E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
www.agronomyjournals.com
2024; SP-7(5): 271-276
Received: 21-03-2024
Accepted: 27-04-2024

Himanshu Saini
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Victor Debbarma
Assistant Professor, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Talakayala Asha
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Ummed Singh
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Himanshu Saini
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India

Effect of Sulphur, Zinc and Boron on Growth and Yield of Mustard (*Brassica juncea* L.)

Himanshu Saini, Victor Debbarma, Talakayala Asha and Ummed Singh

DOI: https://doi.org/10.33545/2618060X.2024.v7.i5Sd.778

Abstract
A field experiment was conducted during *Rabi* season of 2023-24 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences to determine "Effect of Sulphur, Zinc and Boron on growth and yield of Mustard". The treatments consisted of three levels of Sulphur (15, 30 and 45 kg/ha), Zinc (5 kg/ha) and Boron (2 kg/ha) along with recommended doses of fertilizer and a control (80-40-40 kg N-P-K/ha). The results revealed that the significantly higher plant height (213.46 cm), higher plant dry weight (40.77 g), maximum number of siliqua/plant (213.8), maximum number of seeds/siliqua (17.73), higher test weight (5.78 g), higher seed yield (2.15 t/ha), and higher stover yield (6.03 t/ha) were recorded with treatment 9 (Sulphur 45 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha). The maximum gross return (183754.25 INR/ha), net return (129235.00 INR/ha) and B:C ratio (2.37) were also recorded with application of Sulphur 45 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha (treatment 9) was found to be productive as well as economically feasible.

Keywords: Boron, economics, growth, mustard, sulphur, yield and zinc

Introduction

Indian mustard (*B. juncea.* L.) belonging to the Brassicaceae family is one of the most significant and ancient oilseed crops. The Brassicaceae is one of the top ten plant families in terms of economic importance, with over 3500 species and 350 genera. After palm and soybean oil, rapeseed/Toria and mustard are the world's third most significant edible oilseed crops. *Brassica juncea* and *B. campestris* are the two species of mustard and rapeseed that are most often cultivated. The oil content varies from 37 to 49%. The oil quality of mustard and rapeseed has a sufficient percentage of erucic acid (40-60%) and linolinic acid (4.5-13%). About 25-30% of crude oil is made up of the more nutritious acids; oleic and linoleic acid. The protein content range from 25 and 30% that is composed of 14-15% carbohydrates, 10-12% fibre, 1-1.5 percent minerals and vitamins, and 2-3% glucosinolate. However, because mustard contains poisonous glucosinolate, it cannot be utilized as a source of protein for humans, instead, it is now used as animal feed and manure.

Indian mustard is one of the major oilseed crops grown worldwide; according to output and acreage, it is presently the third-most significant oil seed crop worldwide. In 2023-24, the global rapeseed-mustard area, output, and yield were 42.53 million hectares (mha), 88.07 million metric tonnes, and 2.07 metric tons per hectare. India accounts for 19.8% and 9.8%, respectively of the total area and output worldwide (USDA, 2024) [31]. After soybean (14.98 MT), rapeseed-mustard (12.64 MT) is India's second-most significant annual oilseed crop. In India, mustard is farmed on over 6.26 million hectares of area, yielding 8.68 million tons of production and 1.3 t/ha of productivity. Total area coverage under rapeseed-mustard in Uttar Pradesh is 1.27 million hectares with a total production of 1.9 million tonnes and productivity of 1.5 t/ha (GOI, 2023) [8].

Sulphur is the fourth important nutrient in the Indian agriculture after nitrogen, phosphorus and potassium. About 42.3%, Indian soils and 32.0% U.P. soils are deficient in sulphur. Due to its immobility in the plants, sulphur deficiencies first appear on the younger growth. The most common deficiency symptoms of Sulphur is fading of the normal green colour of the young leaves, followed by chlorosis.

