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*Research Article*

# Productivity and profitability of mustard [*Brassica juncea* (L.) Czern. and Coss.] under varying levels of sulphur and boron application methods

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**Abstract**
Nearly 50.1 and 80.8% of soils in Odisha are deficient in sulphur and boron, respectively. These two nutrients play multiple roles in the nutrition of mustard [*Brassica juncea* (L.) Czern. and Coss.] crop. The rapeseed and mustard productivity in Odisha is lower than the national average due to non-application of these two nutrients. Hence, an experiment was conducted at Bhubaneswar, India, during *rabi* season of 2021-22 to assess the effects of sulphur levels and boron application methods on the productivity and profitability of the crop. The treatments comprising four levels of sulphur ($S_0$: 0, $S_1$: 20, $S_2$: 40 and $S_3$: 60 kg ha$^{-1}$) assigned in the main plots and four boron application methods ($B_1$: 0.5 kg B ha$^{-1}$ basal, $B_2$: $B_1$ + one foliar spray of boron 0.02%, $B_3$: $B_1$ + two foliar sprays of boron 0.02% and $B_4$: 1.0 kg boron ha$^{-1}$ basal) assigned in the sub plots were tried in split plot design replicated thrice. The application of 60 kg S ha$^{-1}$ recorded the maximum mustard seed yield (1275 kg ha$^{-1}$), which was at par with 40 kg S ha$^{-1}$ (1262 kg ha$^{-1}$). Among boron application methods, 50% RDB basal + two foliar sprays of boron (0.02%) recorded the maximum seed yield (1170 kg ha$^{-1}$) and proved better than other methods. The combined application of 40 kg S ha$^{-1}$ + 50% RDB basal with two foliar sprays of boron (0.02%) produced the maximum mustard seed yield (1283 kg ha$^{-1}$), net return ( ₹ 26,470 or 330.88 USD ha$^{-1}$) and B: C ratio (0.64).

**Keywords**: Gross return, growth parameters, LAI, net return, yield attributes, USD

## INTRODUCTION

Mustard is an important *rabi* season oilseed crop of India next to groundnut and soybean (Patel *et al*., 2023). Mustard oil is good for health and Manchanda and Passi (2016) reported the role of mustard and rapeseed oils in checking coronary heart disease due to their favourable omega-6 linoleic acid/ omega-3 alpha-linolenic acid ratio, low saturated fatty acids (12%), and high monosaturated fatty acid content (60%) and their relative stability during cooking. The average productivity of rapeseed and mustard in Odisha is 293 kg ha$^{-1}$, which is against the Indian national average of 1331 kg ha$^{-1}$ (GOI, 2020), reflecting a wide gap between provincial and national productivity. Negligence in the application of secondary and micronutrients is one of the reasons for the state's low rapeseed and mustard productivity. Besides primary nutrients, application of secondary nutrients, more particularly sulphur and micronutrient like boron is crucial for realising potential yield of mustard in the state. Next to N, P and K, sulphur is the fourth important element for increasing yield and quality of rapeseed and mustard (Atkari *et al.,* 2022). The practice of multiple cropping, the application of sulphur-free fertilizers, and the limited use of organic manures aggravate the sulphur deficiency. Sulphur plays multiple role in nutrition of mustard crop. Sulphur is constituent of several coenzymes (biotin, coenzyme A, thiamine pyrophosphate, lipoic acid and thioredoxin) and sulpholipids (Sao and Pradhan, 2022). Sulphur determines seed yield, oil content and quality, and crop resistance to various stresses. It is required for chlorophyll formation, oil and seed protein synthesis, amino acids (cysteine, cystine and methionine), enzymes, and glucosinolate. This element increases oil content by enhancing the activity of an enzyme called acetyl-CoA carboxylase, which is essential for oil synthesis (Maurya *et al*., 2023). Nearly 50.1% of soils in Odisha are deficient in S (Dixit *et al*., 2020). Singh *et al.* (2023) reported the maximum growth parameters, yield attributes and yield of mustard with application of 60 kg S $ha^{-1}$ in Punjab, India. There is a need to find out the sulphur requirement of the crop under Odisha situation. Boron is the second most essential micronutrient in mustard after zinc (Bhinda and Singh, 2023). Boron plays an important role in the growth and development of crops; Singh and Goswami (2014) underscored need of boron for the growth and development of pollen tubes and the movement of growth regulators within the plants. Boron plays an important role in the cell division and elongation, structural and functional integrity of the cell wall membranes, N and carbohydrate metabolism and sugar transport (Shireen *et al*., 2018). Reproductive growth phases, viz., flowering, fruiting and seed setting, are more sensitive to B deficiency than vegetative growth phases. Nearly 80.8% of soils in Odisha are deficient in boron (Dixit *et al*., 2020). Boron fertilisation is necessary, when the available B status in the soil is below the critical level (0.58 mg $kg^{-1}$) for improvement of crop yields and nutritional quality. Soil application of boron up to 1.0 kg $ha^{-1}$ (Yanthan and Singh, 2021; Tyagi *et al*., 2022) has been recommended for maximising the productivity of mustard. Masum *et al*. (2019) and Sinha *et al.* (2022) achieved the maximum mustard yield with foliar boron spray. Both soil application and foliar spray have advantages and disadvantages. Like other micronutrients, boron applied to soil is subjected to fixation and rendered unavailable to the crop; while excess application leads to toxicity related problems. Soil applied B is available to the crop from the beginning of the crop growth. Foliar application is effective, but the crop gets the nutrients when sprayed at the vegetative and reproductive stages of the crop after sufficient canopy coverage. Thus, there is a need to assess the efficacy of boron application methods viz., soil application alone, foliar spray alone or combination of soil and foliar application. Sulphur and boron fertilisation act synergistically to maximise the productivity and profitability of mustard. Sinha *et al*. (2022) got the maximum productivity of mustard with a combined application of S @40 kg $ha^{-1}$ as soil application followed by two boron sprays.

