



# International Journal of Research in Agronomy

E-ISSN: 2618-0618  
P-ISSN: 2618-060X  
© Agronomy  
NAAS Rating: 5.20  
[www.agronomyjournals.com](http://www.agronomyjournals.com)  
2025; 8(6): 631-637  
Received: 17-03-2025  
Accepted: 19-04-2025

**Subhajit Dutta**  
Department of Soil Science and  
Agricultural Chemistry, Institute  
of Agriculture, Palli Siksha  
Bhavana, Visva-Bharati,  
Sriniketan, Bolpur, West Bengal,  
India

## Effect of boron and sulphur on yield and quality of sesame (*Sesamum indicum* L.)

**Subhajit Dutta**

**DOI:** <https://www.doi.org/10.33545/2618060X.2025.v8.i6h.3087>

### Abstract

To study the effect of sulphur and boron on the yield and quality of sesame, a field experiment was conducted with four levels of sulphur (viz., 0, 20, 40, and 60 kg ha<sup>-1</sup>) and four levels of boron (viz., 0, 0.5, 1.0, and 1.5 kg ha<sup>-1</sup>). After harvesting, plant samples were analyzed for oil content and contents of N, P, K, and S, after recording the seed and stover yield. Sulphur and boron application significantly increased the plant height, number of capsules per plant, and stover yield. Sulphur application significantly increased seed yield up to 40 kg ha<sup>-1</sup>. Boron application increased seed yield significantly up to the highest level. Protein content in seeds was found to be decreased initially up to S<sub>40</sub> level and thereafter increased with the application of the highest dose of sulphur. Boron application significantly increased protein content up to its highest level. The oil content was increased with sulphur application up to its highest level. Oil yield was found to be increased up to the highest level of both nutrients. Boron and sulphur interacted synergistically in increasing oil yield. Sulphur and boron application increased chlorophyll content in leaves. Sulphur application up to 40 kg ha<sup>-1</sup> resulted in higher P, K, and S content in plants. Boron application increased phosphorus content in plants marginally. Nitrogen content in seeds was found to be decreased with sulphur application up to the S<sub>40</sub> level. Thereafter, it reached its maximum value with the application of the maximum dose of sulphur. Sulphur application resulted in increased K and S contents in seeds. The application of sulphur significantly increased N, P, K, and S uptake by stover. Both nutrients interacted synergistically in enhancing phosphorus uptake by the plant. Sulphur and boron application significantly increased N, P, and S uptake by seeds up to their respective highest levels. Boron application also increased P uptake by seeds. Total N, P, and K uptake by sesame was increased with the application of both sulphur and boron.

**Keywords:** Sesame, sulphur, boron, interaction

### 1. Introduction

Among the oil crops, sesame (*Sesamum indicum* L.) has the highest oil content of 46-64% (Raja *et al.*, 2007) [16]. It has a long shelf life. It contains about 47% oleic and 39% linoleic acid. Sesame seed oil is rich in omega-6 fatty acids as well as protein (25%) and carbohydrate (BARI, 2004) [1]. In oilseeds, sulphur plays a significant role in the quality and development of seeds. It is reported that sulphur plays an important role in the primary and secondary plant metabolism as a component of proteins, glucosinolates, and other compounds that are related to several parameters determining the nutritive quality of crops (Ceccotti, 1996) [5]. Sulphur is the fourth major nutrient next to N, P and K. It is required for the synthesis of sulphur containing amino acids such as cystine, cysteine and methionine which are essential components of proteins (Tisdale *et al.*, 1999) [29]. It is also involved in the activity of proteolytic enzymes, increased oil content in oil seeds, metabolism of carbohydrates, proteins and fats and is responsible for the formation of chlorophyll, biotin and thiamine. Therefore, crops of oilseeds require a higher quantity of sulphur for proper growth and development for higher yields (Salwa *et al.*, 2010) [17]. Optimum nutrition, among other agro-techniques, is very important for realizing full yield potential, and the role of sulphur is next only to nitrogen in the nutrition of this crop. S-deficiency causes a decrease in nitrate reductase activity and in the accumulation of chlorophyll, soluble protein, amino acid, and sugar (Tandon, 1986; Badruddin, 1999; Jamal *et al.*, 2006; Jamal *et al.*, 2009; Shilpi *et al.*, 2012) [26, 2, 11, 12, 20]. Lack of S causes retardation of terminal growth and root development. S deficiency induces chlorosis in young leaves and decreases seed

**Corresponding Author:**  
**Subhajit Dutta**  
Department of Soil Science and  
Agricultural Chemistry, Institute  
of Agriculture, Palli Siksha  
Bhavana, Visva-Bharati,  
Sriniketan, Bolpur, West Bengal,  
India

yield by 45% (BARI, 2004)<sup>[1]</sup>. Boron, along with sulphur, plays an important role in the production phenology of oilseed crops. Boron is one of the eight essential micronutrients required for the normal growth of most plants. Boron plays a vital role in oil synthesis. It is associated with the pollen-producing capacity of the anther, the viability of pollen tubes, pollen germination, and pollen tube growth. Boron deficiency is the most widespread among micronutrients around the world and causes large losses in crop production both quantitatively and qualitatively.

## 2. Materials and Methods

The experiment was conducted with four levels of boron (0, 0.5, 1.0, and 1.5 kg ha<sup>-1</sup>) and four levels of sulphur (0, 20, 40, and 60 kg ha<sup>-1</sup>) using sesame as a test crop, laid out in a two-factor factorial randomized block design with 16 treatments and replicated three times. A basal dose of 90 kg N/ha, 60kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, and 60 kg K<sub>2</sub>O ha<sup>-1</sup> was applied in each plot. As per the treatment specification, fertilizers were applied in the form of urea, triple-super phosphate, muriate of potash, gypsum, and borax. Fertilizers were applied at the time of sowing in furrows opened at definite row spacing as per the treatments. Growth and yield parameters like plant height, branches per plant, and number of capsules per plant were recorded. After harvesting, plants were analysed for grain and stover yield, oil contents, and contents of N, P, K, and S, and their uptake by sesame.

## 3. Results and Discussion

### 3.1. Effect of boron and sulphur on growth parameters

Results pertaining to the height of sesame plants are presented in Table 1. The plant height of sesame ranged between 72.33 and 107.33 cm. Sulphur and Boron application significantly increased the plant height, and it attained the highest value when both the nutrients were applied together at their respective highest levels. An increase in plant height with increasing sulphur level might result from the synthesis of sulphur-containing amino acids, proteins, and the activity of proteolytic enzymes.

