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Effect of foliar application of sulphur, zinc, and boron on productivity and profitability of Indian mustard (*Brassica juncea* L.) cultivars

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Abstract
A field experiment was conducted during the *Rabi* seasons of 2021-22 and 2022-23 at the Agricultural Research Farm of Raja Balwant Singh College, Bichpuri, Agra, to assess the effect of foliar application of sulphur, zinc, and boron on the productivity and quality of mustard (*Brassica juncea* L.) cultivars. The experiment was laid out in split plot Design consisting of three varieties, *i.e.*, V_1 (PM-28), V_2 (PM-29) and V_3 (PDZ-31) as in main plot and eight nutrient management practices, *i.e.*, F_1 - (RDF+100 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1}), F_2 - (RDF+Sulphur @ 2.0% at 30-35 DAS and 45-50 DAS), F_3 - (RDF + Zinc @ 0.5% at 30 - 35 DAS and 45-50 DAS), F_4 - (RDF+Boron @ 0.2% at 30 - 35 DAS and 45-50 DAS), F_5 - (RDF + Sulphur @ 2.0% and Zinc @ 0.5% at 30-35 DAS and 45-50 DAS), F_6 - (RDF + Sulphur @ 2.0% and Boron @ 0.2% at 30-35 DAS and 45-50 DAS), F_7 - (RDF+Zinc @ 0.5% and Boron @ 0.2% at 30-35 DAS and 45-50 DAS) and F_8 - (RDF+Sulphur @ 2% +Zinc @ 0.5%+ Boron @ 0.2% at 30-35 DAS and 45-50 DAS) in sub plot. Results indicated that the PM-28 cultivar outperformed PM-29 and PDZ-31 in yield parameters, including, seed yield, and biological yield. Among the nutrient treatments, RDF+Sulphur @ 2% +Zinc @ 0.5%+ Boron @ 0.2% at 30-35 DAS and 45-50 DAS recorded the highest seed yield (22.63 t ha^{-1}). In terms of economics, the PM-28 cultivar combined with the treatment RDF+Sulphur @ 2% +Zinc @ 0.5%+ Boron @ 0.2% at 30-35 DAS and 45-50 DAS achieved the highest gross returns (₹ 123332 ha^{-1}), net returns (₹ 87242 ha^{-1}), and benefit-cost ratio (3.08) across both years.

Keywords: Boron, Indian mustard, net return, profitability, variety, yield zinc

Introduction
Mustard has economic significance as both a condiment crop and an oilseed crop. The seeds are crushed to extract mustard oil, a popular cooking oil in various regions. Mustard seed is the third biggest source of vegetable oil in the world after soybean oil and palm oil (Jat *et al*., 2021) [3]. The contribution of Indian mustard to the total oilseed production in India is around 26 percentage. Domestic production of edible oils meets only 50 percent of the total requirements, while rest is imported. Productivity and quality of oilseed crops can possibly be improved by adopting better agronomic practices and replacing conventional mustard varieties, which has the potential to fit in the current cropping systems due to its premium quality oil (Manaf and Hassan, 2016) [5]. Additionally, the condiment industry utilizes mustard seeds to produce a variety of mustards with distinct flavors and textures. It is a staple condiment in many cuisines globally. The pungent flavor of mustard is attributed to compounds released when the seeds are crushed and mixed with liquids, forming the familiar paste. Different varieties of mustard, such as Dijon, yellow, and brown, offer diverse flavor profiles, ranging from mild to spicy (Sharma *et al.*, 2024) [13]. Apart from being a condiment, mustard leaves are edible and are used in salads or cooked as leafy greens. Mustard seeds find applications in pickling, spice blends, and various recipes, contributing depth and flavor to a wide array of dishes (Norman, 2021) [9]. General components of profit potential are yield potential, fiber quality, response to management, consistency and market acceptance. Region-specific components may include crop maturity, disease resistance, insect resistance, stress tolerance and harvest ability.

