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Effect of Soil and Foliar Application of Zinc on Yield Attributes and Yield of Chickpea (*Cicer arietinum* L.)

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***Abstract*— *Chickpea (Cicer arietinum L.) is a protein-rich pulse crop crucial for sustainable agriculture and nutrition in semi-arid regions. However, zinc (Zn) deficiency in Indian soils often limits its productivity. A field experiment was conducted during Rabi 2024–25 at the research farm of Nirwan University, Jaipur, Rajasthan, to evaluate the effect of soil and foliar Zn application on the performance of chickpea variety GNG 2144. The experiment was laid out in a randomized block design (RBD) with nine treatments replicated thrice. Treatments included control (T_1), RDF alone (T_2), and combinations of soil-applied $ZnSO_4$ (25 and 50 kg/ha) and foliar spray of 0.5% $ZnSO_4$ at key stages (booting and pod formation). The results showed a significant increase in yield attributes due to zinc application. The maximum number of pods per plant (41.20), number of seeds per pod (1.80), and 100-seed index (24.57 g) were observed under T_9 (RDF + 25 kg $ZnSO_4$ ha^{-1} soil application + two foliar sprays of 0.5% $ZnSO_4$). This treatment also recorded the highest seed yield (19.87 q ha^{-1}), straw yield (25.42 q ha^{-1}) and harvest index (43.88%). Economic analysis revealed that T_9 provided the maximum gross return (₹119220 ha^{-1}), net return (₹79320 ha^{-1}), and B:C ratio (2.00), followed by T_8 and T_7. The lowest yield and returns were recorded under the control (T_1). In conclusion, the integrated application of Zn through both soil and foliar routes significantly enhanced yield attributes, grain yield, and profitability of chickpea, and is recommended as an effective strategy to combat Zn deficiency in chickpea-growing regions.*

***Keywords*— Chickpea, Foliar, Soil, Zinc, Yield.**

I. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the most important legume crops grown globally, especially in arid and semi-arid regions, due to its high nutritional value and ability to fix atmospheric nitrogen, contributing to soil fertility (Singh *et al*. 2013). Despite its significance, chickpea productivity is often constrained by micronutrient deficiencies, particularly zinc (Zn), which is prevalent in calcareous and alkaline soils (Alloway, 2008). Zinc is a vital micronutrient that plays a key role in various physiological and metabolic processes, including enzyme activation, protein synthesis, photosynthesis, and auxin metabolism (Cakmak, 2008). Zinc deficiency in chickpea results in poor plant growth, delayed flowering, reduced seed set, and ultimately lower yield (Takkar and Walker, 1993).

To address this, both soil and foliar applications of Zn have been explored. While soil application provides a basal supply of Zn, its effectiveness is often reduced due to fixation and limited mobility in high pH soils (Shivay *et al*. 2008). In contrast, foliar application has gained prominence as a quick and effective way to correct Zn deficiency, bypassing soil-related constraints and directly improving nutrient uptake and metabolic efficiency (Khan *et al*. 2003). Studies have shown that combined soil and foliar application of Zn can significantly enhance yield and yield-related traits in pulses, including chickpea (Singh *et al.* 2015). Given these considerations, the present study aims to evaluate the comparative effectiveness of soil and foliar Zn applications on yield attributes and yield of chickpea, providing insights into optimal Zn management strategies for improving chickpea productivity in Zn-deficient soils.