The number of branches per plant varied between 2.67 and 5.00 (Table 1). The minimum number of branches was obtained with the application of sulphur @ 20 kg ha<sup>-1</sup> and B @ 0.5 kg ha<sup>-1</sup>, and the maximum number of branches per plot was recorded in plots receiving the same level of boron along with application of sulphur @ 40 kg ha<sup>-1</sup>. The effect of different levels of sulphur and boron was not found to be statistically significant.

The data pertaining to the number of capsules in the plant is presented in Table 1. It indicated that application of sulphur @ 60 kg ha<sup>-1</sup> recorded the highest number of capsules plant<sup>-1</sup> over other treatments. A higher number of capsules in a plant with the application of sulphur may be attributed to an increase in photosynthetic activity of the plants and increased plant growth, which ultimately resulted in higher yield. These results were corroborated by the findings of Yadav *et al.* (2009)<sup>[32]</sup>. Boron application significantly increased the number of capsules per plant up to its highest level. Boron promotes the pollen-producing capacity of anthers and hence might have produced a higher number of seeds per capsule. It also has a positive effect on the photosynthetic performance of plants by influencing

phosphorylation processes, reducing the quantity of assimilates consumed by respiration to obtain energy, and accelerating the removal of products of photosynthesis.

### 3.2. Effect of boron and sulphur on yield of sesame

There was an increase in stover yield with increasing levels of sulphur (Table 1). The maximum stover yield was obtained with the application of sulphur and boron at their highest level. Minimum stover yield was recorded in the control plots. The yield at control was at par with the yield obtained with the application of sulphur @ 20 Kg ha<sup>-1</sup>. Beyond this level, increasing the sulphur level increased stover yield significantly up to the highest level of sulphur. Boron application also increased stover yield significantly up to the highest level. Sulphur, like N, improves cell division and cell elongation and has a favourable influence on chlorophyll synthesis. This might have contributed to the increased stover yield. The positive influence of S and B in improving yield and yield attributes of sunflower was reported earlier by Shekawat and Shivay (2008)<sup>[21]</sup>.

Seed yield of sesame ranged between 3.85 and 5.73 q ha<sup>-1</sup> (Table 1). Minimum yield was recorded in control plots, and the maximum yield was obtained with the application of a full dose of boron along with sulphur application @ 40 kg ha<sup>-1</sup>. Sulphur application significantly increased seed yield up to 40 kg ha<sup>-1</sup>. Beyond this level, there was no significant response of sulphur in increasing seed yield. Boron application increased seed yield significantly up to the highest level. The highest per cent increase in yield (49%) was recorded with the highest levels of B along with sulphur application @ 40 kg ha<sup>-1</sup>. This shows that both S and B play an important role in the production of oilseed crops. The increase in seed yield might be due to the fact that sulphur promotes photosynthesis, net assimilation rate, and crop growth rate, which causes more seed yield. Sulphur helps in primordial floral initiation, resulting in a greater number of capsules per plant and an increasing number of seeds per capsule. Also, S is required for the synthesis of S-containing amino acids and proteins, increases oil content, helps in the formation of chlorophyll, biotin, and thiamine, and plays an important role in the metabolism of carbohydrates, proteins, and fats (Takahashi *et al.*, 2000)<sup>[28]</sup>. On the other hand, boron is associated with cell division, flowering and fruiting, water relations, and catalyst for certain reactions (Berger, 1949; Sprague, 1951)<sup>[3, 25]</sup>. B is needed for carbohydrate transport as well as cellular differentiation and development. It also enhances the pollen-producing capacity of anthers, the viability of pollen tubes, pollen germination, and pollen tube growth. Moreover, a balanced supply of nutrients owing to sulphur and boron addition might be involved in the improvement of yield-related traits of sesame, leading to higher seed yield. Saren *et al.* (2004)<sup>[18]</sup> found that the grain yield of sesame was increased due to increasing levels of S. The increase in grain yield is largely a function of improvement in the yield attributes. These results are in agreement with the findings of Sarkar and Saha (2005)<sup>[19]</sup>. The positive influence of S and B in improving the yield and yield attributes was also reported by Shekawat and Shivay (2008)<sup>[21]</sup> in case of sunflower.

**Table 1:** Effect of boron and sulphur levels on Growth parameter & Yield attribute of sesame-

|                 | Levels (Kg ha <sup>-1</sup> )    | Plant height (cm) | Branches per plant | Capsules per plant | Stover yield (q ha <sup>-1</sup> ) | Seed yield (q ha <sup>-1</sup> ) |
|-----------------|----------------------------------|-------------------|--------------------|--------------------|------------------------------------|----------------------------------|
| Sulphur         | S <sub>0</sub>                   | 89.08             | 3.92               | 54.00              | 20.89                              | 4.84                             |
|                 | S <sub>20</sub>                  | 88.08             | 3.33               | 56.50              | 21.01                              | 4.87                             |
|                 | S <sub>40</sub>                  | 93.00             | 3.92               | 58.58              | 23.07                              | 5.45                             |
|                 | S <sub>60</sub>                  | 99.08             | 4.58               | 60.83              | 24.03                              | 5.32                             |
| Boron           | B <sub>0</sub>                   | 81.50             | 4.17               | 50.83              | 21.62                              | 4.65                             |
|                 | B <sub>0.5</sub>                 | 83.92             | 4.08               | 58.92              | 21.50                              | 4.77                             |
|                 | B <sub>1</sub>                   | 100.83            | 3.83               | 56.08              | 22.67                              | 5.36                             |
|                 | B <sub>1.5</sub>                 | 103.00            | 3.67               | 64.08              | 23.21                              | 5.70                             |
| Sulphur X Boron | S <sub>0</sub> B <sub>0</sub>    | 72.33             | 4.67               | 46.67              | 17.07                              | 3.85                             |
|                 | S <sub>0</sub> B <sub>0.5</sub>  | 85.00             | 4.00               | 53.67              | 19.40                              | 4.23                             |
|                 | S <sub>0</sub> B <sub>1</sub>    | 101.67            | 4.00               | 55.00              | 23.83                              | 5.53                             |
|                 | S <sub>0</sub> B <sub>1.5</sub>  | 97.33             | 3.00               | 60.67              | 23.27                              | 5.73                             |
|                 | S <sub>20</sub> B <sub>0</sub>   | 76.00             | 4.00               | 49.67              | 21.57                              | 4.26                             |
|                 | S <sub>20</sub> B <sub>0.5</sub> | 78.33             | 2.67               | 55.67              | 19.13                              | 4.25                             |
|                 | S <sub>20</sub> B <sub>1</sub>   | 97.33             | 3.33               | 55.67              | 22.03                              | 5.33                             |
|                 | S <sub>20</sub> B <sub>1.5</sub> | 100.67            | 3.33               | 65.00              | 21.30                              | 5.64                             |
|                 | S <sub>40</sub> B <sub>0</sub>   | 82.00             | 3.33               | 50.33              | 23.67                              | 5.27                             |
|                 | S <sub>40</sub> B <sub>0.5</sub> | 81.67             | 5.00               | 65.33              | 23.17                              | 5.34                             |
|                 | S <sub>40</sub> B <sub>1</sub>   | 101.67            | 3.67               | 55.67              | 22.37                              | 5.47                             |
|                 | S <sub>40</sub> B <sub>1.5</sub> | 106.67            | 3.67               | 63.00              | 23.07                              | 5.73                             |
|                 | S <sub>60</sub> B <sub>0</sub>   | 95.67             | 4.67               | 56.67              | 24.17                              | 5.19                             |
|                 | S <sub>60</sub> B <sub>0.5</sub> | 90.67             | 4.67               | 61.00              | 24.30                              | 5.27                             |
|                 | S <sub>60</sub> B <sub>1</sub>   | 102.67            | 4.33               | 58.00              | 22.43                              | 5.10                             |
|                 | S <sub>60</sub> B <sub>1.5</sub> | 107.33            | 4.67               | 67.67              | 25.20                              | 5.70                             |
| S.Em (±)        | Boron                            | 0.89              | 0.30               | 1.64               | 0.22                               | 0.08                             |
|                 | Sulphur                          | 0.89              | 0.30               | 1.64               | 0.22                               | 0.08                             |
|                 | Sulphur X Boron                  | 1.78              | 0.60               | 3.28               | 0.44                               | 0.17                             |
| C.D (P=0.05)    | Boron                            | 2.57              | NS                 | 4.74               | 0.64                               | 0.24                             |
|                 | Sulphur                          | 2.57              | NS                 | 4.74               | 0.64                               | 0.24                             |
|                 | Sulphur X Boron                  | 5.14              | NS                 | NS                 | 1.28                               | 0.48                             |