Plants require a variety of nutrients for their growth and development, including nitrogen, phosphorus, potassium, and several micronutrients. Fertilizers are essential in supplying these nutrients to the soil, compensating for deficiencies and ensuring robust plant growth (Nadeem *et al*., 2018) [8]. Foliar application of essential nutrients such as sulphur, zinc, and boron has gained significant attention in modern agriculture due to its potential to enhance crop nutrition and overall yield. Sulphur, zinc, and boron are micronutrients crucial for various physiological processes in plants. While these elements are generally present in soil, their availability to plants can be limited, especially in regions with alkaline soils or under certain environmental conditions. Foliar application provides a targeted and efficient method to supplement these nutrients directly to plant foliage, bypassing soil-related limitations. Foliar application offers a more targeted approach to nutrient supplementation, reducing the risk of nutrient runoff and environmental impact.

Materials and Methods

The field experiment was carried out during *Rabi* season of 2021-22 and 2022-23 at Agricultural Research Farm, Department of Agronomy, R.B.S. College, Bichpuri, Agra (U.P.). The Variables involved in this study were three varieties, *i.e.*, V_1 (PM-28), V_2 (PM-29) and V_3 (PDZ-31) as in main plot and eight nutrient management practices, *i.e.*, F_1 - (RDF+100 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1}), F_2 - (RDF+Sulphur @ 2.0% at 30-35 and 45-50 DAS), F_3 - (RDF + Zinc @ 0.5% at 30 - 35 and 45-50 DAS), F_4 - (RDF+Boron @ 0.2% at 30-35 and 45-50 DAS), F_5 - (RDF + Sulphur @ 2.0% and Zinc @ 0.5% at 30-35 and 45-50 DAS), F_6 - (RDF + Sulphur @ 2.0% and Boron @ 0.2% at 30-35 and 45-50 DAS), F_7 - (RDF+Zinc @ 0.5% and Boron @ 0.2% at 30-35 and 45-50 DAS) and F_8 - (RDF+Sulphur @ 2% +Zinc @ 0.5%+ Boron @ 0.2% at 30-35 and 45-50 DAS) in sub plot. Thus, in all 24 treatment combinations were compared in a split plot design having with three replications. The study aimed to evaluate productivity and profitability of mustard cultivars under varying foliar nutrient management strategies. A recommended dose of fertilizer for mustard was Nitrogen @ 100 kg ha^{-1}, Phosphorous @ 60 kg ha^{-1} and Potassium @ 40 kg ha^{-1}. Full dose of phosphorus and potassium and half dose of nitrogen were applied at the time of sowing and remaining half dose of nitrogen in timely sown two splits as top dressing at 25 and 45 DAS. The N, P and K fertilizers were applied as urea (46% N), Diammonium phosphate (46% P_2O_5) and Muriate of potash (60% K_2O), respectively.Foliar application of zinc (Zn-EDTA @ 0.5%), boron (Boric acid @ 0.2%) and sulphur (Sulphur @ 2%) at 30-35 DAS and at 45-50 DAS as per treatment were sprayed. All the micronutrients were sprayed as per treatments stage (30-35 DAS and 45-50 DAS). Zinc, Boron and sulphur were sprayed as 0.5 per cent $ZnSO_4$ (containing 21% Zinc), 0.2% borax (containing 10.6% boron) and 2%, respectively. Spray fluid at a rate of 500 1 ha^{-1} was used for foliar spray.

Results and Discussion

Effect of Varieties

The results reveal that varietal differences significantly influenced biological yield, seed yield and stover yield in both the years of experimentation. Among the tested varieties, V_1 (PM-28) recorded the highest biological yield (7.51 and 7.38 t ha^{-1}) during 2021 and 2022, respectively. This variety also produced the maximum seed yield (2.16 and 2.21 t ha^{-1}) and stover yield (4.99 and 5.18 t ha^{-1}). The superior performance of V_1 (PM-28) may be attributed to its better genetic potential, efficient utilization of applied nutrients, and improved assimilate translocation to reproductive structures. Such varietal variations in mustard have also been reported by Meena *et al.* (2020) [6] and Rathore *et al.* (2017) [12], who emphasized the role of genotype in determining yield potential. Varieties V_2 (PM-29) and V_3 (PDZ-31) recorded comparatively lower biological and seed yields, although V_3 (PDZ-31) showed a slightly higher harvest index (31.06 and 30.95%). The harvest index remained statistically non-significant, suggesting that although total biomass differed among varieties, the proportion of biomass converted into economic yield remained similar across genotypes. This is in line with the findings of Singh and Shivani (2018) [14], who also observed non-significant differences in harvest index among Indian mustard varieties.

