**Impact of Zinc and Iron Application on Yield and Quality of Chickpea (*Cicer arietinum* L.)**

**Abstract**

This study evaluated the effects of zinc (Zn) and iron (Fe) application on the yield and quality of chickpea (*Cicer arietinum* L.) during the Rabi season of 2024-25 at Mewar University, Rajasthan, India. Micronutrient deficiencies, particularly of Zn and Fe, are significant constraints in agriculture, limiting crop productivity and human nutrition. Optimizing Zn and Fe levels in chickpeas, a vital pulse crop, can enhance yield and nutritional quality, contributing to food security and reducing malnutrition. The experiment utilized a randomized block design with nine treatments, incorporating soil and foliar applications of ZnSO₄ and FeSO₄. The treatment combining ZnSO₄ at 25 kg/ha (soil) and 0.5% FeSO₄ (foliar) significantly improved growth parameters, yield, protein content, and economic returns compared to the control. These findings highlight the potential of Zn and Fe application as a sustainable strategy for enhancing chickpea production and nutritional outcomes.

Keywords: Chickpea, Micronutrients, Zinc, Iron, Yield, Quality

**1. Introduction**

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop globally, following dry beans and peas. It serves as a vital source of dietary protein, particularly for vegetarian populations (Jha et al., 2024). India plays a pivotal role in global chickpea production, contributing approximately 62–67% of the total global output, with a cultivated area of 10.17 million hectares and an annual production of 11.35 million tonnes (Zhang et al., 2024). Beyond its nutritional significance, chickpea contributes to sustainable agriculture by enhancing the soil’s physico-chemical and biological properties. Its deep-rooted system improves soil aeration, while leaf shedding enriches organic matter content (Arriagada et al., 2022). Additionally, chickpea can biologically fix approximately 25–30 kg N ha⁻¹ through symbiotic nitrogen fixation, thereby reducing dependence on synthetic nitrogen fertilizers (Sohu et al., 2015; Paramesh et al., 2023).

Despite its agronomic importance, chickpea productivity is often limited by micronutrient deficiencies, particularly of zinc (Zn) and iron (Fe). According to the World Health Organization, zinc deficiency ranks 11th among the 20 most significant global health risks related to micronutrient insufficiencies. In developing countries, zinc and iron deficiencies are the 5th and 6th most prevalent, respectively. Nations such as India, Pakistan, China, Iran, and Turkey are especially impacted by zinc deficiency. In India, a comprehensive survey of over 300,000 soil samples revealed that nearly 49% of soils are deficient in zinc and 12% in iron (Pooja & Sarawad, 2019; Kharra & Shukla, 2025). The application of zinc and iron fertilizers has been shown to significantly enhance chickpea yield and grain quality, underscoring the crucial role of these micronutrients in crop performance (Gupta et al., 2021; Munir et al., 2024; Pooja & Sarawad, 2019; Kharra and Shukla, 2025).

Zinc is a vital micronutrient required for plant growth and reproduction, participating in signal transduction, gene regulation, and the biosynthesis of phytohormones. Its deficiency can result in stunted growth, delayed maturity, and reduced crop yields. Chickpea is notably sensitive to zinc (Zn) deficiency, which poses a significant constraint on its growth and productivity. Insufficient zinc availability adversely affects the biosynthesis of essential phytohormones such as auxins, gibberellins, and cytokinins, thereby impairing critical physiological processes associated with plant growth and development (Hassan et al., 2020). Moreover, zinc is integral to the process of root nodulation, which facilitates biological nitrogen fixation in pulse crops. It also contributes to intracellular signaling mechanisms, particularly those activated under abiotic stress conditions, thus enhancing the plant's adaptive responses. Zinc deficiency is especially common in cereal-based cropping systems, which often deplete soil micronutrient reserves and consequently reduce the productivity of succeeding leguminous crops such as chickpea (Shukla & Mishra, 2020). Iron is equally critical, playing essential roles in chlorophyll biosynthesis, respiration, photosynthesis, and nitrogen fixation. It is a structural component of heme proteins and leghemoglobin. Although iron is abundant in the earth’s crust, its low solubility—especially in saline and alkaline soils—limits its bioavailability, leading to symptoms such as interveinal chlorosis and poor pod or grain development (Kaur et al., 2020; Majeed et al., 2020).