NS- Non-Significant

### 3.3. Effect of boron and sulphur on protein content, oil content, and oil yield of sesame

Results on crude protein content in sesame are present in Table 2. A close perusal of data reveals that significantly maximum protein content (17.38%) was observed in plots receiving no sulphur with B application @1.5kg ha<sup>-1</sup> and the minimum value (9.57%) was seen in the plots receiving no sulphur and B application @ 0.5 kg ha<sup>-1</sup>. Like nitrogen content in seeds, it was found to be decreased initially up to the S40 level and thereafter increased with the application of the highest dose of sulphur. Boron application significantly increased protein content up to its highest level. The increase in protein content might be due to the accumulation of biological molecules like cysteine, methionine, and cysteine. It is clear from the table that significantly maximum protein content (17.38%) was observed when no sulphur was applied. This is because sulphur is the essential component of cysteine, methionine, and cysteine, which are the protein-building amino acids, and as the oil content increases, the protein content decreases.

Oil content of sesame seeds varied from 32.73% to 44.47% (table 2). The minimum value was recorded in plots receiving B @ 1kg ha<sup>-1</sup> with no sulphur, and the maximum value was recorded in plots receiving the highest level of sulphur with boron application @ 0.5 kg ha<sup>-1</sup>. Sulphur application significantly increased oil content up to its highest level. The effect of boron on oil content was not found to be statistically significant. The interaction effect between boron and sulphur was also not significant. Higher levels of S application improved the oil contents at the expense of protein contents. The increase in oil content might be due to more sulphur storage in the plant. An increase in oil content was also observed in the soybean seed by Malewar *et al.* (2001)<sup>[15]</sup>. They concluded that the increase in oil content was the result of the direct involvement of S in the

synthesis of lipids, fatty acids, and the synthesis of acetyl-CoA enzyme. In this conversion, an enzyme thiokinase is involved in sulphur supply; moreover, acetyl co-enzyme itself contains S and sulphydryl groups. Increase in oil content of sesame with the application of boron might be due to its role in different metabolic processes of the plant. Bhonwase and Tamboli (2002)<sup>[4]</sup> also found a beneficial effect of the integrated use of potassium, sulphur, and boron on the yield and oil content of sunflower under dry land conditions. Sulphur is an integral part of biological molecules like cysteine, methionine, and cystine, which cause variation in oil content. They concluded that as the sulphur level increased, the oil content increased in sesame. This is because the availability of sulphur enhances the sulphur storage, which is involved in oil formation.

Both nutrients exerted their positive response on increasing oil yield significantly (Table 2). Oil yield was found to be increased up to the highest level of both nutrients. Boron and sulphur interacted synergistically in increasing oil yield. Increase in oil yield of sesame with application of boron and sulphur was attributed to the favourable effect of both the nutrients on oil content as well as seed yield.

### 3.4. Effect of boron and sulphur on chlorophyll content in leaves before and after the flowering stage of sesame

Leaf chlorophyll content before the flowering stage ranged between 1.76 and 3.36 mg g<sup>-1</sup> fresh weight (Table 2). The application of sulphur significantly increased chlorophyll contents. Boron application also increased chlorophyll content in leaves before the flowering stage.

A similar trend was observed after flowering also. At this stage, leaf chlorophyll content varied from 1.29 to 2.61 mg g<sup>-1</sup> fresh weight (Table 2). The highest value was recorded in the plot receiving the highest doses of both nutrients.

**Table 2:** Effect of boron and sulphur levels on protein (%), oil content (%), Oil Yield (Kg ha<sup>-1</sup>), and Chlorophyll content before and after flowering of sesame (mg g<sup>-1</sup> FW)

