International Journal of Plant & Soil Science

Volume 36, Issue 12, Page 623-629, 2024; Article no.IJPSS.128955
ISSN: 2320-7035

Influence of Different Levels of Sulphur and Phosphorus on Growth and Productivity of Mustard (*Brassica juncea* L.)

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Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i125236

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128955

Original Research Article

Received: 25/10/2024
Accepted: 30/12/2024
Published: 30/12/2024

ABSTRACT

A field experiment was conducted at the Agronomy Research Farm of Nirwan University, Jaipur (Rajasthan) during the *Rabi* season of 2023-24. The experiment consisted of ten treatments with different combinations of phosphorus and sulphur. The results revealed that the combined application of phosphorus and sulphur significantly enhanced the growth and yield parameters of

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Cite as: *Sharma, Sanjay, Akashdeep Singh, Bharti Yadav, Vikash Choudhary, and Bharat Bhushan Rana. 2024. "Influence of Different Levels of Sulphur and Phosphorus on Growth and Productivity of Mustard (Brassica Juncea L.)". International Journal of Plant & Soil Science 36 (12):623-29. https://doi.org/10.9734/ijpss/2024/v36i125236.*

Indian mustard compared to the control. The highest plant height (152.91 cm), dry matter accumulation (436.47 g m^{-2}), number of siliquae per plant (340.58), number of seeds per siliqua (13.45), seed yield (1897.89 kg ha^{-1}), stover yield (4723.33 kg ha^{-1}), and biological yield (6621.22 kg ha^{-1}) were obtained with the application of 45 kg ha^{-1} phosphorus and 40 kg ha^{-1} sulphur. The significant improvements in growth and yield attributes can be attributed to enhanced metabolic activity, better cell division, and increased photosynthetic efficiency resulting from phosphorus and sulphur availability. Consequently, the application of 45 kg ha^{-1} phosphorus and 40 kg ha^{-1} sulphur was found to significantly improve overall productivity of Indian mustard.

Keywords: Indian mustard; sulphur; phosphorus; growth; yield.

1. INTRODUCTION

Rapeseed and mustard crops, belonging to the family *Cruciferae* (Brassicaceae), are widely cultivated in India. Indigenous species such as Indian mustard (*Brassica juncea*), brown sarson (*Brassica campestris* var. brown sarson), yellow sarson (*Brassica campestris* var. yellow sarson), toria (*Brassica campestris* var. toria), and taramira (*Eruca sativa*) are complemented by non-traditional species like gobhi sarson (*Brassica napus*), white mustard (*Brassica alba*), and Ethiopian mustard (*Brassica carinata*). This group constitutes the most significant Rabi oilseed crops, contributing substantially to India's vegetable fat economy. The oil content in mustard seeds ranges between 37-49% (Bhowmik et al., 2014). The seeds are highly nutritious, containing 38-57% erucic acid and 27% oleic acid. After oil extraction, the residual oil cake serves as valuable cattle feed and manure, providing approximately 5.1% nitrogen (N), 1.8% phosphorus (P_2O_5), and 1.1% potassium (K_2O). Mustard seeds are used as a condiment for pickles and to flavour curries and vegetables, while mustard oil is a staple for cooking, particularly in northern India. The crop's adaptability to residual soil moisture during the Rabi season makes it particularly advantageous (Mukherjee, 2010). Edible oils and fats are essential dietary components, supplying energy and acting as carriers for fat-soluble vitamins. Mustard oil cake or meal is a valuable source of protein for animal feed, contributing to balanced nutrition.

Agronomic practices play a vital role in improving crop productivity, especially during times of climate change (Sharma et al., 2024). Major agronomic practices are seed rate, spacing, mixed cropping, residue retention, tillage practices, weed management, irrigation and fertilization (inorganic or organic) (Das et al., 2024; Devi et al., 2024; Sharma et al., 2024; Salaria et al., 2024; Kumar et al., 2024; Singh et al., 2024; Kaur et al., 2024; Thakur et al., 2023; Sharma et al., 2023; Mrabet et al., 2023; Sharma et al., 2023; Mrabet et al., 2022). Nutrient application is the primary practice to enhance crop productivity. Phosphorus (P) and sulphur (S) are essential nutrients for the optimal growth and productivity of mustard crops (Ryan et al., 2001). Phosphorus plays a critical role in the early stages of growth, root development, reproductive organ formation, early maturity, and disease resistance. It is particularly essential during seed development, as a sufficient supply of phosphorus is necessary for seed formation (Gidago et al., 2012). Sulphur, the fourth major essential nutrient after nitrogen, phosphorus, and potassium, is crucial for oilseed crops' growth and productivity (Singh & Stoskopt, 1971). Sulphur supports the synthesis of amino acids like cysteine and methionine, chlorophyll formation, and enhances oil content (Dawar et al., 2023). It also aids in synthesizing vitamins such as biotin and thiamine and is involved in carbohydrate and protein metabolism, as well as flavor compound formation in cruciferous plants (Bhatla et al., 2023). In recent years, sulphur deficiency has become widespread due to continuous nutrient depletion by high-yielding crops, intensive cropping systems, and reduced application of organic manure and sulphur-containing fertilizers and pesticides (Zenda et al., 2021). This deficiency can significantly limit the growth, development, and yield potential of mustard crops. Proper phosphorus and sulphur management is, therefore, imperative to achieve optimal productivity and maintain soil fertility for sustainable mustard cultivation.