In Brassicas, which are more vulnerable to S-deficiency due to the growth points being stopped and the leaf edges curling, the lamina is constricted and the leaves exhibit cupping. Zinc is one of the first micronutrients recognized as essential for plants that transported to plant root surface through diffusion. Zinc deficiency is the most pervasive micronutrient deficiency in the world. It is, therefore considered as the most serious cause of hidden hunger in plants. It not only reduces the productivity but also the nutritional quality of the crop (Graham *et al.,* 1992) [10]. Zinc deficiency results into inhibition of RNA synthesis, reduces chlorophyll content of the leaves also root and shoot growth is hampered. Further, Boron deficiency symptoms usually appear on leaves, stems, and reproductive parts and affects flowering and plant reproduction (Bolanos *et al.* 2004) [6]. Boron is also required for pollen germination and pollen tube growth and due to lack of boron at flowering can affect pollen viability and abortion of stamens and pistils, which contributes to low seed set. Lack of Boron can result in sterility, which means fewer siliqua and fewer seeds per siliqua, resulting in low seed yield (Islam and Anwar, 1994) [13].

Sulphur performs many physiological functions like synthesis of cystein, methionine, chlorophyll and oil content of oilseed crops. It is also responsible for synthesis of certain vitamins (biotin and thiamine), metabolism of carbohydrates, proteins, activates enzyme system and oil formation of flavoured compounds in crucifers. Brassica has the highest sulphur requirement owing to the presence of sulphur-rich glucosinolates (Karthikeyan and Shukla, 2008 [14]. Three amino acids *viz*. methionine (21% S), cysteine (26% S) and cystine (27% S) contain S which are the building blocks of proteins and about 90% of sulphur is present in these amino acids. Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in oilseeds.

Beside sulphur, mustard crop is responsive to micronutrients application especially Zn and B in moderate to low fertile soils. Application of Zinc in Indian mustard increases yield from 11 to 40%. Zinc is an important constituent of several enzymes, which regulates various metabolic processes in the plants and influences the formation of several growth hormones like IAA and Auxin in plants. Zinc stimulates the pod setting, seed formation and oil synthesis in the seeds of mustard and it increases the biological seed and stover yield of mustard (Sinha *et al*., 2000) [29]. It is an essential component for stability of cytoplasmic ribosomes, cell division, dehydrogenase, proteinase, peptidase enzymes and promotes starch formation, seed maturation and production; and helps in the synthesis of protein and carotene (Mandal *et al.,* 2002) [18].

Boron is the second most important micronutrient constrained in crops in the world after that of zinc (Behera *et al.,* 2016) [2]. It plays an important role in the cell division, differentiation, and elongation of meristemic region (Shireen *et. al.,* 2018) [24]. It also helps regulation of various physiological and metabolic reactions of the plant such as nucleic acid synthesis, cell wall synthesis, glucose synthesis, root elongation and carbohydrate transportation (Yadav *et al.,* 2016) [33]. It is essential for reproductive growth of plant and increases flower production, pollen viability, seed and fruit development in crop plant (Havlin *et. al.,* 2013) [12]. Thus, application of nutrient in balanced and adequate amount is necessary for increasing the mustard yield accompanied with improvement in quality of the produce. Keeping in view of the above fact, the experiment was conducted to find out “Effect of sulphur, zinc and boron on growth and yield of mustard.”

Materials and Methods

The experiment was conducted during *Rabi* season 2023-24 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The soil of the experimental field was sandy loam in texture, with soil (pH 7.8), low level of organic carbon (0.72%), available N (178.48 Kg/ha), P (27.80 kg/ha), K (233.24 kg/ha), S (15.42 kg/ha), Zn (0.70 mg/kg) and B (0.46 mg/kg). The treatment consists of three levels of Sulphur along with the combination of Zinc and Boron. The experiment was laid out in RBD with 10 treatments each replicated thrice. The treatment combinations are T_1 - Sulphur (15 kg/ha) + Zinc (5 kg/ha), T_2 - Sulphur (15 kg/ha) + Boron (2 kg/ha), T_3 - Sulphur (15 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha), T_4 - Sulphur (30 kg/ha) + Zinc (5 kg/ha), T_5 - Sulphur (30 kg/ha) + Boron (2 kg/ha), T_6 - Sulphur (30 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha), T_7 - Sulphur (45 kg/ha) + Zinc (5 kg/ha), T_8 - Sulphur (45 kg/ha) + Boron (2 kg/ha), T_9 - Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha), T_{10} - Control N:P:K (80:40:40 Kg/ha). Data recorded on different aspects of crop, *viz*., growth, yield attributes and yield were subjected to statistically analysed by analysis of variance method as described by Gomez and Gomez, (1976) [9].

