

## Nutrient uptake and quality of sesame (*Sesamum indicum* L.) as influenced by sulphur and boron

### Abstract

At the Agronomy Field Unit, ZARS, UAS, GKVK, Bengaluru, a field experiment was carried out in kharif 2017 to examine the impact of sulphur and boron on sesame yield and quality (*Sesamum indicum* L.). Twelve treatments were reproduced three times in the experiment, which was set up using a factorial RCBD design. The application of the recommended dose of fertilisers (RDF) with 30 kg sulphur and 5 kg borax per ha resulted in significantly higher seed yield (470.00 kg ha<sup>-1</sup>) and stalk yield (3126 kg ha<sup>-1</sup>) than the application of the recommended dose of fertilisers with 40 and 5, 40 and 2.5, 30 and 5 kg sulphur and borax per ha (461.56 and 2826.67, 455.13 and 2733.33, 445.67 and 2626.67 kg per ha, respectively). Increased nutrient uptake of nitrogen (40.23 kg ha<sup>-1</sup>) phosphorus (15.01 kg ha<sup>-1</sup>) potassium (45.23 kg ha<sup>-1</sup>) sulphur (13 kg ha<sup>-1</sup>) and boron (162.4 ppm) was primarily responsible for increased seed and stalk yield. The application of the recommended dose of fertilisers with 40 kg sulphur and 5 kg borax per ha resulted in higher seed protein (10.72%). This matched RDF + 40 kg sulphur + 2.5 kg borax (10.66%). RDF+30 kg sulphur + 5 kg borax per ha produced the highest C: B ratio (3.5).

Comment [U1]: Spelling

Comment [U2]: Spelling

**Keywords:** Sulphur, Boron, Sesame, Nutrient uptake

### INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the world's oldest oil seed crops. It is composed of 46-64 percent oil and 15-16 percent protein [1]. It is known by various names such as gingely, til, simsim, biniseed, and so on. Sesame is known as the Queen of Oilseeds due to its high concentration of poly unsaturated stable fatty acids, which provide resistance to rancidity. Sesame oil contains methionine, tryptophan, niacin, and minerals (Ca and P). Because of the high antioxidant activity of seeds, their oil has a longer shelf life and is known as seeds of immortality [2].

Oil seed cake is the residue left over after oil extraction and is used as cattle feed. Sesame cakes are used as organic manure as well as a good feed concentrate for livestock. Because of the

higher methionine content in sesame seeds, it is highly valued as poultry feed [3].

India leads the world in terms of sesame area and production. Sesame is grown on an area of 18.50 lakh ha in India, with a production of 8.30 lakh tonnes and a productivity of 474 kg per ha. Maharashtra, Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, West Bengal, Gujarat, and Karnataka are the major growing states. It is grown on 0.45 lakh ha in Karnataka, with a production of 0.23 lakh tonnes and a productivity of 480 kg per ha [4].

**Comment [U3]:** It is good if you write in clear word

Sesame's lower productivity is primarily due to poor management and cultivation in marginal and sub-marginal lands with low input, starved, rainfed conditions. Yield is the result of various physiological processes in plants, which can be altered by management practises in a given environment. Nutrient management is the most important factor in determining sesame yield among management practises.

**Comment [U4]:** Spelling

Sulphur requirements are equivalent to phosphorus requirements, where it is required for plant growth and development [5]. Sulphur is required for the synthesis of sulphur-containing amino acids such as methionine (21%), cysteine (26%), and cystine (27%), which are essential protein constituents in sesame [6]. These amino acids contain approximately 90% of the plant sulphur. Sulphur is also required for the synthesis of metabolites such as coenzyme A, biotin, thiamin or vitamin B1, and glutathione, as well as the synthesis of chlorophyll, glucosides and glucosinolates, enzyme activation, and sulphhydryl linkages, which provide pungency in oils. It also encourages root growth and seed formation in sesame. Sulphur is also important in plant metabolism, as it is required for the synthesis of essential oils and the formation of chlorophyll, which is required for cell development [7]. It also provides cold resistance and drought resistance to oilseed crops. It is found in a variety of organic compounds [8]. It also raises the percentage of seed oil [9].

Boron is one of the essential micronutrients required for normal crop growth [10,11]. Its deficiency is the most common worldwide, causing significant losses in crop production both quantitatively and qualitatively. It is associated with the pollen producing capacity of the anther, viability of pollen tubes, pollen tube germination, and pollen tube growth [12]. Boron supply reduction degrades oil quality [13,14]. The occurrence of secondary and micronutrient deficiency

in India is primarily due to the cultivation of high yielding crops, varieties that remove greater amounts of nutrients, leaching and erosion losses, intensive agriculture, reduced recycling of plant residues, and a gap between secondary and micronutrient removal and addition.

## **MATERIAL AND METHODS**

The field experiment was carried out at the Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru, in Plot No. 2 of E block. The farm is located at 13° 05' N latitude and 77° 34' E longitude, at an elevation of 924 m above mean sea level, in Karnataka's Eastern Dry Zone (ACZ-V). The experimental site's soil was sandy red clay loam in nature. Before sowing, composite soil samples to a depth of 0-30 cm were collected from the experimental site and analysed for physicochemical properties. The experiment used a factorial randomised block design with three replications and twelve treatments. The first factor was sulphur levels (4): S<sub>0</sub>-0 kg ha<sup>-1</sup>, S<sub>1</sub>-20 kg ha<sup>-1</sup>, S<sub>2</sub>-30 kg ha<sup>-1</sup>, S<sub>3</sub>-40 kg ha<sup>-1</sup> and second factor as borax levels (3): B<sub>0</sub>-0 kg ha<sup>-1</sup>, B<sub>1</sub>-2.5 kg ha<sup>-1</sup>, B<sub>2</sub>-5.0 kg ha<sup>-1</sup>. GT-1 is a white seeded sesame variety released by UAS, GKVK, Bengaluru during 2012 and the duration is 85-90 days. This variety is short stature and grows to a height of 1-1.5 m with more of branches and arranged oppositely instead of alternate branching in other varieties. Plant bears more number of pods per plant and more number of locules per pod, under good management practices with favourable climate yields 750- 800 kg per ha. The observations on crop growth and other parameters were taken at different growth stages. The various growth indices were calculated using following methods.

### **Absolute growth rate**

It expressed the dry weight increase per unit time and is calculated by using the following formula and expressed as g per day [15].

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W<sub>2</sub> and W<sub>1</sub> are the total dry weight plant<sup>-1</sup> at time t<sub>2</sub> and t<sub>1</sub>, respectively.

### **Crop growth rate**

Crop growth rate is defined as the amount of dry matter produced per unit ground area per unit time [15]. It was calculated using the formula below and expressed in grammes per square metre per day.