Considering all these factors, the present research work aimed to assess the impact of S levels and B application methods on the productivity and profitability of mustard under Odisha condition.

## MATERIALS AND METHODS

### Study area

The experiment was carried out at Agricultural Research Farm, Binjhagiri, Chhatabar, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, India which is situated at 28$^{o}$ 40' N latitude and 27$^{o}$ 12' E longitude with an altitude of 45m above the mean sea level. The Research Station comes under 'East and South Eastern Coastal Plain' Agro-Climatic Zone of Odisha. The soil of the experimental site was sandy clay loam in texture with bulk density 1.58 Mg $m^{-3}$, field capacity of 12.7% and permanent wilting point of 5.2%. The soil was low in organic carbon (0.43%) and available N (178 kg $ha^{-1}$); while it was medium for available P (12.8 kg $ha^{-1}$) and K (196 kg $ha^{-1}$). The soil was low in available S (8.5 mg $kg^{-1}$) and B (0.32 mg $kg^{-1}$). The location is characterised by a warm, moist humid climate with hot summer and short mild winter. The weekly average maximum temperature of the cropping season ranged from 26.2 $^{o}$C (Standard Meteorological Week - 2$^{nd}$ SMW, 2022) to 36.2 $^{o}$C (11$^{th}$ SMW, 2022). The mean minimum temperature varied from 14 $^{o}$C (5$^{th}$ SMW, 2022) to 22.2 $^{o}$C (11$^{th}$ SMW, 2022). The relative humidity in the morning during the cropping season remained around 86 to 95%, while it was around 41 to 82% in the afternoon. The average bright sunshine hours per day ranged from 2.7 to 8.8 hours.

### Treatment details

The experiment was laid out in a split-plot design with three replications. Four levels of sulphur viz., $S_0$: 0 kg $ha^{-1}$, $S_1$: 20 kg $ha^{-1}$, $S_2$: 40 kg $ha^{-1}$ and $S_3$: 60 kg $ha^{-1}$ were put in the main plot, while four boron application methods viz., $B_1$: 50% recommended dose of boron as basal (50% RDB basal), $B_2$: 50% RDB as basal + foliar spray of borax 0.2% once at 30 DAS (50% RDB+BFSO), $B_3$: 50% RDB as basal + 2 foliar spray of borax 0.2% twice at 30 and 45 DAS (50% RDB+BFST) and $B_4$: 100% RDB @1 kg B $ha^{-1}$ as basal (100% RDB basal) in the subplot. The boron requirement for basal application was met through borax containing 11% boron. The test variety taken was 'NRCHB 101', developed by National Research Centre on Rapeseed and Mustard, Directorate of Rapeseed and Mustard Research, Bharatpur, Rajasthan. Before the sowing of mustard, one primary tillage was done followed by levelling. Then, FYM @ 5t $ha^{-1}$ was applied and incorporated in the soil at final ploughing as basal application. Recommended dose @ 80-40-40 N-$P_2O_5$-$K_2O$ kg $ha^{-1}$ was applied as diammonium phosphate (DAP), urea and muriate of potash (MOP) in furrows. Out of the RDF, 50% N, full $P_2O_5$ and $K_2O$ were applied as basal, and the rest 50% N was top dressed at 23 DAS after hoeing, weeding and thinning operations. Elemental sulphur containing 85% S was applied as per the treatments (basal and foliar applications). The seeds were treated with Carbendazim 1.0g + Thiram 1.5g per kg of seed prior to sowing. Seeds were sown @ 6.0 kg $ha^{-1}$ in lines drawn manually with a row spacing of 45 cm at a depth of 3 cm.