|                 | Levels (Kg ha <sup>-1</sup> )    | Protein (%) | Oil content (%) | Oil yield (kg ha <sup>-1</sup> ) | Chlorophyll content before flowering (mg g <sup>-1</sup> FW) | Chlorophyll content after flowering (mg g <sup>-1</sup> FW) |
|-----------------|----------------------------------|-------------|-----------------|----------------------------------|--------------------------------------------------------------|-------------------------------------------------------------|
| Sulphur         | S <sub>0</sub>                   | 14.35       | 34.15           | 164.6                            | 2.39                                                         | 1.86                                                        |
|                 | S <sub>20</sub>                  | 13.13       | 35.69           | 173.2                            | 2.55                                                         | 2.10                                                        |
|                 | S <sub>40</sub>                  | 13.50       | 37.98           | 207.0                            | 2.79                                                         | 2.28                                                        |
|                 | S <sub>60</sub>                  | 15.37       | 42.74           | 226.8                            | 2.82                                                         | 2.19                                                        |
| Boron           | B <sub>0</sub>                   | 13.48       | 38.44           | 179.6                            | 2.09                                                         | 1.76                                                        |
|                 | B <sub>0.5</sub>                 | 13.65       | 37.92           | 182.3                            | 2.58                                                         | 2.09                                                        |
|                 | B <sub>1</sub>                   | 13.71       | 37.86           | 202.2                            | 2.68                                                         | 2.12                                                        |
|                 | B <sub>1.5</sub>                 | 15.52       | 36.35           | 207.5                            | 3.19                                                         | 2.47                                                        |
| Sulphur X Boron | S <sub>0</sub> B <sub>0</sub>    | 13.30       | 35.13           | 135.4                            | 1.76                                                         | 1.29                                                        |
|                 | S <sub>0</sub> B <sub>0.5</sub>  | 9.57        | 34.70           | 146.8                            | 2.34                                                         | 2.18                                                        |
|                 | S <sub>0</sub> B <sub>1</sub>    | 17.15       | 32.73           | 180.7                            | 2.42                                                         | 1.92                                                        |
|                 | S <sub>0</sub> B <sub>1.5</sub>  | 17.38       | 34.03           | 195.6                            | 3.05                                                         | 2.07                                                        |
|                 | S <sub>20</sub> B <sub>0</sub>   | 13.30       | 37.47           | 159.8                            | 2.20                                                         | 1.86                                                        |
|                 | S <sub>20</sub> B <sub>0.5</sub> | 13.65       | 36.03           | 153.2                            | 2.50                                                         | 2.07                                                        |
|                 | S <sub>20</sub> B <sub>1</sub>   | 12.02       | 36.20           | 192.9                            | 2.48                                                         | 2.07                                                        |
|                 | S <sub>20</sub> B <sub>1.5</sub> | 13.53       | 33.07           | 187.0                            | 3.01                                                         | 2.42                                                        |
|                 | S <sub>40</sub> B <sub>0</sub>   | 13.53       | 39.80           | 209.9                            | 2.19                                                         | 2.00                                                        |
|                 | S <sub>40</sub> B <sub>0.5</sub> | 14.58       | 36.47           | 195.0                            | 2.69                                                         | 2.20                                                        |
|                 | S <sub>40</sub> B <sub>1</sub>   | 10.38       | 39.47           | 215.7                            | 2.94                                                         | 2.16                                                        |
|                 | S <sub>40</sub> B <sub>1.5</sub> | 15.52       | 36.20           | 207.5                            | 3.35                                                         | 2.76                                                        |
|                 | S <sub>60</sub> B <sub>0</sub>   | 13.77       | 41.37           | 213.3                            | 2.22                                                         | 1.87                                                        |
|                 | S <sub>60</sub> B <sub>0.5</sub> | 16.80       | 44.47           | 234.2                            | 2.81                                                         | 1.94                                                        |
|                 | S <sub>60</sub> B <sub>1</sub>   | 15.28       | 43.03           | 219.6                            | 2.90                                                         | 2.34                                                        |
|                 | S <sub>60</sub> B <sub>1.5</sub> | 15.63       | 42.10           | 240.1                            | 3.36                                                         | 2.61                                                        |
| S.Em (±)        | Boron                            | 0.19        | 0.73            | 4.2                              | 0.10                                                         | 0.08                                                        |
|                 | Sulphur                          | 0.19        | 0.73            | 4.2                              | 0.10                                                         | 0.08                                                        |
|                 | Sulphur X Boron                  | 0.39        | 1.46            | 8.4                              | 0.19                                                         | 0.17                                                        |
| C.D (P=0.05)    | Boron                            | 0.56        | NS              | 12.2                             | 0.28                                                         | 0.24                                                        |
|                 | Sulphur                          | 0.56        | 2.11            | 12.2                             | 0.28                                                         | 0.24                                                        |
|                 | Sulphur X Boron                  | 1.12        | NS              | 24.3                             | 0.56                                                         | NS                                                          |

FW- Fresh Weight; NS- Non-Significant

### 3.5. Effect of boron and sulphur on nutrient contents

#### 3.5.1. Effect of boron and sulphur on nutrient contents in stover

Nitrogen content in plants ranged between 0.45% and 0.54% (Table 3). The minimum value was recorded in the control plots, and the maximum one was recorded in the plots receiving the highest dose of sulphur with boron application @ 1 kg ha<sup>-1</sup>. However, no treatment effect was found to be significant in influencing nitrogen content in plants.

Phosphorus content in plants ranged between 0.13 and 0.29% (Table 3) depending on treatment combinations. Sulphur application up to 60 kg ha<sup>-1</sup> resulted in higher phosphorus content in plants. Application of sulphur at 60 kg ha<sup>-1</sup> did not increase phosphorus content in the plant. The phosphorus content in plants become doubled with the application of sulphur. It was found to be increased from 0.13% in S<sub>0</sub> treatment to 0.29% in S<sub>60</sub> treatment. Boron application increased phosphorus content in plants marginally.

Sulphur application significantly increased potassium content up to the highest dose (Table 3). The effect of boron on potassium content in plants was not found to be statistically significant. The interaction effect between these nutrients was also not statistically significant.

Sulphur application increased the sulphur content in the plant nearly three times (Table 3). The minimum value of 0.11% was recorded in plots receiving no sulphur and a full dose of boron. The maximum value (0.32%) was recorded in plots receiving the full dose of sulphur with application of boron @ 0.5 kg ha<sup>-1</sup>. The effect of boron on sulphur content was not significant.

#### 3.5.2. Effect of boron and sulphur on nutrient contents in seed

Data on nitrogen content in seed is presented in Table 3. It ranged between 1.53 and 2.78%. It was found to be decreased with sulphur application up to the S<sub>40</sub> level. Thereafter, it reached its maximum value with the application of the maximum dose of sulphur. The initial decrease in the value may be due to the dilution effect due to increased seed yield with the application of sulphur up to the S<sub>40</sub> level. Thereafter, it was increased due to the influence of sulphur on protein synthesis. Boron application significantly increased nitrogen content in seeds.

Phosphorus content in sesame seed varied between 0.52 and 0.67% (Table 3). No treatment effect was found to be statistically significant in influencing phosphorus concentration in the seeds of sesame.

Potassium content in seeds was influenced by the application of both nutrients (Table 3). Sulphur application resulted in increased potassium content in seeds. However, the increase in potassium content with sulphur application beyond the S<sub>20</sub> level was not statistically significant. Boron application initially decreased the values and thereafter increased potassium content, resulting in maximum potassium content at the B<sub>1</sub> level. Further increase in boron application did not result significant change in potassium content.

Sulphur content in the seed was increased significantly with sulphur application (Table 3). Here, the effect of boron was not significant. The minimum value was recorded with application of no sulphur, and the maximum value was recorded in plots receiving the full dose of sulphur along with the full dose of boron.