**Comment [U5]:** Statistical Methods of data analyzing and its application is not seen.

**Comment [U6]:** Why make bold?

**Comment [U7]:** Sometimes you make the word in Oxford and used in other word using Cambridge dictionary word so you have to use one standard language for the whole paper. Keep the consistence of language form. This comment seen many times.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times P$$

**Comment [U8]:** It is good if it is written in the formula symbol.

$W_2$  = Dry matter production per plant (g) at  $t_2$   
 $W_1$  = Dry matter production per plant (g) at  $t_1$   
 $t_1$  and  $t_2$  = time intervals  
 $P$  = land area ( $\text{cm}^2$ )

### Net assimilation rate

Net assimilation rate is the rate of dry weight increases per unit leaf area per unit time. It was calculated by following formula [16] and expressed in  $\text{g dm}^2$  per day.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

**Comment [U9]:** Formula form?

Where,

$L_2$  and  $W_2$  = Leaf area ( $\text{dm}^2$ ) and total dry weight of the plant (g), respectively at time  $t_2$

$L_1$  and  $W_1$  = Leaf area ( $\text{dm}^2$ ) and total dry weight of the plant (g), respectively at time  $t_1$  and  $t_2$  = time intervals

### Leaf area duration

The integration of the leaf area index over a growth period is known as leaf area duration [15]. LAD was calculated using the formula of [17] and expressed in days for various growth periods.

$$LAD = \frac{L_1 + L_2}{(t_2 - t_1)} \times$$

**Comment [U10]:** Formula equation form

Where,

$L_1$  = LA at time  $t_1$

$L_2$  = LA at time  $t_2$

$t_2 - t_1$  = Time interval between crop growth period in days

The plant sample was collected and analysed for the nutrient content and nutrient uptake.

### Nitrogen uptake

Nitrogen content was calculated in percentage using a modified Micro-method Kjeldhal's as described in [18]. Nitrogen uptake ( $\text{kg ha}^{-1}$ ) by crop was calculated separately for each treatment using the formula below.

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

### Phosphorus uptake

Phosphorus content in the digested plant sample was estimated by Vanadomolybdate phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 660 nm wave length as outlined by [18]. It is calculated using the following formula.

$$\text{Phosphorus uptake (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

### Potassium uptake

The amount of potassium in the plant samples digest was calculated by atomizing the diluted acid extract in a flame photometer, as described in [18]. It is calculated using the formula below.

$$\text{Potassium uptake (kg ha}^{-1}\text{)} = \frac{\text{Potassium concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

### Sulphur uptake

Sulphur in plant parts was estimated by turbidometric method using spectrophotometer at 420 nm [19]. Uptake was calculated by using the following formula and expressed in kg per ha.

$$\text{S uptake (kg ha}^{-1}\text{)} = \frac{\text{S content in seed (\%)} \times \text{seed yield (kg/ha)}}{100} + \frac{\text{S content in stalk (\%)} \times \text{stalk yield (kg/ha)}}{100}$$

### Boron uptake

Boron was estimated by using spectrophotometer.

$$\text{B uptake (g ha}^{-1}\text{)} = \frac{\text{B content in seed (\%)} \times \text{seed yield (kg/ha)}}{100} + \frac{\text{B content in stalk (\%)} \times \text{stalk yield (kg/ha)}}{100}$$

The experimental data on various growth and yield parameters of the sesame plant were subjected to Fishers method of -Analysis of Variance (ANOVA) as outlined by [20]. Wherever the F-test was found to be significant for comparing treatment means, an appropriate critical difference (CD) was calculated. Otherwise, the abbreviation NS was placed next to the CD values. All data was analysed, and the findings were presented and discussed at a probability level of 5% for the field experiment and 1% for the laboratory experiment.

**Comment [U11]:** Where is its application in this paper?

## RESULTS AND DISCUSSION

### Leafareaduration

The data on leaf area duration (LAD) of sesame as influenced by different levels of sulphur and boron are presented in table 1. Application of 40 kg sulphur per ha reported significantly higher leaf areaduration of 63.97 days at 30- 60 DAS and 103.47 days at 60 DAS- at harvest. This found on par with leaf area duration of 63.67 days and 102.27 days at 30 - 60 DAS and at 60 DAS - at harvest, respectively with application of 30 kg sulphur per ha. Significantly lowest leaf area duration of 49.43 days and 68.71 days at 30 - 60 DAS and at 60 DAS - at harvest, respectively were observed with no sulphur application. Significantly higher leaf area duration of 60.52 days at 30 - 60 DAS and 93.34 days at 60 DAS - at harvest reported for application of 5 kg borax per ha. It found on par with leaf area duration of 58.57 days and 89.68 days at 30 - 60 DAS and at 60 DAS - at harvest, respectively with application of 2.5 kg borax per ha. Significantly lowest (54.44 days and 82.79 days) at 30-60 DAS and at 60 DAS- at harvest, respectively were observed with no borax application.

**Comment [U12]:** How can you say significantly? Where is your significance level obtained? / p-value???

**Comment [U13]:** p-value or significance test

At 30 - 60 DAS, interactions did not vary significantly. At 60 DAS - at harvest, application of 30 kg sulphur with 5 kg borax per ha recorded significantly higher LAD of 110.12 days, it found on par with 40 kg sulphur with 5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha (107.26 days and 106.59 days, respectively). Significantly lowest LAD (61.67 days) observed with no sulphur and borax application.

**Comment [U14]:** The obtained result is not compared with other findings??? I have seen in Appendix but it is required to interperate in this result and discussion.

### Absolute growth rate

The data on absolute growth rate (AGR) of sesame as influenced by different level of

sulphur and boron are presented in table 2. At 30 - 60 DAS, application of 40 kg sulphur per ha reported significantly higher Absolute growth rate of 0.45 g per day and it found on par with 30 kg sulphur per ha (0.44 g day<sup>-1</sup>). Significantly lowest (0.27 g day<sup>-1</sup>) observed with no sulphur application. At 60 DAS – at harvest different treatments did not differ significantly. Application of 5 kg borax per ha reported significantly higher Absolute growth rate of 0.40 g per day at 30 - 60 DAS. It found on par with 2.5 kg borax per ha (0.39 g day<sup>-1</sup>). Significantly lowest (0.32 g day<sup>-1</sup>) observed with no borax application. At 60 DAS – at harvest different treatments did not differ significantly. Interactions did not vary significantly at 30 - 60 DAS. At 60 DAS – at harvest, application of 30 kg sulphur with 5 kg borax per ha recorded significantly higher AGR of 0.28 g per day, and it found on par with 40 kg sulphur with 5 kg borax per ha (0.25 g day<sup>-1</sup>). Significantly lowest (0.20 g day<sup>-1</sup>) observed with no sulphur and borax application.

