International Journal of Environment and Climate Change

Volume 14, Issue 3, Page 405-418, 2024; Article no.IJECC.110094
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Nutrient Uptake and Quality of Sesame (*Sesamum indicum* L.) as Influenced by Sulphur and Boron

Ramesh Malakari Padasalagi [a], Lalitha B. S. [a] and Gurunath Raddy [a*]

[a] *Department of Agronomy, UAS, GKVK, Bangalore, India.*

Authors' contributions

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

Article Information

DOI: 10.9734/IJECC/2024/v14i34052

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/110094

Original Research Article

Received: 07/10/2023
Accepted: 12/12/2023
Published: 14/03/2024

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^{-1}) and stalk yield (3126 kg ha^{-1}) 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^{-1}) phosphorus (15.01 kg ha^{-1}) potassium (45.23 kg ha^{-1}) sulphur (13 kg ha^{-1}) 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).

**Corresponding author: E-mail: gbpsreddy6762@gmail.com;*

Keywords: Sulphur; boron; sesame; nutrient uptake.

1. INTRODUCTION

"Sesame (Sesamum indicum L.) stands as one of the earliest cultivated oilseed crops globally. With an oil content ranging from 46-64% and a protein content of 15-16%, it goes by various names like gingely, til, simsim, biniseed, and more" [1]. Recognized as the Queen of Oilseeds, sesame owes this title to its abundance of polyunsaturated stable fatty acids, imparting resistance to rancidity. Sesame oil boasts essential components such as methionine, tryptophan, niacin, and minerals like calcium and phosphorus. The seeds' potent antioxidant activity contributes to the oil's prolonged shelf life, earning it the moniker "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 holds the global forefront in both sesame cultivation area and production. In India, sesame is cultivated across 18.50 lakh hectares, yielding a production of 8.30 lakh tonnes and a productivity rate of 474 kg per hectare. The primary sesame-producing states include Maharashtra, Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, West Bengal, Gujarat, and Karnataka. Specifically, in Karnataka, sesame is cultivated on 0.45 lakh hectares, resulting in a production of 0.23 lakh tonnes and a productivity rate of 480 kg per hectare" [4].

The relatively lower productivity of sesame can be attributed mainly to inadequate management practices and cultivation in marginal and sub-marginal lands with limited inputs, particularly under rainfed conditions. Yield is an outcome of diverse physiological processes in plants, and these can be influenced by the implementation of various management practices within a specific environment. Notably, nutrient management emerges as the pivotal factor in determining sesame yield among these practices.

"Sulphur plays a crucial role in plant growth and development, with its requirements being comparable to those of phosphorus" [5]. "In sesame, sulphur is essential for the synthesis of sulphur-containing amino acids like methionine (21%), cysteine (26%), and cystine (27%), which constitute vital protein components, accounting for approximately 90% of the plant's sulphur content" [6]. "Moreover, sulphur is necessary for the synthesis of metabolites such as coenzyme A, biotin, thiamin (vitamin B1), and glutathione. It also contributes to the synthesis of chlorophyll, glucosides, and glucosinolates, as well as enzyme activation and sulphydryl linkages, imparting pungency to oils. Additionally, sulphur promotes root growth and seed formation in sesame. In plant metabolism, sulphur is crucial for the synthesis of essential oils and chlorophyll, which is vital for cell development" [7]. "Furthermore, sulphur enhances cold and drought resistance in oilseed crops and is present in various organic compounds" [8]. "Its presence also positively influences the percentage of seed oil" [9].

Boron stands out as an essential micronutrient crucial for normal crop growth [10,11]. "Its deficiency is a widespread issue globally, leading to substantial losses in both quantitative and qualitative aspects of crop production. Boron plays a crucial role in the pollen-producing capacity of the anther, the viability of pollen tubes, as well as pollen tube germination and growth" [12]. A reduction in boron supply has been linked to a decline in oil quality [13,14]. In India, the occurrence of secondary and micronutrient deficiencies is largely attributed to the cultivation of high-yielding crops and varieties that extract higher amounts of nutrients, as well as factors such as leaching and erosion losses, intensive agricultural practices, reduced recycling of plant residues, and a disparity between the removal and addition of secondary and micronutrients.

2. MATERIALS 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 13º 05' N latitude and 77º 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_0-0 kg ha^{-1}, S_1-20 kg ha^{-1}, S_2-30 kg ha^{-1}, S_3-40 kg ha^{-1} and second factor as borax levels (3): B_0-0 kg ha^{-1}, B_1-2.5 kg ha^{-1}, B_2-5.0 kg ha^{-1}. 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.

