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EFFECT OF BORON AND ZINC FERTILIZATION ON GROWTH, YIELD ATTRIBUTES AND ECONOMICS OF INDIAN MUSTARD (*BRASSICA JUNCEA*)

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ABSTRACT

A field experiment was carried out at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, during the *rabi* season in the clayey and slightly alkaline soils to study the "Response of Indian Mustard (*Brassica juncea*) to Boron and Zinc Fertilization". The experiment was conducted using a Randomized Block Design (RBD) with three replications, involving nine treatment combinations applied to the Indian mustard variety GDM-4. The treatments were as follows: T1: RDF, T2: RDF + 1 kg B/ha, T3: RDF + 2 kg B/ha, T4: RDF + 4 kg Zn/ha, T5: RDF + 8 kg Zn/ha, T6: RDF + 1 kg B + 4 kg Zn/ha, T7: RDF + 2 kg B + 4 kg Zn/ha, T8: RDF + 1 kg B + 8 kg Zn/ha, and T9: RDF + 2 kg B + 8 kg Zn/ha. Significant differences were observed among treatments for most growth and yield parameters. Plant height increased notably from 30 DAS, with the tallest plants (206.38 cm) recorded under T9, followed by T8, T7, and T6. T9 also produced the highest number of branches per plant (18.33), statistically at par with T8, T7, T6, and T5. Key yield-attributing traits such as siliqua length (4.03 cm), number of siliquae per plant (283.40), and seeds per silique (13) were significantly influenced, with the highest values recorded under T9. However, plant population, test weight, and harvest index were not significantly affected by the treatments. In terms of productivity, T9 recorded the highest seed yield (2518 kg/ha) and stover yield (5417 kg/ha), followed closely by T8, T7, and T6. T8 yielded the highest net returns (Rs. 76,306.54/ha) and benefit-cost ratio (BCR) of 3.88, making it the most economically viable treatment, followed by T9, T7, and T6.
Keywords: Indian Mustard, Growth, Yield, Economics, Boron and Zinc

Introduction

Indian mustard (*Brassica juncea* L.) is a major *rabi* oilseed cultivated in India, ranked 3rd and 4th in area and production of rapeseed-mustard, respectively (Chauhan *et al.,* 2020) and accounts for nearly one third of the oil production in India. Mustard seeds contain nearly 40% oil and 28-36% protein with a high nutritive value. Mustard oil is considered a vital component of the Indian diet and is commonly used as the primary cooking medium, particularly in northern India. Despite the country's increased production and productivity of rapeseed-mustard, the per capita consumption of fats and oils (8.2 kg/capita/year) remains quite low (Yadav *et al.,* 2018).

India's rapeseed and mustard production stood at 126.06 lakh tonnes in 2024- 25 crop year (July-June) with an acreage of 86.29 lakh hectares and an average yield of 1,461 kg ha^{-1} (Anonymous, 2025 a). Although rapeseed-mustard is cultivated in majority of states of the country, bulk of the production comes from Rajasthan (45.40 %), Madhya Pradesh (13.28%) Uttar Pradesh (14.24 %) Haryana (10.78%) and West Bengal (6.0 %) during 2023-24 (Anonymous, 2025 b). By 2030, the projected demand for oilseeds is estimated at 82–101 million tonnes, of which rapeseed–mustard is expected to contribute around 16.4–20.5 million tonnes, accounting for 20–25% of total production (Chauhan *et al*., 2020).

Micronutrients are vital for sustaining soil health and enhancing crop productivity (Rattan *et al*., 2009). Over the past three decades, their deficiency has increased significantly, becoming a major constraint in oilseed production. Among them, zinc (Zn) is essential for growth, development, and quality of crops (Singh *et al*., 2017). Zn deficiency impairs carbohydrate metabolism, damages pollen structure, and reduces yield, while higher seed-Zn content supports germination and seedling growth (Shoja *et al*., 2018). Boron (B) is equally important, especially in mustard, which responds strongly to B fertilization (Sharma et al., 2019). Globally, B deficiency ranks second only to Zn (Ahmad *et al*., 2012), and in mustard, it causes sterility, leading to fewer pods and seeds per pod, thereby lowering yield. B application not only improves yield but also enhances seed nutritional quality, with positive responses in mustard widely reported (Saha *et al*., 2003; Jaiswal *et al*., 2015).