### **Crop growth rate**

The data on crop growth rate (CGR) of sesame as influenced by different levels of sulphur and boron are presented in table 3. At 30 - 60 DAS, application of 40 kg sulphur per ha reported significantly higher crop growth rate of 9.99 g per m<sup>2</sup> per day and it found on par with 30 kg sulphur per ha (9.71 g m<sup>-2</sup> day<sup>-1</sup>). Significantly lowest (5.98 g m<sup>-2</sup> day<sup>-1</sup>) observed with no sulphur application. Different treatments did not differ significantly for CGR at 60 DAS – at harvest. Application of 5 kg borax per ha reported significantly higher crop growth rate of 9 g per m<sup>2</sup> per day at 30 - 60 DAS, it found on par with 2.5 kg borax per ha (8.57 g m<sup>-2</sup> day<sup>-1</sup>). Significantly lowest crop growth rate of 7.10 g per m<sup>2</sup> per day observed with no borax application. At 60 DAS – at harvest different treatments did not differ significantly. At 30 - 60 DAS, interactions did not vary significantly. At 60 DAS – at harvest, application of 40 kg sulphur with 0 kg borax per ha recorded significantly higher CGR of 6.14 g per m<sup>2</sup> per day followed by 20 kg sulphur with 5 kg borax per ha (5.56 g m<sup>-2</sup> day<sup>-1</sup>). Significantly lowest CGR (3.73 g m<sup>-2</sup> day<sup>-1</sup>) observed with no sulphur and borax application.

### **Net assimilation rate**

The data on net assimilation rate (NAR) of sesame as influenced by different levels of sulphur and boron are presented in table 4. Application of 40 kg sulphur per ha reported significantly higher net assimilation rate ( $6.52 \text{ g}^{-1} \text{ dm}^{-2} \text{ leaf area}^{-1} \text{ day}^{-1}$  at 30 - 60 DAS and  $3.48 \text{ g}^{-1} \text{ dm}^{-2} \text{ leaf area}^{-1} \text{ day}^{-1}$  at 60 DAS - at harvest). This found on par with 30 kg sulphur per ha ( $6.25 \text{ g}^{-1} \text{ dm}^{-2} \text{ leaf area}^{-1} \text{ day}^{-1}$  at 30 - 60 DAS and  $2.85 \text{ g}^{-1} \text{ dm}^{-2} \text{ leaf area}^{-1} \text{ day}^{-1}$  at 60 DAS - at harvest). Significantly lowest ( $4.98 \text{ g}^{-1} \text{ dm}^{-2} \text{ leaf area}^{-1} \text{ day}^{-1}$  at 30 - 60 DAS and  $2.11 \text{ g}^{-1} \text{ dm}^{-2} \text{ leaf area}^{-1} \text{ day}^{-1}$  at 60 DAS - at harvest) were observed with no sulphur application. The different treatments did not differ significantly due to application of different levels of borax at different growth stages of sesame for net assimilation rate. Interactions did not found significant for net assimilation rate at different growth stages of sesame.

Sulphur at 40 kg per ha improved the plant vigour by increased availability of nutrients, resulting in better assimilation and increased dry matter, associated with higher leaf area per plant and in turn higher leaf area index, because of increased chlorophyll formation [21]. Leaf area index is often used as indicator of plant growth for evaluating assimilation, transpiration rate and is a major factor in determining the solar radiation interception and canopy photosynthesis. Amount of dry matter production influenced the leaf area by effective translocation of photosynthates by sulphur nutrition. The leaf area index was increased due to increase in the total dry matter production per plant, in turn increased the leaf area duration by increasing the major factor determining the photosynthesis by sulphur application [22]. Enhanced sugars and carbohydrates transport resulted increased absolute growth rate, net assimilation rate and crop growth rate due to increased dry matter production within a short time by 40 kg sulphur per ha nutrition [2].

5 kg per ha borax application recorded higher leaf area index significantly. This might be due to increased dry matter production and leaf area through increased metabolic activities. Increased LAI led to increased leaf area duration by effective translocation of photosynthates [11, 14]. Boron nutrition increased dry matter per plant and induced the cell division. This became responsible for enhanced absolute growth rate and crop growth rate. These findings are in accordance with findings of in soybean [7].

Sulphur and boron nutrients being synergistic in action, both help for cell division, expansion and elongation of cells. This resulted more growth parameters which in turn recorded higher growth indices. These results are in accordance with findings of [2].

### **Seedyield**

The data on seed yield of sesame as influenced by different levels of sulphur and boron are represented in table 5. The application of 40 kg sulphur per ha recorded significantly higher seed yield ( $424.67 \text{ kg ha}^{-1}$ ) and which was on par with 30 kg per ha sulphur application ( $423.90 \text{ kg ha}^{-1}$ ). Significantly lowest seed yield ( $290.53 \text{ kg ha}^{-1}$ ) was recorded with no sulphur application.

Significantly higher seed yield ( $393.25 \text{ kg ha}^{-1}$ ) recorded with application of 5 kg borax per ha. It was on par with 2.5 kg per ha borax ( $381.29 \text{ kg ha}^{-1}$ ). Significantly lowest seed yield ( $347.12 \text{ kg ha}^{-1}$ ) was recorded with no borax application. Among interaction, application of 30 kg sulphur with 5 kg borax per ha recorded significantly higher seed yield ( $470 \text{ kg ha}^{-1}$ ). And it was on par with application of 40 kg sulphur with 5 kg borax per ha, 40 kg sulphur with 2.5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha ( $461.56$ ,  $455.13$  and  $445.67 \text{ kg ha}^{-1}$ , respectively). Significantly lowest seed yield of  $273.33 \text{ kg ha}^{-1}$  was recorded with no sulphur and borax application.

### **Stalk yield**

The data on stalk yield of sesame as influenced by different levels of sulphur and boron are represented in table 5. Application of 40 kg sulphur per ha recorded significantly higher stalk yield ( $2578.89 \text{ kg ha}^{-1}$ ) and it found on par with 30 kg per ha sulphur ( $2473.33 \text{ kg ha}^{-1}$ ). Significantly lowest stalk yield ( $1985.56 \text{ kg ha}^{-1}$ ) was recorded with no sulphur application. Significantly higher stalk yield ( $2507.50 \text{ kg ha}^{-1}$ ) recorded with application of 5 kg borax per ha. It was on par with 2.5 kg per ha borax ( $2355 \text{ kg ha}^{-1}$ ). Significantly lowest stalk yield ( $1981.92 \text{ kg ha}^{-1}$ ) was recorded with no borax application. Among interaction, treatment receiving 30 kg sulphur with 5 kg borax per ha recorded significantly higher stalk yield ( $3126.67 \text{ kg ha}^{-1}$ ). It was on par with application of 40 kg sulphur with 5 kg borax per ha, 40 kg sulphur with 2.5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha ( $2826.67$ ,  $2733.33$  and  $2626.67 \text{ kg ha}^{-1}$ , respectively). Significantly lowest stalk yield ( $2006.67 \text{ kg ha}^{-1}$ ) was recorded with no sulphur and borax application.

### **Protein content**

The data on protein content (%) of sesame seed as influenced by application of different levels of sulphur and boron is presented in the table 5. Application of 30 kg sulphur per ha recorded significantly higher protein content of 10.46 per cent, which found on par with 40 kg sulphur per ha (10.44 %). Significantly lowest (9.69 %) was recorded with no sulphur application. Significantly higher protein content (10.33 %) recorded with 5 kg per ha borax application and it found on par (10.19 %) with 2.5 kg per ha borax application. Significantly lowest protein (10.03 %) reported with no borax application. Among interactions, Application of 40 kg sulphur with 5 kg borax per ha reported significantly higher protein (10.72 %), and it was on par with application of 40 kg sulphur with 2.5 kg borax per ha, 30 kg sulphur with 5 kg borax per ha and 30 kg sulphur with 0 kg borax per ha (10.66, 10.45 and 10.53 %, respectively). Significantly lowest (9.56 %) recorded with no sulphur and borax application.