2.1 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].

$$AGR = W_2 - W_1 / t_2 - t_1$$

Where, W_2 and W_1 are the total dry weight plant^{-1} at time t_2 and t_1, respectively.

2.2 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.

$$CGR = W_2 - W_1 / t_2 - t_1 \times P$$

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 (cm^2)

2.3 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 g dm^2 per day.

$$NAR = W_2 - W_1 / t_2 - t_1 \times \text{Log}_e L_2 - \text{Log}_e L_1 / L_2 - L_1$$

Where,

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

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

2.4 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 Powar et al. [17] and expressed in days for various growth periods.

$$LAD = \underline{L_1 + L_2} \times (t_2 - t_1) 2$$

Where,

L_1 = LAI at time t_1
L_2 = LAI 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.

2.6 Nitrogen Uptake

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

Nitrogen uptake (kg ha-1) = Nitrogen concentration (%) / 100 x Dry matter (kg ha-1)

2.7 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 Jackson [18]. It is calculated using the following formula.

Phosphorus uptake (kg ha-1) = Phosphorus concentration (%) / 100 x Dry matter (kg ha-1)

2.8 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.

Potassium uptake (kg ha-1) = Potassium concentration (%) / 100 × Dry matter (kg ha-1)

2.9 Sulphur Uptake

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

S uptake (kg ha-1) = S content in seed (%) x seed yield (kg/ha) / 100 + S content in stalk (%) x stalk yield (kg/ha) / 100

2.10 Boron Uptake

Boron was estimated by using spectrophotometer.

B uptake (g ha-1) = B content in seed (%) x seed yield (kg/ha) / 100 + + B content in stalk (%)
x stalk yield (kg/ha) /100

The data obtained from experiments on different growth and yield parameters of the sesame plant underwent analysis using Fisher's method of Analysis of Variance (ANOVA), following the procedure outlined by Sonia et al. [20]. In cases where the F-test yielded significance in comparing treatment means, the corresponding critical difference (CD) was calculated. Otherwise, the abbreviation "NS" (not significant) was indicated alongside the CD values. All data underwent thorough analysis, and the results were presented and discussed at a significance level of 5% for the field experiment and 1% for the laboratory experiment.

3. RESULTS AND DISCUSSION

3.1 Leaf area Duration

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 area duration 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 wereobserved with no borax application.

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.

3.2 Absolute Growth Rate

The data on absolute growth rate (AGR) of sesame as influenced by different levels 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^{-1}). Significantly lowest (0.27 g day^{-1}) 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^{-1}). Significantly lowest (0.32 g day^{-1}) 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^{-1}). Significantly lowest (0.20 g day^{-1}) observed with no sulphur and borax application.

3.3 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^2 per day and it found on par with 30 kg sulphur per ha (9.71 g m^{-2} day^{-1}). Significantly lowest (5.98 g m^{-2} day^{-1}) 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^2 per day at 30 - 60 DAS, it found on par with 2.5 kg borax per ha (8.57 g m^{-2} day^{-1}). Significantly lowest crop growth rate of 7.10 g per m^2 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^2 per day followed by 20 kg sulphur with 5 kg borax per ha (5.56 g m^{-2} day^{-1}). Significantly lowest CGR (3.73 g m^{-2} day^{-1}) observed with no sulphur and borax application.

3.4 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 g^{-1} dm^{-2} leaf $area^{-1}$ day^{-1} at 30 - 60 DAS and 3.48 g^{-1} dm^{-2} leaf $area^{-1}$ day^{-1} at 60 DAS - at harvest). This found on par with 30 kg sulphur per ha (6.25 g^{-1} dm^{-2} leaf $area^{-1}$ day^{-1} at 30 - 60 DAS and 2.85 g^{-1} dm^{-2} leaf $area^{-1}$ day^{-1} at 60 DAS - at harvest). Significantly lowest (4.98 g^{-1} dm^{-2} leaf $area^{-1}$ day^{-1} at 30 - 60 DAS and 2.11 g^{-1} dm^{-2} leaf $area^{-1}$ 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.