Results and Discussion

Growth Attributes

Plant height (cm)

The data revealed that significantly higher plant height (213.46 cm) was recorded in treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. However, treatment 6 [Sulphur (30 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)], treatment 7 [Sulphur (45 kg/ha) + Zinc (5 kg/ha)], treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and higher plant height was observed with application of Sulphur (45 kg/ha) may be due to improved nutritional conditions for plant growth during active vegetative stages, leading to an increase in cell multiplications, elongation, and expression in the plant body, all of which contributed to the increase in plant height. These results are in accordance with the findings of Singh *et al.* (2016) [27]. Further, significantly increased plant height was recorded with application of Zinc (5 kg/ha) with NPK may be the result of sufficient nutrients, which support the plants reliable vegetative development and, in turn, increase plant height through cell elongation, cell division, photosynthesis, and turbidity of plant cell. These results are in close conformity with the findings of Upadhyay *et al.* (2017) [30]. Another reason, for significantly increased in plant growth characteristics was ultimately attributed to the positive effect of Boron (2 kg/ha) applied, which was sufficient to correct the initial deficiency level of Boron and the beneficial effect of Boron on fast-growing meristematic tissues. These findings confirm the result of Singh *et al.* (2022) [26].

Number of branches/plant

The data observed that significant and maximum number of branches/plant (19.6) was recorded in Treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)]. However, treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] was found to be statistically at par with treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)]. Significant and maximum number of branches/plant was observed with the application of sulphur (45 kg/ha) might be due to sulphur is known to have contributed to increased photosynthesis, and also necessary for the production of chlorophyll and the activation of enzymes. These results are in accordance with the findings of Kumar *et al.* (2021) [16]. Further, significantly increased in number of branches/plant was recorded with Zinc (5 kg/ha) might be due to the availability of nutrients in appropriate levels allowed for an adequate generation of photosynthates, which in turn promote metabolic activities, faster cell division, and the development of meristematic tissues. These results are in close conformity with the findings of Chowhan and Islam (2021) [7]. Another reason, significantly increased in number of branches/plant was resulted with the application of Boron (2 kg/ha) might be due to the involvement of boron in division of cells, tissue differentiation, glucose metabolism, and preservation of conducting tissues. These findings confirm the result of Meena *et al*. (2020) [19].

Plant dry weight (g)

The data recorded that significantly higher plant dry weight (40.77) was observed in treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. However, treatment 4 [Sulphur (30 kg/ha) + Zinc (5 kg/ha)], treatment 6 [Sulphur (30 kg/ha) + (Zinc 5 kg/ha) + Boron (2 kg/ha)], treatment 7 [Sulphur (45 kg/ha) + Zinc (5 kg/ha)], and treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and higher plant dry weight was observed with application of sulphur (45 kg/ha) might be due to increased amino acid synthesis, higher levels of chlorophyll in the growing medium, and enhanced photosynthetic activity, which eventually results in more cell division and accelerated plant development, an adequate supply of sulphur increased photosynthetic output and easier transport of the chemical to the sink. These results are in accordance with the findings of Pravalika and Dawson (2023) [21]. Further, significantly increased in plant dry weight was recorded with zinc (5 kg/ha) might be due to the breakdown of IAA growth hormones, cell enlargement, cell division, and cell multiplication, all of which improved leaf growth and stimulated plant growth by abundant supply of the nutrients. These results are in close conformity with the findings of Haritha *et al*. (2022) [11]. Another reason, significantly increased in plant dry weight was resulted with the application of boron (2 kg/ha) might be due to boron generally affects cell division, and it might have improved plant development by absorbing nitrogen from the soil. These findings confirm the result of Bhavana *et al.* (2022) [4].

Crop Growth Rate (g/m2/day)

The data revealed that during 80-100 interval DAS, no significant difference was recorded among all the treatments. Statistically highest crop growth rate (16.67 g/m2/day) was recorded in treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)].

Relative Growth Rate (g/g/day)

The data revealed that during 80-100 interval DAS, no significant difference was recorded among all the treatments. Statistically highest relative growth rate (0.0157 g/g/day) was recorded in treatment 2 [Sulphur (15 kg/ha) + Boron (2 kg/ha)].