This might be due to the fact that at 40 kg per ha sulphur with borax 5 kg per ha application involved in several structural regulation of secondary metabolites and catalytic functions in the sense of proteins, tripeptide glutathione (redox buffer) and certain proteins such

as thioredoxin, glutaredoxin and protein disulphide isomerase. This attributing to regulation activity, involved in light reaction ( $\text{CO}_2$  fixation) of photosynthesis, which will increase the assimilation of nitrogen and sulphur responsible for sulphur containing amino acids, viz., methionine and cysteine. This result was in close association with the findings of [23 and 24]. In plant system boron enhances enzymatic activities for protein synthesis [24 and 25].

### **Effect of different levels of sulphur and boron on total nutrient uptake of sesame**

Data on the uptake of major nutrients (nitrogen, phosphorus, potassium), secondary nutrient (sulphur) and micronutrient (boron) at harvest as influenced by application of different levels of sulphur and borax are represented below.

#### **Nitrogen**

Data pertaining to uptake of nitrogen in sesame ( $\text{kg ha}^{-1}$ ) are presented in the table 6. Total uptake of nitrogen in sesame was found to be significantly higher with the application of 40 kg sulphur per ha ( $33.86 \text{ kg ha}^{-1}$ ) and which found on par with application of 30 kg sulphur per ha ( $32.73 \text{ kg ha}^{-1}$ ). Treatment applied with no sulphur showed significantly less total nitrogen accumulation in sesame ( $23.57 \text{ kg ha}^{-1}$ ). Significantly higher total nitrogen uptake found with the application of 5 kg borax per ha ( $32.30 \text{ kg ha}^{-1}$ ) and which found on par with application of 2.5 kg borax per ha ( $30.12 \text{ kg ha}^{-1}$ ). Significantly less ( $25.26 \text{ kg ha}^{-1}$ ) observed with no borax application. Application of 30 kg sulphur with 5 kg borax per ha recorded significantly higher total nitrogen uptake at harvest ( $40.23 \text{ kg ha}^{-1}$ ) and it found on par with application of 40 kg sulphur with 5 kg borax per ha, 40 kg sulphur with 2.5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha ( $37.24$ ,  $36$  and  $34.59 \text{ kg ha}^{-1}$ ). Significantly lowest uptake of  $23.19 \text{ kg per ha}$  observed with no sulphur and borax application.

This was mainly due to higher growth and yield parameters that recorded by application of recommended dose of nitrogen, phosphorous and potassium with sufficient quantity of sulphur and borax. This quantity element (nitrogen) since has synergistic action with both sulphur and boron, resulted increased uptake. These findings are similar with findings of [10, 26, 27 and 28].

#### **Phosphorous**

Data pertaining to uptake of phosphorous in sesame ( $\text{kg ha}^{-1}$ ) are presented in the table 6. Significantly higher total phosphorous uptake found with the application of 40 kg sulphur per ha ( $12.13 \text{ kg ha}^{-1}$ ) and which was on par with application of 30 kg sulphur per ha ( $11.76 \text{ kg ha}^{-1}$ ). Treatment applied with no sulphur showed significantly less total phosphorous accumulation in sesame ( $7.40 \text{ kg ha}^{-1}$ ). Total uptake of phosphorous in sesame was found to be significantly higher with the application of 5 kg borax per ha ( $11.25 \text{ kg ha}^{-1}$ ) and which found on par with application of 2.5 kg borax per ha ( $10.28 \text{ kg ha}^{-1}$ ). Significantly less ( $8.38 \text{ kg ha}^{-1}$ ) observed with no borax application. Application of 30 kg sulphur with 5 kg borax per ha

recorded significantly higher total phosphorous uptake at harvest ( $15.01 \text{ kg ha}^{-1}$ ) and it found on par with application of 40 kg sulphur with 5 kg borax per ha, 40 kg sulphur with 2.5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha ( $13.21$ ,  $12.71$  and  $12.52 \text{ kg ha}^{-1}$ ). Significantly lowest uptake ( $7.05 \text{ kg ha}^{-1}$ ) found with no sulphur and borax application. This increased phosphorous uptake is mainly due to enhanced uptake of nitrogen by higher root proliferation, anchorage to deep penetration which in turn increases the uptake from rhizosphere. Also the sulphur and boron are in synergistic for uptake with phosphorous. These findings are in line with [29, 30 and 31].

### Potassium

Data pertaining to uptake of potassium in sesame ( $\text{kg ha}^{-1}$ ) are presented in the table 6. Total uptake of potassium in sesame was found to be significantly higher with the application of 40 kg sulphur per ha ( $36.78 \text{ kg ha}^{-1}$ ) and which found on par with application of 30 kg sulphur per ha ( $36.21 \text{ kg ha}^{-1}$ ). Treatment applied with no sulphur showed significantly fewer uptakes ( $25.95 \text{ kg ha}^{-1}$ ). Significantly higher total potassium uptake found with the application of 5 kg borax per ha ( $35.60 \text{ kg ha}^{-1}$ ) and which found on par with application of 2.5 kg borax per ha ( $32.90 \text{ kg ha}^{-1}$ ). Significantly less ( $27.49 \text{ kg ha}^{-1}$ ) total potassium accumulation in sesame found with application of no borax.

Application of 30 kg sulphur with 5 kg borax per ha recorded significantly higher total potassium uptake at harvest ( $45.23 \text{ kg ha}^{-1}$ ) and it found on par with application of 40 kg sulphur with 5 kg borax per ha, 40 kg sulphur with 2.5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha ( $40.47$ ,  $39.09$  and  $38.14 \text{ kg ha}^{-1}$ ). Significantly lowest uptake ( $25.36 \text{ kg ha}^{-1}$ ) found with no sulphur and borax application. The increased potassium uptake might be due to sufficient quantity of potassium present in soil and also supplied through MOP fertilizer. In addition, being responsive for more storage in plant even when not required. The higher photosynthetic activity in leaf exerted by potassium with nitrogen and sulphur nutrition indirectly led to efficient utilization of nutrient applied to the soil. Similar findings were reported by [3 and 10].

