Plant Archives Vol. 26, Supplement 1, 2026 pp. 1462-1466 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.194

EFFECT OF ZINC AND SULPHUR FERTILIZATION ON YIELD, BIOMASS, AND ECONOMIC RETURNS OF INDIAN MUSTARD (*BRASSICA JUNCEA* L.) UNDER DOON VALLEY CONDITIONS

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(Date of Receiving : 20-08-2025; Date of Acceptance : 28-11-2025)

ABSTRACT

Mustard (*Brassica juncea* L.) is an important rabi oilseed crop in India, valued for edible oil, protein-rich seed cake, fodder, and medicinal uses. In Uttarakhand, mustard productivity remains low, averaging 858 kg ha^{-1}, which is below national and global levels. Low productivity, coupled with rising domestic demand for edible oil, necessitates improved nutrient management. Sulphur (S) and zinc (Zn) are key nutrients affecting mustard growth, yield, and seed quality. A field study was conducted during the 2023–24 rabi season at the Agronomy Research Farm, Jigyasa University, Dehradun, to assess the effect of Zn and S on yield and economic returns of mustard (variety HY-805). Eight treatments, including the recommended dose of fertilizer (RDF: 60 kg N, 40 kg P_2O_5, 40 kg K_2O ha^{-1}) alone or combined with Zn (10–12 kg ha^{-1}) and S (25–75 kg ha^{-1}), were laid out in a factorial Randomized Block Design with three replications. Grain yield, stover yield, biological yield, harvest index, and economic parameters (cost of cultivation, gross return, net return, and benefit–cost ratio) were recorded. Results indicated that Zn and S supplementation significantly enhanced yield and profitability. The highest grain yield (18.23 q/ha), stover yield (104.09 q/ha), biological yield (122.32 q/ha), and harvest index (14.90%) were recorded in RDF + Zn 12 kg/ha + S 75 kg/ha, while RDF + Zn 12 kg/ha + S 50 kg/ha provided the highest net return (Rs 66,683/ha) and benefit–cost ratio (1.98). Control plots showed the lowest yields and economic returns. Enhanced performance under Zn and S application was attributed to better growth, increased siliqua and seed formation, and greater biomass accumulation. The study concludes that integrating Zn and S with RDF improves both yield and economic efficiency of mustard under Doon Valley conditions, with RDF + Zn 12 kg/ha + S 50 kg/ha identified as the most effective and profitable nutrient management strategy.

Keywords: Zinc and Sulphur Fertilization, Yield, Biomass, Economic Returns, Indian Mustard (*Brassica juncea* L.).

Introduction

Mustard (*Brassica juncea* L.) is one of the most important rabi oilseed crops in India, cultivated mainly for its edible oil, which forms an essential part of the Indian diet. Apart from oil, mustard is also valued for its protein-rich seed cake, green fodder, and use in tanning and medicinal applications (Kumari *et al.*, 2025; Singh *et al.*, 2015). Globally, mustard is grown on about 36.54 million hectares, producing 72.80 million tonnes of seeds. India accounts for 6.23 mha area with 9.34 mt of production, but average productivity remains low compared to global benchmarks (Directorate of Economics & Statistics, 2020–21). In Uttarakhand, the situation is even more challenging with an average productivity of 858 kg ha^{-1} (Directorate of Agriculture, 2021–22).

The widening gap between domestic edible oil production and demand has made India heavily dependent on imports, draining valuable foreign exchange. Enhancing mustard productivity is therefore vital not only for nutritional security but also for economic sustainability of oilseed farming. Among the various yield-limiting factors, sulphur and zinc have been identified as critical nutrients. Sulphur increases seed yield, stover yield, oil percentage, and overall biomass, while zinc improves seed setting, siliqua filling, and seed weight through its role in enzymatic and physiological processes (Jahan, 2021; Sultana *et al*., 2020).

While yield is the primary concern for farmers, profitability is equally important. Economic evaluation in terms of gross returns, net returns, and benefit–cost (B:C) ratio is essential to recommend nutrient management strategies that are not only productive but also financially viable. Yet, comprehensive studies on the interactive effects of sulphur and zinc on both yield performance and farm-level economics under Doon Valley conditions are limited.

Hence, the present study entitled *"Effect of Zinc and Sulphur Fertilization on Yield, Biomass, and Economic Returns of Indian Mustard (Brassica juncea L.) under Doon Valley Conditions"* was carried out with the following objectives:

- To assess the impact of zinc application on yield performance of mustard.
- To analyze the economic feasibility of sulphur and zinc fertilization in mustard cultivation.