The application of 40 kg of sulphur per hectare had a positive impact on plant vigor by enhancing nutrient availability. This, in turn, led to improved assimilation and increased dry matter, contributing to higher leaf area per plant. Consequently, there was an elevation in the

Table 1. Leaf area duration of sesame as influenced by application of differentlevels of sulphur and boron

Treatments	30-60 DAS(Days)	60 DAS -At harvest(Days)
Factor A : Sulphur levels (S)		
S_0: 0 kg ha^{-1}	49.43	68.71
S_1: 20 kg ha^{-1}	54.31	79.98
S_2: 30 kg ha^{-1}	63.67	102.27
S_3: 40 kg ha^{-1}	63.97	103.47
S.Em±	1.18	1.12
CD (P=0.05)	3.45	3.29
Factor B : Boron levels (B)		
B_0: 0 kg ha^{-1}	54.44	82.79
B_1: 2.5 kg ha^{-1}	58.57	89.68
B_2: 5.0 kg ha^{-1}	60.52	93.34
S.Em±	1.02	0.97
CD (P=0.05)	2.99	2.85
Interaction (A x B)		
S_0B_0	44.98	61.67
S_0B_1	50.28	69.21
S_0B_2	53.02	75.24
S_1B_0	51.87	79.12
S_1B_1	55.00	80.06
S_1B_2	56.07	80.75
S_2B_0	58.86	90.10
S_2B_1	64.98	106.59
S_2B_2	67.17	110.12
S_3B_0	62.06	100.28
S_3B_1	64.04	102.88
S_3B_2	65.81	107.26
S.Em±	2.04	1.94
CD (P=0.05)	NS	5.70

Table 2. Absolute growth rate of sesame as influenced by application of differentlevels of sulphur and boron

Treatments	30-60 DAS (g day^{-1})	60 DAS At harvest(g day^{-1})
Factor A : Sulphur levels (S)		
S_0: 0 kg ha^{-1}	0.27	0.21
S_1: 20 kg ha^{-1}	0.32	0.20
S_2: 30 kg ha^{-1}	0.44	0.20
S_3: 40 kg ha^{-1}	0.45	0.22
S.Em±	0.02	0.01
CD (P=0.05)	0.05	NS
Factor B : Boron levels (B)		
B_0: 0 kg ha^{-1}	0.32	0.22
B_1: 2.5 kg ha^{-1}	0.39	0.20
B_2: 5.0 kg ha^{-1}	0.40	0.21
S.Em±	0.02	0.01
CD (P=0.05)	0.05	NS
Interaction (A x B)		
S_0B_0	0.23	0.20
S_0B_1	0.26	0.20
S_0B_2	0.31	0.18
S_1B_0	0.31	0.17
S_1B_1	0.32	0.19
S_1B_2	0.34	0.20
S_2B_0	0.33	0.19
S_2B_1	0.48	0.20
S_2B_2	0.50	0.28
S_3B_0	0.40	0.21
S_3B_1	0.48	0.19
S_3B_2	0.47	0.25
S.Em±	0.03	0.02
CD (P=0.05)	NS	0.06

leaf area index due to augmented chlorophyll formation [21]. The leaf area index serves as an indicator of plant growth, reflecting assimilation and transpiration rates, and is a significant factor in determining solar radiation interception and canopy photosynthesis. The increase in dry matter production, influenced by effective translocation of photosynthates through sulphur nutrition, played a role in augmenting the leaf area. This rise in leaf area index was attributed to an increase in total dry matter production per plant, subsequently extending the leaf area duration. This extension became a major factor influencing photosynthesis through sulphur application [22]. The heightened transport of sugars and carbohydrates resulting from sulphur application at 40 kg per hectare led to an increased absolute growth rate, net assimilation rate, and crop growth rate. This effect was attributed to the accelerated dry matter production within a short time frame due to the nutritional boost from sulphur [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 Jeena [2].

3.5 Seed Yield

Table 5 presents the seed yield data for sesame influenced by varying levels of sulphur and boron. Notably, the application of 40 kg sulphur per hectare resulted in a significantly higher seed yield at 424.67 kg/ha, on par with the yield from 30 kg/ha sulphur application (423.90 kg/ha). The lowest seed yield of 290.53 kg/ha was observed in the absence of sulphur application. Similarly, the application of 5 kg borax per hectare led to a significantly higher seed yield of 393.25 kg/ha, comparable to the yield from 2.5 kg/ha borax application (381.29 kg/ha). The lowest seed yield of 347.12 kg/ha was recorded when no borax was applied. In terms of interaction effects, the combined application of 30 kg sulphur with 5 kg borax per hectare resulted in a significantly higher seed yield of 470 kg/ha. This was on par with the yields from the combinations of 40 kg sulphur with 5 kg borax per hectare, 40 kg sulphur with 2.5 kg borax per hectare, and 30 kg sulphur with 2.5 kg borax per hectare, which recorded yields of 461.56 kg/ha, 455.13 kg/ha, and 445.67 kg/ha, respectively. The lowest seed yield of 273.33 kg/ha was recorded when neither sulphur nor borax was applied.

