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Effect of zinc, boron and vermicompost on growth of cabbage (*Brassica oleracea* var. *capitata*)

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Abstract
The present investigation was conducted during the Rabi season of 2024-25 at the Research Farm, Department of Horticulture, Faculty of Agriculture and Veterinary Sciences, Mewar University, Gangrar, Chittorgarh, Rajasthan. The study aimed to evaluate the integrated effects of foliar-applied micronutrients Zinc (0.5%) and Boron (0.5%) and organic nutrient source vermicompost at 0, 2.5, 5.0, and 7.5 t/ha on the growth of cabbage. The experiment followed a Factorial Randomized Block Design (FRBD) comprising 16 treatment combinations replicated thrice. Results revealed that the combined application of Zinc and Boron (Zn_1B_1) significantly enhanced plant height (45.71 cm at 90 DAT), number of leaves per plant (27.98 cm at 90 DAT), stalk girth (4.81 cm at 90 DAT), Leaf Length (35.88 cm 60 DAT) and Leaf Width (34.87 cm at 60 DAT). Among vermicompost levels, 5.0 t/ha (V_2) was also most effective for vegetative growth attributes. The study concludes that the integrated nutrient management strategy involving Zinc 0.5% + Boron 0.5% with 5.0 t/ha vermicompost significantly improves growth of cabbage and can be recommended for sustainable and profitable cultivation under similar agro-climatic conditions.

Keywords: Cabbage, zinc, boron, vermicompost, foliar spray, micronutrients, organic manure, growth attributes, integrated nutrient management, sustainable agriculture

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.), a biennial herbaceous crop belonging to the family Brassicaceae, holds a significant place in vegetable cultivation due to its nutritional, medicinal, and economic importance. Its historical roots trace back to the Mughal era in the Indian subcontinent, though it gained widespread popularity during British rule. According to Chauhan (1986), its origin is believed to be in Western Europe and the northern Mediterranean region. Today, cabbage thrives equally well in tropical and subtropical climates, although it is particularly favored as a winter crop in India. It is cultivated year-round in various agro-climatic zones, with primary production concentrated in the Rabi season. The edible portion of the cabbage is the compact head formed by tightly overlapping leaves around the apical bud. This head is widely consumed in multiple forms—raw in salads, cooked in curries, boiled, fermented as sauerkraut, and dehydrated for preservation. Apart from its culinary use, cabbage has a long-standing reputation for medicinal value. Traditional uses include treatments for gout, digestive disorders, ulcers, and even poisoning from mushrooms. The leaves are also applied topically to aid wound healing and inflammation reduction. Its fermentation technique, notably used in sauerkraut, helps preserve vitamin C and is known to combat scurvy. Cabbage is widely cultivated across the globe, especially in countries like China, Russia, Korea, Japan, Indonesia, and India. India stands as the second-largest cabbage producer after China, covering approximately 4 lakh hectares and producing 9.039 million metric tonnes, with a productivity of 22.6 metric tonnes per hectare. Among cole crops, cabbage ranks first in terms of both area and production. Within India, states such as Uttar Pradesh, Bihar, Orissa, West Bengal, Maharashtra, Karnataka, and Assam dominate its cultivation, while in Rajasthan, notable districts include Jaipur, Ajmer, Alwar, Bharatpur, and Jodhpur. Nutritionally, cabbage is rich in essential vitamins and minerals. Per 100 grams of its edible portion, it contains 92% water, 24 kcal of energy, 1.5 g protein, 4.8 g carbohydrate, 40 mg calcium, 0.6 mg iron, 600 IU

