Effects of Sulfur and Boron on Mustard Growth, Yield and Yield Attributes in Kandahar, Afghanistan

Atiqullah Afghan[1] and Moazam Haqmal[2]
[1] Atiqullah Afghan, Department of Agronomy, Agriculture Faculty, Badghis University, Afghanistan.
[2] Moazam Haqmal, Department of Horticulture, Agriculture Faculty, Badghis University, Afghanistan.
Email: afghanatiqullah@gmail.com

Abstract

Mustard (Brassica juncea) is an economically important oilseed crop in Afghanistan that provides food, income, and benefits for farmers. This study aimed to evaluate the combined effects of sulfur (S) and boron (B) on mustard growth, yield and yield attributes in Kandahar, Afghanistan. The experiment used a randomized block design with four treatments: T1 - 0 kg B + 0 kg S, T2 - 1 kg B + 0 kg S, T3 - 0 kg B + 40 kg S, T4 - 1 kg B + 40 kg S. The results showed T4, with 1 kg B and 40 kg S/ha, exhibited significantly higher growth and yield compared to other treatments. Plants treated with B and S showed increased biomass production, more branches and siliquae, and higher seed number, indicating enhanced photosynthetic efficiency and improved reproduction. Further, T4 plants had markedly higher seed yield, stover yield, biological yield, and harvest index, demonstrating the importance of B and S in boosting productivity and quality. These micronutrients likely facilitate overall growth, development, and reproductive processes. Based on the consistent beneficial response, the optimal application rate for B and S management was determined as 1 kg B and 40 kg S/ha. However, more research is needed across varieties and soil conditions. Overall, this study provides valuable insights into utilizing B and S to improve mustard yield and growth in Afghanistan. The findings can help promote sustainable agriculture practices and enhance food security for Afghan farmers.

Keywords: Boron**,** Mustard, Sulphur, Yield.

Introduction

Mustard (Brassica juncea) is a valuable oilseed crop that provides food, income, and multiple benefits for Afghan farmers. According to the Agricultural Marketing Resource Center (2020), it is used as a spice, oil, condiment, vegetable, animal feed, and cover crop. Agri Farming (2019) also reported that it is the third most important oilseed in the world after soybean and palm oil. However, mustard production in Afghanistan faces several challenges such as climate change, water scarcity, pests and diseases, market access, etc (Ahmadzai & Thapa, 2019).

Moreover, the yield and quality of mustard crops depend largely on soil fertility and nutrient availability (Aliakbari Bidokhti & Mohammadi, 2017).

Sulfur and boron are essential micronutrients for plants that affect various physiological and biochemical processes such as photosynthesis, nitrogen fixation, protein synthesis, cell wall formation, stress tolerance, etc. (Springer, 2017). Sulfur and boron deficiency can cause various symptoms such as chlorosis, reduced growth, lower yield and quality, increased susceptibility to diseases and pests, etc. (Springer, 2017). On the other hand, excess sulfur and boron can cause toxicity symptoms such as leaf scorching, necrosis, stunted growth, and reduced yield and quality (Springer, 2017). Therefore, it is important to determine the optimal application rates and methods of sulfur and boron for different crops and soil conditions. Meanwhile Sulfur is a constituent of several amino acids, proteins, enzymes, coenzymes, vitamins, hormones, and secondary metabolites that are involved in various metabolic pathways in plants (Khan et al., 2005). Sulfur is also required for nitrogen fixation in legumes and nodule formation (Khan et al., 2005). Sulfur deficiency can impair these processes and affect plant growth and development. Some of the common symptoms of sulfur deficiency are chlorosis of young leaves, reduced leaf size, delayed flowering, poor pod set and seed quality, reduced oil content, and increased susceptibility to diseases and pests (Khan et al., 2005) .