### Growth, yield and economic parameters

Five plants were uprooted from destructive sampling rows for dry matter accumulation, air-dried in the shade, followed by oven drying at 70 °C until a constant weight was obtained. The LAI values were calculated as per Watson (1952). Crop growth rate (g $m^{-2}$ $day^{-1}$) was calculated by using the formula:

$$Crop\ growth\ rate\ (CGR) = \frac{W_2 - W_1}{t_2 - t_1}\ g\ m^{-2}\ day^{-1} \quad \text{Eq. 1}$$

Where, $W_1$ and $W_2$ are dry matter accumulation per unit area at time $t_1$ and $t_2$, respectively.

The crop from net plot area was harvested treatment-wise manually and threshed after sun drying. The final seed and stover weight were recorded in kg per plot and converted into kg $ha^{-1}$. Harvest index (%) was computed as the ratio of economic yield to the biological yield. The production efficiency of mustard was calculated by dividing the seed yield (kg $ha^{-1}$) by the maturity duration of the crop. The economics of the treatments was calculated by considering the prevailing market prices of inputs and crop output. The net return was calculated by deducting the total cost of cultivation from the gross return. The benefit: cost was computed by dividing net return by cost of cultivation. The treatment-wise economic efficiency was determined by dividing the value of produce, i.e., seed yield (kg $ha^{-1}$) x minimum support price ( ₹ $kg^{-1}$), by the duration of the crop.

$$Economic\ efficiency = \frac{Seed\ yield\ (kg\ ha^{-1})\ x\ MSP\ (₹\ kg^{-1})}{Crop\ duration(days)} \quad \text{Eq. 2}$$

### Statistical analysis

The analysis of variance for split-plot design was used and the significance was tested by employing 'F-test' as per the procedure of Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

### Growth attributes

#### Leaf area index

The LAI values were minimum at 30 DAS, increased till the maximum values at 60 DAS and decreased thereafter due to leaf shedding and senescence (Table 1). The values were minimum in absence of the sulphur application and higher with increase in sulphur levels with the maximum values at 60 kg S $ha^{-1}$. Application of 60 kg S $ha^{-1}$ recorded the highest value of LAI (4.24) at 60 DAS and proved significantly superior to all other S levels. The increase in LAI depends on increase in number of leaves and size of leaves. Higher values of LAI with application of sulphur was due to role of the nutrient in chlorophyll formation (hence, higher photosynthesis), synthesis of amino acids (cystine, cysteine and methionine) and protein, leaf expansion and enhanced leaf area. The results corroborate the findings of Prajapati *et al*. (2023), who reported the maximum value of LAI when applied to 60 kg S $ha^{-1}$. Different B application methods significantly influenced LAI at all the growth stages. Application of 50% RDB+BFST, 100% RDB Basal and 50% RDB+BFSO were statistically at par with respect to the LAI at 60 DAS and proved superior to 50% RDB basal. Higher LAI with 50% RDB basal+BFST, 100% RDB basal and 50% RDB basal +BFSO was due to adequate accumulation of the nutrient by the crop that favoured cell division and differentiation and increased LAI (Shireen *et al.,* 2018). Sinha *et al.* (2022) reported increased number of leaves (indicator of higher LAI) with two foliar boron sprays.

#### Dry matter accumulation

The dry matter accumulation increased with advancement in growth stages till harvest (Table 1). The increase was rapid up to 90 DAS and slow thereafter. Applying 60 kg S $ha^{-1}$ recorded the maximum dry matter per plant (25.57 g $plant^{-1}$) and proved significantly superior to the rest of the treatments. This may be ascribed to the maximum LAI (4.24) noted at the maximum level of S application. Higher LAI led to better capture of sunlight, higher rate of photosynthesis and dry matter accumulation. The maximum dry weight in mustard due to application of S @ 60 kg $ha^{-1}$ corroborates the findings of Kumar *et al*. (2022). Application of 50% RDB basal+BFST recorded the highest dry matter of 4.48, 12.81 and 23.94 g $plant^{-1}$ at 30, 60 and 90 DAS, respectively, being at par with 50% RDB basal+BFSO and 100% RDB basal at 30 DAS, 100% RDB basal at 60 DAS and 50% RDB basal+BFSO at 90 DAS. Higher LAI with 50% RDB basal+BFST, 50%

RDB basal+BFSO and 100% RDB basal than 50% RDB basal led to higher dry matter accumulation. Pandey *et al.* (2018) reported higher values of plant height and branches/plant of mustard (indicator of dry matter accumulation) with an application of boron @ 1.0 and 2.0 kg $ha^{-1}$. Choudhary *et al*. (2023) reported the maximum dry matter accumulation with an application of 10 kg borax $ha^{-1}$ (1.0 kg B $ha^{-1}$).