Yield and Yield Attributes

Number of silique/plant

The data revealed that treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] recorded significant and maximum number of siliqua/plant (213.8). However, treatment 6 [Sulphur (30 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] and treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and maximum number of siliqua/plant was observed with the application of sulphur (45 kg/ha) might be due to sulphur improved the nutrition, metabolite production and encouraged the growth of the crop plants, particularly the reproductive organs. These results are in accordance with the findings of Singh *et al.,* (2023) [25]. Further, significantly increased in number of siliqua/plant was resulted with application of zinc (5 kg/ha) might be due to zinc regulates meristematic cell elongation and division, which increases the potential for blooming and seed setting and promotes vegetative growth. These results are in close conformity with the findings of Yadav *et al.,* (2020) [32]. Another reason, significantly increased in number of siliqua/plant was recorded with application of boron (2 kg/ha) might be due to boron increases photosynthetic activity, which results in the synthesis and build-up of more carbohydrates and auxins, which moreover promotes the retention of more flowers, increases the number of reproductive organs per plant. These findings confirm the result of Akshatha and Rajkumara (2018) [1].

Number of seeds/silique

The data showed that treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] recorded significant and maximum number of seeds/siliqua (17.73). However, treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] was found to be statistically at par with treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and maximum number of seeds/silique was observed with the application of sulphur (45 kg/ha) might be due to growth of floral components, such as reproductive organs, which contributes to the production of siliqua and seeds in plants. These results are in accordance with the findings of Yadav *et al.,* (2020) [32]. Further, significantly increased in number of siliqua/plant was recorded with application of zinc (5 kg/ha) might be due to its role in the metabolism of starch as zinc affected the activity of aldolase in the plant tissue which is involved in the conversion of fructose 1-6 diphosphate to its subsequent compounds. These findings confirm the result of Singh *et al.* (2009) [28]. Another reason, significantly increased in number of siliqua/plant was resulted with application of boron (2 kg/ha) might be due to boron promotes the pollen-producing capacity of anthers and has an impact on the photosynthetic performance of plants by affecting the phosphorylation process, lowering the amount of assimilates utilized in respiration to get energy, and speeding up the removal of photosynthesis products. These findings confirm the result of Kumar *et al.* (2023) [15].

Test weight (g)

The data revealed that treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] recorded significant and higher test weight (213.8). However, treatment 6 [Sulphur (30 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)], treatment 7 [Sulphur (45 kg/ha) + Zinc (5 kg/ha)] and treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and higher test weight was observed with the application of sulphur (45 kg/ha) might be due to during growth and development stages the optimal number, size, and length of silique may have stimulated the availability of more photoassimilates and additionally, an increased supply of photosynthates to siliqua allowed seeds to grow to their full potential and appeared to increase test weight. These results are in accordance with the findings of Kumar *et al.,* (2021) [16]. Further, significantly increased in test weight was recorded with application of zinc (5 kg/ha) might be due to improved silique growth through synthesis of tryptophan and auxin and enhanced nutrient metabolism, biological activity and growth parameters, and furthermore enhanced enzyme activity that produced higher test weight of seeds. These results are in close conformity with the findings of Pravalika and Dawson (2023) [21]. Another reason, significantly increased in seed yield was resulted with application of boron (2 kg/ha) might be due to its beneficial impact in boosting the vegetative structure for nutrient absorption and supply strong sink through the evolution of the reproductive structure and the synthesis of assimilates to fill crucial economic sites like siliqua and seed. The findings confirm the result of Mounika *et al.* (2021) [20].