Table 1: Effect of foliar application of sulphur, zinc and boron on biological yield, seed yield, stover yield and harvest index of Mustard (*Brassica juncea* L.) cultivars

Treatments	Biological yield (t ha^{-1})		Seed yield (t ha^{-1})		Stover yield (t ha^{-1})		Harvest index (%)	
	2021	2022	2021	2022	2021	2022	2021	2022
Varieties								
V_1	7.51	7.38	2.16	2.21	4.99	5.18	30.49	30.11
V_2	6.47	6.63	1.98	2.01	4.49	4.62	30.81	30.54
V_3	6.30	6.39	1.94	1.96	4.36	4.43	31.06	30.95
SEm±	1.173	0.941	0.33	0.33	0.12	0.09	0.625	0.533
CD (P=0.05)	4.60	3.69	1.32	1.32	0.46	0.37	NS	NS
Nutrients Combinations								
F_1	5.97	6.15	1.93	1.97	4.04	4.18	32.57	32.16
F_2	6.38	6.55	1.95	1.98	4.43	4.56	30.72	30.48
F_3	6.32	6.48	1.99	2.02	4.33	4.46	31.76	31.47
F_4	6.40	6.56	1.95	1.99	4.44	4.58	30.77	30.50
F_5	7.07	7.23	2.10	2.14	4.97	5.10	29.82	29.66
F_6	6.91	7.08	2.08	2.12	4.83	4.96	30.26	30.05
F_7	6.65	6.82	1.99	2.02	4.67	4.80	30.08	29.87
F_8	7.40	7.56	2.22	2.26	5.17	5.30	30.30	30.09
SEm±	0.199	0.191	0.064	0.063	0.18	0.18	1.06	1.04
CD (P=0.05)	0.567	0.545	0.180	0.182	0.53	0.51	NS	NS

Effect of Foliar Nutrient Treatments

Foliar application of sulphur, zinc and boron exerted a significant influence on biological yield, seed yield and stover yield during both years. The highest biological yield was recorded with treatment F_8 (sulphur @ 2%, zinc @ 0.5% and boron @ 0.2%) (7.40 and 7.56 t ha⁻¹), followed by F_5 (7.07 and 7.23 t ha⁻¹). The superior performance of F8 could be attributed to the synergistic effect of sulphur, zinc and boron in enhancing photosynthesis, improving reproductive growth, and increasing nutrient uptake efficiency. These results corroborate the findings of Yadav *et al*. (2021) [15], who reported enhanced biomass accumulation in mustard with combined application of micronutrients. Seed yield also followed a similar trend, with F_8 producing the highest seed yield (2.22 and 2.26 t ha⁻¹) in 2021 and 2022, respectively. Improved pollen viability, better siliqua formation, and enhanced seed filling under combined foliar nutrition may have contributed to this improvement. Comparable effects of foliar S, Zn and B on seed yield enhancement in mustard were documented by Patel *et al*. (2019) [10] and Choudhary *et al.* (2020) [2]. Stover yield was also significantly influenced by nutrient treatments. The maximum stover yield was recorded in F_8 (sulphur @ 2%, zinc @ 0.5% and boron @ 0.2%) treatment (5.17 and 5.30 t ha⁻¹), followed by F_5 (4.97 and 5.10 t ha⁻¹). Increased vegetative growth under micronutrient supplementation may have contributed to these results. Unlike yields, harvest index did not differ significantly among treatments in either year, with values ranging from 29.66 to 32.57%, indicating that while nutrient treatments enhanced total biomass production, the proportional distribution of biomass toward seed and stover remained largely unaffected. This observation is supported by earlier studies (Singh & Shivani, 2018) [14], which also reported non-significant changes in harvest index with micronutrient foliar sprays.

Effect of Varieties on Economic Attributes
The data presented in Table 2 clearly indicate that the economics of Indian mustard cultivation were significantly influenced by varietal differences during both years of study. Among the three varieties, V_1 (PM-28) recorded the highest gross return (₹109380 ha⁻¹ in 2021 and ₹120514 ha⁻¹ in 2022), which consequently resulted in the maximum net return (₹78053 and ₹89186 ha⁻¹, respectively) and the highest benefit cost (B:C) ratio (2.49 and 2.78). This economic superiority of V_1 (PM-28)may be attributed to its comparatively higher yield potential and better physiological efficiency, which are consistent with the findings of Meena *et al.* (2020) [6], who reported that varietal genetic makeup plays a crucial role in enhancing productivity and profitability in mustard. In contrast, V_2 (PM-29) and V_3 exhibited comparatively lower returns, although V_3 (PDZ-31) showed a slightly higher B:C ratio than V_2 (PM-29) in both years. Earlier studies by Singh and Shivani (2018) [14] also highlighted variation among mustard genotypes in terms of economic returns due to differences in seed yield, oil content, and stress tolerance.