**Table 3:** Effect of boron and sulphur levels on nutrient content of stover and seed-

|                 | Levels (Kg ha <sup>-1</sup> )    | Stover (%) |      |      |      | Seed (%) |      |      |      |
|-----------------|----------------------------------|------------|------|------|------|----------|------|------|------|
|                 |                                  | N          | P    | K    | S    | N        | P    | K    | S    |
| Sulphur         | S <sub>0</sub>                   | 0.51       | 0.15 | 0.39 | 0.12 | 2.30     | 0.56 | 1.06 | 0.17 |
|                 | S <sub>20</sub>                  | 0.51       | 0.18 | 0.42 | 0.15 | 2.10     | 0.61 | 1.14 | 0.19 |
|                 | S <sub>40</sub>                  | 0.49       | 0.23 | 0.43 | 0.18 | 2.16     | 0.55 | 1.12 | 0.21 |
|                 | S <sub>60</sub>                  | 0.51       | 0.24 | 0.48 | 0.26 | 2.46     | 0.56 | 1.14 | 0.25 |
| Boron           | B <sub>0</sub>                   | 0.49       | 0.20 | 0.42 | 0.18 | 2.16     | 0.57 | 1.11 | 0.21 |
|                 | B <sub>0.5</sub>                 | 0.50       | 0.22 | 0.42 | 0.19 | 2.18     | 0.54 | 1.06 | 0.20 |
|                 | B <sub>1</sub>                   | 0.53       | 0.17 | 0.46 | 0.18 | 2.19     | 0.58 | 1.16 | 0.20 |
|                 | B <sub>1.5</sub>                 | 0.50       | 0.22 | 0.42 | 0.17 | 2.48     | 0.59 | 1.14 | 0.20 |
| Sulphur X Boron | S <sub>0</sub> B <sub>0</sub>    | 0.45       | 0.14 | 0.34 | 0.13 | 2.13     | 0.54 | 1.14 | 0.17 |
|                 | S <sub>0</sub> B <sub>0.5</sub>  | 0.54       | 0.16 | 0.40 | 0.12 | 1.53     | 0.54 | 0.92 | 0.18 |
|                 | S <sub>0</sub> B <sub>1</sub>    | 0.56       | 0.13 | 0.45 | 0.12 | 2.74     | 0.57 | 1.11 | 0.16 |
|                 | S <sub>0</sub> B <sub>1.5</sub>  | 0.50       | 0.18 | 0.37 | 0.11 | 2.78     | 0.60 | 1.09 | 0.15 |
|                 | S <sub>20</sub> B <sub>0</sub>   | 0.53       | 0.14 | 0.44 | 0.16 | 2.13     | 0.59 | 1.13 | 0.19 |
|                 | S <sub>20</sub> B <sub>0.5</sub> | 0.47       | 0.21 | 0.36 | 0.15 | 2.18     | 0.53 | 1.10 | 0.19 |
|                 | S <sub>20</sub> B <sub>1</sub>   | 0.50       | 0.15 | 0.43 | 0.14 | 1.92     | 0.62 | 1.16 | 0.19 |
|                 | S <sub>20</sub> B <sub>1.5</sub> | 0.52       | 0.20 | 0.44 | 0.15 | 2.17     | 0.68 | 1.19 | 0.18 |
|                 | S <sub>40</sub> B <sub>0</sub>   | 0.49       | 0.22 | 0.42 | 0.18 | 2.17     | 0.60 | 1.06 | 0.20 |
|                 | S <sub>40</sub> B <sub>0.5</sub> | 0.46       | 0.27 | 0.45 | 0.18 | 2.33     | 0.55 | 1.09 | 0.21 |
|                 | S <sub>40</sub> B <sub>1</sub>   | 0.53       | 0.18 | 0.47 | 0.21 | 1.66     | 0.55 | 1.28 | 0.21 |
|                 | S <sub>40</sub> B <sub>1.5</sub> | 0.49       | 0.25 | 0.39 | 0.18 | 2.48     | 0.52 | 1.04 | 0.21 |
|                 | S <sub>60</sub> B <sub>0</sub>   | 0.50       | 0.29 | 0.50 | 0.25 | 2.20     | 0.56 | 1.12 | 0.27 |
|                 | S <sub>60</sub> B <sub>0.5</sub> | 0.53       | 0.23 | 0.47 | 0.32 | 2.69     | 0.52 | 1.11 | 0.23 |
|                 | S <sub>60</sub> B <sub>1</sub>   | 0.54       | 0.20 | 0.48 | 0.23 | 2.45     | 0.57 | 1.08 | 0.23 |
|                 | S <sub>60</sub> B <sub>1.5</sub> | 0.48       | 0.23 | 0.48 | 0.26 | 2.50     | 0.57 | 1.23 | 0.25 |
| S.Em (±)        | Boron                            | 0.02       | 0.01 | 0.02 | 0.01 | 0.03     | 0.01 | 0.01 | 0.01 |
|                 | Sulphur                          | 0.02       | 0.01 | 0.02 | 0.01 | 0.03     | 0.01 | 0.01 | 0.01 |
|                 | Sulphur X Boron                  | 0.03       | 0.02 | 0.03 | 0.02 | 0.06     | 0.03 | 0.02 | 0.01 |
| C.D (P=0.05)    | Boron                            | NS         | 0.02 | NS   | NS   | 0.09     | NS   | 0.03 | NS   |
|                 | Sulphur                          | NS         | 0.02 | 0.05 | 0.02 | 0.09     | NS   | 0.03 | 0.02 |
|                 | Sulphur X Boron                  | NS         | 0.04 | NS   | 0.05 | 0.18     | NS   | 0.07 | NS   |

### 3.6. Effect of boron and sulphur on nutrient uptake

#### 3.6.1. Effect of boron and sulphur on nutrient uptake by stover

Data pertaining to nitrogen uptake by stover is presented in Table 4. A close perusal of the data reveals that the application of sulphur significantly increased nitrogen uptake by stover. It was found to be increased significantly up to the highest dose of sulphur application. Boron application also increased nitrogen uptake by stover, and the maximum nitrogen uptake was recorded in plots receiving boron @1 kg ha<sup>-1</sup>. However, the effect of boron was not found to be statistically significant.

Phosphorus uptake by stover was also increased significantly up to the highest levels of both nutrients. Both nutrients interacted synergistically in enhancing phosphorus uptake by the plant.

Sulphur application significantly increased potassium uptake by stover. Like nitrogen uptake, boron application also increased potassium uptake by stover at B<sub>1</sub> treatments. However, the effect of boron was statistically insignificant.

Sulphur application increased sulphur uptake by stover from 2.26% in the control to 7.75% in plots receiving S @ 60 kg ha<sup>-1</sup>. The effect of boron in enhancing sulphur uptake by stover was not statistically significant.