The impact of sulphur and zinc on mustard yield has been well documented. Bhinda *et al.* (2023) observed maximum seed yield (1.84 t ha^{-1}), stover yield (4.91 t ha^{-1}), and harvest index (27.3%) with S @ 40 kg ha^{-1} + Zn @ 5 kg ha^{-1}. Verma and Dawson (2018) reported similar increases in seed yield with 10 kg Zn ha^{-1} + 50 kg S ha^{-1}. Verma *et al*. (2022) and Pant (2023) confirmed that the highest seed and stover yields were obtained with Zn and S supplementation. Shahria (2020) showed that both nutrients enhanced biological yield, seed yield, and harvest index. Additional studies by Meena *et al*. (2021), Halim *et al.* (2023), Sultana *et al*. (2020), Tomar *et al*. (2021) and Singh *et al*. (2017) demonstrated significant increases in seed and stover yield with appropriate levels of S and Zn. These results highlight the critical role of sulphur and zinc in improving the productivity and oil yield of mustard crops.

The economic evaluation of mustard production has revealed that combined application of sulphur and zinc not only enhances yield but also improves profitability. Raj *et al*. (2022) reported that Zn @ 15 kg ha^{-1} produced the highest gross returns (Rs. 95,906.66 ha^{-1}), net returns (Rs. 57,686.66 ha^{-1}), and B:C ratio (1.50). Tomar *et al*. (2021) found the highest B:C ratio of 2.32 with Zn @ 10 kg ha^{-1}. Singh *et al.* (2017) reported that S @ 40–60 kg ha^{-1} with Zn application significantly increased gross and net returns as well as B:C ratio. Singh *et al*. (2010) and Sahoo *et al*. (2021) also confirmed that nutrient management with S and Zn substantially improved economic returns in mustard cultivation. Overall, these studies suggest that judicious use of sulphur and zinc enhances not only the growth and yield of mustard but also ensures higher profitability, making these nutrients essential for sustainable and economically viable mustard production.

Materials and Methods

The present study was conducted during the rabi season of 2023–2024 at the Agronomy Research Farm, Department of Agriculture, Jigyasa University, Selaqui, Dehradun, Uttarakhand, situated at 31°21'50" N latitude and 78°18'27" E longitude, with an altitude of 650 m above mean sea level. The experimental site experiences a sub-tropical climate with hot summers (up to 44°C), cool winters (below 1°C), and an average annual rainfall of 2073 mm, mainly concentrated during the monsoon months of June to September.

The experiment was designed to evaluate the effect of zinc and sulphur on yield and economic returns of Indian mustard (*Brassica juncea* L., variety HY-805). Eight treatments, comprising the recommended dose of fertilizer (RDF: 60 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1}) alone or in combination with zinc (10–12 kg ha^{-1}) and sulphur (25–75 kg ha^{-1}), were arranged in a factorial Randomized Block Design (RBD) with three replications. Each plot measured 2 × 3 m with 50 cm row-to-row spacing, separated by 1 m irrigation channels. Standard agronomic practices, including land preparation, basal fertilization, seed sowing, irrigation, and weeding, were followed uniformly across all treatments.

At maturity, the crop was harvested when 90% of siliqua had turned yellow. Biological yield was determined by weighing the total above-ground biomass (grain plus straw) from the net plot area and expressed in q ha^{-1}. Grain yield was recorded from 1 m² of the harvested area after threshing and drying, while stover yield was obtained from the remaining straw. The harvest index (HI) was calculated using the formula:

HI (%) = Grain yield/Biological yield × 100

For economic analysis, the cost of cultivation per hectare was calculated by summing all field operations, labor, fertilizers, irrigation, and treatment-specific inputs based on prevailing market rates. Gross return was computed by multiplying grain and stover yields with their respective market prices and summing them. Net return was obtained by subtracting the total cost of cultivation from the gross return, and the benefit-cost ratio (B:C) was calculated as the ratio of net return to total cost of cultivation. All yield and economic data were statistically analyzed using OPSTAT software at a 5% level of significance to determine the effect of treatments on productivity and profitability.