Material and Methods

A field experiment was carried out at college farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during the *rabi* season to study the Response of Indian Mustard (*Brassica juncea*) to Boron and Zinc Fertilization". The soil of the experimental field was clayey in texture, with low available N (238.6 kg ha^{-1}), medium available P (50.8 kg ha^{-1}), and high available K (356.2 kg ha^{-1}). The electric conductivity of the soil was normal (0.38) and had a slightly alkaline pH of 7.68. The experiment was laid out in randomized block design (RBD) with factorial concept in three replications constituting the following treatment combinations of T1 (RDF), T2 (1 Kg B/ha), T3 (2 Kg B/ha), T4 (4 Kg Zn/ha), T5 (8 Kg Zn/ha), T6 (1 Kg B + 4 Kg Zn/ha), T7 (2 Kg B + 4 Kg Zn/ha), T8 (1 Kg B + 8Kg Zn/ha) and T9 (2 Kg B + 8Kg Zn/ha). The field preparation included ploughing, harrowing and planking to achieve a fine tilth congenial for sowing. The Basal application of FYM, biocompost and fertilizers like urea, SSP, zinc sulphate and borax was carried out to supplement the respective treatments. The sowing of GDM-4 variety of mustard was carried out on 19th November, 2019 with the recommended seed rate and spacing of 3.5-4 kg ha^{-1} and 45 cm x 15 cm, respectively. The post-sowing operations, *viz.,* thinning and gap filling were carried out at 10 DAS, two hand weedings and irrigation was managed according to the critical stages of the crops. Various biometric observations were recorded at different growth stages of the crop including plant population, Plant height at 30 DAS and at harvest, number of branches per plant at harvest, days to 50% flowering, number of siliquae/plant, number of seed/ siliquae, Siliquae length, Seed and stover yield (kg/ha), Harvest index and test weight (g). Harvesting of the crop was carried out in the first week of March, 2020. After the crop was sufficiently dried, the total weight was recorded and plot-wise threshing was done by beating with sticks, winnowing and cleaning of grains were done manually.

The cost of cultivation was estimated for each operation from preparatory tillage to threshing based on prevailing market rates. Gross returns (Rs./ha) were calculated from seed and straw yield according to local market prices, while net returns were obtained by deducting the cost of cultivation from gross returns. The benefit–cost (B:C) ratio was determined as the ratio of gross returns to total cultivation cost. Data on growth, yield, and yield attributes were analyzed through analysis of variance (ANOVA) for randomized block design (Fisher, 1950), and treatment means were compared using the critical difference (CD) at 5% probability level when the F-test was significant.

Results and Discussion

Growth and Growth Attributes

The results indicated that zinc and boron fertilization had no significant effect on plant population at 30 DAS as well as at harvest. Plant height at 30 DAS was also found to be non-significant; however, a significant difference was observed at harvest. The maximum plant height (206.83 cm) was recorded with treatment T9, which was statistically at par with T8, T7, and T6, and represented a 12.65% increase over the control (T1), where the lowest plant height (183.60 cm) was observed. Growth parameters responded positively to the combined application of Zn and B along with balanced NPK, which could be attributed to their synergistic interaction, corroborating the findings of Hallur (2011) and Modi *et al*. (2019).