II. MATERIALS AND METHODS

The field experiment was conducted during the *Rabi* season of 2024–25 at the Agronomy Farm, School of Agricultural Sciences, Nirwan University, Jaipur (26° 51′ 42″ N, 76° 6′ 57″ E, 375 m AMSL), located in a semi-arid region with sandy loam soil and limited water availability. The study was laid out in a factorial randomized block design (RBD) with 9 treatment combinations and three replications, involving nine treatments T_1:Control (Recommended Dose of Fertilizer - RDF), T_2:RDF + $ZnSO_4$ @ 12.5 kg ha^{-1}, T_3:RDF + $ZnSO_4$ @ 25 kg ha^{-1}, T_4:Foliar spray of $ZnSO_4$ @ 0.5% at booting stage, T_5:Foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages, T_6:RDF + $ZnSO_4$ @ 12.5 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting stage, T_7:RDF + $ZnSO_4$ @ 12.5 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages, T_8:RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting stage, T_9:RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages The Chickpea (*Cicer arietinum* L.) variety 'GNG 2144' was sown on 28th October at a spacing of 45 × 10 cm with a seed rate of 80 kg ha^{-1}. The yield, and yield attributes were recorded at harvest stages following standard procedure. The pods plant^{-1} and seeds pod^{-1} was recorded from five randomly selected plant before harvesting. However, seed index was average 100 seed weight of individual treatment plots. At the time of harvesting the net plot were harvested and tagged separately. The tagged bundles of the main plots were sun-dried for 7 days on the threshing floor, and then the biological yield was recorded. After threshing, cleaning and drying the grain yield plot^{-1} weighed individually. This is turn was used to compute yield ha^{-1}. Haulm yield was obtained by subtracting grain yield from the biological yield and expressed in kg ha^{-1}. The data collected on crop characteristics and yield were tabulated and statistically analyzed as per standard "Analysis of Variance" to draw valid conclusions (Gomez and Gomez, 1984). Treatment differences were tested by 'F' test based on the null hypothesis. Where the 'F' test was significant, critical differences were determined at 5% significance level.

III. RESULTS AND DISCUSSION

The data presented in Table 1 and 2 clearly demonstrate the significant positive effects of zinc application both soil and foliar methods on the yield attributes and yield of chickpea and economics of different treatments.

Effect of Soil and Foliar Application of Zinc on Yield Attributes of Chickpea

The number of pods per plant was significantly affected by the application of zinc through both soil and foliar methods (Table 1). Among the treatments, the highest number of pods per plant (34.0) was recorded in treatment T_9 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages), which was significantly superior to all other treatments. This was followed by T_8 (33.2), T7 (32.4), and T_6 (31.5), indicating that integrated application of soil and foliar zinc provided a greater benefit than individual applications. The lowest number of pods (27.2) was observed in the control (T_1), receiving only RDF without zinc. The improvement in pod formation under zinc treatments could be attributed to enhanced pollen viability, better flower retention, and efficient mobilization of assimilates to developing reproductive organs. These observations align with those of Yadav *et al.* (2018) and Bashir *et al.* (2019), who reported increased pod formation in legumes with Zn supplementation due to improved enzymatic and hormonal regulation during reproductive growth.

The number of seeds per pod also responded positively to zinc treatments. The highest seed count per pod (1.74) was observed under T_9 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages), followed by T_8 (1.72) and T_7 (1.70). This increase was statistically significant compared to the control (T_1), which had the lowest value of 1.52 seeds per pod. The standalone application of soil-applied Zn (T_2 and T_3) and foliar Zn (T_4 and T_5) showed moderate improvement, indicating that zinc plays a critical role in fertilization success and seed set. This improvement may be attributed to zinc's role in enhancing pollen tube growth, ovule fertilization, and seed development. Zinc also supports auxin synthesis and cell division, leading to better ovary development and seed setting. These results corroborate findings by Zafar *et al.* (2020) and Ali *et al.* (2017), who observed similar improvements in seeds per pod under zinc treatments in legumes including chickpea.