Seed Yield (t/ha)

The data showed that treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] recorded significant and higher seed yield (2.15 t/ha). However, treatment 6 [Sulphur (30 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)], treatment 7 [Sulphur (45 kg/ha) + Zinc (5 kg/ha)] and treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and higher seed yield was observed with the application of sulphur (45 kg/ha) might be due to higher meristematic activity, development of the floral primordial, and the differentiation of somatic to reproductive tissues that are all enhanced by sulphur, potentially leading to longer and more abundant siliqua, as well as improved flower and seed output. These results are in accordance with the findings of Rakesh and Banik (2016) [22]. Further, significantly increased in seed yield was recorded with application of zinc (5 kg/ha) might be due to its role in a variety of enzymatic reactions, biosynthesis of indole acetic acid (IAA), growth processes, hormone development and protein synthesis, and especially due to its role in initiation of primordia for reproductive parts and partitioning of photosynthates towards them, resulting in better flowering and fruiting. These results are in close conformity with the findings of Yadav *et al.* (2020) [32]. Another reason, significantly increased in seed yield was resulted with application of boron (2 kg/ha) might be due to boron is directly related to the pollen-producing capacity of the anther, the pollen germination process, the viability of the pollen grains and the expansion of the pollen tubes. The findings confirm the result of Kumararaja *et al.* (2015) [17].

Stover Yield (t/ha)

The data revealed that treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] recorded significant and higher stover yield (6.03 t/ha). However, treatment 4 [Sulphur (30 kg/ha) + Zinc (5 kg/ha)], treatment 5 [Sulphur (30 kg/ha) + Boron (2 kg/ha)], treatment 6 [Sulphur (30 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)], treatment 7 [Sulphur (45 kg/ha) + Zinc (5 kg/ha)] and treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and higher stover yield was observed with the application of sulphur (45 kg/ha) might be due to higher biomass build-up from having more leaves as well as yield features like having more seeds and siliqua/plant can be attributed to it, crop matured quicker and more consistently after applying sulphur, which led to the faster and higher development of plant organs and an increase in stover yield. These results are in accordance with the findings of Singh *et al.* (2023) [5]. Further, significantly increased in stover yield was recorded with application of zinc (5 kg/ha) might be due to physiological processes such as stomata control, enzyme activation, and chlorophyll production, which in turn cause increase in, number of siliqua/plant, seed yield and stover yield. These results are in close conformity with the findings of Bhadake *et al.* (2022) [3]. Another reason, significantly increased in stover yield was resulted with application of boron (2 kg/ha) might be due to enhanced uptake of major nutrients resulting in greater photosynthetic activities and leading to greater vegetative growth in plants, which particularly accelerated growth due to proper metabolic activities and produced higher stover yield. The findings confirm the result of Kumar *et al.* (2023) [15].

Harvest Index (%)

The data showed that treatment 3 [Sulphur (15 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] recorded significant and higher harvest index (26.44%). However, treatment 1 [Sulphur (15 kg/ha) + Zinc (5 kg/ha)], treatment 2 [Sulphur (15 kg/ha) + Boron (5 kg/ha)], treatment 4 [Sulphur (30 kg/ha) + Zinc (5 kg/ha)], treatment 5 [Sulphur (30 kg/ha) + Boron (2 kg/ha)], treatment 6 [Sulphur (30 kg/ha) + Zinc (5kg/ha) + Boron (2 kg/ha)], treatment 7 [Sulphur (45 kg/ha) + Zinc (5 kg/ha)], treatment 8 [Sulphur (45 kg/ha) + Boron (2 kg/ha)] and treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] were found to be statistically at par with treatment 3 [Sulphur (15 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)]. Significant and higher harvest index was observed with the application of sulphur (45 kg/ha) might be due to better translocation of photosynthates leading to more siliqua/plant, more seeds/siliqua and higher test weight. These results are in accordance with the findings of Rana and Rana (2003) [23]. Further, significantly increased in harvest index was recorded with application of zinc (5 kg/ha) might be due to numerous enzymes involved in carbohydrate metabolism and enhanced carbon dioxide fixation, including carbonic anhydrate and ribulose bisphosphate carboxylase, stimulated by improved zinc availability and additionally increased seed yield, stover yield and harvest index. These results are in close conformity with the findings of Bhinda and Singh (2023) [5]. Another reason, significantly increased in harvest index was resulted with application of boron (2 kg/ha) might be due to improved transfer of photosynthates from source to sink, pollen viability, and pollen tube development, all of which led to increased dry matter and seed production. The findings confirm the result of Bhinda and Singh (2023) [5].