**Crop growth rate**

The crop growth rates were computed at 30-day intervals commencing from 30 DAS till harvest (Fig. 1). There was a progressive increase in CGR (g $m^{-2}$ $day^{-1}$) from 30 to 90 DAS and declined thereafter. The CGR at 30-60 DAS varied from 4.94 g $m^{-2}$ $day^{-1}$ (control) to 5.56 g $m^{-2}$ $day^{-1}$ (60 kg S $ha^{-1}$). During the period 60-90 DAS, application of 40 kg S $ha^{-1}$ recorded the highest CGR value (7.95 g $m^{-2}$ $day^{-1}$), being at par with CGR at 20 and 60 kg S $ha^{-1}$. During the period from 90 DAS till harvest, the CGR varied from 2.93 g $m^{-2}$ $day^{-1}$ (control) to 3.98 g $m^{-2}$ $day^{-1}$ (S @40 kg $ha^{-1}$). The CGR value varied from 5.34 to 5.52, 7.18 to 7.77 and 3.14 to 3.67 g $m^{-2}$ $day^{-1}$ during 30-60 DAS, 60-90 DAS and 90 DAS to harvest, respectively, due to different boron application methods. However, application of 50% RDB+BFST registered the highest CGR for all the intervals.

**Yield attributes and yield**

**Yield attributes**

Different sulphur levels significantly influenced the yield attributes of mustard, viz., siliquae $plant^{-1}$, seeds $siliqua^{-1}$, and test weight (Table 2). The application of 60 kg S $ha^{-1}$ recorded the highest siliquae $plant^{-1}$ (86.6), placing 40 kg S $ha^{-1}$ at par and proved significantly superior to 0 and 20 kg S $ha^{-1}$. 60 kg S $ha^{-1}$ application recorded the highest seeds $siliqua^{-1}$ (13.4) and test weight (4.13g), keeping 40 and 20 kg S $ha^{-1}$ statistically at par. Increase in test weight due to an increase in S levels was due to the role of sulphur in synthesis of oil and protein. The trend of sulphur levels for the yield attributes is in agreement with the findings of Kumar *et al*. (2022), Bhinda and Singh (2023), Patel *et al*. (2023), Prajapati *et al*. (2023) and Dixit *et al*. (2023). Among the boron application methods, the application of 50% RDB+BFST recorded the highest siliquae $plant^{-1}$ (82.1), keeping 50% RDB+BFSO at par and proved significantly superior to the other two boron application methods. Application of 50% RDB+BFST recorded the highest test weight (4.13g), keeping 100% RDB basal at par and proving significantly superior to the other two boron application methods. Increase in yield attributes was due to the role of boron in reproductive growth of plants, pollen viability and seed and fruit development (Shireen *et al.,* 2018). Raku *et al*. (2023) reported higher values of effective pods $plant^{-1}$ and seeds $pod^{-1}$ with 100% RDB basal+25% B as foliar spray. Choudhary *et al.* (2023) reported the maximum values of yield attributes with application of 10 kg borax $ha^{-1}$ (1.0 kg B $ha^{-1}$).

**Seed yield**

Application of 60 kg S $ha^{-1}$ recorded the highest seed yield, keeping 40 kg S $ha^{-1}$ at par and proved to be superior to other sulphur levels (Table 2). The extent of yield increase due to application of 40 kg S $ha^{-1}$ over 20 kg S $ha^{-1}$ and control were 34 and 58%, respectively, while the increase in seed yield due to 20 kg S $ha^{-1}$ over the control was 19 %. In mustard, seed yield is directly related to number of plants per unit area, siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and test weight of 1000 seeds. Since plant population was kept constant in all plots by thinning, seed yield was decided by siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and test weight of 1000 seeds. Increase in val-

**Table 1.** Effect of sulphur levels and boron application methods on leaf area index and dry matter accumulation of mustard at different growth stages