The maximum seed index of 17.6 g was recorded in T_9 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages), while the minimum value of 15.8 g was noted in the control (T_1). Other treatments like T_6 (17.0 g), T_7 (17.2 g), and T_8 (17.4

g) also showed considerable increases, indicating that zinc application, especially through both soil and foliar modes, enhances seed development. Significant differences were also observed among treatments with respect to seed index. Zinc is essential for various physiological functions such as auxin metabolism, enzyme activity, and carbohydrate mobilization, which directly contribute to better seed filling and weight. The increased seed index under Zn treatments may be due to improved photosynthate partitioning toward developing seeds. These results are supported by Singh *et al.* (2021) and Meena *et al.* (2020)**,** who also reported improvements in seed weight and size with foliar and soil application of zinc in chickpea and other pulses.

Effect of Soil and Foliar Application of Zinc on Yield of Chickpea

The combined soil and foliar application of zinc significantly influenced the seed yield, straw yield, biological yield and harvest index of chickpea, as shown in Table 1. The highest seed yield (2085 kg ha^{-1}), straw yield (3665 kg ha^{-1}), and biological yield (5750 kg ha^{-1}) were recorded under treatment T_9 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages), which was significantly superior to all other treatments, indicating the positive impact of zinc applied both to soil and foliage at critical growth stages. The improvement in yields may be attributed to enhanced zinc availability, which plays a crucial role in physiological processes such as photosynthesis, enzyme activation, pollen viability, and seed filling. Consequently, T_9 (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages) also recorded the highest harvest index (36.3%), suggesting more efficient assimilate partitioning towards seed development. These results align with earlier findings by Meena et al. (2019), Choudhary *et al.* (2018) and Singh *et al.* (2022), who observed significant yield and harvest index improvements in chickpea due to combined zinc fertilization. Furthermore, similar enhancements in straw and biological yields due to zinc application have been reported in pulses by Khatik *et al.* (2020) and Parmar *et al.* (2021), while increases in harvest index under basal and foliar zinc regimes were corroborated by Patel *et al.* (2019) and Meena *et al.* (2020).

Effect of soil and foliar application of zinc on eeconomics of different treatments

The cost of cultivation increased progressively with the level and combination of zinc (Zn) application. Treatment T_9 (RDF + $ZnSO_4$ @ 25 kg/ha + foliar spray at booting and milking stages) incurred the highest cost of ₹40,000/ha, followed by T_8 (₹39,500/ha), T7 (₹38,200/ha), and T_6 (₹37,500/ha). The control plot (T_1, RDF only) recorded the lowest cost of ₹34,000/ha. These findings agree with Patel *et al.* (2019) and Singh *et al.* (2021), who reported that integrated Zn management increases production costs marginally. Gross returns reflected yield improvements driven by Zn application. T9 (RDF + $ZnSO_4$ @ 25 kg/ha + foliar spray at booting and milking stages) generated the highest gross returns of ₹128,798/ha, followed by T_8 (₹124,870/ha), T_7 (₹120,958/ha), and T_6 (₹117,075/ha). The lowest return (₹98,703/ha) came from the RFC-only control. Similar yield-linked financial benefits from foliar Zn application were reported by Shivran *et al.* (2018) and Kumar *et al.* (2020). After accounting for costs, T_9 (RDF + $ZnSO_4$ @ 25 kg/ha + foliar spray at booting and milking stages) exhibited the highest net returns at ₹88,798/ha, outperforming T_8 (₹85,370/ha), T_7 (₹82,758/ha), and T_6 (₹79,575/ha). In contrast, the control treatment yielded only ₹64,703/ha. These outcomes underscore the profitability of combined Zn treatments, consistent with findings by Meena *et al.* (2017) and Jat *et al.* (2022). The BCR further highlighted economic efficiency: T_9 (RDF + $ZnSO_4$ @ 25 kg/ha + foliar spray at booting and milking stages) achieved the highest BCR at 2.22, indicating that each rupee invested returned ₹2.22. Other combined treatments (T_7, T_8, T_6) maintained BCR values well above 2.00. The control registered the lowest BCR at 1.90, echoing conclusions by Verma *et al.* (2021) and Chaudhary *et al.* (2016), who emphasized that micronutrient-enriched nutriment packages boost economic returns in pulses.