Economics

The results revealed that maximum gross return (183754.25 INR/ha), net return (129235.00 INR/ha) and B:C ratio (2.37) were recorded in treatment 9 [Sulphur (45 kg/ha) + Zinc (5 kg/ha) + Boron (2 kg/ha)] as compared to other treatments. Higher B:C ratio was observed with the application of sulphur (45 kg/ha) along with zinc (5 kg/ha) and boron (2 kg/ha) might be due to increased economical performance of crop such as yield of seed and stover, which in turn led to higher gross returns and net returns. These results are in accordance with the findings of Yanthan and Singh (2021) [34].

Table 1: Effect of Sulphur, zinc and boron on growth attributes of Mustard

Sr. No.	Treatment combinations	Plant height (cm)	Number of branches/plant	Plant dry weight (g)	Crop Growth Rate (g/m2/day)	Relative Growth Rate (g/g/day)
1.	Sulphur 15 kg/ha + Zinc 5 kg/ha	196.69	16.33	34.75	13.89	0.0140
2.	Sulphur 15 kg/ha + Boron 2 kg/ha	197.76	17.00	37.05	16.11	0.0157
3.	Sulphur 15 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	200.78	16.40	36.91	15.61	0.0147
4.	Sulphur 30 kg/ha + Zinc 5 kg/ha	199.65	17.67	37.75	15.56	0.0143
5.	Sulphur 30 kg/ha + Boron 2 kg/ha	202.90	17.00	36.86	14.44	0.0134
6.	Sulphur 30 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	205.58	16.80	37.44	15.11	0.0142
7.	Sulphur 45 kg/ha + Zinc 5 kg/ha	206.31	16.53	38.86	16.66	0.0148
8.	Sulphur 45 kg/ha + Boron 2 kg/ha	207.80	19.60	40.19	16.52	0.0141
9.	Sulphur 45 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	213.46	18.87	40.77	16.67	0.0134
10.	Control (RDF) - 80:40:40 NPK kg/ha	194.84	16.13	29.29	11.11	0.0126
	F Test	S	S	S	NS	NS
	SEm (±)	3.06	0.55	1.17	2.23	0.00
	CD (p=0.05)	9.09	1.65	3.47	-	-

Table 2: Effect of Sulphur, zinc and boron on yield and yield attributes of mustard

Sr. No.	Treatment combinations	Number of siliqua/plant	Number of seeds/siliqua	Yield and yield attributes		Stover yield (t/ha)	Harvest Index (%)
				Test weight (g)	Seed yield (t/ha)		
1.	Sulphur 15 kg/ha + Zinc 5 kg/ha	184.33	15.60	5.31	1.72	5.02	25.54
2.	Sulphur 15 kg/ha + Boron 2 kg/ha	183.33	15.93	5.34	1.83	5.10	26.36
3.	Sulphur 15 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	188.60	16.00	5.55	1.89	5.27	26.44
4.	Sulphur 30 kg/ha + Zinc 5 kg/ha	184.53	16.13	5.53	1.86	5.43	25.59
5.	Sulphur 30 kg/ha + Boron 2 kg/ha	188.20	16.33	5.58	1.84	6.18	23.08
6.	Sulphur 30 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	203.07	16.40	5.64	1.99	5.94	25.06
7.	Sulphur 45 kg/ha + Zinc 5 kg/ha	195.33	17.13	5.69	1.95	5.95	24.83
8.	Sulphur 45 kg/ha + Boron 2 kg/ha	208.07	17.53	5.72	2.02	6.00	25.18
9.	Sulphur 45 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	213.80	17.73	5.78	2.15	6.03	26.28
10.	Control (RDF) - 80:40:40 NPK kg/ha	178.53	15.40	5.26	1.26	4.94	20.38
	F Test	S	S	S	S	S	S
	SEm (±)	5.90	0.10	0.05	0.08	0.21	1.16
	CD (p=0.05)	17.54	0.30	0.14	0.24	0.63	3.44

