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Comparative efficacy of soil and foliar application of zinc on garlic (*Allium sativum*) production in sandy loam soils of Rajasthan

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Abstract

An experiment was conducted to assess the impact of various levels and modes of zinc (Zn) application on garlic (*Allium sativum* L.) at College of Agriculture, Jodhpur during rabi 2021-22. There were seven treatments, three soil applications of $ZnSO_4$ (5, 10, and 15 kg/ha), three foliar applications of $ZnSO_4$ (0.3%, 0.5%, and 0.7%), and control in a randomized block design with three replications. The results indicated that $ZnSO_4$ applications significantly improved growth parameters, yield attributes and bulb yield of garlic. The highest plant height (69.5.cm) and number of leaves (8.64 at 120 days after planting) were observed with soil application of $ZnSO_4$ 15 kg/ha and foliar application of $ZnSO_4$ 0.7%. Foliar application of $ZnSO_4$ 0.7% also recorded significantly highest values of bulb weight (26.1 g), neck thickness (0.78 cm), and weight of 50 cloves (65.2 g). Both soil application of $ZnSO_4$ 15 kg/ha and foliar application $ZnSO_4$ 0.7% treatments achieved the maximum bulb yield (15.4 t/ha), compared to the control (11.5 t/ha), indicating a 33.9% increase in bulb yield. Zinc use efficiency was highest with soil application of $ZnSO_4$ 15 kg/ha (0.29 t/ha/kg $ZnSO_4$). The highest net returns (₹ 465,154/ha) were recorded with foliar application of $ZnSO_4$ 0.7% and the highest B:C ratio (3.08) in soil application of $ZnSO_4$ 15 kg/ha. These results highlights the higher efficacy of $ZnSO_4$ applications, particularly with foliar, enhancing growth, yield, quality, and economic returns of garlic in arid regions.

Key words: Arid regions, Foliar fertilization, micronutrient application, Zinc application

Garlic (*Allium sativum* L.) is a widely cultivated bulb crop known for its culinary, nutritional, and medicinal properties. India ranks second globally in garlic production, with Rajasthan being a major garlic-producing state. However, the productivity and quality of garlic in arid regions are often constrained by deficiencies of essential micronutrients, particularly zinc (Zn) (Anonymous, 2021). The deficiency of Zn can adversely impact plant growth, bulb development, and overall yield, necessitating external supplementation. Among all micronutrients, Zn meticulously regulates various metabolic processes in plants which helps to enhance growth, and storage organs (Rani *et al.*, 2017; Vyas *et al.*, 2024).

As an alternative, foliar application of Zn has gained attention as a more effective approach, allowing plants to absorb Zn directly through leaf surfaces, bypassing soil-related constraints (Alam *et al.*, 2019). Foliar fertilization has been reported to improve plant growth, yield, and nutrient-use efficiency while enhancing the effectiveness of macronutrient uptake (Tripathi *et al.*, 2022). Therefore, study was undertaken to evaluate the effect of different levels and modes of Zn application (soil and foliar) on garlic production.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2021-22 at College of Agriculture, Jodhpur, located at an altitude of 231 m above sealevel (26°15' to 26°45' N latitude and 73°00' to 73°29' E longitude). The sandy loam soil of the experimental field is slightly alkaline (pH 8.3), low in organic carbon (0.13%), deficient in available zinc (0.48 ppm), low in available nitrogen (174 kg/ha), medium in phosphorus (22.2 kg/ha), and high in potassium (325 kg/ha).

The experiment was laid out in a randomized block design with three replications comprising seven treatment *viz*, soil applications of $ZnSO_4$ (5, 10, and 15 kg/ha), foliar applications of $ZnSO_4$ (0.3%, 0.5%, and 0.7%), and the control. Farmyard manure (25 t/ha) was incorporated into the soil during final field preparation. A uniform dose of 50 kg P_2O_5/ha (DAP), 100 kg K_2O/ha (MoP), and 50 kg N/ha (urea) was applied at planting, with an additional 50 kg N/ha was broadcast in two splits 30 and 45 days after transplanting (DAT). $ZnSO_4$ was applied either through broadcasting at sowing (soil application) or as a foliar spray at 60 and 90 DAT. The garlic cultivar 'G-282' was planted on 29 October, 2021, and harvested on 28 March, 2022. Garlic cloves were planted in rows (15 cm x 7.5 cm) at a seed rate of 500 kg/ha.