Significantly higher number of branches per plant at harvest (18.33) was recorded under T9, which was at par with T8, T7, T6, and T5. Treatment T9 showed a 29.08% increase in branches per plant over control, while the lowest value (14.20) was observed in T 1. This improvement may be ascribed to better soil conditions, enhanced availability of nutrients, and the synergistic effect of Zn and B in promoting photosynthesis and overall plant growth. These findings are in close agreement with those reported by Singh *et al*. (2017). Days to 50% flowering in mustard variety GDM-4 were not significantly affected by different levels of zinc and boron fertilization.

Table 1: Influence of Zinc and Boron Fertilization on Growth attributes of Indian Mustard

Treatments		Plant Population / meter row length	Plant height (cm) at harvest	Number of branches/ plant	Days to 50% flowering
T1	RDF	6.37	183.60	14.20	64.33
T2	1 Kg B/ha	6.47	185.53	15.47	63.00
T3	2 Kg B/ha	6.27	186.37	15.90	64.33
T4	4 Kg Zn/ha	6.27	186.63	16.23	61.67
T5	8 Kg Zn/ha	6.50	191.53	16.70	65.67
T6	1 Kg B + 4 Kg Zn/ha	6.40	198.03	17.03	63.00
T7	2 Kg B + 4 Kg Zn/ha	6.63	198.53	17.50	65.00
T8	1 Kg B + 8 Kg Zn/ha	6.60	200.90	17.87	62.00
T9	2 Kg B + 8 Kg Zn/ha	6.47	206.83	18.33	64.00
S.Em. ±		0.35	5.00	0.66	1.71
C.D at 5 %		NS	15.01	2.00	NS
C. V. %		9.60	4.49	6.97	4.65

Yield and Yield Attributes

Application of treatment T9 significantly increased siliqua length (4.03 cm), which was statistically at par with T8, T7, T6, T5, T4, and T3. This represented a 22.21% increase over the control (T1), where the lowest siliqua length (3.30 cm) was recorded, remaining at par with T 2 and T3. A significantly higher number of siliquae per plant (283.40) was also observed under T9, which was at par with T8, T7, T6, and T5, showing a 16.88% increase over the control (242.47). The lowest number of siliquae per plant was recorded under T1. Similarly, the maximum number of seeds per siliqua (13) was obtained in T9 and T8, which were at par with T7, T6, T5, T4, and T3, whereas the lowest value (8.67) was observed in T1.

The higher siliqua length, number of siliquae per plant, and seeds per siliqua recorded under Zn and B fertilization may be attributed to the synergistic effect of these micronutrients, which ensured better nutrient uptake and translocation, thereby enhancing reproductive growth. Boron, in particular, plays a key role in the translocation of water and nutrients from roots to shoots, the synthesis of chlorophyll and IAA, and delaying senescence, which prolongs photosynthesis. This leads to higher carbohydrate production and efficient translocation to developing seeds, as also reported by Shoja *et al.* (2018).

The test weight of mustard seed was not significantly influenced by Zn and B fertilization, as it is largely a genetically governed trait.

Table 2: Influence of Zinc and Boron Fertilization on yield attributes of Indian mustard

Treatments		Length of siliquae (cm)	Number of siliquae/ Plant	Number of seed/ siliquae	Test weight (g)
T1	RDF	3.30	242.47	8.67	3.70
T2	1 Kg B/ha	3.37	254.80	9.33	3.76
T3	2 Kg B/ha	3.80	257.83	10.33	3.75
T4	4 Kg Zn/ha	3.83	261.23	11.33	3.79
T5	8 Kg Zn/ha	3.87	262.17	12.00	3.85
T6	1 Kg B + 4 Kg Zn/ha	3.93	264.17	12.33	3.90
T7	2 Kg B + 4 Kg Zn/ha	3.97	277.23	12.67	4.16
T8	1 Kg B + 8 Kg Zn/ha	4.00	280.40	13.00	4.21
T9	2 Kg B + 8 Kg Zn/ha	4.03	283.40	13.00	4.23
S.Em. ±		0.16	7.21	1.00	0.15
C.D at 5 %		0.49	21.63	3.00	NS
C. V. %		7.49	4.71	15.20	6.62

Boron and zinc fertilization significantly increased seed yield of mustard over control (T1). The highest seed yield (2518 kg/ha) was recorded under T9, which was at par with T8, T7, and T6, representing a 30.61% increase over T1 (1928 kg/ha). Similarly, the highest stover yield (5416 kg/ha) was observed in T9, at par with T8, T7, and T6, while the lowest was in T1

(3746 kg/ha), showing a 44.57% increase with T9 over control.