Table 3: Effect of sulphur, zinc and boron on economics of mustard

Sr. No.	Treatment combinations	Cost of cultivation (INR/ha)	Economics		Benefit cost ratio (B:C)
			Gross Return (INR/ha)	Net Return (INR/ha)	
1.	Sulphur 15 kg/ha + Zinc 5 kg/ha	49319.55	153099.55	103780.00	2.10
2.	Sulphur 15 kg/ha + Boron 2 kg/ha	50080.30	160015.30	109935.00	2.20
3.	Sulphur 15 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	51519.55	165064.55	113545.00	2.20
4.	Sulphur 30 kg/ha + Zinc 5 kg/ha	50819.85	163049.85	112230.00	2.21
5.	Sulphur 30 kg/ha + Boron 2 kg/ha	51580.60	164220.60	112640.00	2.18
6.	Sulphur 30 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	53019.85	173354.85	120335.00	2.27
7.	Sulphur 45 kg/ha + Zinc 5 kg/ha	52319.25	170494.25	118175.00	2.26
8.	Sulphur 45 kg/ha + Boron 2 kg/ha	53080.00	175170.00	122090.00	2.30
9.	Sulphur 45 kg/ha + Zinc 5 kg/ha + Boron 2 kg/ha	54519.25	183754.25	129235.00	2.37
10.	Control (RDF) - 80:40:40 NPK kg/ha	46607.70	125157.70	78550.00	1.69

Conclusion

It is concluded that with the application of Sulphur 45 kg/ha along with Zinc 5 kg/ha and Boron 2 kg/ha (Treatment 9), was observed with higher growth attributes, yield attributes and benefit-cost ratio in mustard.

Acknowledgement

The authors are thankful to Department of Agronomy, Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture Technology And Sciences, (U.P) India for providing necessary facilities to undertake the studies.

References

1. Akshatha S, Rajkumara S. Response of sesame to different levels and methods of boron application. J Farm Sci. 2018;31(1):46-49.
2. Behera SK, Shukla AK, Singh M, Dwivedi BS. Extractable boron in some acid soils of India: status, spatial variability and relationship with soil properties. J Indian Soc Soil Sci. 2016;64(2):183-192.
3. Bhadake M, Ananda N, Umesh MR, Rathod PS, Bhat SN. Effect of zinc and iron enrichment through ferti-fortification on growth, yield and economics of sesame (*Sesame indicum* L.). J Farm Sci. 2022;35(4):426-429.
4. Bhavana K, Singh V, George SG, Singh SK. Effect of boron and bio-fertilizers on growth and yield of sesame (*Sesamum indicum* L.). Int J Plant Soil Sci. 2022;34(16):71-76.
5. Bhinda NK, Singh Y. Effect of sulphur, zinc and boron application on productivity, quality and profitability of Indian mustard in Bundelkhand region. Ann Agric Res. 2023;44(2):197-203.
6. Bolanos L, Lukaszewski K, Bonilla I, Blevins D. Why