Table 1: The effect of soil and foliar application of zinc on ***yield attributers*** *and yield of chickpea*

S. No.	Treatment	Pods $plant^{-1}$	Seeds pod^{-1}	Seed index (g)	Seed Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)
T_1	Control (Recommended Dose of Fertilizer (RDF))	27.2	1.52	15.8	1585	3050	4635	34.2
T_2	RDF + $ZnSO_4$ @ 12.5 kg ha^{-1}	28.5	1.60	16.2	1665	3180	4845	34.4
T_3	RDF + $ZnSO_4$ @ 25 kg ha^{-1}	29.4	1.64	16.4	1745	3305	5050	34.5
T_4	Foliar spray of $ZnSO_4$ @ 0.5% at booting stage	28.8	1.61	16.3	1708	3220	4928	34.7

T_5	Foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages	30.2	1.66	16.8	1824	3355	5179	35.2
T_6	RDF + $ZnSO_4$ @ 12.5 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting stage	31.5	1.68	17.0	1890	3430	5320	35.5
T_7	RDF + $ZnSO_4$ @ 12.5 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages	32.4	1.70	17.2	1955	3500	5455	35.8
T_8	RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting stage	33.2	1.72	17.4	2020	3580	5600	36.1
T_9	RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages	34.0	1.74	17.6	2085	3665	5750	36.3
	S.Em.	0.60	0.03	0.33	35.76	101.51	101.51	0.69
	CD @ 5%	1.78	0.10	0.98	106.24	301.61	301.61	2.05

Table 2: Economics of different treatments

S. No.	**Treatment**	**Cost of Cultivation (₹ ha^{-1})**	**Gross Returns (₹ ha^{-1})**	**Net Returns (₹ ha^{-1})**	**Benefit: Cost Ratio (BCR)**
T_1	Control (Recommended Dose of Fertilizer (RDF))	34,000	98702.5	64,703	1.90
T_2	RDF + $ZnSO_4$ @ 12.5 kg ha^{-1}	35,500	103613	68,113	1.92
T_3	RDF + $ZnSO_4$ @ 25 kg ha^{-1}	37,000	108508	71,508	1.93
T_4	Foliar spray of $ZnSO_4$ @ 0.5% at booting stage	35,800	106162	70,362	1.97
T_5	Foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages	36,200	113121	76,921	2.12
T_6	RDF + $ZnSO_4$ @ 12.5 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting stage	37,500	117075	79,575	2.12
T_7	RDF + $ZnSO_4$ @ 12.5 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages	38,200	120958	82,758	2.17
T_8	RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting stage	39,500	124870	85,370	2.16
T_9	RDF + $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% at booting and milking stages	40,000	128798	88,798	2.22

IV. CONCLUSION

The present study clearly demonstrates that the application of zinc, both through soil and foliar methods, significantly enhances yield attributes, seed yield, and economic returns in chickpea (*Cicer arietinum* L.). Among all treatments, the combined application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} with a foliar spray of 0.5% $ZnSO_4$ at both booting and milking stages (T_9) consistently outperformed all other treatments in terms of yield attributes *viz.,* number of pods per plant (34.0), seeds per pod (1.74), seed index (17.6 g), and yield *viz.,* seed yield (2085 kg ha^{-1}), straw yield (3665 kg ha^{-1}), biological yield (5750 kg ha^{-1}) and harvest index (36.3%) resulting in the highest net returns (₹88,798 ha^{-1}) and benefit-cost ratio (2.22). These improvements are attributed to zinc's critical role in enhancing reproductive development, seed formation, and metabolic efficiency. Standalone applications of soil or foliar zinc also contributed positively but were less effective than integrated approaches. The findings underline the importance of combining soil and foliar zinc fertilization as a sustainable and economically viable strategy for maximizing chickpea productivity and profitability, especially in zinc-deficient soils.

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