| Treatment | LAI | | | Dry matter accumulation (g $plant^{-1}$) | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 30 DAS | 60 DAS | 90 DAS | Harvest |
| S level (kg $ha^{-1}$) | | | | | | | |
| $S_0$ | 0.86 | 3.35 | 2.76 | 4.01 | 11.13 | 21.42 | 23.28 |
| $S_1$ | 0.91 | 3.67 | 3.47 | 4.29 | 11.83 | 21.63 | 24.01 |
| $S_2$ | 1.01 | 4.08 | 3.88 | 4.32 | 11.63 | 21.75 | 23.59 |
| $S_3$ | 1.39 | 4.24 | 4.14 | 4.56 | 12.03 | 22.54 | 25.57 |
| SEm± | 0.08 | 0.02 | 0.27 | 0.12 | 0.14 | 0.39 | 0.18 |
| CD (p=0.05) | 0.29 | 0.09 | 0.82 | 0.36 | 0.48 | 1.35 | 0.61 |
| B application methods | | | | | | | |
| $B_1$ | 0.87 | 3.62 | 2.74 | 4.28 | 10.56 | 19.22 | 24.02 |
| $B_2$ | 1.08 | 3.85 | 3.28 | 4.33 | 11.71 | 22.81 | 24.02 |
| $B_3$ | 1.09 | 3.94 | 3.31 | 4.48 | 12.81 | 23.94 | 24.15 |
| $B_4$ | 1.05 | 3.93 | 3.43 | 4.44 | 12.66 | 20.59 | 24.28 |
| SEm± | 0.09 | 0.03 | 0.16 | 0.06 | 0.12 | 0.39 | 0.21 |
| CD (p=0.05) | 0.25 | 0.09 | 0.47 | 0.18 | 0.36 | 1.35 | NS |

**Table 2.** Effect of sulphur levels and boron application methods on yield attributes and yield of mustard

| Treatment | Siliquae plant$^{-1}$ | Seeds siliqua$^{-1}$ | 1000 seed weight (g) | Seed yield (kg ha$^{-1}$) | Stover yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| S level (kg ha$^{-1}$) | | | | | |
| $S_0$ | 68.7 | 11.7 | 3.80 | 794 | 1696 |
| $S_1$ | 77.2 | 13.0 | 4.09 | 941 | 1917 |
| $S_2$ | 83.5 | 13.1 | 4.10 | 1262 | 2588 |
| $S_3$ | 86.6 | 13.4 | 4.13 | 1275 | 2643 |
| SEm± | 1.9 | 0.3 | 0.05 | 19.58 | 76.03 |
| CD (p=0.05) | 6.6 | 1.1 | 0.18 | 67.75 | 263.07 |
| B application methods | | | | | |
| $B_1$ | 76.7 | 12.7 | 3.97 | 995 | 2041 |
| $B_2$ | 79.3 | 12.7 | 3.97 | 1040 | 2197 |
| $B_3$ | 82.1 | 13.1 | 4.13 | 1170 | 2343 |
| $B_4$ | 77.9 | 12.9 | 4.03 | 1065 | 2149 |
| SEm± | 1.2 | 0.4 | 0.05 | 6.47 | 47 |
| CD (p=0.05) | 3.4 | NS | 0.13 | 18.87 | 127 |

ues of yield attributes with an increase in levels of S was finally reflected as higher seed yield at higher S levels. Seed yield of mustard increased up to 45 kg S ha$^{-1}$ at Umerkote, Odisha (Sahoo *et al*., 2018). Kumar *et al*. (2022) and Dixit *et al.* (2023) achieved the maximum seed yield of mustard at the highest level of sulphur (60 kg S ha$^{-1}$), being at par with 40 kg S ha$^{-1}$. Bhinda and Singh (2023) and Patel *et al.* (2023) reported the maximum mustard seed yield at 40 kg S ha$^{-1}$. There was a significant difference in seed yield due to different B application methods. Application of 50% RDB basal produced the minimum seed yield of 995 kg ha$^{-1}$. Additional one and two foliar sprays of borax 0.2% increased seed yields by 4.7 and 17.6 %, respectively. There was a significant difference in seed yield due to basal application of 100% RDB (1 kg B ha$^{-1}$) over 50% RDB, which was 10.6 %. Application of 50% RDB+BFST recorded the highest seed yield (1170 kg ha$^{-1}$) and proved superior to all other boron application methods, reflecting an increase of 10, 13 and 18% over 100% RD of B, 50% RDB+BFSO and 50% RDB basal, respectively. Yanthan and Singh (2021) reported the maximum seed yield with the application of 1 kg B ha$^{-1}$. Masum *et al.* (2019) reported superiority of foliar Spray of B @ 1% at vegetative and pod formation stage over basal application of B @ 2kg ha$^{-1}$. The interaction effect of S levels and B application methods was found to be significant on the seed yield of mustard (Table 3). Application of 40 kg sulphur ha$^{-1}$ and B application method involving 50 % RDB as basal followed by 2 foliar sprays (0.2 % borax) at 30 and 45 DAS gave the highest seed yield (1283 kg ha$^{-1}$).