carotene, and 60 mg vitamin C. It also provides indole-3-carbinol, a compound believed to boost DNA repair and inhibit cancer cell growth. Its distinct flavor is attributed to the glucoside compound "sinigrin". Additional studies have shown the presence of vitamin A, thiamine, riboflavin, niacin, potassium, phosphorus, and iron in notable quantities (Fageria *et al.*, 2003) [26], making cabbage a complete health-supportive food. Despite its high productivity, cabbage cultivation faces challenges that limit yield and profitability, particularly in Rajasthan. One major factor is the suboptimal use of nutrients. To address this, the foliar application of micronutrients like zinc and boron, alongside plant growth regulators such as Naphthalene Acetic Acid (NAA), Gibberellic Acid (GA_3), and Benzyl Adenine, has been identified as an effective strategy to enhance both growth and yield. Micronutrients play a vital role in metabolic activities—zinc, for example, regulates enzyme activity, chlorophyll synthesis, auxin production, and reproductive development, while boron is critical for cell wall formation, sugar transport, nitrogen fixation, and pollination. Iron also significantly contributes to photosynthesis and chloroplast maintenance. Foliar application ensures more efficient absorption and utilization of these nutrients, reducing overall input cost while improving output quality. However, exclusive reliance on chemical fertilizers may not sustain long-term soil health. Therefore, the integrated application of micronutrients with organic manures such as vermicompost has gained prominence. Vermicompost, derived from decomposed organic matter using earthworms, is a slow-releasing, nutrient-rich, and environmentally friendly amendment. It supplies essential nutrients including nitrogen, phosphorus, potassium, calcium, and magnesium, and improves soil's physical, chemical, and biological properties. It enhances microbial activity, soil structure, water retention, and nutrient buffering capacity. Moreover, vermicompost contains plant growth-promoting substances like humic acid, vitamins, and hormones, which foster root development and disease resistance. Research has shown that it can substantially reduce the carbon-to-nitrogen ratio and increase humus content, thereby promoting better plant health and higher yields. Given the growing population and the corresponding increase in demand for nutritious vegetables, there is a need to improve cabbage productivity sustainably. Modern agriculture requires a shift towards integrated nutrient management that combines chemical, organic, and biological sources. Such practices not only enhance cabbage growth and yield but also restore soil fertility and maintain ecological balance. The present study is thus designed to explore the combined effects of zinc, boron, and vermicompost on the growth, yield, and profitability of cabbage cultivation, aiming to develop a cost-effective and environmentally sustainable nutrient management strategy.

Materials and Methods

A field experiment was conducted during the *Rabi* season of winter at the Research Farm, Department of Horticulture, Faculty of Agriculture and Veterinary Sciences, Mewar University, Chittorgarh, Rajasthan.

Experimental material

The experimental material for the present study consisted of Cabbage (*Brassica oleracea* var. *capitata* L.), variety NCAH-620, a widely cultivated high-yielding variety suitable for the agro-climatic conditions of Rajasthan. The experiment was conducted during the *Rabi* season of 2024-25 at the Research Farm, Department of Horticulture, Faculty of Agriculture and Veterinary Sciences, Mewar University, Gangrar, Chittorgarh, Rajasthan.

Table 1: Treatment Details

Treatments		Dedicated Symbol
Micronutrients		
I.	Control	Zn_0B_0
II.	Zinc 0.5%	Zn_1B_0
III.	Boron 0.5%	Zn_0B_1
IV.	Zinc 0.5% + Boron 0.5%	Zn_1B_1
Vermicompost		
I.	Control	V_0
II.	Vermicompost 2.5 Ton ha^{-1}	V_1
III.	Vermicompost 5 Ton ha^{-1}	V_2
IV.	Vermicompost 7.5 Ton ha^{-1}	V_3

Table 2: Treatment Combinations

Treatment Combination	V0	V1	V2	V3
Zn_0B_0	$Zn_0B_0V_0$	$Zn_0B_0V_1$	$Zn_0B_0V_2$	$Zn_0B_0V_3$
Zn_1B_0	$Zn_1B_0V_0$	$Zn_1B_0V_1$	$Zn_1B_0V_2$	$Zn_1B_0V_3$
Zn_0B_1	$Zn_0B_1V_0$	$Zn_0B_1V_1$	$Zn_0B_1V_2$	$Zn_0B_1V_3$
Zn_1B_1	$Zn_0B_1V_0$	$Zn_0B_1V_1$	$Zn_0B_1V_2$	$Zn_0B_1V_3$

