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Effect of foliar micronutrient application on yield, quality and return of garlic (*Allium sativum*) in Western Rajasthan

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Abstract

A field experiment was conducted at the Dr B.R. Choudhary Agricultural Research Station, Mandor (Jodhpur) to evaluate the effect of foliar application of micronutrients on growth, yield and return of garlic (*Allium sativum* L.) during *rabi* seasons of 2022–23 and 2023–24. The randomized block design with three replications and eight micronutrient treatments was used. Foliar sprays of different micronutrient concentrations were applied 30, 60 and 90 days after planting. The results revealed that treatment T_8 ($ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + Boron 0.25%) significantly improved plant height (50.97 cm), number of leaves/plant (10.13) and neck thickness (10.07 mm). Yield parameters, including polar diameter of bulb (36.68 mm), equatorial diameter of bulb (41.75 mm), fresh weight of bulb (34.39 g), number of cloves/ bulb (23.21), total soluble solids (39.70 °Brix) and bulb yield (57.60 q/ha), were also highest under treatment T_8. This treatment recorded the maximum net return (₹3,84,222/ha) and most favourable benefit: cost ratio (5.71), indicating its economic superiority over other treatments.

Key words: Boron, Zinc, Yield, Quality, Parameters, Economics, Micronutrients

Garlic (*Allium sativum* L.), a member of family *Amaryllidaceae*, is considered the second most important bulbous vegetable crop after onion. India ranks second globally in garlic production after China. Major garlic-producing states include Madhya Pradesh, Rajasthan, Gujarat, Uttar Pradesh and Punjab. However, average productivity of garlic in India is still lower than the crop's genetic yield potential indicating a substantial yield gap. This yield gap is largely attributed to suboptimal management practices, continuous use of traditional low-yielding varieties, insufficient fertilizer use and depletion of both macro- and micronutrients from the soil (Singh *et al.,* 2014 and Rathore *et al.,* 2017). Essential micronutrients like zinc (Zn), copper (Cu), iron (Fe) and boron (B) are involved in vital physiological processes such as respiration, cell division, chlorophyll formation, enzyme activation, photosynthesis, nitrogen metabolism and reproductive development (Tiwari *et al.,* 2010). Deficiency of these micronutrients leads to poor vegetative growth, reduced photosynthetic efficiency, impaired bulb development and ultimately low yields in garlic (Rathore *et al.,* 2017).

Foliar application ensures rapid nutrient absorption through leaf surfaces, bypassing soil-related constraints and supplying nutrients directly during critical growth stages (Vekaria *et al.,* 2018). The foliar application of micronutrients can significantly enhance plant growth, improve physiological activity and boost both yield and quality parameters in bulb crops like garlic and onion (Singh *et al.,* 2014). Moreover, it promotes efficient nutrient use and minimizes environmental losses compared to conventional fertilization methods. Given the nutritional and economic importance of garlic and the role of micronutrient management in enhancing productivity, the present investigation was undertaken to assess the effect of foliar application of different micronutrient combinations on growth, yield and return of garlic under the agroclimatic conditions of western Rajasthan.

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MATERIALS AND METHODS

A field experiment was conducted during *rabi* seasons (2022–23 and 2023–24) at the Dr B.R. Choudhary Agricultural Research Station, Mandor, Jodhpur (Rajasthan). The experimental site is located in semi-arid region with sandy loam soil characterized by low organic matter. Garlic cultivar Yamuna Safed-3 was selected for study. The experiment was laid out in a randomized block design comprising eight treatments with four replications. Each plot measured 2.4 m × 3.0 m with planting done at a spacing of 15 cm × 8 cm. The treatments consist of various concentrations of micronutrients (Zn, Fe and B) applied 30, 60 and 90 days after planting through foliar application. The treatments include: T_1: control (water spray), T_2: $ZnSO_4$ 0.5%, T_3: $FeSO_4$ 0.5%, T_4: Boron 0.25%, T_5: $ZnSO_4$ 0.5% + $FeSO_4$ 0.5%, T_6: $ZnSO_4$ 0.5% + boron 0.25%, T_7: $FeSO_4$ 0.5% + boron 0.25% and T_8: $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + boron 0.25%.