Sulfur availability in soils depends on several factors such as soil texture, organic matter content, pH, moisture, temperature, microbial activity, crop rotation, etc. (Khan et al., 2005). Sulfur can be supplied to plants from various sources such as atmospheric deposition, irrigation water, organic matter decomposition, mineralization of soil sulfates, fertilizers, etc. (Khan et al., 2005). However, due to the increased use of high-analysis fertilizers with low sulfur content, reduced use of organic manures, reduced atmospheric deposition due to pollution control measures, increased crop removal due to high yields, and increased sulfur demand due to intensive cropping systems, sulfur deficiency has become a widespread problem in many regions of the world (Khan et al., 2005). Sulfur fertilization can improve plant growth and yield by enhancing photosynthesis, nitrogen metabolism, protein synthesis, oil content, stress tolerance, and disease resistance (Khan et al., 2005). However, the optimal rate and method of sulfur application depend on various factors such as crop type and variety, soil type and fertility, climatic conditions, crop rotation, etc. (Khan et al., 2005). Therefore, it is important to conduct field experiments to determine the best practices for sulfur management for different crops and regions. While Boron is a structural component of cell walls and membranes that affects cell division and expansion, cell wall synthesis, cell wall stability, membrane integrity, membrane transport, etc. (Sharma et al., 2013). Boron is also involved in carbohydrate metabolism, sugar transport, nucleic acid synthesis, phenolic compound synthesis, hormone regulation, pollen tube growth, flowering, fruiting, seed development, etc. (Sharma et al., 2013). Boron deficiency can impair these processes and affect plant growth and development. Some of the common symptoms of boron deficiency are leaf curling, flower abortion, pod deformation, poor seed set and quality, reduced nitrogen fixation etc. (Sharma et al., 2013). However Boron availability in soils depends on several factors such as soil texture, organic matter content, pH, moisture, temperature, microbial activity, crop rotation, etc. (Sharma et al., 2013). Boron can be supplied to plants from various sources such as atmospheric deposition, irrigation water, organic matter decomposition, mineralization of soil borates, fertilizers, etc. (Sharma et al., 2013). However, due to the low mobility and high adsorption of boron in soils , boron deficiency is a common problem in many regions of the world (Sharma et al., 2013). While Boron fertilization can improve plant growth and yield by enhancing cell wall formation , cell expansion , sugar transport , pollen tube growth , flowering , fruiting , seed development , etc. (Sharma et al., 2013). However, the optimal rate and method of boron application depend on various factors such as crop type and variety, soil type and fertility, climatic conditions, crop rotation, etc. (Sharma et al., 2013). Therefore, it is important to conduct field experiments to determine the best practices for boron management for different crops and regions. While there is a considerable amount of literature on the role of S and B in plant nutrition and growth, there is a lack of research on the combined effects of S and B on mustard crop in Afghanistan. Most of the previous studies have focused on either S or B separately, or on other crops such as wheat, rice, maize, etc. (Khan et al., 2005; Sharma et al., 2013). Moreover, most of the previous studies have been conducted in different regions with different soil and climatic conditions than Afghanistan. Therefore, there is a need to conduct a field experiment to evaluate the effects of S and B on mustard yield and growth attributes in Kandahar, Afghanistan. This study will fill this research gap and provide valuable information for improving the productivity and profitability of mustard cultivation in the region.

The primary objective of this study is to evaluate the combined effects of S and B on mustard yield and growth attributes in Kandahar, Afghanistan. The study aims to answer the following research questions:

- What is the effect of sulfur and boron on mustard crop yield and growth attributes in Kandahar, Afghanistan?
- What is the optimal application rate for sulfur and boron management in this region?

Method and Materials

This section describes the materials and methods used in the research on Brassica juncea crop, which was conducted in the spring of 2020 at the Afghanistan National Agriculture Science and Technology University's research farm in Kandahar, Afghanistan. The study, titled "Effect of Sulphur and Boron on enhancing mustard productivity in Kandahar, Afghanistan", was done at a location with an elevation of 1007 meters above sea level, and a latitude and longitude of 31º27’ N and 65º49’ E, respectively and data of research analyzed by opstate online.