Table 3: Treatment Combination

Sr. No.	Treatments	Symbols
1.	Control	T_1
2.	Vermicompost 2.5 Ton ha^{-1}	T_2
3.	Vermicompost 5 Ton ha^{-1}	T_3
4.	Vermicompost 7.5 Ton ha^{-1}	T_4
5.	Zinc 0.5%	T_5
6.	Zinc 0.5% + Vermicompost 2.5 Ton ha^{-1}	T_6
7.	Zinc 0.5% + Vermicompost 5 Ton ha^{-1}	T_7
8.	Zinc 0.5% + Vermicompost 7.5 Ton ha^{-1}	T_8
9.	Boron 0.5%	T_9
10.	Boron 0.5% + Vermicompost 2.5 Ton ha^{-1}	T_{10}
11.	Boron 0.5% + Vermicompost 5 Ton ha^{-1}	T_{11}
12.	Boron 0.5% + Vermicompost 7.5 Ton ha^{-1}	T_{12}
13.	Zinc 0.5% + Boron 0.5%	T_{13}
14.	Zinc 0.5% + Boron 0.5% + Vermicompost 2.5 Ton ha^{-1}	T_{14}
15.	Zinc 0.5% + Boron 0.5% + Vermicompost 5 Ton ha^{-1}	T_{15}
16.	Zinc 0.5% + Boron 0.5% + Vermicompost 7.5 Ton ha^{-1}	T_{16}

Experimental Details

The experiment was laid out in Factorial Randomized Block Design with Sixteen treatments and three replications. The random allocation of treatments was done using statistical table prepared by Fisher and Yates (1963) [27].

Table 4: Experimental Details

Sr. No.	Particulars		Details
1.	Duration	:	*Rabi* 2024-25
2.	Crop	:	Cabbage
3.	Variety	:	NCAH-620
4.	Location	:	Research Farm, Department of Horticulture, Faculty of Agriculture and Veterinary Sciences, Mewar University
5.	Experimental Design	:	FRBD (Factorial Randomised Block Design)
6.	Number of Treatments	:	16
7.	Number of Replications	:	3
8.	Total Number of Plots	:	48
9.	Spacing	:	45 cm x 45 cm
10.	Gross Plot Size	:	2.75 m x 2.0 m
11.	Net Plot Size	:	2.25 m x 1.8 m

Results and Discussion

Physical attributes of different genotypes

The data presented in Table No. 5. clearly reveal that the growth attributes of Cabbage were significantly influenced by the foliar application of different levels of Nutrients and Vermicompost the sub-humid conditions of Southern Rajasthan. The observations recorded at the time of harvest indicated distinct and notable variations among the treatment combinations, thereby reflecting the positive impact of Zinc, Boron and Vermicompost application on the growth performance of Cabbage

Table 5: Effect of Zinc, Boron and Vermicompost on Growth Attributes of Cabbage (*Brassica oleracea* var. *capitata*)