### Sulphur

Data pertaining to uptake of sulphur in sesame ( $\text{kg ha}^{-1}$ ) are presented in the table 6. Significantly higher total sulphur uptake found with the application of 40 kg sulphur per ha ( $10.42 \text{ kg ha}^{-1}$ ) and which was on par with application of 30 kg sulphur per ha ( $9.89 \text{ kg ha}^{-1}$ ). Treatment with no sulphur showed significantly less total sulphur accumulation in sesame ( $5.96 \text{ kg ha}^{-1}$ ). Total uptake of sulphur in sesame was found to be significantly higher with the application of 5 kg borax per ha ( $9.55 \text{ kg ha}^{-1}$ ) and which found on par with application of 2.5 kg borax per ha ( $8.54 \text{ kg ha}^{-1}$ ). Significantly less ( $6.91 \text{ kg ha}^{-1}$ ) reported with no borax application. Application of 30 kg sulphur with 5 kg borax per ha recorded significantly

high total sulphur uptake at harvest ( $13 \text{ kg ha}^{-1}$ ) and it found on par with application of 40 kg sulphur with 5 kg borax per ha, 40 kg sulphur with 2.5 kg borax per ha and 30 kg sulphur with 2.5 kg borax per ha ( $11.49$ ,  $11.16$  and  $11.12 \text{ kg ha}^{-1}$ ). Significantly lowest uptake ( $5.84 \text{ kg ha}^{-1}$ ) found with no sulphur and borax application. The increased uptake of sulphur might be due to application of sulphur, supplied through elemental sulphur [32]. In addition, the higher photosynthetic activity in leaf exerted by sulphur nutrition, indirectly led to efficient utilization of nutrients applied to the soil [10 and 33]. Since sulphur is structural part of proteins involved in various biological functions, it increased the root proliferation and rhizosphere area that helped for more uptake of [34]. Increased sulphur uptake synergistically also increases the uptake of boron. Similar findings were reported by [35].

## Boron

Data pertaining to uptake of boron in sesame ( $\text{g ha}^{-1}$ ) are presented in the table 6.

Total uptake of boron in sesame was found to be significantly higher with the application of 40 kg sulphur per ha ( $125.3 \text{ g ha}^{-1}$ ) and which found on par with application of 30 kg sulphur per ha ( $123 \text{ g ha}^{-1}$ ). Treatment with no sulphur showed significantly less total boron accumulation in sesame ( $79.9 \text{ g ha}^{-1}$ ). Significantly higher total boron uptake found with the application of 5 kg borax per ha ( $120.6 \text{ g ha}^{-1}$ ) followed by application of 2.5 kg borax per ha recorded ( $107.7 \text{ g ha}^{-1}$ ). Significantly less ( $87.5 \text{ g ha}^{-1}$ ) total boron accumulation in sesame found with no borax application. Application of 30 kg sulphur with 5 kg borax per ha recorded significantly high total boron uptake at harvest ( $162.4 \text{ g ha}^{-1}$ ) and it found on par with application of 40 kg sulphur and 5 kg borax per ha ( $139.9 \text{ g ha}^{-1}$ ). Significantly lowest uptake ( $78.7 \text{ g ha}^{-1}$ ) found with no sulphur and borax application.

This is mainly due to sulphur application where it reduced soil pH and increased root growth, so ability of roots to absorb and translocate boron enhanced. Reduced soil pH increased the micronutrient availability [33 and 36]. Sufficient quantity of borax application also enhanced the uptake due to its sufficiency in soil and higher photosynthetic activity in leaf exerted by sulphur nutrition, indirectly led to efficient utilization of boron nutrient applied to the soil [11 and 14]. Increased rhizosphere area by sulphur also helps for more uptake of boron. These findings are in agreement with findings of [24].

## Economics

The data on economics as influenced by application of different levels of sulphur and boron in sesame ( $\text{kg ha}^{-1}$ ) are presented in the table 7. Higher gross returns, net returns and C: B ratio were recorded in treatment with application of 30 kg sulphur with 5 kg borax per ha (Rs 58750, 41918 and 3.5, respectively). Lower gross returns, net returns and C: B ratio (Rs 34166, 21633 and 2.7, respectively) were obtained with 40 kg sulphur with 0 kg borax per ha application. This could be attributed to higher seed yield of sesame recorded in this treatment. Maximum net return and C: B ratio was realized by application of 30 kg sulphur per ha, although it was on par

with 40 kg sulphur per ha [6]. This is due to the increase in the uptake of nutrients which intern increased the seed yield which increased the net monetary returns and the benefit cost ratio. Similar results were reported by [30].

## CONCLUSION AND FUTURE SCOPE

The application of sulphur and boron will not only improve the yield but also quality parameters. The foliar application of these two nutrients has immense importance in crop nutrition. Quality parameter like protein content of seed has recorded significantly high with application of 40 kg sulphur with 5 kg borax per ha. It was on par with 40 and 2.5, 30 and 5 And 30 and 0 kg sulphur and borax per ha and significantly lower protein content was recorded with no sulphur and borax application. Application of 30 kg sulphur and 5 kg borax per ha along with RDF recorded higher sesame seed yield ( $470 \text{ kg ha}^{-1}$ ), net return ( $41918 \text{ Rs ha}^{-1}$ ) and C: B ratio of 3.5. Effect of different sources of sulphur and boron along with efficient sulphur oxidizing strain on growth, yield and quality of sesame is required. Use of INM studies along with micronutrients is required.

## REFERENCES

- N.D.Bhosale,B.M.Dabhi,V.P.Gaikwad,andM.C.Agarwal,Influenceofpotashandsulphurlevelsonyield,qualityandeconomicsofsesamum(*Sesamumindicum*L.).*Int. J. Agric. Sci.*, **6**(2): 335-337 (2011).
- M. Jeena,andG.Sumam, Sustaining the productivity of sesame (*Sesamumindicum*L.) grown in Onattukaraandy soil through the application of sulphur andboron.*Asian J. Soil Sci.*, **11** (2): 318-323 (2016).
- D.P.Jadav,D.R.Padamani,K.B.Polara,K.B.Parmar,andN. B.Babaria, Interaction effect of sulphur and potassium on yield andnutrients uptake by sesame (*Sesamumindicum*L.). *Asian J. Soil Sci.*, **5** (1) : 144-147 (2010).
- Anonymous,2018,DirectorateofEconomicsandStatistics,DepartmentofAgricultureand Co-operation, Ministryof Agriculture, Govt.ofIndia.
- S.D.Shinde,B.S.Raskar,andB.D.Tamboli,Effectofspacingand sulphur levels on productivity of sesame (*Sesamumindicum*L.) under summercondition. *J. Maharashtra Agric. Univ.*, **36** (1): 28-31 (2011).
- M.R.,Deshmukh,S.S.Duhoon,andA.,Jyotishi,Effectofsourcesand levels of sulphur on seed yield, oil content and economics of sesame (*Sesamumindicum*L.) in Kymore plateau zone of Madhya Pradesh (India). *J. Oil seeds Res.*,**27** (1): 34-35 (2010).