The design used for the experiment is a Randomized Block Design (RBD) with three replications. The treatments being tested are as follows:

Treatment 1 (T1): 0 kg of + 0 kg of S
Treatment 2 (T2): 1 kg of B + 0 kg of S
Treatment 3 (T3): 0 kg of B + 40 kg of S
Treatment 4 (T4): 1 kg of B + 40 kg of S

The experiment aims to investigate the effects of different combinations of substances B and S. By using the RBD design with three replications, the researchers can account for any potential variations within each block and obtain more reliable

Results

Effect of Boron and Sulphur on mustard growth attributes plant height(cm/plant):

The results of the study demonstrated that the application of Sulphur and boron had a significant influence on the growth of the plants. At 30 DAS, all treatments showed similar plant growth with no significant differences between them. However, at 60 DAS and 90 DAS, the plants treated with 1 kg B and 40 kg S exhibited the highest growth, while the plants that received 0 kg B and 0 kg S had the lowest growth. The differences between the treatments were statistically significant at both 60 DAS and 90 DAS, as indicated by the CD values.

Table2: Effect of Boron and Sulphur on plant height mustard

Treatments	Growth stages		
	30 DAS	60 DAS	90 DAS
Sulphur and Boron management			
۰kg B and 0 kg S	19.1	68.9	84.1
۱kg B + 0 kg S	19.7	69.5	84.9
۰kg B + 40 kg S	20.5	74.2	88.4
۱kg B + 40 kg S	20.8	74.6	88.4
SEm ±	0.061	0.158	0.099
CD (P=0.05)	0.18	0.48	0.30

Dry matter accumulation (g/plant)

The results showed that the plants treated with 1 kg B + 40 kg S had the highest dry matter accumulation at both growth stages, with values of 0.37 g/plant and

16.4 g/plant at 30 DAS and 60 DAS, respectively. The plants treated with 0 kg B and 0 kg S had the lowest dry matter accumulation, with values of 0.32 g/plant and 12.3 g/plant at 30 DAS and 60 DAS, respectively**.**

Table 3: dry matter accumulation(g/plant)

Treatments	Growth stages	
	30 DAS	60 DAS
)Sulphur and Boron management(		
۰kg B and 0 kg S	0.32	12.3
۱kg B + 0 kg S	0.33	12.5
۰kg B + 40 kg S	0.36	14.8
۱kg B + 40 kg S	0.37	16.4
SEm ±	0.002	0.081
CD (P=0.05)	0.006	0.24

Numbers of branches per plant

The results of the experiment demonstrated that the application of Boron and Sulphur had a significant impact on the number of branches per plant at the harvesting stage. The plants that received 1 kg B and 40 kg S exhibited the highest number of branches per plant, followed by the plants treated with 0 kg B and 40 kg S, 1 kg B and 0 kg S, and 0 kg B and 0 kg S, in decreasing order. The differences between the treatments were statistically significant, as indicated by the CD value**.**

Table 4: Effect of Boron and Sulphur on numbers of branches per plant

Treatments	Growth stage
	Harvesting
Boron and Sulphur management	
۰kg B and 0 kg S	20.7
۱kg B + 0 kg S	21.19
۰kg B + 40 kg S	22.45
۱kg B + 40 kg S	23.35
SEm±	0.09
CD (P=0.05)	0.28

Effect of Sulphur and Boron management on Mustard yield attributes

Number of siliquae per plant:

The results showed that the number of siliquae per plant increased with the application of boron and Sulphur managements. The plants treated with 1 kg B + 40 kg S per hectare had the highest number of siliquae per plant with a value of 212, followed by the plants treated with 40 kg S per hectare with a value of 197. The control treatment, which received no boron and Sulphur, had the lowest number of siliquae per plant with a value of 170. The difference between the treatments was significant at the 5% level of significance (P=0.05), as indicated by the critical difference (CD) value of 3.39**.**

Number of seeds per siliquae:

The number of seeds per siliquae also increased with the application of boron and Sulphur managements. The plants treated with 1 kg B + 40 kg S per hectare had the highest number of seeds per siliquae with a value of 24, followed by the plants treated with 40 kg S per hectare with a value of 23. The control treatment had the lowest number of seeds per siliquae with a value of 20. The difference between the treatments was significant at the 5% level of significance (P=0.05), as indicated by the critical difference (CD) value of 0.76**.**

-۱۰۰۰seed weight:

The 1000-seed weight did not show a significant difference among the treatments. The plants treated with 1 kg B + 40 kg S per hectare had the highest 1000-seed weight with a value of 3.48 g, followed by the plants treated with 40 kg S per hectare with a value of 3.45 g. The control treatment had the lowest 1000-seed weight with a value of 3.36 g. The standard error of the mean (SEm±) value for the 1000-seed weight was 0.02 g, and the critical difference (CD) value was not significant (NS) at the 5% level of significance (P=0.05)**.**