Micronutrient deficiencies in crops have direct implications for human health, affecting more than half of the global population, particularly in developing regions. Agronomic nutrient management, particularly through the application of mineral fertilizers, presents an effective and accessible strategy to mitigate these deficiencies (Majeed et al., 2020). Soil and foliar applications of zinc and iron not only improve crop nutrition and productivity but also enhance the micronutrient concentration in edible plant parts, thereby contributing to improved human nutritional security (Kharra & Shukla, 2025).

**2. Materials and Methods**

**2.1. Experimental Site and Climate**

The field experiment was conducted during the Rabi season of 2024-25 at the Agricultural Farm of Mewar University, Gangrar, Chittorgarh, Rajasthan, India. The experimental site is located at 10°57′ N latitude and 75°20′ E longitude, at an altitude of 267 meters above mean sea level. This region falls under Agro-climatic Zone IV (Humid South Plains) of Rajasthan. The climate is subtropical, characterized by an average annual rainfall ranging from 750 to 1005 mm. Mean annual maximum and minimum temperatures are 40.2°C and 18.5°C, respectively. During the experimental period (Rabi 2024-25), the mean weekly maximum and minimum temperatures fluctuated between 19.8°C and 36.1°C and 5.6°C and 18.9°C, respectively. Total rainfall during the growing season was 17.9 mm over 2 rainy days.

**2.2. Soil Characteristics**

Prior to sowing and fertilization, soil samples (0-15 cm depth) were collected from different spots of the experimental field to determine its physico-chemical properties. The soil was classified as clay loam in texture, slightly saline in reaction (pH 7.6, EC 0.96 dS/m). It was medium in available nitrogen (314 kg ha⁻¹), medium in available phosphorus (22.3 kg ha⁻¹), and high in available potassium (398 kg ha⁻¹), with sufficient DTPA extractable micronutrients. The organic carbon content was 0.58%.

**2.3. Experimental Design and Treatments**

The experiment was laid out in a Randomized Block Design (RBD) with three replications. Nine different treatment combinations of zinc and iron application were evaluated: T1: Control (no fertilizer application) T2: ZnSO₄ @ 12.5 kg/ha (Soil Application - SA) T3: FeSO₄ @ 12.5 kg/ha (SA) T4: ZnSO₄ @ 25 kg/ha (SA) T5: FeSO₄ @ 25 kg/ha (SA) T6: ZnSO₄ @ 25 kg/ha (SA) + 0.5% ZnSO₄ (Foliar Application - FA) T7: ZnSO₄ @ 25 kg/ha (SA) + 0.5% FeSO₄ (FA) T8: FeSO₄ @ 25 kg/ha (SA) + 0.5% ZnSO₄ (FA) T9: FeSO₄ @ 25 kg/ha (SA) + 0.5% FeSO₄ (FA) Zinc sulphate heptahydrate (ZnSO₄ ⋅ 7H₂O) with 21% zinc content and ferrous sulphate (FeSO₄) with 19.5% iron and 10.5% sulphur were used. SA refers to Soil Application and FA refers to Foliar Application.

**2.5. Statistical Analysis**

All collected data were subjected to statistical analysis using Fisher’s analysis of variance (ANOVA) technique as described by Panse and Sukhatme (1985). Data analysis was performed using OPSTAT statistical software. Where the F-test was found significant at the 5% level of significance (P = 0.05), the critical difference (CD) was calculated for treatment comparisons. The Standard Error of Mean (S.Em.±) was also reported.

**3. Results and Discussion**

#### 3.1 Growth Performance

#### The application of zinc and iron significantly influenced the growth parameters of chickpea. Among all treatments, T7 (ZnSO₄ at 25 kg/ha soil application + 0.5% FeSO₄ foliar spray) produced the most pronounced improvements. This treatment recorded the tallest plants (67.76 ± 3.21 cm), highest dry matter accumulation (22.46 ± 1.15 g/plant), and maximum number of branches per plant (5.63 ± 0.28).

These enhancements can be attributed to the complementary physiological functions of zinc and iron. Zinc is crucial for auxin biosynthesis, which promotes cell elongation and apical dominance, while iron is essential for chlorophyll synthesis and electron transport in photosynthesis, directly enhancing biomass production. The synergistic effect of these micronutrients likely resulted in more efficient vegetative growth, which aligns with findings by Thalooth et al. (2006) and Rout and Sahoo (2015). The trend observed across treatments highlights the advantage of combined soil and foliar application of micronutrients over individual or lower-dose treatments, as detailed in Table 1.