3.6 Stalk Yield

Table 5 outlines the data on stalk yield of sesame under the influence of different levels of sulphur and boron. Notably, the application of 40 kg sulphur per hectare resulted in a significantly higher stalk yield of 2578.89 kg/ha, on par with the yield from 30 kg/ha sulphur application (2473.33 kg/ha). The lowest stalk yield of 1985.56 kg/ha was recorded in the absence of sulphur application. Similarly, the application of 5 kg borax per hectare led to a significantly higher stalk yield of 2507.50 kg/ha, comparable to the yield from 2.5 kg/ha borax application (2355 kg/ha). The lowest stalk yield of 1981.92 kg/ha was observed when no borax was applied. In terms of interaction effects, the treatment receiving 30 kg sulphur with 5 kg borax per hectare recorded a significantly higher stalk yield of 3126.67 kg/ha. This was on par with the yields from the combinations of 40 kg sulphur with 5 kg borax per hectare, 40 kg sulphur with 2.5 kg borax per hectare, and 30 kg sulphur with 2.5 kg borax per hectare, which recorded yields of 2826.67 kg/ha, 2733.33 kg/ha, and 2626.67 kg/ha, respectively. The lowest stalk yield of 2006.67 kg/ha was recorded when neither sulphur nor borax was applied.

3.7 Protein Content

Table 5 provides data on the protein content (%) of sesame seeds influenced by varying levels of sulphur and boron. Notably, the application of 30 kg sulphur per hectare resulted in a significantly higher protein content of 10.46%, on par with the protein content from 40 kg sulphur per hectare (10.44%). The lowest protein content of 9.69% was recorded in the absence of sulphur application. Similarly, a significantly higher protein content of 10.33% was observed with the application of 5 kg borax per hectare, on par with the protein content from 2.5 kg borax per hectare (10.19%). The lowest protein content of 10.03% was reported when no borax was applied. Regarding interaction effects, the application of 40 kg sulphur with 5 kg borax per hectare resulted in significantly higher protein content (10.72%). This was on par with the protein content from the combinations of 40 kg sulphur with 2.5 kg borax per hectare, 30 kg sulphur with 5 kg borax per hectare, and 30 kg sulphur with 0 kg borax per hectare, which recorded protein contents of 10.66%, 10.45%, and 10.53%, respectively. The lowest protein content of 9.56% was recorded when neither sulphur nor borax was applied. The observed results may be attributed to the joint action of 40 kg sulphur and 5 kg borax per hectare, playing a role in structural regulation of secondary metabolites and catalytic functions, particularly in proteins. This involvement is seen in proteins such as tripeptide glutathione (redox buffer) and certain proteins like thioredoxin, glutaredoxin, and protein disulphide isomerase. These regulatory activities are associated with the light reaction (CO2 fixation) of photosynthesis, leading to increased assimilation of nitrogen and sulphur, which is responsible for sulphur-containing amino acids, namely methionine and cysteine. These findings align closely with the results of Prakash et al. [23], Tahir et al. [24]. Additionally, in plant systems, boron is known to enhance enzymatic activities for protein synthesis [24,25].

3.8 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 presented below.

3.8.1 Nitrogen

Data pertaining to uptake of nitrogen in sesame (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 kg ha^{-1}) and which found on par with application of 30 kg sulphur per ha (32.73 kg ha^{-1}). Treatment applied with no sulphur showed significantly less total nitrogen accumulation in sesame (23.57 kg ha^{-1}). Significantly higher total nitrogen uptake found with the application of 5 kg borax per ha (32.30 kg ha^{-1}) and which found on par with application of 2.5 kg borax per ha (30.12 kg ha^{-1}). Significantly less (25.26 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 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 kg ha^{-1}). Significantly lowest uptake of 23.19 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 Afifi et al. [10],[26,27,28].

3.8.2 Phosphorous

Data pertaining to uptake of phosphorous in sesame (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 kg ha^{-1}) and which was on par with application of 30 kg sulphur per ha (11.76 kg ha^{-1}). Treatment applied with no sulphur showed significantly less total phosphorous accumulation in sesame (7.40 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 kg ha^{-1}) and which found on par with application of 2.5 kg borax

Table 3. Crop growth rate of sesame as influenced by application of differentlevels of sulphur and boron