#### 3.6.2. Effect of boron and sulphur on nutrient uptake by seed

Nitrogen uptake by seeds of sesame ranged between 6.48 kg ha<sup>-1</sup> and 15.96 kg ha<sup>-1</sup> (Table 4). Sulphur application significantly increased nitrogen uptake up to its highest level. Boron application also resulted in increased nitrogen uptake by seeds.

There was a significant increase in phosphorus uptake by seeds with the application of boron (Table 4). The values ranged from 2.08 kg ha<sup>-1</sup> in the control plots to 3.86 kg ha<sup>-1</sup> in plots receiving the full dose of boron application along with sulphur @ 20 kg

ha<sup>-1</sup>. Boron application significantly increased phosphorus uptake by seeds; however, the effect of sulphur on phosphorus uptake by seeds was not significant.

Potassium uptake by sesame seeds ranged between 3.89 kg ha<sup>-1</sup> and 7.06 kg ha<sup>-1</sup>. Sulphur application significantly increased potassium uptake by seeds. Boron application also resulted in increased potassium uptake by the seeds. Boron and sulphur interacted synergistically in increasing potassium uptake by crops.

Sulphur uptake by sesame seeds ranged between 0.65 kg ha<sup>-1</sup> and 1.44 kg ha<sup>-1</sup> (Table 4). The minimum value was recorded in the control plots, and the maximum value was obtained in the plots receiving the highest doses of both nutrients. However, the interaction effect of these two nutrients was not statistically significant. The above results revealed that with the increase in S dose, the uptake of sulphur was also increased due to high S content and high grain yield. These results are in agreement with those of Ganeshamurthy (1996) [9], who reported that sulphur significantly increased the S uptake. A similar result was documented by Chand *et al.* (1997) [6] in mustard. The increased seed yield was mainly responsible for increased uptake of nitrogen, phosphorus, and sulphur by seeds. The results are in close agreement with Yadav *et al.* (1996) [31].

#### 3.6.3. Effect of boron and sulphur on total nutrient uptake by sesame

Total nitrogen uptake by sesame ranged between 16.98 kg ha<sup>-1</sup> and 26.97 kg ha<sup>-1</sup> (Table 4). Both values were recorded in plots receiving B @ 0.5kg ha<sup>-1</sup>. The minimum value was recorded in plots receiving no sulphur, and the maximum value was recorded in plots receiving the full dose of sulphur, i.e., 60 kg ha<sup>-1</sup>. Increased uptake of N by crop due to S may be result of

assimilation pattern of N and S in plant, they go hand in hand (Dayanand and Shivram *et al.*, 2002) [7]. An increase in uptake of N, P, K, and S with every incremental dose of S to mustard was recently reported by Upadhyay (2012) [30]. Debnath and Ghosh (2011) [8] opined that the application of boron in boron-deficient soil might have resulted in increased availability of boron, which in turn has influenced DNA and protein synthesis, leading to increased nitrogen content and uptake.

Total phosphorus uptake was also increased with the application of both nutrients (Table 4). The beneficial role of sulphur in mobilizing soil P and its use by crops was also reported by Jain and Saxena (1991) [13]. Moreover, increase in the phosphorus content with the increase in boron application could be due to favourable influence of boron on various metabolic processes like photosynthesis, respiration, enzyme activity (Gannie *et al.*, 2013) [10] which augments the production of metabolites and their translocation to different parts including seed which ultimately increases the concentration of nutrients in seed and stover.

Potassium uptake by sesame was found to be increased with increasing doses of both nutrients. The values ranged between 10.08 kg ha<sup>-1</sup> and 19.22 kg ha<sup>-1</sup> (Table 4). The minimum value was recorded in the control plots, and the maximum value was recorded in the plots receiving the highest doses of both nutrients. Both nutrients interacted synergistically in increasing potassium uptake by the crop. Malewar *et al.* 2001 [15] observed increased uptake of phosphorus and potassium by soybean. They opined that this increased uptake of P and K was due to the synergistic effect of B on P and K absorption and their utilization by the crop. Singh *et al.* (1996) [22] also found an increase in uptake of P and K with the application of boron.

Total sulphur uptake was increased nearly threefold with the application of sulphur (Table 4). The minimum value of 2.91 kg ha<sup>-1</sup> in control plots and the maximum value of 8.96 kg ha<sup>-1</sup> were obtained in plots receiving the full dose of sulphur with the combined application of boron @ 0.5 kg ha<sup>-1</sup>. The effect of boron in enhancing the sulphur uptake of sesame was not statistically significant.

This shows the synergistic influence of S and B in making the availability of nutrients to the plant parts. Uptake of N, P, K, and S was positively influenced by the interaction between these two nutrients for both stover and grain. This shows the favourable influence of S and B in making the availability of these nutrients to the plant parts. Better translocation of nutrients to the reproductive part due to boron was also reported by Survase *et al.* (1986) [24], a synergistic effect of boron with NPK and sulphur was also given by Tandon *et al.* (1989) [27]. The increase in the content and uptake of potassium, sulphur, and boron by boron fertilization could be attributed to better growth of the crop, resulting in greater absorption of nutrients from the soil, leading to its higher content and uptake. They concluded that the increase in the boron content with the increase in levels of boron could be attributed to the increased concentration of boron in the soil.

The increased availability of nutrients in the root zone, coupled with increased metabolic activity, might have increased potassium, sulphur, and boron absorption, accumulation, and uptake subsequently (Jat and Mehra, 2007) [14]. Sulphur content also increases due to rapid absorption and translocation of sulphur by the plant with adequate sulphur from the soil (Shrivastava *et al.*, 2000) [23], leading to improved sulphur content and uptake by the crop.

