Journal of Experimental Agriculture International

Volume 46, Issue 5, Page 556-562, 2024; Article no.JEAI.114655
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Role of Sulphur Nutrition in Oilseed Crops: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2024/v46i52410

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc. are available here: https://www.sdiarticle5.com/review-history/114655

Review Article

Received: 16/01/2024
Accepted: 22/03/2024
Published: 06/04/2024

ABSTRACT

India is a significant importer of edible oils and an important producer of oilseed. India stands as fourth leading oilseeds producing countries after USA, China and Brazil. Oilseed has become one of the most valuable agricultural commodities. Sulphur (S) plays an important role in determining the quality of oil seed from these crops. It is referred to as the fourth major nutrient after N, P and K because crops need sulphur slightly less than they require P. It is required for the formation of proteins, vitamins and chlorophyll. It is an integral part of amino acid such as cystine, cysteine and

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methionine which are essential components of protein. Plant can absorb sulphur in the form of sulphate (SO4 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.

1. 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 [1]. Oilseed self-sufficiency achieved during the "Yellow Revolution" in the early 1990s could only last for a limited time [2]. India is also one of the major oils importing country in the world. 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 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 [3]. Oilseeds are a vital component of our nutrition and the oil extracted from them is used in number of ways such as paints, varnishes, hydrogenated oil, soaps, perfumes, lubricants and other. Growing oilseeds may significantly alert the diet of human, improving food security and creating income generation.

Sulphur is one of the essential micronutrients that is need for higher yield and quality of oilseed crops. In accordance with its chemical nature, it plays significant role in a number of cellular metabolic process [4]. With an average concentration of 0.06 percent, it is the 13th most prevalent element in the crust of the earth. Sulphur comprises amino acids are cysteine, cystine and methionine, which makes it an essential factor for plant growth [5]. These amino acids contain almost 90% of the sulphur present in plant [6]. Crop cannot reach their maximum potential in terms of protein content, oil quality and yield without satisfying sulphur requirement [7,8,9]. 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 [10]. 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 [11]. Sulphur fertilization in oilseed crops help to increase the productivity of oilseed crops. It also 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.

Oilseed productivity is low, due to inadequate and unbalanced fertilization is the most important one. One of the main causes of imbalanced fertilization is sulphur deficiency. The shortage of S causes a reduction in plants' photosynthetic efficiency, which in turn causes a decline in crop productivity particularly in oilseed crops, which have a high S demand [12]. Sulphur deficiency causes by decreasing the supply of sulphate, which delays the crop maturity and reduces the plant height and quality [13,14]. And also reduces oil content and quality of oilseeds [15]. Sulphur deficiency in coarse texture soils is due to low availability of organic matter [16].

2. SULPHUR NUTRITION REQUIREMENTS IN OILSEED CROPS

Several researchers have determined the S need for oilseed crops in the field [17,18,19,20,21,22]. 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 [23,24,25]. 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 [23]. 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 [26]. Among various crops, oilseeds have higher sulphur requirements than cereals and pulses due to the crucial function that sulphur plays in the synthesis of oil and the

production of bold grains, which are necessary for the production of oil [27].

3. 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 ($S_2O_3^{-2}$). In addition, leaves can absorb a little amount of SO_2 [28]. The amount of sulphur present in oilseed crops is 1.1-1.7 %. Reduced amount of sulphur is applied to oilseed crops, which results in the production of low-quality seed [29]. In rapeseed-mustard, sulphur is necessary to enhance the quantity of glucosides, glucosinolate and protein [30]. Rapeseed-mustard is an important oilseed crop, has a high demand for sulphur. Due to its high sulphur requirements, application of 60 kg/ha significantly affected the amount of glucosinolate present and oil percentage increased by 44.6%.

When sulphur fertilizer levels increased from 0 to 60 kg S kg^{-1}, the content of allyl isothiocyanate in mustard seeds increased [30]. 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 [31].