## Stover yield

The application of 60 kg S ha$^{-1}$ (2643 kg ha$^{-1}$) recorded the maximum stover yield, which was at par with 40 kg S ha$^{-1}$ (Table 2). The highest S level increased stover yields by 37.8 and 55.8 % over 20 kg and control, respectively. The increase in stover yield with application of sulphur was due to higher growth parameters and yield attributes. Bhinda and Singh (2023) and Patel *et al.* (2023) reported the maximum stover yield up to 40 kg S ha$^{-1}$, while Patel and Tiwari (2021) reported the maximum stover yield at 70 kg S ha$^{-1}$. There was a significant difference in stover yield due to different boron application methods. Application of 50% RDB basal produced the minimum stover yield of 2041 kg ha$^{-1}$. Inclusion of additional one and two foliar spray of boron 0.2% increased stover yield by 7.8 and 13.4 %, respectively. Application of 50% RDB+BFST recorded the highest stover yield (2343 kg ha$^{-1}$) and proved superior to all other boron application methods.

## Production efficiency

Application of 60 kg S ha$^{-1}$ recorded the highest production efficiency of 37.68 kg ha$^{-1}$ day$^{-1}$, keeping 40 kg S ha$^{-1}$ statistically at par with production efficiency of 36.64 kg ha$^{-1}$ day$^{-1}$ (Fig. 2). Application of 20 kg S ha$^{-1}$ registered 24.3% less production efficiency than 40 kg S ha$^{-1}$. Among the boron application methods, application of 50% RDB+BFST recorded the highest produc-

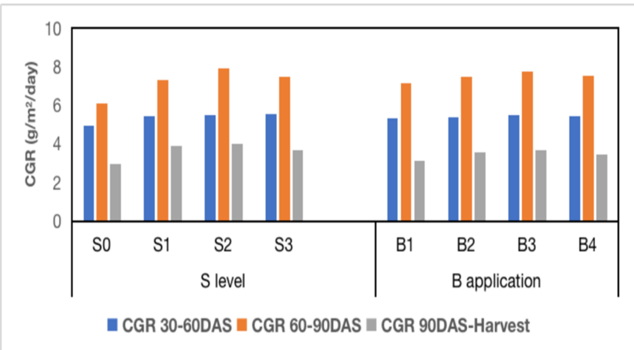


**Fig. 1.** *Effect of sulphur levels and boron application methods on crop growth rate of mustard*

tion efficiency of 34.12 kg ha$^{-1}$ day$^{-1}$ and proved significantly superior to all other methods.

## Economics

### Gross return

The gross return was the minimum of ₹ 41,780 ha$^{-1}$ (522.25 USD ha$^{-1}$) in the absence of sulphur application (Table 4). Application of S @ 20, 40 and 60 kg ha$^{-1}$ increased gross return by 18, 65 and 66 %, respectively, over 0 kg S ha$^{-1}$. Application of 60 kg S ha$^{-1}$ accrued the maximum gross return of ₹ 66,890 ha$^{-1}$(836.13 USD ha$^{-1}$), keeping 40 kg S ha$^{-1}$ with gross return of ₹ 66,400 ha$^{-1}$ (830.00 USD ha$^{-1}$ ) at par. Application of 1.0 kg B ha$^{-1}$ recorded significantly higher gross return than 0.5 kg B ha$^{-1}$ alone and 0.5 kg B ha$^{-1}$+foliar spray once. Yanthan and Singh (2021) reported the maximum gross return with 1.0 kg B ha$^{-1}$ application. Application of 50% RDB+BFST accrued the maximum gross return ₹ 61,380 ha$^{-1}$ (767.25 USD ha$^{-1}$) and proved significantly superior to all other boron application methods, registering 17, 12 and 9% increase over 50% RDB basal, 50% RDB+BFSO and 100% RDB basal, respectively. The trend of treatments (sulphur levels and boron application methods) for gross return is a reflection of the trend for yield.

### Net return

The net return of mustard with an application of 40 kg S ha$^{-1}$ was the maximum of ₹ 25,710 ha$^{-1}$ (321.38 USD ha$^{-1}$) and 60 kg S ha$^{-1}$ with net return of ₹ 24,720 ha$^{-1}$ (309.00 USD ha$^{-1}$) remained at par (Table 4). These results corroborate the findings of Kumar *et al*. (2022) who reported the maximum net return with application of S @40 kg ha$^{-1}$. The crop gave higher seed yield at 60 kg S ha$^{-1}$ (1275 kg ha$^{-1}$) than 40 kg S ha$^{-1}$ (1262 kg ha$^{-1}$), but the increase in seed yield could not compensate the cost of additional sulphur application. The net return was the minimum of ₹ 3960 ha$^{-1}$ (49.50 USD ha$^{-1}$) in absence of sulphur application and it increased by 183.5% due to application of 20 kg S ha$^{-1}$. Application of 1.0 kg B ha$^{-1}$ recorded significantly higher net return than 0.5 kg B ha$^{-1}$ alone and 0.5 kg B ha$^{-1}$+foliar spray once. The results are in agreement with findings of Yanthan and Singh (2021) who reported the maximum net return with application of 1.0 kg B ha$^{-1}$. Application of 50% RDB+BFST accrued the maximum net return of ₹ 21,380 ha$^{-1}$ (267.25 USD ha$^{-1}$) and proved significantly superior to all other boron application methods. Application of 50% RDB+BFST and 50% RDB+BFSO gave 64 and 42 % higher net return over 50% RDB alone, which underscores the role of foliar spraying of boron in increasing the net return. Combined application of 40 kg S ha$^{-1}$ and 50% RDB+BFST (Table 5) accrued the maximum net return of ₹ 26470 ha$^{-1}$ (330.88 USD ha$^{-1}$).