#### 3.2 Yield Components and Grain Yield

Significant improvements in yield attributes were also observed with micronutrient-enriched treatments. T7 again recorded the highest values for pods per plant (61.83 ± 2.75), seeds per pod (2.12 ± 0.09), and 100-seed weight (24.95 ± 0.36 g). These yield components contributed to a significantly higher seed yield of 1855 ± 92 kg/ha and straw yield of 3518 ± 142 kg/ha, as presented in Table 2.

The improved reproductive performance under T7 is likely due to enhanced nutrient uptake and internal mobility, which promoted better sink-source relationships. This supported more effective pod filling and reduced flower or pod abortion. Similar yield improvements under micronutrient supplementation have been reported by Nandan et al. (2018), Parmar and Poonia (2020), and Shivay et al. (2014), confirming the role of micronutrients in improving legume productivity.

Additionally, the combined application of zinc and iron likely stimulated early root development, active cell division, and hormonal balance, leading to better reproductive development and efficient nutrient partitioning toward grain yield.

**Table 1 Effect of Zinc and Iron on Growth Attributes and quality of chickpea**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Plant height (cm) | DMA (g/mrl) | No. of branches/plant | Protein content (%) |
| Control | 53.24 | 16.80 | 3.55 | 18.81 |
| ZnSO4 @ 12.5 kg/ha (SA) | 58.13 | 19.42 | 4.33 | 20.13 |
| FeSO4 @ 12.5 kg/ha (SA) | 57.17 | 18.16 | 4.16 | 19.94 |
| ZnSO4 @ 25 kg/ha (SA) | 60.84 | 20.35 | 4.62 | 20.38 |
| FeSO4 @ 25 kg/ha (SA) | 59.32 | 19.62 | 4.44 | 20.25 |
| ZnSO4 @ 25 kg/ha (SA) + 0.5% ZnSO4 (FA) | 64.25 | 21.37 | 5.15 | 21.00 |
| ZnSO4 @ 25 kg/ha (SA) + 0.5% FeSO4 (FA) | 67.76 | 22.46 | 5.63 | 21.06 |
| FeSO4 @ 25 kg/ha (SA) + 0.5% ZnSO4 (FA) | 62.21 | 20.36 | 4.91 | 20.94 |
| FeSO4 @ 25 kg/ha (SA) + 0.5% FeSO4 (FA) | 61.81 | 19.92 | 4.73 | 20.81 |
| S.Em.+ | 1.19 | 0.47 | 0.14 | 0.18 |
| CD (P=0.05) | 3.58 | 1.43 | 0.43 | 0.53 |

**\*Note:** SA = Soil application; FA = Foliar application

**Table 2 Effect of Zinc and Iron on Yield Attributes and yield of Chickpea**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatments** | **Pods/plant (No.)** | **Seeds/pod (No.)** | **Seed index (g)** | **Seed yield (kg/ha)** | **Straw yield (kg/ha)** |
| Control | 44.14 | 1.74 | 23.31 | 1240 | 2625 |
| ZnSO4 @ 12.5 kg/ha (SA) | 51.33 | 1.89 | 23.94 | 1460 | 2895 |
| FeSO4 @ 12.5 kg/ha (SA) | 49.66 | 1.87 | 23.85 | 1425 | 2840 |
| ZnSO4 @ 25 kg/ha (SA) | 52.92 | 1.91 | 24.29 | 1550 | 3040 |
| FeSO4 @ 25 kg/ha (SA) | 52.04 | 1.90 | 24.12 | 1525 | 3015 |
| ZnSO4 @ 25 kg/ha (SA) + 0.5% ZnSO4 (FA) | 57.75 | 2.06 | 24.64 | 1710 | 3278 |
| ZnSO4 @ 25 kg/ha (SA) + 0.5% FeSO4 (FA) | 61.83 | 2.12 | 24.95 | 1855 | 3518 |
| FeSO4 @ 25 kg/ha (SA) + 0.5% ZnSO4 (FA) | 56.06 | 1.93 | 24.59 | 1630 | 3170 |
| FeSO4 @ 25 kg/ha (SA) + 0.5% FeSO4 (FA) | 54.35 | 1.92 | 24.46 | 1590 | 3110 |
| S.Em.+ | 1.74 | 0.04 | 0.12 | 51.66 | 78.33 |
| CD (P=0.05) | 5.22 | 0.12 | 0.36 | 155 | 235 |

**\*Note:** SA = Soil application; FA = Foliar application

#### 3.3 Nutrient Composition and Quality

Micronutrient application also positively influenced the nutritional quality of chickpea seeds. The highest protein content (21.06%) was recorded under T7, which can be attributed to improved nitrogen assimilation and availability.