Table 2: Effect of foliar application of sulphur, zinc and boron on economics attributes of Mustard (*Brassica juncea* L.) cultivars

Treatments	Cost of cultivation (₹ ha⁻¹)		Gross return (₹ ha⁻¹)		Net return (₹ ha⁻¹)		Benefit: cost ratio	
	2021	2022	2021	2022	2021	2022	2021	2022
Varieties								
V_1	31327	32027	109380	120514	78053	89186	2.49	2.78
V_2	31957	32657	100137	109993	68180	78035	2.13	2.39
V_3	30477	31177	98197	107244	67720	76767	2.22	2.46
SEm±	-	-	1698.2	1829.8	1698.2	1829.8	0.06	0.06
CD (P=0.05)	-	-	6668.2	7184.8	6668.2	7184.8	0.23	0.25
Nutrients Combinations								
F_1	26417	27117	88285	90961	61868	63844	2.34	2.35
F_2	30201	30901	98705	101993	68504	71092	2.27	2.30
F_3	30125	30725	99521	106312	69396	75587	2.30	2.46
F_4	31697	32397	98829	108526	67132	76129	2.12	2.35
F_5	30809	32509	105230	111695	74421	79186	2.42	2.44
F_6	35481	36181	105517	115744	70036	79563	1.97	2.20
F_7	32305	33005	100478	110306	68173	77301	2.11	2.34
F_8	34089	34789	122548	126332	88459	91543	2.59	2.63
SEm±	-	-	3216.2	3473.5	3216.2	3473.5	0.11	0.11
CD (P=0.05)	-	-	9179.0	9913.3	6543.4	7015.5	0.30	0.32

Effect of Foliar Applications of Sulphur, Zinc, and Boron on Economic Attributes
A wide variation in economic parameters was observed due to different nutrient combinations. The maximum gross return (₹122548 ha⁻¹ in 2021 and ₹126332 ha⁻¹ in 2022) and net return (₹88459 and ₹91543 ha⁻¹) were recorded under treatment F_8 (sulphur @ 2%, zinc @ 0.5% and boron @ 0.2%), the treatment receiving the most balanced and effective combination of sulphur, zinc, and boron. This treatment also produced the highest B:C ratio (2.59 and 2.63), indicating the best economic viability. The improvement may be linked to enhanced nutrient uptake, increased photosynthesis, and higher seed setting, as supported by the findings of Yadav *et al*. (2021) [16], who emphasized the synergistic effects of micronutrients on mustard productivity. Treatments F_5 and F_3 also performed well, showing relatively higher gross and net returns with B:C ratios above 2.40 in most cases. Foliar feeding of micronutrients at critical growth stages has been reported to enhance yield components such as siliquae per plant and seed weight (Rathore *et al.*, 2017) [12], which ultimately improve economic returns. Treatment F_6 showed the lowest B:C ratio (1.97 and 2.20) due to the highest cultivation cost (₹35481 and ₹36181 ha⁻¹). Despite moderate returns, the increased input cost reduced profitability. Similar trends were observed by Patel *et al.* (2019) [10], who reported that higher nutrient doses do not always translate into proportionate economic benefits unless applied in a balanced manner.

Conclusion
The study revealed that both varieties and foliar micronutrient applications significantly influenced the productivity of Indian mustard. Among the cultivars, PM-28 consistently produced the highest biological and seed yields, confirming its superior genetic potential. The combined foliar application of sulphur @ 2%, zinc @ 0.5% and boron @ 0.2% resulted in maximum biological yield, seed yield and stover yield. This treatment also recorded the highest gross and net returns along with the best

B:C ratio, indicating strong economic viability. Although harvest index remained unaffected, overall productivity improved substantially. Thus, cultivar PM-28 with sulphur @ 2%, zinc @ 0.5% and boron @ 0.2% emerges as the most effective and profitable nutrient management strategy for mustard cultivation.

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