Result and discussion

Yield

Grain yield was significantly influenced by different treatments of zinc and sulphur in combination with RDF (Table 4.1). The highest grain yield (18.23 q/ha) was recorded in T8 (RDF + Zn 12 kg/ha + S 75 kg/ha), followed by 17.75 q/ha in T7 (RDF + Zn 12 kg/ha + S 50 kg/ha) and 16.22 q/ha in T6 (RDF + Zn 12 kg/ha + S 25 kg/ha). The control (T1) produced the lowest yield of 6.85 q/ha. The enhanced grain yield under higher Zn and S levels can be attributed to improved plant growth, increased siliqua formation, and better seed filling. These findings are in agreement with Singh *et al*. (2024).

Stover yield also varied significantly among treatments (Table 4.1). T8 recorded the maximum stover yield of 104.09 q/ha, followed by 101.71 q/ha in T7 and 93.32 q/ha in T6, while T1 (Control) recorded the lowest at 42.47 q/ha. The increase in stover yield indicates that zinc and sulphur supplementation promotes vegetative growth, biomass accumulation, and overall crop vigor. These results corroborate findings of Singh *et al.* (2024) and Jaiswal *et al.* (2025).

Biological yield showed a similar trend, with T8 producing the highest value of 122.32 q/ha, followed by 119.46 q/ha in T7 and 109.55 q/ha in T6, and the control yielding the lowest at 49.32 q/ha (Table 4.1). The increase in biological yield reflects the cumulative effect of improved vegetative growth, siliqua number, seed set, and dry matter accumulation under higher Zn and S levels, as also reported by Jaiswal *et al*. (2025) and Kumar *et al*. (2025).

Harvest index, representing the efficiency of partitioning assimilates into grain, was highest in T8 (14.90%), closely followed by T7 (14.86%) and T6 (14.81%), while the control (T1) had the lowest index of 13.89% (Table 4.1). This indicates that nutrient supplementation improved the proportion of total biomass allocated to grains. Similar results were reported by Bhinda *et al*. (2023).

Economic Studies

The cost of cultivation increased with nutrient application (Table 4.2). The highest cost (Rs 39,908/ha) was observed in T3 (RDF + Zn 10 kg/ha + S 25 kg/ha), while the control (T1) incurred the lowest cost of Rs 20,500/ha. Variation in cost reflects differences in input usage, including fertilizers and micronutrients. Singh *et al.* (2010) reported similar trends. Gross returns were significantly higher with higher Zn and S levels. T8 recorded the maximum gross return of Rs 1,02,999/ha, followed by T7 at Rs 1,00,287/ha, whereas the control yielded the lowest return of Rs 38,702/ha. The increase in gross return was directly related to enhanced grain and stover yield under improved nutrient management.

Net returns were highest in T7 (Rs 66,683/ha), followed by T8 (Rs 66,395/ha), while T1 (Control) recorded the lowest net return of Rs 18,202/ha. The higher net returns under T7 suggest that optimum levels of Zn and S maximize profitability, balancing cost of cultivation and yield gains. Similar observations were reported by Singh *et al*. (2017). The highest B:C ratio (1.98) was obtained with T7, indicating the most profitable treatment, whereas T3 had the lowest B:C ratio of 0.87 (Table 4.2). These results confirm that judicious application of zinc and sulphur improves economic efficiency by enhancing crop productivity relative to input costs. Singh *et al.* (2017) also observed maximum B:C ratio with similar nutrient combinations.

Overall, the integration of zinc and sulphur with RDF significantly improved grain, stover, and biological yield, harvest index, and economic returns in Indian mustard. The combination of T7 (RDF + Zn 12 kg/ha + S 50 kg/ha) emerged as the most efficient, providing maximum net return and B:C ratio while maintaining high yield, indicating it as the optimum nutrient management strategy for Doon Valley conditions. These findings emphasize the dual advantage of enhancing productivity and profitability through balanced micronutrient application.

Summary

The experiment demonstrated that sulphur and zinc significantly influence mustard yield and biomass. Increasing levels of Zn and S improved number of siliqua per plant, seeds per siliqua, and test weight,

leading to higher grain, stover, and biological yield. Harvest index also increased marginally with nutrient supplementation, reflecting improved partitioning of assimilates to grain. Economic analysis indicated that nutrient management with Zn and S increases gross and net returns and benefit–cost ratio. The combination of RDF with Zn 12 kg/ha and S 50 kg/ha was most profitable, balancing high productivity and input costs efficiently.

Conclusion

Balanced application of zinc and sulphur with RDF is crucial for enhancing both yield and economic returns of mustard in the Doon Valley. T7 (RDF + Zn 12 kg/ha + S 50 kg/ha) emerged as the optimum nutrient management strategy, providing maximum net return and B:C ratio while sustaining high grain and stover yield. The study highlights the importance of micronutrient supplementation for sustainable and profitable mustard production.