2. MATERIALS AND METHODS

The field experiment was carried out during the *Rabi* season of 2023-24 at Agronomy Research Farm, School of Agricultural Sciences, Nirwan University, Jaipur. The experiment was laid out in a randomized complete block design with ten treatments replicated thrice. The mustard variety

Table 1. Treatment details

T_1	Control
T_2	Phosphorus @ 15 kg ha^{-1}
T_3	Phosphorus @ 15 kg ha^{-1} + Sulphur @ 20 kg ha^{-1}
T_4	Phosphorus @ 15 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}
T_5	Phosphorus @ 30 kg ha^{-1}
T_6	Phosphorus @ 30 kg ha^{-1} + Sulphur @ 20 kg ha^{-1}
T_7	Phosphorus @ 30 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}
T_8	Phosphorus @ 45 kg ha^{-1}
T_9	Phosphorus @ 45 kg ha^{-1} + Sulphur @ 20 kg ha^{-1}
T_{10}	Phosphorus @ 45 kg ha^{-1} + Sulphur @ 40 kg ha^{-1}

under observation was Bio-902. The treatments consisted of different levels of sulphur and phosphorus, and their combinations applied at the time of sowing (Table 1). The experimental farm is geographically located at 75° 51'44" E longitude, 26°48'35" N latitude and an altitude of 432 m above mean sea level (AMSL). The experimental fields were sandy loam in texture, low in available nitrogen (137.8 kg ha^{-1}) (Subia & Asija, 1996), medium in available phosphorus (16.3 kg ha^{-1}) (Olsen et al., 1954) and potassium (250.12 kg ha^{-1}) (Jackson, 1973). The organic carbon content was from 0.34-0.38%. The observations recorded were subjected to Fisher's F- test and means were subsequently reported (Fisher, 1950).

3. RESULTS AND DISCUSSION

Growth attributes: Phosphorus and sulphur play crucial roles in enhancing plant height by improving the plant's nutritional environment (Table 2). The highest plant height (152.91 cm) was recorded in T_9 (45 kg ha^{-1} P + 40 kg ha^{-1} S), indicating the optimum availability of these nutrients for robust growth. Treatments such as T_6 (30 kg ha^{-1} P + 40 kg ha^{-1} S), T_3 (15 kg ha^{-1} P + 40 kg ha^{-1} S), and T_7 (45 kg ha^{-1} P) also showed statistically similar results, suggesting that a combination of moderate to high levels of phosphorus and sulphur effectively enhances plant height. The increase in height is attributed to the role of phosphorus in energy transfer, cell division, and root development, while sulphur aids in protein synthesis, chlorophyll production, and enzymatic activities. These findings align with those reported by Khanpara et al. (2020), Prajapati et al. (2023) and Kumar and Kumar (2021).

Dry matter accumulation progressively increased with the application of higher levels of phosphorus and sulphur (Table 2). The maximum dry matter (436.47 g m^{-2}) was observed in T_9, followed by T_8 (45 kg ha^{-1} P + 20 kg ha^{-1} S; 413.32 g m^{-2}) and T_3 (393.22 g m^{-2}). The application of phosphorus and sulphur enhances root growth and nutrient uptake, contributing to greater photosynthetic efficiency and biomass production. The increase in dry matter can be attributed to the formation of more primary and secondary branches, larger leaf area, and sustained vegetative growth, which facilitate higher photosynthetic activity (Lambers et al., 2019). The synergistic effect of phosphorus and sulphur is evident in the higher growth parameters observed in treatments with combined nutrient applications (Assefa et al., 2021). The balanced availability of these nutrients creates a favorable environment for plant growth, enhancing cell elongation, multiplication, and expansion. The application of 45 kg ha^{-1} phosphorus combined with 40 kg ha^{-1} sulphur (T_9) yields the highest growth attributes. Treatments T_6, T_3, and T_7 showed statistically similar results, indicating that moderate to high levels of phosphorus and sulphur are critical for optimal growth. These results reinforce the importance of phosphorus and sulphur in nutrient management strategies for Indian mustard, confirming findings by previous researchers such as Prajapati et al. (2024), Khanpara et al. (2020), Kumar and Kumar (2021), Singh and Dhiman (2005), Potdar et al. (2019), and Sahoo et al. (2021).