- D.N.Gokhale,A.G.Kanade,P.N.Karanjekar,andV.D.Patil,Effect of sources and levels of sulphur on seed yield, quality and sulphur uptake by soybean (*Glycine max*L.).*J. Oil seeds Res.*,**22** (1): 192-193.(2005).
- Shamina and Imamul, Mineralization pattern of added sulphur in some Bangladesh soils under submerged condition. *Indian J. Agric. Chem.*, **36** (4) : 13-21 (2003).
- F.Hassan, S.Hakim,G.Qadir,andS.Ahmad,Response of sunflower (*Helianthus annuus*L.) to sulphur and seasonal variations.*Int.J.Agric.andBio.*,**9** (3): 499–503 (2007).
- M.H.M.Afifi,R.K.M.Khalifa,andY.Camilia,Borax foliar application as a partial substitution of soil-applied boron fertilization for some groundnut cultivars grown in newly cultivated soil. *Australian J. Basic Appl. Sci.*,**5** (7): 826-832 (2011).
- B.Kallol,M.Jajati,B.Hirak,A.Ayon,R.Krishnendu,andP.Amit,Boron fertilization in sunflower (*Helianthus annuus*L.) in an inceptisol of West Bengal.*Commun.Soil Sci. Plant Anal.*, **46** (4): 528–544(2015).
- N.Hamedeldin, andO. S.Hussein, Response of sesame (*Sesame indicum*L.) plants to foliar spray with different concentration of boron. *J. American Oil Chem. Soc.*, **91** : 1949–1953.(2014).
- S.Soleimani,Effect of boron level on potato and sesame crop sequence.*Ann. Hort.*, **6** (1): 60–64.(2006).
- R.Kabir,Y.Sabina,I.Mominul,andS.Rahman,Effect of phosphorus,calcium and boron on the growth and yield of groundnut (*Arachis hypogea*L.).*Int. J. Biosci. Biotech.*,**5** (3):12-16(2013).
- D. J.Watson, The physiological basis for variation in yield. *Adv. Agron.*, **4** :101-145.(1952).
- F.G.Gregory,The effect of climatic conditions on growth of barley.*Ann.Bot.*, **46**: 1-26.(1926).
- J.F.Powar,W.O.Willid,D.I.Grunes,andC.A.Reichman,Effect of soil temperature,phosphorus and plant age on growth analysis of barley.*Agron.J.*,**59** :231-234.(1967).
- M. K. Jackson, Soil chemical analysis. Prentice-Hall. Inc. Engle Wood Cliffs, New Jersey (1973).
- L. Chesnin, andC. H. Yien, Turbidimetric determination of available sulphur. *Proc. Soil Sci. Soc. Amer.*, **15** : 149-151 (1951).

V. G. Panse, and P. V. Sukhatme, *Statistical methods for agricultural workers*. ICAR, Publ., New Delhi, pp : 359 (1967).

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A. Sonia, M. Nuruzzaman, Fahmina Akhter, M. N. Islam, and G. N. C. Sutradher, Response of nitrogen and sulphur on the oil content of sesame and nutrient status of soil. *Int. J. Bio-resource and Stress Mangt.*, **5** (1): 41-46 (2014).

K. Prajapat, A. C. Shivran, G. L. Choudhary, and H. R. Choudhary, Influence of planting pattern and sulphur on mung bean (*Vigna radiate* L.) and sesame (*Sesamum indicum* L.) intercropping under semi-arid region of Rajasthan. *Indian J. Agron.*, **57** (1): 89-91 (2012).

M. Prakash, K. Saravanan, B. Sunil Kumar, S. Jagadeesan, and J. Ganesan, Effect of plant growth regulators and micronutrients on yield attributes of sesame. *Sesame Safflower Newslett.*, p. 18 (2013).

M. Tahir, M. A. Ibrahim, S. Tahir, A. Ayub, A. Tanveer, and H. Rehman, Effect of sulphur levels on two sesame (*Sesamum indicum* L.) varieties under climatic conditions of Pakistan. *Int. J. Plant & Soil Sci.*, **3** (3): 281-288 (2014).

R. N. Kewat, Chandrashekhar, R. P. Singh, and D. Saurabh, Influence of sulphur application on oil content and fatty acid profile in sesame (*Sesamum indicum* L.). *Agril. Biol. Res.*, **25** (2): 119-127 (2009).

S. J. Dhage, and P. A. Patil, Effect of sulphur sources and their rates on yield, growth parameters, uptake of nutrients and quality of sunflower. *Asian J. Soil Sci.*, **3** (2): 323-325 (2008).

S. S. Duhoon, M. R. Deshmukh, A. Jyotishi, and H. C. Jain, Effect of sources and levels of sulphur on seed and oil yield of sesame (*Sesamum indicum* L.) under different agro-climatic situations of India. *J. Oil seeds Res.*, **22**(1): 199-200 (2005).

C. K. Kundu, S. Mondal, B. Basu, and P. Bandopadhyay, Effect of doses and time of sulphur application on yield and oil content of sesame (*Sesamum indicum* L.). *Environ. Ecol.*, **28** (4): 2629-2631 (2010).

A. K. Chaubey, M. K. Kaushik, and S. B. Singh, Response of sesame (*Sesamum indicum*) to nitrogen and sulphur in light-textured soil. *Indian Agriculturist.*, **14** (2): 61-64 (2003).

V. P. Dange, S. D. Jadhav, D. N. Nalge, and P. V. Mohod, Effect of sulphur and zinc on nutrient uptake and quality of semi-rabi sesame. *Ann. J. Plant Physiol.*, **22** (1): 81-83 (2008).

S. George, Effect of boron on the performance of sesame in sandy soil of Kerala, (India). *Indian J. Agric.*

Res., **47**(3): 214–219 (2012).

B.K.Patil, P.Patra, G. K.Ghosh, S.Mondal, G. C.Malik, and P.K.Biswas, Efficacy of phosphogypsum and magnesium sulphate as sources of sulphur to sesame (*Sesamum indicum* L.) in red and lateritic soil of West Bengal. *J. Crop and Weed*, **7**(1): 133-135. (2011).

Mathew and Suman, Sulphur and boron improve the yield of oil seeds sesame in sandy loam soil of Kerala. *Indian J. Agron.*, **53** (2): 129-134 (2013).

K.Mallik, and Raj, Effect of different levels of phosphorus, sulphur and boron on growth and yield of sesame (*Sesamum indicum* L.). *J. Oilseeds Res.*, **29**(2): 75-77 (2015).

R.Mahajan, K.Bharathi, S.H.Sekhar, and G.Ranganath, Effect of integrated nutrient management on seed yield and economics of sesame. *J. Oilseeds Res.*, **27**(5): 79–81 (2013).

K.Mamatha, S. Vidya, and N.Laxmi, Influence of different levels of boron along with application of farm yard manure on nutrient uptake and yield of sesame. *Int. J. Farm Sci.*, **6** (2): 37-45 (2016).

**Table 1: Leaf area duration of sesame as influenced by application of different levels of sulphur and boron.**

Treatments	30-60DAS(Days)	60DAS-Atharvest(Days)
Factor A : Sulphur levels (S)		
S <sub>0</sub> : 0 kg ha <sup>-1</sup>	49.43	68.71
S <sub>1</sub> : 20 kg ha <sup>-1</sup>	54.31	79.98
S <sub>2</sub> : 30 kg ha <sup>-1</sup>	63.67	102.27
S <sub>3</sub> : 40 kg ha <sup>-1</sup>	63.97	103.47
S.Em±	1.18	1.12
CD(P=0.05)	3.45	3.29
Factor B: Boron levels (B)		
B <sub>0</sub> : 0 kg ha <sup>-1</sup>	54.44	82.79
B <sub>1</sub> : 2.5 kg ha <sup>-1</sup>	58.57	89.68
B <sub>2</sub> : 5.0 kg ha <sup>-1</sup>	60.52	93.34
S.Em±	1.02	0.97
CD(P=0.05)	2.99	2.85
Interaction (AxB)		
S <sub>0</sub> B <sub>0</sub>	44.98	61.67