The synergistic interaction of Zn and B significantly enhanced both seed and stover yields. Zinc, as an enzyme activator, improved photosynthesis and seed vigour, while boron promoted chlorophyll synthesis, pollen development, and fertilization, leading to higher yields. The strong crop response likely reflected their low native availability in soil. Yield improvement with Zn was associated with more branches, siliquae per plant, seeds per siliqua, and thousand-seed weight (Jat *et al.*, 2012; Azam *et al.*, 2013; Kumar *et al.*, 2014). Boron application further increased siliquae per plant and seeds per siliqua, corroborating its essential role in reproductive growth (Hossain *et al.*, 2012). Harvest index ranged from 31.55% to 34.09% and was not significantly affected by the treatments, The present results are in close conformity with the findings of Quddus *et al.* (2011).

Table 3: Seed yield, Stover yield and harvest index of Indian mustard as influenced by zinc and boron fertilization.

Treatments		Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
T1	RDF	1928	3746	34.09
T2	1 Kg B/ha	1948	4270	31.55
T3	2 Kg B/ha	2018	4306	32.38
T4	4 Kg Zn/ha	2071	4363	32.43
T5	8 Kg Zn/ha	2147	4396	33.08
T6	1 Kg B + 4 Kg Zn/ha	2249	5228	30.09
T7	2 Kg B + 4 Kg Zn/ha	2494	5268	32.09
T8	1 Kg B + 8 Kg Zn/ha	2503	5336	31.79
T9	2 Kg B + 8 Kg Zn/ha	2518	5416	31.74
	S.Em. ±	118.55	287.07	1.95
	C.D at 5 %	355.41	860.63	NS
	C.V. %	9.29	10.57	10.54

Economics

Zinc and boron fertilization significantly influenced economics. The highest gross return (Rs. 103441/ha) was recorded in T9, while the maximum net return (Rs. 76306/ha) and the highest cost–benefit ratio (3.88) were observed in T8, followed by T9, T7 and T6. The lowest gross return and net return were from T1 and T2, respectively, with the lowest cost–benefit ratio (3.20) in T3. These results agree with earlier reports (Khan *et al.*, 2008; Azam *et al.*, 2013; Sahito *et al.*, 2014; Mallick & Raj, 2015; Kour *et al.*, 2017; Singh *et al.*, 2017; Modi *et al.*, 2019).

Table 4: Economics of Indian mustard as influenced by zinc and boron fertilization

Treatment	Total cost of cultivation	Gross income (Rs/ha)	Net income (Rs/ha)	BCR
T1	22320	78993	56673	3.53
T2	24071	80081	56010	3.32
T3	25822	82886	57064	3.20
T4	23532	85048	61516	3.61
T5	24744	88078	63334	3.55
T6	25283	92601	67318	3.66
T7	27034	102394	75360	3.78
T8	26495	102801	76306	3.88
T9	28246	103441	75195	3.66

Conclusion

From the results of the experiment, it can be inferred that the combined application of RDF + 2 Kg B + 8 Kg Zn/ha over other combinations as well as sole Zn and B fertilization significantly improved growth, yield attributes and profitable yield in *rabi* Indian mustard. It can be concluded that higher profitable yield and higher net income in rabi Indian mustard can be achieved by RDF + 1 Kg B + 8 Kg Zn/ha and RDF + 2 Kg B + 8 Kg Zn/ha over other combined as well as sole Zn and B fertilization treatments.

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