Symbol	Treatments	Plant Height (cm)			No. of Leave/Plant			Stalk Girth (cm)			Leaf Length (cm)		Leaf Width (cm)	
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	45 DAT	60 DAT	45 DAT	60 DAT
Factor-1: Micronutrients														
Zn_0B_0	Control	15.72	28.87	38.70	5.68	12.21	14.64	2.49	3.48	4.37	21.33	30.67	20.32	29.66
Zn_1B_0	Zinc 0.5%	15.86	30.08	40.57	7.15	13.74	18.73	2.57	3.75	4.58	25.63	32.09	25.34	31.58
Zn_0B_1	Boron 0.5%	15.65	29.61	44.64	7.57	15.96	26.32	2.51	3.58	4.83	26.76	33.99	25.25	32.48
Zn_1B_1	Zinc 0.5% + Boron 0.5%	16.83	30.87	45.71	8.38	18.42	27.98	2.94	3.61	4.81	27.29	35.88	26.29	34.87
S.Em.±		0.126	0.243	0.366	0.086	0.165	0.287	0.065	0.128	0.125	0.331	0.403	0.256	0.365
C.D. @ 5%		0.364	0.701	1.056	0.250	0.479	0.833	0.139	0.273	0.267	0.961	1.168	0.744	1.059
Factor-2: Vermicompost Levels														
V_0	Control	13.95	27.39	41.57	6.96	14.23	20.85	2.45	3.55	4.59	24.00	31.68	24.00	31.17
V_1	Zinc 0.5%	15.33	29.14	41.79	7.08	15.06	21.76	2.70	3.62	4.36	25.36	33.22	24.85	31.46
V_2	Boron 0.5%	17.32	31.33	43.70	7.60	16.72	22.43	2.69	3.79	4.87	26.89	34.96	25.38	33.71
V_3	Zinc 0.5% + Boron 0.5%	16.45	30.34	42.97	7.21	14.82	22.26	2.67	4.22	5.13	26.28	34.49	25.12	32.98
S.Em.±		0.152	0.287	0.429	0.098	0.176	0.301	0.065	0.128	0.125	0.382	0.465	0.296	0.422
C.D. @ 5%		0.441	0.832	1.243	0.284	0.510	0.873	0.139	0.273	0.267	1.109	1.348	0.860	1.227

The growth performance of cabbage was significantly influenced by the combined application of micronutrients and vermicompost across all measured parameters—namely plant height, number of leaves, stalk girth, leaf length, and potentially leaf width. At all intervals (30, 60, and 90 DAT), the tallest plants were recorded under the combined foliar application of Zinc 0.5% + Boron 0.5% (Zn_1B_1), peaking at 45.71 cm at 90 DAT, which significantly surpassed the control and single nutrient applications. The synergistic role of zinc in auxin synthesis and membrane stability, along with boron's contribution to sugar transport and cell wall development, likely accounted for this vegetative enhancement. Among the organic treatments, vermicompost at 5.0 t/ha (V_2) produced the most robust plant height, notably 43.70 cm at 90 DAT, likely due to improved soil aeration, organic matter, and slow-release nutrient effects. Leaf development followed a similar trend. The treatment Zn_1B_1 resulted in the highest leaf count (27.98 leaves/plant at 90 DAT), indicating vigorous canopy development. The V_2 level again proved most effective among vermicompost levels, supporting a higher leaf count of 22.43 per plant at 90 DAT. The increase in foliage density can be attributed to improved nitrogen assimilation and cytokinin activity induced by the nutrient synergy and microbial activity from organic matter. Stalk girth, an indicator of structural strength and translocation efficiency, was also significantly enhanced. Zn_1B_1 yielded the maximum stalk girth (4.81 cm at 90 DAT) while the highest vermicompost level V_3 (7.5 t/ha) achieved a slightly greater value (5.13 cm at 90 DAT), although the difference with V_2 was statistically minimal. This supports the notion that nutrient-enriched organics improve turgidity and tissue density. Regarding leaf size, Zn_1B_1 consistently produced the longest leaves (35.88 cm at 60 DAT), closely followed by Zn_0B_1 and Zn_1B_0, showing the positive impact of foliar micronutrients on photosynthetic area. Vermicompost at 5.0 t/ha (V_2) again led among organic treatments, producing a leaf length of 34.96 cm, validating its effectiveness in enhancing vegetative growth. This may be due to its hormone-like compounds and gradual nutrient release that supports continuous cell expansion. Overall, the integrated treatment Zn_1B_1 + Vermicompost @ 5.0 t/ha (V_2) emerged as the most effective combination for promoting optimal vegetative growth in cabbage, confirming the benefits of a balanced approach to nutrient management. These results align with past studies by Jahan *et al.*, (2021) [12], which also emphasized the synergistic effect of Zn, B, and vermicompost on Brassica crop development.