S <sub>0</sub> B <sub>1</sub>	50.28	69.21
S <sub>0</sub> B <sub>2</sub>	53.02	75.24
S <sub>1</sub> B <sub>0</sub>	51.87	79.12
S <sub>1</sub> B <sub>1</sub>	55.00	80.06
S <sub>1</sub> B <sub>2</sub>	56.07	80.75
S <sub>2</sub> B <sub>0</sub>	58.86	90.10
S <sub>2</sub> B <sub>1</sub>	64.98	106.59
S <sub>2</sub> B <sub>2</sub>	67.17	110.12
S <sub>3</sub> B <sub>0</sub>	62.06	100.28
S <sub>3</sub> B <sub>1</sub>	64.04	102.88
S <sub>3</sub> B <sub>2</sub>	65.81	107.26
S.Em±	2.04	1.94
CD(P=0.05)	NS	5.70

**Table2: Absolute growth rate of sesame as influenced by application of different levels of sulphur and boron.**

Treatments	30-60DAS (g day <sup>-1</sup> )	60DAS at harvest (g day <sup>-1</sup> )
<b>Factor A : Sulphur levels (S)</b>		
S <sub>0</sub> : 0 kg ha <sup>-1</sup>	0.27	0.21
S <sub>1</sub> : 20 kg ha <sup>-1</sup>	0.32	0.20
S <sub>2</sub> : 30 kg ha <sup>-1</sup>	0.44	0.20
S <sub>3</sub> : 40 kg ha <sup>-1</sup>	0.45	0.22
S.Em±	0.02	0.01
CD(P=0.05)	0.05	NS
<b>Factor B: Boron levels (B)</b>		
B <sub>0</sub> : 0 kg ha <sup>-1</sup>	0.32	0.22
B <sub>1</sub> : 2.5 kg ha <sup>-1</sup>	0.39	0.20
B <sub>2</sub> : 5.0 kg ha <sup>-1</sup>	0.40	0.21
S.Em±	0.02	0.01
CD(P=0.05)	0.05	NS
<b>Interaction (AxB)</b>		
S <sub>0</sub> B <sub>0</sub>	0.23	0.20
S <sub>0</sub> B <sub>1</sub>	0.26	0.20

S <sub>0</sub> B <sub>2</sub>	0.31	0.18
S <sub>1</sub> B <sub>0</sub>	0.31	0.17
S <sub>1</sub> B <sub>1</sub>	0.32	0.19
S <sub>1</sub> B <sub>2</sub>	0.34	0.20
S <sub>2</sub> B <sub>0</sub>	0.33	0.19
S <sub>2</sub> B <sub>1</sub>	0.48	0.20
S <sub>2</sub> B <sub>2</sub>	0.50	0.28
S <sub>3</sub> B <sub>0</sub>	0.40	0.21
S <sub>3</sub> B <sub>1</sub>	0.48	0.19
S <sub>3</sub> B <sub>2</sub>	0.47	0.25
S.Em±	0.03	0.02
CD(P=0.05)	NS	0.06

**Table 3: Crop growth rate of sesame as influenced by application of different levels of sulphur and boron.**

Treatments	30-60DAS (g m <sup>-2</sup> day <sup>-1</sup> )	60 DAS -At harvest(g m <sup>-2</sup> day <sup>-1</sup> )
<b>Factor A : Sulphur levels (S)</b>		
S <sub>0</sub> : 0 kg ha <sup>-1</sup>	5.98	4.58
S <sub>1</sub> : 20 kg ha <sup>-1</sup>	7.21	4.48
S <sub>2</sub> : 30 kg ha <sup>-1</sup>	9.71	4.46
S <sub>3</sub> : 40 kg ha <sup>-1</sup>	9.99	4.97
S.Em±	0.41	0.31
CD(P=0.05)	1.20	NS
<b>Factor B: Boron levels (B)</b>		
B <sub>0</sub> : 0 kg ha <sup>-1</sup>	7.10	4.80
B <sub>1</sub> : 2.5 kg ha <sup>-1</sup>	8.57	4.47
B <sub>2</sub> : 5.0 kg ha <sup>-1</sup>	9.00	4.59
S.Em±	0.35	0.27
CD(P=0.05)	1.04	NS
<b>Interaction (AxB)</b>		
S <sub>0</sub> B <sub>0</sub>	5.21	3.73
S <sub>0</sub> B <sub>1</sub>	5.83	4.65
S <sub>0</sub> B <sub>2</sub>	6.91	3.95
S <sub>1</sub> B <sub>0</sub>	6.90	3.74
S <sub>1</sub> B <sub>1</sub>	7.06	4.15

S <sub>1</sub> B <sub>2</sub>	7.65	5.56
S <sub>2</sub> B <sub>0</sub>	7.41	4.20
S <sub>2</sub> B <sub>1</sub>	10.68	4.80
S <sub>2</sub> B <sub>2</sub>	11.05	4.37
S <sub>3</sub> B <sub>0</sub>	8.89	6.14
S <sub>3</sub> B <sub>1</sub>	10.71	4.30
S <sub>3</sub> B <sub>2</sub>	10.37	4.48
S.Em±	0.71	0.24
CD(P=0.05)	NS	0.57

**Table 4: Net assimilation rate of sesame as influenced by application of different levels of sulphur and boron.**

Treatments	30-60DAS (g <sup>-1</sup> dm <sup>-2</sup> leaf area <sup>-1</sup> day <sup>-1</sup> )	60DAS-Atharvest (g <sup>-1</sup> dm <sup>-2</sup> leaf area <sup>-1</sup> day <sup>-1</sup> )
<b>Factor A : Sulphur levels (S)</b>		
S <sub>0</sub> : 0 kg ha <sup>-1</sup>	4.98	2.11
S <sub>1</sub> : 20 kg ha <sup>-1</sup>	5.49	2.32
S <sub>2</sub> : 30 kg ha <sup>-1</sup>	6.25	2.85
S <sub>3</sub> : 40 kg ha <sup>-1</sup>	6.52	3.48
S.Em±	0.36	0.23
CD(P=0.05)	1.05	0.67
<b>Factor B: Boron levels (B)</b>		
B <sub>0</sub> : 0 kg ha <sup>-1</sup>	5.42	2.95
B <sub>1</sub> : 2.5 kg ha <sup>-1</sup>	5.92	2.56
B <sub>2</sub> : 5.0 kg ha <sup>-1</sup>	6.08	2.50
S.Em±	0.31	0.20
CD(P=0.05)	NS	NS
<b>Interaction (AxB)</b>		
S <sub>0</sub> B <sub>0</sub>	4.82	4.21
S <sub>0</sub> B <sub>1</sub>	4.73	3.51
S <sub>0</sub> B <sub>2</sub>	5.38	2.73
S <sub>1</sub> B <sub>0</sub>	5.51	2.35
S <sub>1</sub> B <sub>1</sub>	5.30	2.57
S <sub>1</sub> B <sub>2</sub>	5.65	3.37
S <sub>2</sub> B <sub>0</sub>	5.19	2.27
S <sub>2</sub> B <sub>1</sub>	6.77	2.16
S <sub>2</sub> B <sub>2</sub>	6.78	1.91
S <sub>3</sub> B <sub>0</sub>	6.17	2.96
S <sub>3</sub> B <sub>1</sub>	6.89	1.99