Treatments	30-60 DAS (g m^{-2} day^{-1})	60 DAS -At harvest(g m^{-2} day^{-1})
Factor A : Sulphur levels (S)		
S_0: 0 kg ha^{-1}	5.98	4.58
S_1: 20 kg ha^{-1}	7.21	4.48
S_2: 30 kg ha^{-1}	9.71	4.46
S_3: 40 kg ha^{-1}	9.99	4.97
S.Em±	0.41	0.31
CD (P=0.05)	1.20	NS
Factor B : Boron levels (B)		
B_0: 0 kg ha^{-1}	7.10	4.80
B_1: 2.5 kg ha^{-1}	8.57	4.47
B_2: 5.0 kg ha^{-1}	9.00	4.59
S.Em±	0.35	0.27
CD (P=0.05)	1.04	NS
Interaction (A x B)		
S_0B_0	5.21	3.73
S_0B_1	5.83	4.65
S_0B_2	6.91	3.95
S_1B_0	6.90	3.74
S_1B_1	7.06	4.15
S_1B_2	7.65	5.56
S_2B_0	7.41	4.20
S_2B_1	10.68	4.80
S_2B_2	11.05	4.37
S_3B_0	8.89	6.14
S_3B_1	10.71	4.30
S_3B_2	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 differentlevels of sulphur and boron

Treatments	30-60 DAS (g^{-1} dm^{-2} leaf area^{-1} day^{-1})	60 DAS-At harvest (g^{-1} dm^{-2} leaf area^{-1} day^{-1})
Factor A : Sulphur levels (S)		
S_0: 0 kg ha^{-1}	4.98	2.11
S_1: 20 kg ha^{-1}	5.49	2.32
S_2: 30 kg ha^{-1}	6.25	2.85
S_3: 40 kg ha^{-1}	6.52	3.48
S.Em±	0.36	0.23
CD (P=0.05)	1.05	0.67
Factor B : Boron levels (B)		
B_0: 0 kg ha^{-1}	5.42	2.95
B_1: 2.5 kg ha^{-1}	5.92	2.56
B_2: 5.0 kg ha^{-1}	6.08	2.50
S.Em±	0.31	0.20
CD (P=0.05)	NS	NS
Interaction (A x B)		
S_0B_0	4.82	4.21
S_0B_1	4.73	3.51
S_0B_2	5.38	2.73
S_1B_0	5.51	2.35
S_1B_1	5.30	2.57
S_1B_2	5.65	3.37
S_2B_0	5.19	2.27
S_2B_1	6.77	2.16
S_2B_2	6.78	1.91
S_3B_0	6.17	2.96
S_3B_1	6.89	1.99
S_3B_2	6.51	2.01
S.Em±	0.62	0.40
CD (P=0.05)	NS	NS

per ha (10.28 kg ha^{-1}). Significantly less (8.38 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 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 kg ha^{-1}). Significantly lowest uptake (7.05 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 Chaubey et al. [29], [30,31].

3.8.3 Potassium

Table 6 presents data on the uptake of potassium in sesame (kg/ha), influenced by different levels of sulphur and boron. Notably, the total uptake of potassium in sesame was significantly higher with the application of 40 kg sulphur per hectare (36.78 kg/ha), on par with the uptake from 30 kg sulphur per hectare (36.21 kg/ha). The treatment with no sulphur application showed significantly lower uptake (25.95 kg/ha). Similarly, significantly higher total potassium uptake was found with the application of 5 kg borax per hectare (35.60 kg/ha), on par with the uptake from 2.5 kg borax per hectare (32.90 kg/ha). Significantly less total potassium accumulation in sesame (27.49 kg/ha) was observed with no borax application. Regarding interaction effects, the treatment with 30 kg sulphur and 5 kg borax per hectare recorded significantly higher total potassium uptake at harvest (45.23 kg/ha). This was on par with the total potassium uptake from the combinations of 40 kg sulphur with 5 kg borax per hectare, 40 kg sulphur with 2.5 kg borax per hectare, and 30 kg sulphur with 2.5 kg borax per hectare, which recorded uptakes of 40.47 kg/ha, 39.09 kg/ha, and 38.14 kg/ha, respectively.

The lowest uptake (25.36 kg/ha) was found with no sulphur and borax application. The observed increase in potassium uptake could be attributed to the sufficient quantity of potassium present in the soil and supplied through MOP fertilizer. Additionally, potassium, even when not required, tends to be responsive for more storage in the plant. The higher photosynthetic activity in the leaf, influenced by potassium with nitrogen and sulphur nutrition, indirectly led to the efficient utilization of nutrients applied to the soil. Similar findings were reported by Jadav et al. [3], Afifi et al. [10].