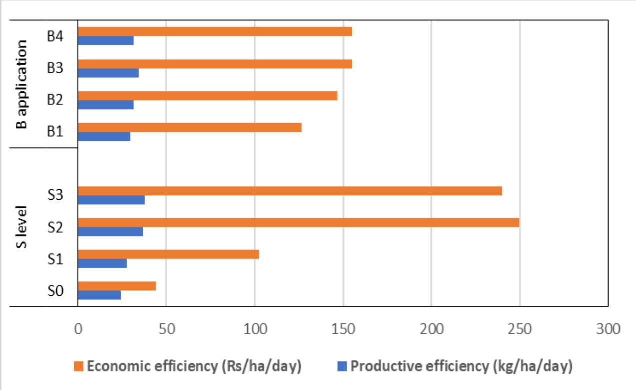


**Fig. 2.** *Effect of S levels and B application methods on production and economic efficiency of mustard*

### Benefit : cost ratio

The maximum benefit : cost ratio (0.59) was recorded with application of 40 kg S ha$^{-1}$ which was statistically at par with that of 60 kg S ha$^{-1}$ (Table 4). These results corroborate the findings of Kumar *et al*. (2022) who reported the maximum B:C with application of S @40 kg ha$^{-1}$. Applying 20 kg S ha$^{-1}$ resulted in a significant increase in the B:C ratio (0.25) over no sulphur (0.12). The B: C with application of 20 kg ha$^{-1}$ was 59.7% less than that of 40 kg S ha$^{-1}$. Application of 1.0 kg B ha$^{-1}$ recorded significantly higher B: C than 0.5 kg B ha$^{-1}$ alone and 0.5 kg B ha$^{-1}$+foliar spray once. The results corroborate the findings of Yanthan and Singh (2021)

**Table 3.** Interaction effect of S levels and B application methods on seed yield of mustard (kg ha$^{-1}$)

| Treatment | B application methods | | | |
|---|---|---|---|---|
| | $B_1$ | $B_2$ | $B_3$ | $B_4$ |
| S level (kg ha$^{-1}$) | | | | |
| $S_0$ | 727 | 769 | 858 | 821 |
| $S_1$ | 769 | 861 | 1250 | 941 |
| $S_2$ | 1238 | 1260 | 1283 | 1262 |
| $S_3$ | 1245 | 1270 | 1273 | 1191 |
| | S | B | S x B | B x S |
| SEm± | 19.58 | 6.47 | 22.56 | 12.93 |
| CD (p=0.05) | 67.75 | 18.87 | 64.90 | 35.12 |

**Table 4.** Effect of S levels and B application methods on the economics of mustard

| Treatment | GR | | NR | | B:C ratio | Economic efficiency | |
|---|---|---|---|---|---|---|---|
| | X10$^3$ ₹ ha$^{-1}$ | USD ha$^{-1}$ | X10$^3$ ₹ ha$^{-1}$ | USD ha$^{-1}$ | | ₹ ha$^{-1}$ day$^{-1}$ | USD ha$^{-1}$ day$^{-1}$ |
| Sulphur level (kg ha$^{-1}$) | | | | | | | |
| $S_0$ | 41.78 | 522.25 | 3.96 | 49.50 | 0.12 | 44.06 | 0.55 |
| $S_1$ | 49.47 | 618.38 | 10.55 | 131.88 | 0.25 | 102.39 | 1.28 |
| $S_2$ | 66.40 | 830.00 | 25.71 | 321.38 | 0.62 | 249.65 | 3.12 |
| $S_3$ | 66.89 | 836.13 | 24.72 | 309.00 | 0.59 | 240.01 | 3.00 |
| SEm± | 0.98 | 12.25 | 0.90 | 11.25 | 0.02 | 9.98 | 0.12 |
| CD (p=0.05) | 3.39 | 42.38 | 3.11 | 38.88 | 0.08 | 34.53 | 0.43 |
| Boron application methods | | | | | | | |
| $B_1$ | 52.28 | 653.50 | 13.01 | 162.63 | 0.31 | 126.74 | 1.58 |
| $B_2$ | 54.72 | 684.00 | 15.11 | 188.88 | 0.37 | 146.66 | 1.83 |
| $B_3$ | 61.38 | 767.25 | 21.38 | 267.25 | 0.53 | 155.20 | 1.94 |
| $B_4$ | 56.15 | 701.88 | 15.40 | 192.50 | 0.37 | 155.20 | 1.94 |
| SEm± | 0.31 | 3.88 | 0.49 | 6.13 | 0.01 | 3.26 | 0.04 |
| CD (p=0.05) | 0.90 | 11.25 | 1.43 | 17.88 | 0.04 | 9.52 | 0.12 |