A uniform soil moisture was maintained throughout the growing period, with shallow hoeing for weed control and need based pest control. Observations on plant height at 120 DAT, number of leaves/plant at 30, 60, 90, and 120 DAT, bulb weight, number of cloves/bulb, and weight of 50 cloves were recorded. Bulb yield (t/ha) was calculated

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from the harvest of net plot. The TSS content in bulbs was measured using a digital refractometer. Zinc content in bulbs and foliage was analyzed using standard laboratory procedure.

Economic calculations are based on average bulb yields, market rates, and input costs, using the following formulas:

Gross returns (₹/ha) = bulb yield (kg) × bulb market rate (₹/kg)

Net returns (₹/ha) = gross returns (₹/ha) − cost of cultivation (₹/ha)

Benefit: Cost ratio = net returns (₹/ha)/cost of cultivation (₹/ha)

Relative Yield Increase (%) = $(yield_{treatment} - yield_{control} / yield_{control}) \times 100$

Zinc Use Efficiency (ZUE) = $(yield_{treatment} - yield_{control})$ /amount of znso4 applied

Cost per Unit Yield = total cost / $yield_{treatment}$

Return on Investment (ROI %) = (net returns / total cost) × 100

Yield per unit cost = $yield_{treatment}$ / total cost

Data were analyzed using ANOVA as per Fisher (1950), with treatment differences tested by the 'F' test at a 5% significance level. Additionally, t-test was used to compare the effectiveness of soil *versus* foliar application methods.

RESULTS AND DISCUSSION

The application of $ZnSO_4$, both as soil application and foliar application, significantly influenced the growth parameters of garlic plants. Soil application of $ZnSO_4$ 15 kg/ha resulted in highest plant height (69.5 cm) at 120 DAP, followed by soil application of $ZnSO_4$ 10 kg/ha (65.5 cm) and foliar application of $ZnSO_4$ 0.7% (64.8 cm), which were significantly higher than control (47.2 cm) (Fig. 1). It may be possible due to the fact that Zn induces the synthesis of tryptophan, an amino acid, which is the processor of IAA which stimulates plant growth and act as plant hormone. These results are consistant with Nehra and Malik (2024). Similarly, number of leaves/plant increased significantly with $ZnSO_4$ treatments at all growth stages (30, 60, 90, and 120 DAP), with soil application of $ZnSO_4$ 15 kg/ha consistently outperforming other treatments (Fig. 2). This can be attributed to essential role of Zn in various biochemical processes, including enzyme activation, protein synthesis, and hormone production (Alam *et al.*, 2019). These findings align those of Gar *et al.* (2021) and Vyas *et al.* (2024).

Application of $ZnSO_4$ significantly enhanced yield attributes such as the weight of bulb, neck thickness, number of cloves/bulb, and weight of 50 cloves (Table 1). Foliar application of $ZnSO_4$ (0.7%) recorded highest weight

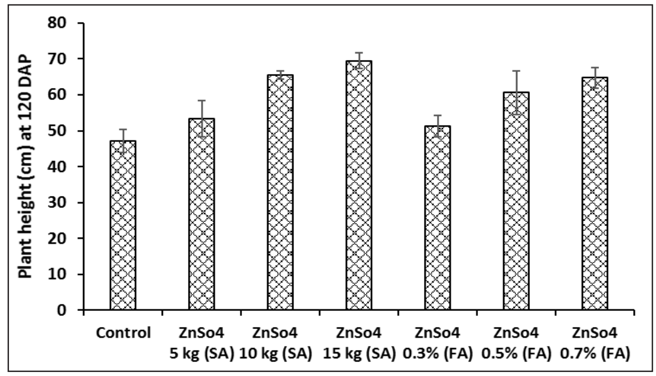

Fig. 1. Effect of soil appliction and foliar application of $ZnSo_4$ on plant height of garlic at 120 DAP.

of bulb (26.1 g) and bulb yield (15.4 t/ha), significantly higher than the control (19.7 g and 11.5 t/ha, respectively). Similarly, number of cloves/bulb and the weight of 50 cloves were highest with soil application of $ZnSO_4$ (15 kg/ha) and foliar application of $ZnSO_4$ (0.7%). The significant increase in yield attributes can be attributed to enhanced Zn uptake and utilization, which play a critical role in chlorophyll synthesis, photosynthesis, and nutrient translocation within plant (Maurya *et al.*, 2018). These results are consistent with those of Pramanik and Tripathy (2017) and Jat *et al.* (2023).