Ten plants were selected randomly from per plot as a unit for observations on plant height, number of leaves per plant and neck thickness at 60 and 90 DAP, polar diameter of bulb (mm), equatorial diameter of bulb (mm), fresh weight of bulb (g), number of cloves/bulb, TSS (°Brix) and bulb yield. Gross return, net return and B:C ratio were also calculated. Pooled data of the two years were used to analyzed as per Panse and Sukhatme (1984). Statistical analysis was performed using the OPSTAT statistical software developed by Sheoran (Sheoran *et al.,* 1998) and treatment means were compared using the critical difference (CD) test at the 5% level of significance.

RESULTS AND DISCUSSION

Among the treatments, T_8 ($ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + boron 0.25%) consistently recorded superior performance across all parameters. The maximum plant height was observed in T_8 with 37.21 cm 60 days after planting (DAP) and 50.97 cm at 90 DAP, followed by T_6 (36.04 cm and 49.42 cm) and T_5 (35.77 cm and 48.85 cm), while the control treatment T_1 exhibited minimum plant height (33.13 and 45.54 cm). The enhanced plant height under micronutrient application may be attributed to synergistic effects of zinc, iron and boron which collectively promote cell elongation, meristematic activity and chlorophyll synthesis that ultimately supporting better vegetative growth (Marschner, 2012). Similar enhancements in garlic and onion were reported by Alam *et al.* (2019) and Kaur *et al.* (2022).

In number of leaves/plant, T_8 produced highest number (7.53 at 60 DAP and 10.13 at 90 DAP), followed by T_6 and T_5, whereas the control recorded minimum number of leaves. This improvement could be linked to increased photosynthetic activity and enhanced nutrient assimilation due to balanced micronutrient availability (Tiwari *et al.,* 2010). These results align with those of Rahman *et al.* (2022) and Singh *et al.* (2015) in garlic and onion. As similar, neck thickness showed significant variation with T_8 producing the maximum neck girth (7.41 mm at 60 DAS and 10.07 mm at 90 DAS) followed by T_6 and T_5 while minimum neck thickness was noted in T_1.

The increased neck girth may be associated with boron's role in strengthening cell walls and iron's contribution to improved chlorophyll synthesis, facilitating better assimilate translocation and overall plant vigor (Alam *et al.,* 2019 & Biswas *et al.,* 2020). The results demonstrate that foliar application of $ZnSO_4$, $FeSO_4$ and boron not only enhances individual growth traits but also synergistically improves the overall vegetative development of garlic.

The T_8 ($ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + boron 0.25%) consistently outperformed all other treatments across parameters. The highest polar diameter (36.68 mm) and equatorial diameter (41.75 mm) were recorded under T_8, followed by T_6 and T_5 while smallest bulb dimensions were observed in the control (T_1) (Table 1). The significant increase in bulb size with micronutrient application may be attributed to enhanced photosynthate translocation and cell expansion due to the synergistic effects of zinc, iron and boron as also reported by Goyal *et al.* (2017) and Aske *et al.* (2017). The fresh weight of bulbs found a similar trend with T_8 recording the maximum bulb weight (34.39 g) followed by T_6 (32.26 g) and T_5 (28.45 g) while T_1 recorded the lowest bulb weight (23.79 g). The superiority of T_8 in fresh bulb weight can be ascribed to zinc's role in enzyme activation, protein synthesis and auxin production, which directly promote cell division and enlargement contributing to bulb growth (Marschner, 2012), in line with the findings of El-Tohamy *et al.* (2009), Jat *et al.* (2023) and Pramanik and Tripathy (2017).

Similarly, significant differences were observed in the number of cloves per bulb with T_8 producing the maximum cloves (23.51), followed by T_6 and T_5 and the lowest number of cloves was found in T_1. The increase in clove number under combined micronutrient application reflects improved nutrient uptake and metabolic efficiency that favors differentiation and clove formation (Vekaria *et al.,* 2018 and Rahman *et al.,* 2022). Total soluble solids (TSS) content ranged from 37.38 °Brix in T_1 to a maximum of 39.70 °Brix in T_8. This improvement in TSS could be linked to enhanced carbohydrate synthesis and storage resulting from better photosynthetic activity under balanced micronutrient supply, as similarly noted by Aske *et al.* (2017) and Kaur *et al.* (2022) in onion. In terms of total bulb yield, highly significant differences were noted among treatments. T_8 recorded highest yield (57.60 q/ha), followed by T_6 (54.21 q/ha) and T_5 (52.04 q/ha).