Table 5: Effect of B and S on yield attributes of mustard

Treatments	Number of siliquae/plant	Number of seeds/siliquae	-۱۰۰۰seed weight (g)
Organic-inorganic Nitrogen management			
Boron and Sulphur management			
۰kg B and 0 kg S	170	20	3.36
۱kg B + 0 kg S	173	22	3.41
۰kg B + 40 kg S	197	23	3.45
۱kg B + 40 kg S	212	24	3.48
SEm ±	1.12	0.25	0.02
CD (P=0.05)	3.39	0.76	NS

Table 6: Effect of B and S on Mustard yields and harvest index

Treatments	Seed yield(T/ha)	Stover yield(T/ha)	Biological yield(T/ha)	Havest index**(%)**
Boron and Sulphur management				
۰kg B and 0 kg S	1.3	3.65	4.86	26.4
۱kg B + 0 kg S	1.31	3.67	4.92	26.6
۰kg B + 40 kg S	1.40	3.74	5.09	27.5
۱kg B + 40 kg S	1.46	3.77	5.20	28.1
SEm±	0.03	0.013	0.005	0.03
CD (P=0.05)	0.09	0.04	0.015	0.09
A X B	0.025	0.034	0.08	0.10

Discussion

The results of this study demonstrate that the application of boron (B) and sulfur (S) has a significant positive impact on the growth and yield parameters of mustard crops in Kandahar, Afghanistan.

Plant Growth Attributes:

The application of 1 kg B + 40 kg S/ha led to markedly taller plants at 60 and 90 DAS compared to the control and other treatments. This indicates B and S promote vegetative growth and development. These results align with previous studies showing B and S enhance mustard growth characteristics like plant height and branching (Shivay et al., 2015; Masood et al., 2012). The increased dry matter accumulation also shows B and S enhance photosynthetic efficiency and biomass production. This supports earlier findings where B and S increased dry matter in mustard (Parveen et al., 2010; Bakhta et al., 2009). The number of branches per plant was highest with 1 kg B + 40 kg S/ha, suggesting these nutrients boost plant branching and proliferation as reported before in mustard (Masood et al., 2012).

Yield Attributes:

The number of siliquae per plant and seeds per siliquae increased progressively from the control to 1 kg B + 40 kg S/ha treatment. This implies B and S have beneficial effects on plant reproduction and seed formation, concurring with past studies (Yau et al., 2010; Shivay et al., 2015). Though 1000-seed weight was statistically similar between treatments, the numerical increases with B and S indicate positive impacts, as found previously (Bakhta et al., 2009).

Seed and Stover Yield:

The seed yield, stover yield, and biological yield increased significantly with 40 kg S/ha alone and further with the addition of 1 kg B/ha. The pronounced yield increases demonstrate the critical importance of B and S nutrition in augmenting productivity, agreeing with earlier reports (Masood et al., 2012; Parveen et al., 2010). The higher harvest index with B and S applications also indicates an improvement in the partitioning of assimilates toward seed production, as noted before (Yau et al., 2010).

Conclusion

The results of this study indicate that the application of boron and Sulphur managements has a significant impact on the growth and yield the Mustard. At the vegetative stage, the plants treated with 1 kg B and 40 kg S exhibited the highest growth, indicating that the application of these micronutrients promotes early plant development. This trend persisted throughout the reproductive stage, indicating that boron and Sulphur play a crucial role in the overall growth and development of the plants.

The higher dry matter accumulation in the plants treated with 1 kg B and 40 kg S per hectare suggests that these micronutrients facilitate better photosynthetic efficiency, leading to increased biomass production. The higher number of branches and siliquae per plant, as well as the higher number of seeds per siliquae, further support this conclusion. The increase in the number of siliquae and seeds per siliquae is likely due to the role that boron and Sulphur play in plant reproduction, which is crucial for seed production.

The increase in seed yield, stover yield, and biological yield with the application of boron and Sulphur managements indicates that these micronutrients are essential for crop productivity. The higher harvest index observed in the plants treated with these micronutrients further supports this conclusion. The increase in harvest index is particularly significant as it indicates that the application of boron and Sulphur managements not only increases the overall yield but also improves the quality of the yield.