The relative increase in yield compared to the control was highest in soil application of $ZnSO_4$ (15 kg/ha) and

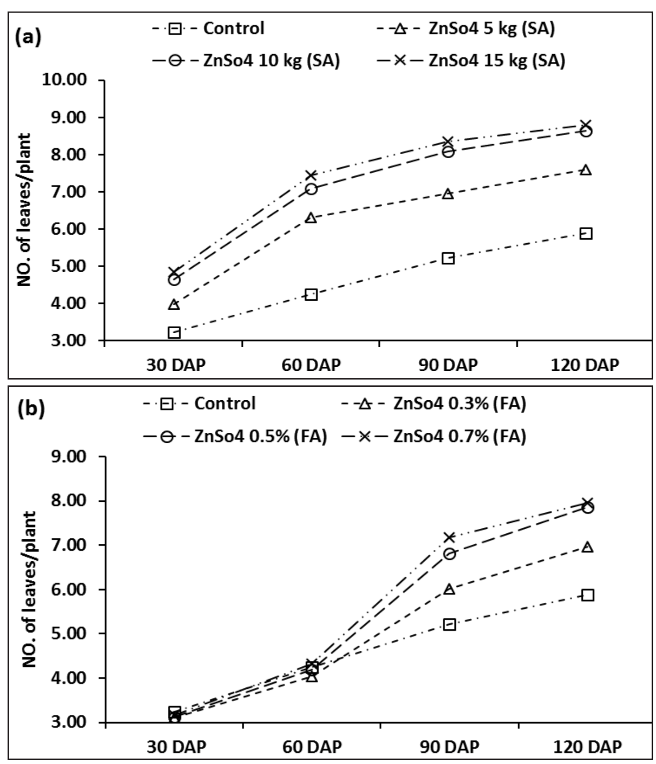

Fig. 2. Effect of a) soil appliction and b) foliar application of $ZnSo_4$ on number of leaves/plant at different growth stages in garlic.

foliar application of $ZnSO_4$ 0.7%, both achieving a 33.91% increase (Table 1). Soil application at 15 kg $ZnSO_4$/ha and foliar application at 0.7% were significantly more effective than other treatments, indicating their more efficacy in enhancing bulb yield. Zinc use efficiency (ZUE) was highest for soil application of $ZnSO_4$ (15 kg/ha) at 0.29 t/ha/kg $ZnSO_4$. The highest foliar application 0.7% achieved a ZUE of 0.14 t/ha/kg $ZnSO_4$. Soil applications of Zn showed higher efficiency, suggesting that direct soil incorporation of $ZnSO_4$ is more effective in improving yield per unit of zinc applied. Further, comparing soil and foliar application of $ZnSO_4$ showed that foliar application significantly improved weight of 50 cloves, TSS content, and zinc content in both foliage and bulbs ($p < 0.05$).

The foliar application $ZnSO_4$ (0.7%) attained the highest TSS content (44.3), significantly higher than the control (37.8). Similarly, Zn content in bulbs was highest with foliar application of 0.7% $ZnSO_4$ (30.0 mg/kg), indicating enhanced Zn accumulation with foliar applications (Table 1). The increase in TSS content can be linked to role of Zn in carbohydrate metabolism and synthesis of soluble solids, which contribute to sweetness and quality of bulbs (Tripathi *et al.*, 2022). The higher Zn content in foliage and bulbs with $ZnSO_4$ treatments is likely due to improved absorption and translocation of Zn within plant, facilitated by both soil and foliar applications. These findings are in agreement with those of Alam *et al.* (2019).