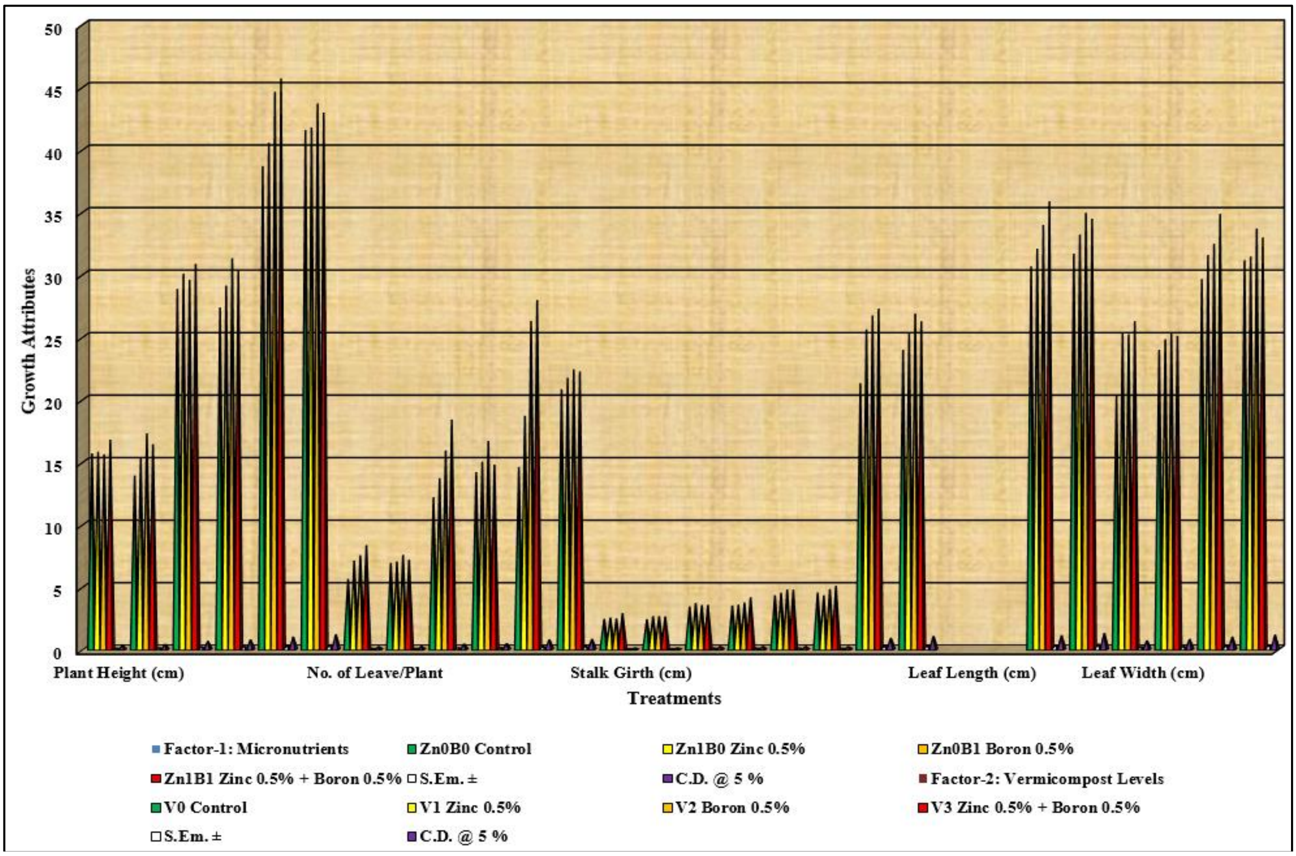

Fig 1: Growth attributes of Integrated Nutrient Management on Wheat (*Triticum aestivum* L.)

Conclusion

From the present study, it may be concluded that the combined foliar application of Zinc 0.5% + Boron 0.5% (Zn_1B_1) significantly improved all growth parameters, yield attributes, productivity, and economic returns in cabbage. Similarly, the application of 5.0 t/ha vermicompost (V_2) proved most effective among organic sources. The integrated use of these inputs not only ensured better crop performance but also enhanced profitability, making them suitable for sustainable cabbage production under similar agro-climatic conditions.

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