**Table 4:** Effect of boron and sulphur levels on nutrient content of stover and seed-

|                 | Levels (Kg ha <sup>-1</sup> )    | Stover (Kg ha <sup>-1</sup> ) |      |       |      | Seed (Kg ha <sup>-1</sup> ) |      |      |      | Total (Kg ha <sup>-1</sup> ) |      |       |      |
|-----------------|----------------------------------|-------------------------------|------|-------|------|-----------------------------|------|------|------|------------------------------|------|-------|------|
|                 |                                  | N                             | P    | K     | S    | N                           | P    | K    | S    | N                            | P    | K     | S    |
| Sulphur         | S <sub>0</sub>                   | 11.10                         | 3.19 | 8.22  | 2.48 | 11.46                       | 2.75 | 5.15 | 0.79 | 22.58                        | 5.94 | 13.38 | 3.28 |
|                 | S <sub>20</sub>                  | 10.64                         | 3.68 | 8.81  | 3.12 | 10.20                       | 2.98 | 5.60 | 0.92 | 20.84                        | 6.66 | 14.40 | 4.04 |
|                 | S <sub>40</sub>                  | 11.36                         | 5.35 | 9.97  | 4.29 | 11.80                       | 3.03 | 6.12 | 1.13 | 23.15                        | 8.38 | 16.09 | 5.42 |
|                 | S <sub>60</sub>                  | 12.25                         | 5.70 | 11.59 | 6.38 | 13.07                       | 2.95 | 6.05 | 1.30 | 25.31                        | 8.65 | 17.64 | 7.69 |
| Boron           | B <sub>0</sub>                   | 10.96                         | 4.37 | 9.31  | 3.98 | 10.02                       | 2.67 | 5.15 | 0.98 | 21.01                        | 7.04 | 14.46 | 4.96 |
|                 | B <sub>0.5</sub>                 | 10.80                         | 4.71 | 9.13  | 4.24 | 10.59                       | 2.56 | 5.06 | 0.98 | 21.39                        | 7.28 | 14.20 | 5.22 |
|                 | B <sub>1</sub>                   | 12.07                         | 3.75 | 10.31 | 3.96 | 11.75                       | 3.11 | 6.22 | 1.06 | 23.82                        | 6.86 | 16.54 | 5.01 |
|                 | B <sub>1.5</sub>                 | 11.51                         | 5.08 | 9.83  | 4.10 | 14.15                       | 3.38 | 6.48 | 1.13 | 25.67                        | 8.45 | 16.31 | 5.23 |
| Sulphur X Boron | S <sub>0</sub> B <sub>0</sub>    | 8.91                          | 2.31 | 5.70  | 2.26 | 8.20                        | 2.08 | 4.38 | 0.65 | 17.20                        | 4.39 | 10.08 | 2.91 |
|                 | S <sub>0</sub> B <sub>0.5</sub>  | 10.50                         | 3.02 | 7.87  | 2.34 | 6.48                        | 2.30 | 3.89 | 0.78 | 16.98                        | 5.32 | 11.76 | 3.12 |
|                 | S <sub>0</sub> B <sub>1</sub>    | 13.41                         | 3.19 | 10.64 | 2.79 | 15.19                       | 3.18 | 6.12 | 0.90 | 28.60                        | 6.37 | 16.76 | 3.69 |
|                 | S <sub>0</sub> B <sub>1.5</sub>  | 11.58                         | 4.24 | 8.68  | 2.55 | 15.96                       | 3.44 | 6.23 | 0.84 | 27.54                        | 7.68 | 14.92 | 3.39 |
|                 | S <sub>20</sub> B <sub>0</sub>   | 11.35                         | 2.95 | 9.60  | 3.40 | 9.07                        | 2.53 | 4.81 | 0.81 | 20.42                        | 5.48 | 14.41 | 4.21 |
|                 | S <sub>20</sub> B <sub>0.5</sub> | 9.10                          | 4.08 | 6.82  | 2.78 | 9.29                        | 2.26 | 4.68 | 0.82 | 18.38                        | 6.34 | 11.51 | 3.60 |
|                 | S <sub>20</sub> B <sub>1</sub>   | 11.04                         | 3.35 | 9.43  | 3.18 | 10.23                       | 3.28 | 6.20 | 1.00 | 21.27                        | 6.63 | 15.63 | 4.18 |
|                 | S <sub>20</sub> B <sub>1.5</sub> | 11.08                         | 4.33 | 9.37  | 3.14 | 12.23                       | 3.86 | 6.69 | 1.03 | 23.30                        | 8.19 | 16.06 | 4.16 |
|                 | S <sub>40</sub> B <sub>0</sub>   | 11.58                         | 5.28 | 9.91  | 4.20 | 11.42                       | 3.18 | 5.61 | 1.04 | 22.99                        | 8.46 | 15.52 | 5.24 |
|                 | S <sub>40</sub> B <sub>0.5</sub> | 10.78                         | 6.29 | 10.37 | 4.10 | 12.46                       | 2.92 | 5.84 | 1.11 | 23.24                        | 9.21 | 16.21 | 5.21 |
|                 | S <sub>40</sub> B <sub>1</sub>   | 11.78                         | 3.95 | 10.52 | 4.78 | 9.10                        | 3.04 | 7.06 | 1.15 | 20.88                        | 6.99 | 17.58 | 5.93 |
|                 | S <sub>40</sub> B <sub>1.5</sub> | 11.31                         | 5.88 | 9.07  | 4.08 | 14.20                       | 2.97 | 5.99 | 1.22 | 25.51                        | 8.85 | 15.05 | 5.30 |
|                 | S <sub>60</sub> B <sub>0</sub>   | 12.02                         | 6.94 | 12.02 | 6.08 | 11.41                       | 2.89 | 5.81 | 1.40 | 23.43                        | 9.83 | 17.83 | 7.48 |
|                 | S <sub>60</sub> B <sub>0.5</sub> | 12.82                         | 5.47 | 11.46 | 7.75 | 14.15                       | 2.76 | 5.85 | 1.21 | 26.97                        | 8.23 | 17.31 | 8.96 |
|                 | S <sub>60</sub> B <sub>1</sub>   | 12.06                         | 4.52 | 10.67 | 5.08 | 12.48                       | 2.93 | 5.51 | 1.17 | 24.54                        | 7.45 | 16.18 | 6.25 |
|                 | S <sub>60</sub> B <sub>1.5</sub> | 12.09                         | 5.85 | 12.20 | 6.62 | 14.23                       | 3.23 | 7.02 | 1.44 | 26.32                        | 9.09 | 19.22 | 8.05 |
| S.Em (±)        | Boron                            | 0.39                          | 0.17 | 0.40  | 0.17 | 0.23                        | 0.09 | 0.14 | 0.04 | 8.40                         | 0.20 | 0.41  | 0.18 |
|                 | Sulphur                          | 0.39                          | 0.17 | 0.40  | 0.17 | 0.23                        | 0.09 | 0.14 | 0.04 | 8.40                         | 0.20 | 0.41  | 0.18 |
|                 | Sulphur X Boron                  | 0.78                          | 0.35 | 0.80  | 0.35 | 0.46                        | 0.18 | 0.27 | 0.08 | 16.81                        | 0.40 | 0.82  | 0.36 |
| C.D (P=0.05)    | Boron                            | NS                            | 0.50 | NS    | NS   | 0.67                        | 0.25 | 0.39 | 0.12 | NS                           | 0.58 | 1.19  | NS   |
|                 | Sulphur                          | 1.12                          | 0.50 | 1.16  | 0.50 | 0.67                        | NS   | 0.39 | 0.12 | NS                           | 0.58 | 1.19  | 0.52 |
|                 | Sulphur X Boron                  | NS                            | 1.00 | 2.32  | 1.01 | 1.33                        | 0.51 | 0.79 | NS   | NS                           | 1.15 | 2.38  | 1.04 |

#### 4. Conclusion

The results obtained from the present study indicate that two essential nutrients, boron and sulphur, significantly improved growth parameters and both yield and quality of sesame. The yield of sesame was increased with sulphur application up to 40 kg ha<sup>-1</sup>, and boron responded up to its highest level, i.e., 1.5 kg ha<sup>-1</sup>. Oil content and protein content were increased with the application of sulphur and boron. Both nutrients interacted synergistically in improving the yield and quality of sesame. There was an increase in nutrient availability after harvest of sesame due to the combined application of boron and sulphur.