The highest net returns (₹ 465,154/ha) was obtained from foliar application of 0.7% $ZnSO_4$, followed by soil application of 15 kg/ha $ZnSO_4$ (₹ 464,979/ha). However, highest B:C ratio (3.08) was recorded with soil application of $ZnSO_4$ 15 kg/ha, indicating economic feasibility of this treatment (Table 2). The higher net return and B:C ratio with $ZnSO_4$ treatments can be attributed to substantial increase in bulb yield, which outweighs the additional costs of $ZnSO_4$ application. These results highlight the economic benefits of using $ZnSO_4$ in garlic cultivation, as also reported by Yadav *et al.* (2018). The economic analysis revealed that the cost per unit yield was lowest for soil application of $ZnSO_4$ (15 kg/ha) at ₹ 9782/t, indicating superior economic efficiency of soil application. Among foliar applications, $ZnSO_4$ (0.7%) had a cost per unit yield of ₹ 9873/t. Soil application of $ZnSO_4$ (15 kg/ha) also

Table 1: Effects of soil and foliar application of $ZnSO_4$ on bulb attributes, bulb yield and Zn content in garlic bulb

Treatment	Weight of bulb (g)	Neck thickness (cm)	No. cloves/ bulb	Weight of 50 cloves (g)	Bulb yield (t/ha)	Relative Increase in Yield (%)	Zinc Use Efficiency (t/ha per kg $ZnSO_4$)	TSS content of bulb	Zinc content in foliage (mg/kg)	Zinc content in bulb (mg/kg)
Control	19.7	1.1	18.3	47.2	11.5	0.00	0.00	37.8	15.2	19.4
$ZnSo_4$ 5 kg/ha (SA)	21.3	0.9	18.5	56.9	12.5	8.70	0.16	38.8	17.6	22.2
$ZnSo_4$ 10 kg/ha (SA)	24.3	0.8	20.5	62.8	14.6	26.96	0.28	41.7	19.3	24.8
$ZnSo_4$ 15 kg/ha (SA)	25.0	0.8	21.3	64.3	15.4	33.91	0.29	41.9	20.0	25.5
$ZnSo_4$ 0.3% (FA)	21.3	0.9	18.7	54.1	12.3	6.96	0.12	39.7	19.1	24.7
$ZnSo_4$ 0.5% (FA)	25.3	0.8	19.0	63.7	15.1	31.30	0.14	42.9	21.3	28.3
$ZnSo_4$ 0.7% (FA)	26.1	0.8	20.3	65.2	15.4	33.91	0.14	44.3	22.3	30.0
SEm±	0.41	0.03	0.71	1.83	0.89			1.26	0.44	0.33
CD (P=0.05)	1.28	0.08	NS	5.63	2.74			3.88	1.35	1.00
Soil appliction versus foliar application (t-test)										
P values (0.05)	0.052	0.374	0.097	0.039	0.05			0.023	0.013	0.017
Significance	NS	NS	NS	*	NS			*	*	*

SA- Soil application; FA- Foliar application *Significant at p=0.05; NS- non-significant

Table 2: Effect of soil and foliar application of different levels of $ZnSO_4$ on economics of garlic cultivation.

Treatment	Treatment cost (₹/ha)	*Total Cost (₹/ha)	**Gross Return (₹/ha)	Net returns (₹/ha)	B:C ratio	Cost/ Unit Yield (₹/t)	Return on Investment (%)	Yield / Unit Cost (kg/₹)
Control	-	149864	460000	310136	2.06	13031	206	0.077
$ZnSo_4$ 5 kg/ha (SA)	630	150494	500133	349639	2.32	12039	232	0.083
$ZnSo_4$ 10 kg/ha (SA)	760	150624	584000	433376	2.88	10317	287	0.097
$ZnSo_4$ 15 kg/ha (SA)	890	150754	615733	464979	3.08	9782	308	0.102
$ZnSo_4$ 0.3% (FA)	2078	151942	490400	338458	2.23	12352	222	0.081
$ZnSo_4$ 0.5% (FA)	2130	151994	604000	452006	2.97	10066	297	0.099
$ZnSo_4$ 0.7% (FA)	2182	152046	617200	465154	3.06	9873	305	0.101

SA- Soil application; FA- Foliar application
* Common cost of cultivation (₹ 149864/ha) ** Soil applicationle price of garlic- ₹ 40/kg

achieved the highest return on investment at 308.3%, slightly outperforming foliar application of $ZnSO_4$ (0.7%) at 305.8%. Yield/unit cost was highest for soil application of $ZnSO_4$ 15 kg 0.102 kg/₹, indicating marginally better efficiency compared to foliar application of $ZnSO_4$ (0.7%), thus emphasizing the economic advantage of soil application.

CONCLUSION

Both soil and foliar applications of $ZnSO_4$ significantly enhance garlic growth, yield, and quality. The economic viability of $ZnSO_4$ applications is crucial for foliar application, as it ensures that additional investment in micronutrients translates to higher profitability.

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