boron? Plant Physiol Biochem. 2004;42:907-912.
7. Chowhan S, Islam M. Zinc effects yield of mustard (*Brassica campestris* L.) under zero tillage. Asian J Soil Sci Plant Nutr. 2021;8(1):27-35.
8. Government of India. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India. DES | Area, Production & Yield Reports; c2023. Available from: desagri.gov.in.
9. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; c1976. p. 680.
10. Graham RD, Ascher JS, Hynes SC. Selecting zinc-efficient cereal genotypes for soils of low zinc status. Plant Soil. 1992;146:241-250.
11. Haritha, Gali, Singh, Rajesh and Indu, Thakur. Studies on growth and yield of sesame (*Sesamum indicum* L.) as influenced by spacing and foliar application of zinc. The Pharma Innovation Journal. 2022:11(3):2366-2369.
12. Havlin JL, Tisdale SL, Nelson WL, Beaton JD. Soil fertility and fertilizers: An introduction to nutrient management. 8th ed. Pearson India Education Services Pvt. Ltd; c2013.
13. Islam MS, Anwar MN. Production technologies of oilseed crops. Recommendations and future plans. In: Proceedings of Workshop on Transfer of Technology of Crops under Research, Extension Linkage Programme. BARI, Gazipur; c1994. p. 20-7.
14. Karthikeyan K, Shukla LM. Effect of boron-sulphur interaction on their uptake and quality parameters of mustard (*Brassica juncea* L.) and sunflower (Helianthus annuus L.). J Indian Soc Soil Sci. 2008;56(2):225-230.
15. Kumar BV, Mehera B, Kumar P. Effect of boron on yield of different varieties of mustard (*Brassica juncea* L.). Int J Environ Climate Change. 2023;13(10):1517-1521.
16. Kumar PP, Singh R, Khan W, Shivakumar EN. Effect of sulphur and row spacing on growth and yield of yellow mustard (*Sinapis alba*). Biol Forum Int J. 2021;13(3):139-143.
17. Kumararaja P, Premi OP, Kandpal BK. Application of boron enhances Indian mustard (*Brassica juncea*) productivity and quality under boron deficient calcareous soil in semi-arid environment. Eco Env Cons. 2015;21
18. Mandal KG, Ghosh PK, Hati KM, Bandyopadhyay KK, Mishra A. Practical implication of nutrient interaction to boost oilseeds productivity in India. Fertilizer News. 2002;47:13-26.
19. Meena VS, Meena MK, Dotaniya ML, Meena MD, Jat RS, Choudhary RL, *et al*. Improvement in growth and yield of Indian mustard by using micro and secondary nutrients fortified FYM in calcareous soil. J Oilseed Brassica. 2021;12(1):38-43.
20. Mounika J, Dawson J, Sagar DRMSV. Influence of boron and sulphur levels on growth and yield of yellow mustard (*Sinapis alba*). Pharma Innovation J. 2021;10(11):174-177.
21. Pravalika K, Dawson J. Effect of basal application of sulphur and foliar application of micro-nutrients on growth and yield of summer sesame. Int J Environ Climate Change. 2023;13(5):11-16.
22. Rakesh S, Banik GC. Effect of sulphur levels and sources on growth, yield and quality of mustard in terai region of West Bengal. Ann Plant Soil Res. 2016;18(2):152-155.
23. Rana KS, Rana DS. Response of mustard (*Brassica juncea*) to nitrogen and sulphur under dryland conditions. Indian J Agron. 2003;48(3):217-219.
24. Shireen F, Nawaz MA, Chen C, Zhang Q, Zheng Z, Sohail H, *et al*. Boron: Functions and approaches to enhance its availability in plants for sustainable agriculture. Int J Mol Sci. 2018;19:1856.
25. Singh G, Dharvankar M, Mathpal B. Role of sulphur in improving growth and yield of Indian mustard (*Brassica juncea* L.). Pharma Innovation J. 2023;12(6):3431-3436.
26. Singh T, Bohra J, Singh R, Kumar S, Deo N, Singh P. Effect of sulphur and boron levels, and integrated nutrient management on growth and yield of Indian mustard [*Brassica juncea* (L.) Czernj. and Cosson]. Ann Agric Res New Ser. 2022;43(3):311-316.
27. Singh V, Singh KA, Nikhil R, Singh RA. Effect of sulphur on growth and yield of mustard (*Brassica juncea* L. Czern and Coss) varieties. Prog Res Int J. 2016;11(II):845-848.
28. Singh Y, Singh T, Singh UN, Rajput PK. Effect of nutrient management on yield, quality and economics of irrigated Indian mustard (*Brassica juncea*). Indian J Agric Sci. 2009;80(8):691-694.
29. Sinha P, Jain R, Chatterjee C. Interactive effect of boron and zinc on growth and metabolism of mustard. Commun Soil Sci Plant Anal. 2000;31(1,2):41-49.
30. Upadhyay Y, Swaroop N, Dhruw S, Singh MA, Verma D. Interaction effects of different doses of sulphur and zinc with NPK on growth and yield of yellow mustard (*Brassica compestris* L.). J Pharmacogn Phytochem. 2017;7(1):1260-1263.
31. USDA/Foreign Agricultural Service, Global Market Analysis (2024). World Agricultural Production | USDA Foreign Agricultural Service.
32. Yadav P, Yadav SS, Garg K, Yadav S. Effect of sulphur and zinc fertilization on growth, yield attributes and grain yield of sesame (*Sesamum indicum*). Indian J Agron. 2020;65(1):120-124.
33. Yadav SN, Singh SK, Kumar O. Effect of boron on yield attributes, seed yield and oil content of mustard (*Brassica juncea* L.) on an Inceptisol. J Indian Soc Soil Sci. 2016;64(3):291-296.
34. Yanthan MR, Singh R. Yield and economics of mustard as influenced by different levels of boron and zinc (*Brassica campestris* L.). J Pharmacogn Phytochem. 2021;10(6):271-273.