4. 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 the quantity of various kind of chemicals and the composition overall. Sulphur improves the forage's digestibility for ruminants [32]. S enhanced the glucosinolate content of rapeseed [33]. S deficient rapeseed crop seed contains lesser erucic acid and linolenic and higher oleic acid [34]. The increase in protein content as a result of S application have been reported to be 14% in soybeans [35], 6% in lentils [36], 19% in sunflower [37], 28-34% in rapeseed and mustard [38]. S is a component of oil compounds and raises the oil content of the majority of crops. With S fertilization, an average 5% increase in oil content has been observed [38]. 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 [18]. Different sources of S for seed and oil yields, sulphur and oil contents and S uptake by mustard and revealed that all of these increased with each source of S, but element S was the best [39]. Sunflower seed weight and head diameter increased after S application [40]. In rapeseed-mustard, the S application increased oil yield by 16% and oil content by 3.4% [41].

5. 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} were effective [18]. Applying pyrites and elemental sulphur 20-25 days before planting is recommended since elemental sulphur requires oxidation, pyrites is a

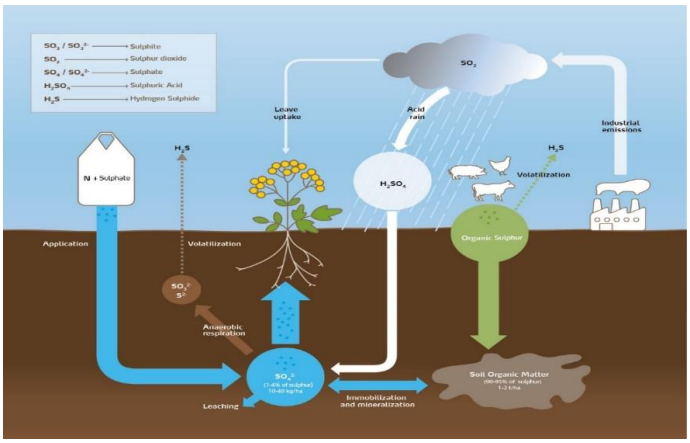

Fig. 1. Sulphur cycle

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

Fig. 2. Effect of sulphur in oilseed crops
Source: agritech.tnau.ac.in/agriculture/plant_nutri/sul.html

slow-release fertilizer [42]. 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 [30]. 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.

6. DEFICIENCY SYMPTOMS OF SULPHUR IN OILSEED CROPS

Since only nitrogen, phosphorus and potassium managed nutrients in India, there are significant sulphur deficiency problems [18]. There is a wide spread sulphur deficiency in the world's soil [43]. 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. Deficiency of sulphur mostly observed in the shoots rather than the roots, which causes plants become stunted and shoot become slender [44]. Sulphur deficiency leads to reduced root hydraulic conductivity, which is likely associated with indicating 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, trifoliate leaves grow and V-shape because they are upright from the petiole [45]. Young leaves of groundnut frequently develop chlorosis due to sulphur deficiency [46,47]. In rapeseeds, the young leaves become cupped shape with various shape ranging from pale green to complete yellow, including the vein, which can occasionally turn into—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.

7. ASSESSMENT OF SULPHUR IN SOIL AND PANT 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% $CaCl_2$ solution [48]. 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 [49].

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, HNO_3 and $HClO_4$ can be used, while dry ashing can be used to extract sulphur from plant digest [50].

8. 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 use–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 SO_4^{-2} and elemental S may be helpful.

9. EFFECT OF SULPHUR ON NUTRIENT UPTAKE OF OILSEED

In an experiment on groundnuts 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) [51]. Ammonium sulphate and the application of 20 kg 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} [52]. 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) [53]. Application of S enhanced the concentration and uptake of N, P, S, Fe and Zn but reported effect on the concentration of K, Mg, Mn or Cu in ground nut leaves [47]. Sulphur uptake (20.7 kg/ha) in Indian mustard has been reported highest because of 45 kg/ha Sulphur application. 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 [54,55].

10. CONCLUSION

In addition to promoting yield and quality, sulphur enhances the oil content in oilseed crops, contributing to better nutritional value. It also plays and 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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