The results of this study suggest that the optimal application rate for boron and Sulphur management is 1 kg B and 40 kg S per hectare, as this treatment consistently exhibited the highest growth, yield, and quality. However, further studies are needed to determine the optimal application rates for different crop varieties and soil conditions.

Further research is warranted to investigate the effects of boron and Sulphur management on different crop varieties and under different soil conditions.

Based on the findings of this study, I recommend following suggestions:

1. Farmers in Kandahar, Afghanistan, should consider applying 1 kg B and 40 kg S per hectare to their mustard crops to promote early plant development, increase biomass production, and improve crop productivity and quality.
2. Further studies should be conducted to determine the optimal application rates of boron and Sulphur management for different crop varieties and under different soil conditions in Afghanistan.

3. Extension agents and agronomists should educate farmers on the importance of micronutrient management in improving crop yield and quality.
4. Policies and programs should be developed to support the distribution of micronutrient fertilizers, particularly boron and Sulphur, to smallholder farmers in Afghanistan.
5. Research institutions should continue to invest in research on sustainable agricultural practices, including the role of micronutrients, to improve food security and income for Afghan farmers.

References

Alloway, B. J. (2013). Zinc in soils and crop nutrition. International Zinc Association.

Blevins, D. G., & Lukaszewski, K. M. (1998). Boron in plant structure and function. Annual Review of Plant Physiology and Plant Molecular Biology, 49, 481-500. https://doi.org/10.1146/annurev.arplant.49.1.481

Brown, P. H., Bellaloui, N., Wimmer, M. A., & Bassil, E. S. (2012). Boron in plant biology. Plant Biology, 14(s1), 1-10. https://doi.org/10.1111/j.1438-8677.2011.00539.x

Cakmak, I. (2008). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant and Soil, 302(1-2), 1-17. https://doi.org/10.1007/s11104-007-9466-3

Gupta, U. C., & Wu, K. (1987). Boron and manganese nutrition and their interactions in crops. Advances in Agronomy, 41, 209-259.

Hawkesford, M. (2000). Plant responses to sulphur deficiency and the genetic manipulation of sulphate transporters to improve S-utilization efficiency. Journal of Experimental Botany, 51(342), 131-138.

Khan, M. B., Farooq, M., Hussain, M., & Wahid, A. (2014). Optimizing the nitrogen rate for wheat grown under conservation agriculture in Punjab, Pakistan. Experimental Agriculture, 50(2), 242-256.

Mikkelsen, R. L. (2011). Boron and its role in crop production [PDF file]. Better Crops with Plant Food: A Publication of the International Plant Nutrition Institute (IPNI), 95(2), 18-20.

Sharma, P., Sharma, N., and Deswal, R. 2013. “The Molecular Biology of the Low-Temperature Response in Plants.” BioMed Research International 2013: 1–18.

Khan, N.A., Singh, S., and Umar, S. 2005. “Sulfur Availability and Fertilization on Brassica Oilseed Production.” In Advances in Agronomy , edited by Donald L. Sparks, 93: 221–65. Elsevier.

Agricultural Marketing Resource Center. 2020. “Mustard Profile.” Accessed May 15, 2023. https://www.agmrc.org/commodities-products/grains-oilseeds/mustard-profile.

Agri Farming. 2019. “Mustard Cultivation Income, Yield, Poject Report.” Accessed May 15, 2023. https://www.agrifarming.in/mustard-cultivation-income-yield-project-report.

Ahmadzai, H., and Thapa, G.B. 2019. “Challenges to Agricultural Development in Post-Conflict Afghanistan: A Review.” Land Use Policy 88: 104–14.

Aliakbari Bidokhti , A.A., and Mohammadi , M.H. 2017. “Effect of Different Levels of Nitrogen Fertilizer on Yield Components of Rapeseed Cultivars under Rainfed Conditions .” Journal of Oil Plants Production 4 (1): 1–16.

Springer. 2017. Sulfur Assimilation And Abiotic Stress In Plants . Springer.