GR – Gross return, NR – Net return, 1 USD = ₹ 80

**Table 5.** Interaction effect of S levels and B application methods on net return and B:C ratio of mustard

| Treatment | B application methods | | | |
|---|---|---|---|---|
| | $B_1$ | $B_2$ | $B_3$ | $B_4$ |
| Net return (x10$^3$ ₹ ha$^{-1}$) | | | | |
| S level (kg ha$^{-1}$) | | | | |
| $S_0$ | 1.45 | 3.56 | 7.57 | 3.23 |
| $S_1$ | 2.05 | 6.52 | 21.23 | 7.16 |
| $S_2$ | 25.00 | 25.68 | 26.47 | 25.69 |
| $S_3$ | 23.73 | 24.66 | 24.99 | 25.50 |
| Net return (USD ha$^{-1}$) | | | | |
| $S_0$ | 18.13 | 44.50 | 94.63 | 40.38 |
| $S_1$ | 25.63 | 81.50 | 265.38 | 89.50 |
| $S_2$ | 312.50 | 321.00 | 330.88 | 321.13 |
| $S_3$ | 296.63 | 308.25 | 312.38 | 318.75 |
| B:C ratio | | | | |
| $S_0$ | 0.04 | 0.09 | 0.20 | 0.14 |
| $S_1$ | 0.05 | 0.17 | 0.61 | 0.13 |
| $S_2$ | 0.57 | 0.63 | 0.64 | 0.62 |
| $S_3$ | 0.57 | 0.59 | 0.59 | 0.60 |

who reported the maximum B:C with 1.0 kg B ha$^{-1}$ application. Application of 50% RDB+BFST fetched the highest B : C (0.53) and proved superior to all the treatments. Application of 50% RDB as basal recorded the minimum B:C ratio of 0.31. Addition of one foliar spray of borax (0.2%) increased B:C ratio to 0.37, equal to that with 100 % RD of boron as basal (0.37). Combined application of 40 kg S ha$^{-1}$+ 50% RDB+BFST gave the highest B-C ratio of 0.64 (Table 5).

## Economic efficiency

Application of 40 kg S ha$^{-1}$ fetched the highest economic efficiency of ₹ 249.65 ha$^{-1}$ day$^{-1}$ (3.12 USD ha$^{-1}$ day$^{-1}$) which was at par with that of 60 kg S ha$^{-1}$ with ₹ 240.01 ha$^{-1}$ day$^{-1}$ (3.00 USD ha$^{-1}$ day$^{-1}$) (Table 4 and Fig. 2). The minimum economic efficiency of ₹ 126.74 ha$^{-1}$ day$^{-1}$ (1.58 USD ha$^{-1}$ day$^{-1}$) was recorded with the treatment 50% RDB basal. When this dose was supplemented with one foliar spray of boron (0.02%) at 30 DAS, the economic efficiency was improved by 15.7% to reach ₹ 146.66 ha$^{-1}$ day$^{-1}$(1.83 USD ha$^{-1}$ day$^{-1}$). Both 50% RDB+BFST and 100% RDB basal recorded the maximum economic efficiency of ₹155.20 ha$^{-1}$ day$^{-1}$(1.94 USD ha$^{-1}$ day$^{-1}$).

## Conclusion

Based on the findings, it was concluded that the maximum productivity and profitability of mustard can be achieved with the application of 80-40-40 N-$P_2O_5$-$K_2O$

kg $ha^{-1}$ along with 40 kg S $ha^{-1}$ through elemental sulphur and 0.5 kg B $ha^{-1}$ (borax @5 kg $ha^{-1}$) as basal followed by two foliar sprays of boron (0.02%) each at 30 and 45 days after sowing ($S_2B_3$) under East and South Eastern Coastal Plains Zone of Odisha.

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### Conflict of interest

The authors declare that they have no conflict of interest.

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