3.8.4 Sulphur

Table 6 provides data on the uptake of sulphur in sesame (kg/ha), influenced by different levels of sulphur and boron. Notably, significantly higher total sulphur uptake was found with the application of 40 kg sulphur per hectare (10.42 kg/ha), on par with the uptake from 30 kg sulphur per hectare (9.89 kg/ha). The treatment with no sulphur application showed significantly lower total sulphur accumulation in sesame (5.96 kg/ha). Similarly, the total uptake of sulphur in sesame was significantly higher with the application of 5 kg borax per hectare (9.55 kg/ha), on par with the uptake from 2.5 kg borax per hectare (8.54 kg/ha). Significantly less (6.91 kg/ha) sulphur uptake was reported with no borax application. Regarding interaction effects, the treatment with 30 kg sulphur and 5 kg borax per hectare recorded significantly higher total sulphur uptake at harvest (13 kg/ha). This was on par with the total sulphur uptake from the combinations of 40 kg sulphur with 5 kg borax per hectare, 40 kg sulphur with 2.5 kg borax per hectare, and 30 kg sulphur with 2.5 kg borax per hectare, which recorded uptakes of 11.49 kg/ha, 11.16 kg/ha, and 11.12 kg/ha, respectively.

Table 5. Seed yield, Stalk yield and Protein content of sesame as influenced byapplication of different levels of sulphur and boron

Treatments	Seed yield(kg ha^{-1})	Stalk yield(kg ha^{-1})	Protein content (%)
Factor A : Sulphur levels (S)			
S_0: 0 kg ha^{-1}	290	1985	9.69
S_1: 20 kg ha^{-1}	356	2088	10.14
S_2: 30 kg ha^{-1}	423	2473	10.46
S_3: 40 kg ha^{-1}	424	2578	10.44
S.Em±	7	129	0.06
CD (P=0.05)	22	380	0.17
Factor B : Boron levels (B)			
B_0: 0 kg ha^{-1}	347	1981	10.03
B_1: 2.5 kg ha^{-1}	381	2355	10.19
B_2: 5.0 kg ha^{-1}	393	2507	10.33
S.Em±	6.51	112.46	0.05
CD (P=0.05)	19.08	329.83	0.15
Interaction (A x B)			
S_0B_0	273	2006	9.56
S_0B_1	302	2033	9.69
S_0B_2	296	1916	9.82
S_1B_0	335	2077	10.07
S_1B_1	381	2026	10.01
S_1B_2	383	2160	10.33
S_2B_0	350	1666	10.53
S_2B_1	445	2626	10.39
S_2B_2	470	3126	10.45
S_3B_0	416	2176	9.95
S_3B_1	455	2733	10.66
S_3B_2	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 byapplication of different levels of sulphur and boron

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	B (ppm)
Factor A : Sulphur levels (S)					
S_0: 0 kg ha^{-1}	23.57	7.40	25.95	5.96	79.9
S_1: 20 kg ha^{-1}	26.75	8.58	29.05	7.06	92.7
S_2: 30 kg ha^{-1}	32.73	11.76	36.21	9.89	123.0
S_3: 40 kg ha^{-1}	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
Factor B : Boron levels (B)					
B_0: 0 kg ha^{-1}	25.26	8.38	27.49	6.91	87.5
B_1: 2.5 kg ha^{-1}	30.12	10.28	32.90	8.54	107.7
B_2: 5.0 kg ha^{-1}	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
Interaction (A x B)					
S_0B_0	23.19	7.05	25.36	5.84	78.7
S_0B_1	24.21	7.61	26.78	5.99	81.0
S_0B_2	23.32	7.55	25.72	6.04	80.0
S_1B_0	26.13	8.20	28.55	6.72	89.2
S_1B_1	25.70	8.30	27.60	6.80	89.1
S_1B_2	28.41	9.24	30.99	7.65	99.9
S_2B_0	23.37	7.78	25.26	6.22	84.0
S_2B_1	34.59	12.52	38.14	10.46	129.4
S_2B_2	40.23	15.01	45.23	13.00	162.4
S_3B_0	28.33	10.48	30.79	11.12	97.9
S_3B_1	36.00	12.71	39.09	11.16	131.2
S_3B_2	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 ofsulphur and boron

Treatments	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net returns (Rs ha^{-1})	C:B ratio
S_0B_0	12533	34166	21633	2.7
S_0B_1	12683	37750	25067	3.0
S_0B_2	12833	37032	24199	2.9
S_1B_0	15199	41959	26760	2.8
S_1B_1	15349	47652	32303	3.1
S_1B_2	15499	47884	32385	3.1
S_2B_0	16532	43820	27288	2.7
S_2B_1	16682	55708	39026	3.3
S_2B_2	16832	58750	41918	3.5
S_3B_0	17865	52111	34246	2.9
S_3B_1	18015	56891	38876	3.2
S_3B_2	18165	57695	39530	3.2

The lowest uptake (5.84 kg/ha) was found with no sulphur and borax application. The observed increase in sulphur uptake could be attributed to the application of sulphur, supplied through elemental sulphur [32]. Additionally, the higher photosynthetic activity in the leaf, influenced by sulphur nutrition, indirectly led to the efficient utilization of nutrients applied to the soil [10,33].

