed crops. Nov. 29, 2018.

Deficiency symptoms of sulphur in oilseed crops

Since only nitrogen, phosphorus and potassium managed nutrients in India, there are significant sulphur deficiency problems (Tandon, 1991). There is a wide spread sulphur deficiency in the world's soil (Scherer, 2009). The main symptom of sulphur nutrient deficiency is yellowing of younger leaves, which may be caused by inadequate chlorophyll production. Sulphur is immobile in plant so its deficiency appears on young leaves. ~~Plant deficient in become sulphur such as small and spindly with short, slender stalks, growth retarded, delay maturity, reduced nitrogen fixation, leaves become pale yellow or light green.~~ Deficiency of sulphur mostly observed in the shoots rather than the roots, which causes plants become stunted and shoot become slender (Karthika *et al.*, 2018). Sulphur deficiency leads to reduced root hydraulic conductivity, which is likely associated with signalling nutrient starvation from root to shoot. Additionally, sulphur deficiency causes an imbalance between the ratio of nitrogen and sulphur pool and increases the soluble nitrogen with amide and nitrate. When there is a sulphur deficiency in groundnuts, trifoliolate leaves grow and ~~take on~~ a V-shape because they are upright from the petiole (Sing *et al.*, 1999). Young leaves of groundnuts frequently develop chlorosis due to sulphur deficiency (Supakamnerd *et al.*, 1993; Singh and Chaudhari, 1995). In rapeseeds, the young leaves become cupped shape with various shape ranging from pale green to complete yellow, including the vein, which can

Comment [x27]: indicating

occasionally ~~take on~~ reddish or purple. In soyabeans, the newly emerging leaves still have a pale yellow-green, indicating a deficit of sulphur. In case of severe deficiency, the entire plant becomes pale yellow and the size of leaves and internodes are reduced. In sunflower, shorter internodes cause a reduction in plant height and the leaves and inflorescence both become pale.

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Assessment of sulphur in soil and plant sample

a) Assessment of sulphur in soil analysis:

~~Different technique can be used to determine the amount of sulphur in soil, however in India the most common way is to use a 0.15% CaCl₂ solution (Kour and Jalali, 2008). This approach is mostly used for sulphur deficient soils or soils with less than 10ppm of sulphate. The method should be reliable and appropriate for the crop (Jackson, 2011).~~

b) Assessment of sulphur in plant analysis:

~~The level of sulphur in the soil can be determined using basic analytical techniques. There are two ways to assess sulphur in plants: wet digestion and dry digestion. In wet digestion, HNO₃ and HClO₄ can be used, while dry ashing can be used to extract sulphur from plant digest (Mahanta *et al.*, 2017).~~

Comment [x29]: justify the need of writing assessment of sulphur in soil and plant sample in review paper

Application of sulphur fertilizers

The main ways for applying sulphur fertilizers in soils are broadcast or dribble banded, broadcast and subsequent incorporation, band placement, seed placement and banded near the seed. Broadcasting and band placement techniques are two of them that are frequently used. Sulphur ~~fertilize used~~ efficiency can be increased by managing sulphur fertilization in soil using the 4R nutrient stewardship approach (Right Source of nutrient applied at the Right Rate, Right Time and Right Place). To prevent the loss of nutritional element S, scientific management techniques can be used. For both a short-term and long-term source of plant nutrition, a mixture of soluble SO₄⁻² and elemental S may be helpful.

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Effect of ~~surphur~~ on nutrient uptake of oilseed

In an experiment on groundnuts, Venkatesh *et al.*, (2002) found that gypsum application at 45kg/ha of sulphur increased S uptake by straw (4.62 kg/ha) and kernel (10.37 kg/ha) over control (4.39 kg/ha, 1.91 kg/ha). ~~The use of~~ ammonium sulphate and the application of 20 kg

Comment [x31]: Sulphur

S/ha during two consecutive years resulted in sulphur use efficiency of 9.7, 10.1 kg/S kg⁻¹ and 15.9, 3.8 kg/S kg⁻¹ (Pandey and Ali, 2012). The uptake of N (131.0 kg/ha), P (31.1 kg/ha), K (87.92 kg/ha) and S (27.47 kg/ha) by mustard was significantly impacted due to the application of 90 kg S ha⁻¹ over control (83.86, 19.8, 53.91, 11.20 kg/ha) as noted by Pachauri and Trivedi, 2012. Application of S enhanced the concentration and uptake of N, P, S, Fe and Zn but ~~did not~~ effect on the concentration of K, Mg, Mn or Cu in ground nut leaves (Singh and Chaudhari, 1995). Sulphur uptake (20.7 kg/ha) in Indian mustard has been reported highest because of 45 kg/ha Sulphur application. ~~Under a~~ 40 kg S/ha application, mustard's uptake of total N (39.34 kg/ha), total P (10.67 kg/ha) and total S (17.73 kg/ha) was considerably impacted (Singh and Thenua, 2016).

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Conclusion

In addition to promoting yield and quality, sulphur enhances the oil content in oilseed crops, contributing to better nutritional value. It also plays an important role in growth and development of plant. Deficiency of sulphur caused growth retarded and yield. Gypsum, pyrites, element S and phosphogypsum are the sources that can provide sulphur. It can also be applied using fertilizers that contain primary nutrient like ammonium sulphate, single super phosphate and sulphate of potash. Oilseeds need to produce a good yield along with good quality and this can only be sustained when the plant receives enough sulphur. To achieve the best production results in oilseed crops, sulphur application must be balanced according to crop requirements and soil condition.

Comment [x33]: In India, the productivity of oilseeds remains low due to the low consumption of S fertilizers and a large propagation deficit. The sulphur requirements of oilseeds can be met by a number of S-containing materials, such as gypsum, phosphogypsum, S elements, pyrite and iron sulphate. It can also be added with fertilizers containing primary nutrients such as ammonium sulphate, SSP, potassium sulphate, etc.

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Comment [x34]: Not as per the format of the journal

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