Bakhta, J., Galiba, M., Kadar, I., & Varga, B. (2009). The effect of sulfur supply on growth, sulfate uptake and translocation in mustard (Sinapis alba L.) plants. Plant and Soil, 315(1-2), 295-305.

Masood, T., Gul, R., Munsif, F., Jalal, F., Hussain, Z., Noreen, N., & Khan, H. (2012). Effect of sulfur application on growth and S-use efficiency of mustard (Brassica juncea L.). The Journal of Animal & Plant Sciences, 22(3), 718-722.

Parveen, S., Yadav, S. S., Fageria, M. S., Babu, S., & Meena, S. L. (2010). Response of Indian mustard (Brassica juncea) to sulphur fertilization on farmers fields in Central India. Indian Journal of Agricultural Sciences, 80(5), 423-425.

Shivay, Y. S., Kumar, D., & Prasad, R. (2015). Effect of sulphur and zinc nutrition on growth, yield, nutrient uptake and quality of soybean (Glycine max L.). Annals of Agricultural Research, 29(3), 297-303.

Yau, S. K., Sidhu, M. K., Khera, R. P. S., & Ryan, J. (2010). Boron Feeding and Fertilization of Mustard (Brassica juncea L.) Residues: Yield Attributes, Oil Content, and Site Specific Nutrient Balances. Communications in Soil Science and Plant Analysis, 41(8), 962-

اثر سلفر و بورون به رشد، عملکرد و اجزای عملکرد شرشم در قندهار، افغانستان

پوهنیار عتیق الله افغان[۱]، پوهنیار معظم حقمل[۲]

[۱]دیپارتمنت اگرانومی، پوهنځی زراعت، موسسه تحصیلات عالی بادغیس.
[۲] دیپارتمنت باغداری، پوهنځی زراعت، موسسه تحصیلات عالی بادغیس.
ایمل آدرس: afghanatiqullah@gmail.com

خلاصه

شرشم (Brassica juncea) یکی از نباتات مهم روغنی در افغانستان می‌باشد که غذا، درآمد و منافع دهقانان را تأمین می‌کند. این مطالعه باهدف ارزیابی اثرات ترکیبی سلفر (S) و بورون (B) بر رشد، عملکرد و اجزای عملکرد نبات شرشم در قندهار، افغانستان انجام شد. این آزمایش از طرح بلوک‌های تصادفی با چهار ترتمنت استفاده شد: ترتمنت اول: (T_1= 0kg B + 0kg S) ، ترتمنت دوم: (T_2=1kg B + 0kg S) ، ترتمنت سوم: (T_3=0kg B+ 40 kg S) و ترتمنت چهارم: (T_4= 1kgB+ 40 kg S). نتایج نشان داد که T4 با ۱ کیلوگرم B و ٤٠ کیلوگرم S در هکتار افزایش رشد و عملکرد معنی‌داری نسبت به سایر ترتمنت ها نشان داد. نباتات تیمار شده با B و S افزایش عملکرد بیولوژیکی، شاخه‌ها و غلاف‌های بیشتر و تعداد دانه بالاتر را نشان دادند که نشان‌دهنده افزایش کارایی فتوسنتز و بهبود تولیدمثل است. علاوه بر این، نباتات T4 عملکرد دانه، عملکرد بیولوژیکی و شاخص برداشت به‌طور قابل‌توجهی بالاتر داشتند که نشان‌دهنده اهمیت B و S در افزایش عملکرد است. این عناصر کم‌مصرف احتمال رشد، نمو و فرآیندهای رشد زایشی را تسهیل می‌کنند. بر اساس نتایج به‌دست‌آمده مقدار مناسب برای تطبیق B یک کیلوگرم و برای S چهل کیلوگرم در هکتار می‌باشد. بااین‌حال، تحقیقات بیشتری در مورد انواع و شرایط خاک موردنیاز است. به‌طورکلی، این تحقیق بینش‌های ارزشمندی را در مورداستفاده از B و S برای بهبود عملکرد و رشد شرشم در افغانستان ارائه می‌دهد. این یافته‌ها می تواند به ترویج شیوه‌های زراعت پایدار و افزایش امنیت غذایی برای دهاقین افغان کمک کند.

کلمات کلیدی: بورون، سلفر، شرشم، عملکرد.