S <sub>3</sub> B <sub>2</sub>	6.51	2.01
S.Em±	0.62	0.40
CD(P=0.05)	NS	NS

**Table5: Seedyield, Stalkyield and Protein**

**content of sesame as influenced by application of different levels of sulphur and boron.**

Treatments	Seed yield(kg ha <sup>-1</sup> )	Stalk yield(kg ha <sup>-1</sup> )	Protein content (%)
<b>Factor A : Sulphur levels (S)</b>			
S <sub>0</sub> : 0 kg ha <sup>-1</sup>	290	1985	9.69
S <sub>1</sub> : 20 kg ha <sup>-1</sup>	356	2088	10.14
S <sub>2</sub> : 30 kg ha <sup>-1</sup>	423	2473	10.46
S <sub>3</sub> : 40 kg ha <sup>-1</sup>	424	2578	10.44
S.Em±	7	129	0.06
CD(P=0.05)	22	380	0.17
<b>Factor B : Boron levels (B)</b>			
B <sub>0</sub> : 0 kg ha <sup>-1</sup>	347	1981	10.03
B <sub>1</sub> : 2.5 kg ha <sup>-1</sup>	381	2355	10.19
B <sub>2</sub> : 5.0 kg ha <sup>-1</sup>	393	2507	10.33
S.Em±	6.51	112.46	0.05
CD(P=0.05)	19.08	329.83	0.15
<b>Interaction (AxB)</b>			
S <sub>0</sub> B <sub>0</sub>	273	2006	9.56
S <sub>0</sub> B <sub>1</sub>	302	2033	9.69
S <sub>0</sub> B <sub>2</sub>	296	1916	9.82
S <sub>1</sub> B <sub>0</sub>	335	2077	10.07
S <sub>1</sub> B <sub>1</sub>	381	2026	10.01
S <sub>1</sub> B <sub>2</sub>	383	2160	10.33
S <sub>2</sub> B <sub>0</sub>	350	1666	10.53
S <sub>2</sub> B <sub>1</sub>	445	2626	10.39
S <sub>2</sub> B <sub>2</sub>	470	3126	10.45
S <sub>3</sub> B <sub>0</sub>	416	2176	9.95
S <sub>3</sub> B <sub>1</sub>	455	2733	10.66
S <sub>3</sub> B <sub>2</sub>	461	2826	10.72
S.Em±	13.01	224.92	0.10
CD(P=0.05)	38.16	659.67	0.30

**Table 6: Total plant uptake of nutrients at harvest of sesame as influenced**

by application of different levels of sulphur and boron.

Treatments	N (kg ha <sup>-1</sup> )	P (kg ha <sup>-1</sup> )	K (kg ha <sup>-1</sup> )	S (kg ha <sup>-1</sup> )	B (ppm)
<b>Factor A : Sulphur levels (S)</b>					
S <sub>0</sub> : 0 kg ha <sup>-1</sup>	23.57	7.40	25.95	5.96	79.9
S <sub>1</sub> : 20 kg ha <sup>-1</sup>	26.75	8.58	29.05	7.06	92.7
S <sub>2</sub> : 30 kg ha <sup>-1</sup>	32.73	11.76	36.21	9.89	123.0
S <sub>3</sub> : 40 kg ha <sup>-1</sup>	33.86	12.13	36.78	10.42	125.3
S.Em±	1.33	0.44	1.49	0.38	4.9
CD(P=0.05)	3.91	1.30	4.37	1.12	14.3
<b>Factor B: Boron levels (B)</b>					
B <sub>0</sub> : 0 kg ha <sup>-1</sup>	25.26	8.38	27.49	6.91	87.5
B <sub>1</sub> : 2.5 kg ha <sup>-1</sup>	30.12	10.28	32.90	8.54	107.7
B <sub>2</sub> : 5.0 kg ha <sup>-1</sup>	32.30	11.25	35.60	9.55	120.6
S.Em±	1.15	0.38	1.29	0.33	4.2
CD(P=0.05)	3.39	1.13	3.78	0.97	12.4
<b>Interaction (AxB)</b>					
S <sub>0</sub> B <sub>0</sub>	23.19	7.05	25.36	5.84	78.7
S <sub>0</sub> B <sub>1</sub>	24.21	7.61	26.78	5.99	81.0
S <sub>0</sub> B <sub>2</sub>	23.32	7.55	25.72	6.04	80.0
S <sub>1</sub> B <sub>0</sub>	26.13	8.20	28.55	6.72	89.2
S <sub>1</sub> B <sub>1</sub>	25.70	8.30	27.60	6.80	89.1
S <sub>1</sub> B <sub>2</sub>	28.41	9.24	30.99	7.65	99.9
S <sub>2</sub> B <sub>0</sub>	23.37	7.78	25.26	6.22	84.0
S <sub>2</sub> B <sub>1</sub>	34.59	12.52	38.14	10.46	129.4
S <sub>2</sub> B <sub>2</sub>	40.23	15.01	45.23	13.00	162.4
S <sub>3</sub> B <sub>0</sub>	28.33	10.48	30.79	11.12	97.9
S <sub>3</sub> B <sub>1</sub>	36.00	12.71	39.09	11.16	131.2
S <sub>3</sub> B <sub>2</sub>	37.24	13.21	40.47	11.49	139.9
S.Em±	2.31	0.77	2.58	0.66	8.43
CD(P=0.05)	6.77	2.51	7.56	1.94	24.72

**Table 7: Economics of sesame as influenced by application of different levels of sulphur and boron.**

Treatments	Cost of cultivation (₹ a <sup>-1</sup> )	Gross return (₹ a <sup>-1</sup> )	Net returns (₹ a <sup>-1</sup> )	C:Brati
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	<b>Rsha<sup>-1</sup></b>			<b>o</b>
S <sub>0</sub> B <sub>0</sub>	1253 3	34166	21633	2.7
S <sub>0</sub> B <sub>1</sub>	1268 3	37750	25067	3.0
S <sub>0</sub> B <sub>2</sub>	1283 3	37032	24199	2.9
S <sub>1</sub> B <sub>0</sub>	1519 9	41959	26760	2.8
S <sub>1</sub> B <sub>1</sub>	1534 9	47652	32303	3.1
S <sub>1</sub> B <sub>2</sub>	1549 9	47884	32385	3.1
S <sub>2</sub> B <sub>0</sub>	1653 2	43820	27288	2.7
S <sub>2</sub> B <sub>1</sub>	1668 2	55708	39026	3.3
S <sub>2</sub> B <sub>2</sub>	1683 2	58750	41918	3.5
S <sub>3</sub> B <sub>0</sub>	1786 5	52111	34246	2.9
S <sub>3</sub> B <sub>1</sub>	1801 5	56891	38876	3.2
S <sub>3</sub> B <sub>2</sub>	1816 5	57695	39530	3.2