#### 5. References

- Bangladesh Agricultural Research Institute (BARI). Annual report for 2003. Joydebpur, Bangladesh: BARI; 2004. p. 28.
- Badrudin M. The effect of sulphur deficiency on ion accumulation with special reference to 15N and 35S transport and metabolism in chickpea [PhD thesis]. Dhaka: University of Dhaka; 1999.
- Berger KC. Boron in soil and crops. *Adv Agron.* 1949;1:321-51.
- Bhonwase DB, Tamboli BD. Studies on integrated use of potassium, sulphur and boron on the yield and oil content of sunflower under dry land condition. Presented at: National Seminar on Development in Soil Science; 2001 Oct 3-Nov 2; JNKVV, Jabalpur.
- Ceccotti SP. Plant nutrition sulphur—a review of nutrient balance, environmental impact and fertilizers. *Fertil Res.* 1996;43:117-25.
- Chand L, Sharma AS, Jat SC. Quality and uptake of nutrients in mustard as affected by foliar spray of urea and sulphur application. *Ann Biol (Ludhiana).* 1997;13:103-6.
- Dayanand, MNL, Shivram AC. Influence of intercrops and sulphur on nutrient uptake and food quality of groundnut (*Arachis hypogaea*). *Indian J Agric Sci.* 2002;72(10):594-6.
- Debnath P, Ghosh SK. Determination of critical limit of available boron for rice in tarai zone soils of West Bengal. *J Indian Soc Soil Sci.* 2011;59:82-6.
- Ganeshamurthy AN. Critical plant sulphur content and effect of sulphur application on grain and oil yield of rainfed soybean in Verticustochrepts. *J Indian Soc Soil Sci.* 1996;44:290-4.
- Gannie AA, Akhter F, Bhat MA, Malik AR, Junaid JM, Shah MA, *et al.* Boron: a critical nutrient element for plant growth and productivity. *Curr Sci.* 2013;4:76-85.
- Jamal A, Fazli IS, Ahmed S, Abdin MZ, Yun SJ. Effect of nitrogen and sulphur application on nitrate reductase and ATP-sulphurylase activities in soybean. *Korean J Crop Sci.* 2006;54:298-302.
- Jamal A, Ko K, Kim HS, Cho TK, Joung H, Ko K. Role of genetic factors and environmental conditions in recombinant protein production for plant molecular biofarming. *Biotechnol Adv.* 2009;27:914-23.
- Jain GL, Saxena S. Effect of indigenous sulphur status on mustard yield, quality and nutrient status. *Ann Agric Res.* 1991;16(3):389-95.
- Jat JR, Mehra RK. Effect of sulphur and zinc on yield, micronutrient content and uptake by mustard on Haplustepts. *J Indian Soc Soil Sci.* 2007;55:190-5.
- Malewar S, Kate D, Waikar SL, Ismail S. Interaction effects of zinc and boron on yield, nutrient uptake and quality of mustard (*Brassica juncea* L.) on a Typic Haplustert. *J Indian Soc Soil Sci.* 2001;49(4):763-5.
- Raja A, Hattab KO, Gurusamy L, Suganya S. Sulphur levels on nutrient uptake and yield of sesame varieties and nutrient availability. *Int J Soil Sci.* 2007;2:278-85.
- Salwa AIE, Mohsen MA, Behary SS. Amelioration productivity of sandy soil by using amino acid, sulphur and micronutrients for sesame production. *Am J Sci.* 2010;6:250-7.
- Saren BK, Tundu S, Nandi P. Effect of irrigation and sulphur on the growth and productivity of summer sesame (*Sesamum indicum* L.). *Madras Agric J.* 2004;91:56-60.
- Sarkar RK, Saha A. Analysis of growth and productivity of sesame (*Sesamum indicum*) in relation to nitrogen, sulphur and boron. *Indian J Plant Physiol.* 2005;10:333-7.
- Shilpi S, Islam MN, Sutradhar GNC, Husna A, Akter F. Effect of nitrogen and sulfur on the growth and yield of sesame. *Int J Bioresour Stress Manag.* 2012;3(2):177-82.
- Shekawat K, Shivay YS. Effect of nitrogen sources, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (*Helianthus annuus*). *Indian J Agron.* 2008;53(2):129-31.
- Singh VK, Sharma HC. Response of Indian mustard (*Brassica juncea* L.) to levels and time of sulphur application. *Cruciferae Newsl.* 1996;18:138-9.
- Shrivastava UK, Rajput RL, Diwivedi ML. Response of soybean-mustard cropping system to sulphur and biofertilizers on farmer's field. *Legume Res.* 2000;23:277-8.
- Survase DN, Dongale, Kandrekhar SB. Growth, yield, quality and composition of groundnut as influenced by FYM, calcium, sulphur and boron in lateritic soil. *J Maharashtra Agric Univ.* 1986;11:49-51.
- Sprague HB. Hunger signs in crops. 3rd ed. New York: McKay; 1951. p. 25-57.
- Tandon HLS. Sulphur research and agricultural production in India. 2nd ed. New Delhi: Fertilizer Development and Consultation Organization; 1986. p. 18-36.
- Tandon HLS. Sulphur fertilizer for Indian agriculture: A guide book. New Delhi: FDCO; 1989. p. 11-15.
- Takahashi H, Watanabe-Takahashi, Smith FW, Blake-Kalff M, Hawkesford MJ, Saito K. The role of three functional sulphate transporters involved in uptake and translocation of sulphate in *Arabidopsis thaliana*. *Plant J.* 2000;23(2):171-82.
- Tisdale PP, Poongothai S, Savithri RK, Bijujoseph OP. Influence of gypsum and green leaf manure application on rice. *J Indian Soc Soil Sci.* 1999;47(1):96-9.
- Upadhyay AK. Effect of sulphur and zinc on yield, uptake of nutrient and quality of mustard. *Ann Plant Soil Res.* 2012;14(1):42-5.
- Yadav NPS, Singh V, Mehta VS. Effect of different levels and sources of sulphur on yield, quality and uptake of sulphur by sesame. *J Oilseeds Res.* 1996;13(1):22-5.
- Yadav RA, Tripathi AK, Yadav AK. Effect of micronutrients in combinations with organic manures on production and net returns of sesame (*Sesamum indicum* L.). *Ann Agric Res.* 2009;30(1-2):53-8.