Table 1 : Impact of Treatments on Yield and Harvest Index

Treatment	Grain Yield (q/ha)	Stover Yield (q/ha)	Biological Yield (q/ha)	Harvest Index (%)
T1 = Control	6.85	42.47	49.32	13.89
T2 = RDF	11.89	70.15	82.04	14.50
T3 = RDF + Zn @ 10kg/ha + S @ 25kg/ha	13.21	77.41	90.62	14.58
T4 = RDF + Zn @ 10kg/ha + S @ 50kg/ha	14.55	84.83	99.38	14.64
T5 = RDF + Zn @ 10kg/ha + S @ 75kg/ha	15.98	92.36	108.35	14.75
T6 = RDF + Zn @ 12kg/ha + S @ 25kg/ha	16.22	93.32	109.55	14.81
T7 = RDF + Zn @ 12kg/ha + S @ 50kg/ha	17.75	101.71	119.46	14.86
T8 = RDF + Zn @ 12kg/ha + S @ 75kg/ha	18.23	104.09	122.32	14.90
C.D. at 5%	0.81	3.37	4.48	N/A
SEm (±)	0.26	1.10	1.47	0.21

Table 2 : Effect of Zn and S on cost of cultivation, gross return, net return and B:C ratio of mustard.

Treatment	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
T1 = (Control)	20500	38702	18202	0.89
T2 = RDF	25204	67178	41974	1.67
T3 = RDF + Zn @ 10kg/ha + S @ 25kg/ha	39908	74636	34728	0.87
T4 = RDF + Zn @ 10kg/ha + S @ 50kg/ha	33204	82207	49003	1.47
T5 = RDF + Zn @ 10kg/ha + S @ 75kg/ha	36204	90237	54083	1.49
T6 = RDF + Zn @ 12kg/ha + S @ 25kg/ha	30604	91643	61039	1.94
T7 = RDF + Zn @ 12kg/ha + S @ 50 kg/ha	33604	100287	66683	1.98
T8 = RDF + Zn @ 12kg/ha + S @ 75kg/ha	36604	102999	66395	1.81

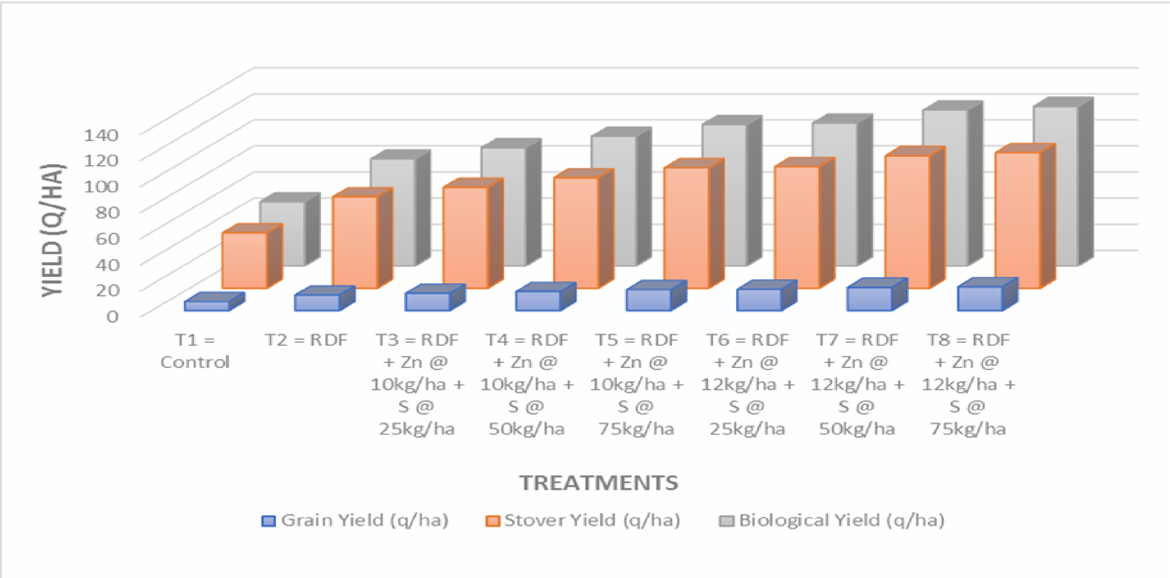

Fig. 1 : Influence of treatments on grain yield, stover yield and harvest index

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