Since sulphur is a structural part of proteins involved in various biological functions, it increased root proliferation and rhizosphere area, aiding in more nutrient uptake [34]. The increased sulphur uptake also synergistically increased the uptake of boron. Similar findings were reported by Mahajan et al. [35].

3.8.5 Boron

Data pertaining to uptake of boron in sesame (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 g ha^{-1}) and which found on par with application of 30 kg sulphur per ha (123 g ha^{-1}). Treatment no sulphur showed significantly less total boron accumulation in sesame (79.9 g ha^{-1}). Significantly higher total boron uptake found with the application of 5 kg borax per ha (120.6 g ha^{-1}) followed by application of 2.5 kg borax per ha recorded (107.7 g ha^{-1}). Significantly less (87.5 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 higher total boron uptake at harvest (162.4 g ha^{-1}) and it found on par with application of 40 kg sulphur and 5 kg borax per ha (139.9 g ha^{-1}). Significantly lowest uptake (78.7 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 [33,36]. 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 [11,14]. Increased rhizosphere area by sulphur also helps for more uptake of boron. These findings are in agreement with findings of Tahir et al.[24].

3.9 Economics

The data on economics as influenced by application of different levels of sulphur and boron in sesame (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 Dange et al.[30].

4. 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 kg ha^{-1}), net return (41918 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.

ACKNOWLEDGEMENT

Authors acknowledge Department of Agronomy, ZARS, GKVK and UAS, Bangalore for providing scientific ways to carry out the research. The moral and technical support provided by friends, juniors, staff and farmers are greatly acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhosale ND, Dabhi BM, Gaikwad VP, MC. Agarwal, Influence of potash and sulphur levels on yield, quality and economics of sesamum (*Sesamum indicum* L.). Int. J. Agric. Sci. 2011;6(2) : 335-337.