Yield attributes and yield: The application of phosphorus and sulphur had a significant impact on various growth and yield parameters of Indian mustard (Table 3). The highest number of branches per plant (8.72) was recorded in T_9 (45 kg ha^{-1} phosphorus + 40 kg ha^{-1} sulphur). Treatments T_8 (8.31 branches) and T_7 (7.84 branches) also demonstrated considerable

Table 2. Effect of sulphur and phosphorus fertilizers on growth attributes of Indian mustard at harvest

Treatments	Plant height (cm)	Dry matter accumulation (g m^{-2})
T_1	129.91	303.00
T_2	138.18	319.84
T_3	139.89	346.96
T_4	150.95	393.22
T_5	138.21	337.78
T_6	140.50	369.68
T_7	149.80	387.67
T_8	148.65	374.74
T_9	146.85	413.32
T_{10}	152.91	436.47
SEm$\pm$	2.89	6.94
LSD (p= 0.05)	4.75	11.05

Table 3. Effect of sulphur and phosphorus fertilizers on yield attributes and yields of Indian mustard

Treatments	Number of branches $plant^{-1}$	Number of siliquae per $plant^{-1}$	Number of seeds per $siliqua^{-1}$	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})
T_1	5.63	233.65	11.73	805.20	2134.67	2939.87
T_2	5.79	237.29	11.82	896.16	2193.33	3089.49
T_3	6.03	259.40	12.15	1160.72	2693.33	3854.05
T_4	7.95	304.91	12.94	1599.46	3963.33	5562.79
T_5	5.89	252.92	12.07	1126.35	2540.07	3666.42
T_6	6.57	308.19	12.36	1305.56	3060.00	4365.56
T_7	7.91	320.59	12.83	1593.67	3780.00	5373.67
T_8	7.84	280.54	12.59	1449.35	3413.33	4862.68
T_9	8.31	323.42	13.14	1750.46	4346.67	6097.13
T_{10}	8.72	340.58	13.45	1897.89	4723.33	6621.22
SEm$\pm$	0.14	7.23	0.20	54.36	191.08	245.44
LSD	0.38	13.26	0.17	142.98	340.30	483.28

increases in branching. The increase in the number of branches can be attributed to the combined effect of phosphorus and sulphur, which enhance metabolic activity, cell division, and structural development. Phosphorus supports root development, energy transfer, and the formation of new tissues, while sulphur is essential for amino acid synthesis, contributing to overall plant growth. Similarly, T_9 also recorded the maximum number of siliquae per plant (340.58), number of seeds per siliqua (13.45), seed yield (1897.89 kg ha^{-1}), stover yield (4723.33 kg ha^{-1}), and biological yield (6621.22 kg ha^{-1}). These improvements can be explained by enhanced nutrient availability, which facilitates better cell division, elongation, and photosynthetic efficiency. This leads to greater production and accumulation of carbohydrates, promoting the retention of more reproductive parts and subsequently higher yield. Treatments such as T_6 (30 kg ha^{-1} phosphorus + 40 kg ha^{-1} sulphur), T_3 (15 kg ha^{-1} phosphorus + 40 kg ha^{-1} sulphur), and T_4 (30 kg ha^{-1} phosphorus) also showed statistically similar results, indicating the beneficial effects of moderate to high phosphorus and sulphur application. The synergistic effect of these nutrients leads to improved branching, reproductive growth, and yield parameters, ultimately enhancing productivity in Indian mustard (Prajapati et al., 2023).

4. CONCLUSION

Agronomic practices play a vital role in improving crop productivity, especially during times of climate change. The study concludes that the combination of phosphorus and sulphur had an additive effect in enhancing the growth and yield of Indian mustard. Significantly higher seed yield, stover yield, and biological yield were achieved with the application of 45 kg ha^{-1} phosphorus and 40 kg ha^{-1} sulphur (T_9) compared to the control and other treatments. Sulphur deficiency has become widespread due to continuous nutrient depletion by high-yielding crops, intensive cropping systems, and reduced application of organic manure and sulphur-containing fertilizers and pesticides.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/128955