Among individual nutrient treatments, T_2 ($ZnSO_4$ 0.5%) performed best with a yield of 48.86 q/ha, indicating the standalone efficacy of zinc although inferior to the combined application. The minimum yield (41.26 q/ha) was recorded in the untreated control T_1. The significant enhancement in bulb yield under T_8 can be attributed to the collective roles of Zn, Fe and B in improving root activity, enzyme function, chlorophyll formation and assimilate partitioning towards bulb development (Marschner, 2012). Similar yield improvements with micronutrient application were also observed by Alam *et al.* (2019), Rahman *et al.* (2022), Singh *et al.* (2015) and Tyagi *et al.* (2025). The study establishes that combined foliar application of $ZnSO_4$ 0.5 %, $FeSO_4$ 0.5% and boron 0.25% concentration is most effective in maximizing bulb size, weight, number of clove, TSS content and overall bulb yield in garlic under semi-arid conditions.

Economic analysis

Economic evaluation revealed that T_8 provided the highest gross return (₹4,65,833/ha), net return

Table 1: Effect of foliar application of micronutrients on growth and yield attributes (pooled data of two years)

Treatment	Plant height (cm)	Plant height (cm)	No. of leaves/ plant	No. of leaves/ plant	Neck thickness (mm)	Neck thickness (mm)	Polar diameter of bulb (mm)	Equatorial diameter of bulb (mm)
	60DAP	90DAP	60DAP	90DAP	60DAP	90DAP		
T_1	33.13	45.54	6.56	7.76	6.34	8.31	30.16	33.80
T_2	35.45	47.50	6.83	8.36	6.93	8.80	32.02	36.77
T_3	34.59	46.40	6.70	8.00	6.77	8.60	30.81	35.74
T_4	34.94	47.09	6.76	8.19	6.80	8.73	31.15	36.35
T_5	35.77	48.85	7.00	9.26	7.12	9.53	34.15	38.26
T_6	36.04	49.42	7.13	9.41	7.09	9.75	34.13	39.72
T_7	35.56	48.34	6.89	8.65	6.87	9.17	34.16	37.45
T_8	37.21	50.97	7.53	10.13	7.41	10.07	36.68	41.75
SE(m)±	0.64	0.93	0.18	0.25	0.21	0.28	1.14	0.78
CD (5%)	1.84	2.66	0.50	0.72	0.61	0.81	3.26	2.24
CV (%)	3.65	3.88	5.06	5.76	6.15	6.20	6.95	4.19

Table 2: Effect of foliar application of micronutrients on yield, quality and economics (pooled data of two years)

Treatment	Fresh weight of bulb (g)	No. of clove/bulb	TSS (%)	Bulb yield (q/ha)	Gross return (₹/ ha)	Net return (₹/ ha)	B : C ratio
T_1	23.79	17.06	37.38	41.26	330192	254562	4.37
T_2	26.60	19.20	38.23	48.86	391527	311959	4.92
T_3	24.90	18.12	37.70	46.80	375776	296059	4.71
T_4	25.81	18.77	38.08	47.27	379709	300123	4.77
T_5	28.45	20.48	38.60	52.04	421530	340875	5.23
T_6	32.26	21.21	38.94	54.21	438963	358439	5.45
T_7	27.03	20.04	38.47	50.31	405527	324854	5.03
T_8	34.39	23.51	39.70	57.60	465833	384222	5.71
SE(m)±	1.59	0.77	0.32	2.37	21633	-	-
CD at 5%	4.55	2.18	0.92	6.75	61740	-	-
CV (%)	11.43	7.73	1.67	9.50	10.79	-	-

(₹3,84,222/ha) and B:C ratio (5.71), followed by T_6 and T_5 (Table 2). The control treatment recorded the lowest returns and B:C ratio. The results confirm the economic feasibility of combined foliar application of Zn, Fe and B. Similar economic benefits of micronutrient foliar feeding have been highlighted by Vekaria *et al.* (2018) and Biswas *et al.* (2020).

CONCLUSION

The foliar application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + boron 0.25% (T_8) consistently produced more plant growth, yield, bulb quality and economic returns in garlic. Therefore, T_8 can be recommended as the most effective treatment for maximizing both productivity and profitability. Alternatively, T_6 ($ZnSO_4$ 0.5% + boron 0.25%) also demonstrated promising results and may be adopted where simpler nutrient management is preferred.

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