2. Jeena M, Sumam G. Sustaining the productivity of sesame (*Sesamum indicum* L.) grown in Onattukara andy soil through the application of sulphur and boron. Asian J. Soil Sci. 2016;11 (2):318-323.
3. Jadav DP, Padamani DR, Polara KB, Parmar KB, Babaria NB. Interaction effect of sulphur and potassium on yield and nutrients uptake by sesame (*Sesamum indicum* L.). Asian J. Soil Sci. 2010;5(1):144- 147.
4. Anonymous. Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Govt. of India; 2018.
5. Shinde SD, Raskar BS, Tamboli BD, Effect of spacing and sulphur levels on productivity of sesame (*Sesamum indicum* L.) under summer condition. J. Maharastra Agric. Univ. 2011;36(1) :28-31
6. Deshmukh MR, Duhoon SS, Jyotishi A, Effect of sources and levels of sulphur on seed yield, oil content and economics of sesame (*Sesamum indicum* L.) in Kymore plateau zone of Madhya Pradesh (India). J. Oil seeds Res. 2010;27(1):34-35.
7. Gokhale DN, Kanade AG, Karanjikar PN, Patil VD, Effect of sources and levels of sulphur on seed yield, quality and sulphur uptake by soybean (*Glycine max* L.). J. Oil seeds Res. 2005;22 (1):192-193.
8. Shamina and Imamul, Mineralization pattern of added sulphur in some Bangladesh soils under submerged condition. Indian J. Agric. Chem. 2003;36(4):13- 21
9. Hassan F, Hakim S, Qadir G, Ahmad S, Response of sunflower (*Helianthus annuus* L.) to sulphur and seasonal variations. Int. J. Agri. and Bio. 2007;9(3):499–503.
10. Afifi MHM, Khalifa RKM, Camilia Y. 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. 2011;5(7):826-832
11. Kallol B, Jajati M, Hirak B, Ayon A, Krishnendu R, Amit P. Boron fertilization in sunflower (*Helianthus annus* L.) in an inceptisol of West Bengal. Commun. Soil Sci. Plant Anal. 2015;46(4):528–544.
12. Hamedeldin N, Hussein OS, Response of sesame (*Sesame indicum* L.) plants to foliar spray with different concentration of boron. J. American Oil Chem. Soc. 2014;91:1949–1953.
13. Soleimani, S. Effect of boron levels on potato and sesame crop sequence. Ann. Hort. 2006;6 (1):60–64.
14. Kabir R, Sabina Y, Mominul I, Rahman S. Effect of phosphorus, calcium and boron on the growth and yield of groundnut (*Arachis hypogea* L.). Int. J. Biosci. Biotech., 2013;5(3):12-16.
15. Watson DJ. The physiological basis for variation in yield. Adv. Agron. 1952;4:101-145.
16. Gregory FG. The effect of climatic conditions on growth of barley. Ann. Bot. 1926;46:1-26.
17. Powar JF, Willid WO, Grunes DI, Reichman CA. Effect of soil temperature, phosphorus and plant age on growth analysis of barley. Agron. J. 1967;59:231-234.
18. Jackson MK, Soil chemical analysis. Prentice-Hall. Inc. Engle Wood Cliffs, New Jersey; 1973.
19. Chesnin L, Yien CH. Turbidimetric determination of available sulphur. Proc. Soil Sci. Soc. Amer. 1951;15:149-151.
20. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. ICAR, Publ., New Delhi. 1967;359.
21. Sonia A, Nuruzzaman M, Fahmina Akhter, Islam MN, Sutradher GNC. Response of nitrogen and sulphur on the oil content of sesame and nutrient status of soil. Int. J. Bio-resource and Stress Mangt. 2014;5(1):41-46.
22. Prajapat K, Shivran AC, Choudhary GL, Choudhary HR, 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. 2012;57(1):89-91.
23. Prakash M, Saravanan K, Sunil Kumar B, Jagadeesan S, Ganesan J. Effect of plant growth regulators and micronutrients on yield attributes of sesame. Sesame Safflower Newslett. 2013;18.
24. Tahir M, Ibrahim MA, Tahir S, Ayub A, Tanveer, A. and Rehman, H., Effect of sulphur levels on two sesame (*Sesamum indicum* L.) varieties under climatic conditions of Pakistan. Int. J. Plant & Soil Sci. 2014;3(3):281-288.
25. Kewat RN, Chandrashekhar Singh RP, Saurabh D. Influence of sulphur application on oil content and fatty acid profile in sesame (*Sesamum indicum* L.). Agril. Biol. Res. 2009;25(2): 119-127.

26. Dhage SJ, Patil PA. Effect of sulphur sources and their rates on yield, growth parameters, uptake of nutrients and quality of sunflower. Asian J. Soil Sci. 2008;3(2):323-325
27. Duhoon SS, Deshmukh MR, Jyotishi A, Jain HC, 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. 2005;22(1):199-200.
28. Kundu CK, Mondal S, Basu B, Bandopadhyay, P., Effect of doses and time of sulphur application on yield and oil content of sesame (Sesamum indicum L.). Environ. Ecol., (2010); 28 (4) : 2629-2631.
29. Chaubey AK, Kaushik MK, Singh SB. Response of sesame (*Sesamum indicum*) to nitrogen and sulphur in light-textured entisol. Indian Agriculturist. 2003;14(2):61-64.
30. Dange VP, Jadhav SD, Nalge DN, Mohod PV. Effect of sulphur and zinc on nutrient uptake and quality of semi-rabi sesame. Ann. J. PlantPhysiol. 2008;22(1):81-83.
31. George S. Effect of boron on the performance of sesame in sandy soil of Kerala, (India). Indian J. Agric. Res. 2012;47(3):214–219.
32. Patil BK, Patra P, Ghosh GK, Mondal S, Malik GC, Biswas PK. Efficacy of phosphogypsum and magnesium sulphate as sources of sulphur to sesame (*Sesamum indicum* L.) in red and lateritic soils of West Bengal. J. Crop and Weed. 2011;7(1):133-135.
33. Mathew and Suman, Sulphur and boron improves the yield of oilseed sesame in sandy loam soil of Kerala. Indian J. Agron. 2013;53(2):129-134.
34. Mallik K, Raj, Effect of different levels of phosphorus, sulphur and boron on growth and yield of sesame (*Sesamum indicum* L.). J. Oilseeds Res. 2015; 29(2):75-77.
35. Mahajan R, Bharathi K, Sekhar SH, Ranganath G. Effect of integrated nutrient management on seed yield and economics of sesame. J. Oilseeds Res. 2013;27(5):79–81.
36. Mamatha K, Vidya S, Laxmi N. Influence of different levels of boron along with application of farm yard manure on nutrient uptake and yield of sesame. Int. J. Farm Sci. 2016;6(2):37-45.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/110094