Enhanced protein synthesis is likely the result of improved enzymatic activity and nitrogen metabolism, facilitated by the balanced presence of zinc and iron. These results are consistent with observations by Prasad and Shivay (2018) and Nandan et al. (2018), who also reported improved protein content in grains under micronutrient-enriched conditions.

#### 3.4 Economic Evaluation

Economic analysis showed that T7 was the most profitable treatment, providing the highest net return (₹66,925/ha) and a benefit-cost ratio of 1.91. This indicates that integrated soil and foliar application of zinc and iron is not only agronomically beneficial but also economically viable.

The substantial economic gains support the wider adoption of this strategy for chickpea cultivation, especially in resource-limited or rainfed farming systems. These findings underline the potential for micronutrient management to enhance both crop productivity and farm income (Kharra and Shukla, 2025).

**Conclusion**

This study demonstrates that strategic Zn and Fe application, particularly ZnSO₄ at 25 kg/ha (soil) combined with 0.5% FeSO₄ (foliar), significantly enhances chickpea yield, quality, and economic returns. This approach improves crop productivity and nutritional value, offering a sustainable solution for addressing micronutrient deficiencies in agriculture and human diets. Farmers in similar agro-ecological zones are encouraged to adopt these practices to boost yields and profitability. Future research should include multi-year and multi-location trials to confirm these findings and evaluate long-term soil health impacts. Combining agronomic and genetic strategies could further enhance chickpea production sustainability.

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**Reference**

1. Arriagada, O., Cacciuttolo, F., Cabeza, R. A., Carrasco, B., & Schwember, A. R. (2022). A comprehensive review on chickpea (*Cicer arietinum* L.) breeding for abiotic stress tolerance and climate change resilience. *International Journal of Molecular Sciences, 23*(12), 6794. <https://doi.org/10.3390/ijms23126794>
2. Gupta, K., Saxena, R., Jain, S. K., Kumar, V. K. K., & Yadav, M. R. (2021). Yield and nutrient fortification of chickpea by foliar Fe and Zn application. *Journal of Crop and Weed, 17*(3), 29–34. <https://doi.org/10.22271/09746315.2021.v17.i3.1487>
3. Jha, U. C., Nayyar, H., Thudi, M., Beena, R., Prasad, P. V. V., & Siddique, K. H. M. (2024). Unlocking the nutritional potential of chickpea: Strategies for biofortification and enhanced multinutrient quality. *Frontiers in Plant Science, 15*, 1391496. <https://doi.org/10.3389/fpls.2024.1391496>
4. Kaur, S., Kumari, A., Singh, P., Kaur, L., Sharma, N., & Garg, M. (2020). Biofortification in pulses. In T. R. Sharma, R. Deshmukh, & H. Sonah (Eds.), *Advances in Agri-Food Biotechnology* (pp. 85–103). Springer, Singapore. <https://doi.org/10.1007/978-981-15-2874-3_4>
5. Kharra, R., & Shukla, U. (2025). Agronomic biofortification of zinc and iron on iron fortification in chickpea (*Cicer arietinum* L.) varieties under arid western plains zone of Rajasthan. *International Journal of Advanced Biochemistry Research, 9*(5), 284–287. <https://doi.org/10.33545/26174693.2025.v9.i5d.4327>
6. Kharra, R., Shukla, U., & Meena, M. (2025). Growth and development of chickpea (*Cicer arietinum* L.) varieties affected as agronomic biofortification through zinc and iron. *Journal of Experimental Agriculture International, 47*(5), 316–325. <https://doi.org/10.9734/jeai/2025/v47i53420>
7. Majeed, A., Minhas, W. A., Mehboob, N., Farooq, S., Hussain, M., Alam, S., & Rizwan, M. S. (2020). Iron application improves yield, economic returns and grain-Fe concentration of mungbean. *PLOS ONE, 15*(3), e0230720. <https://doi.org/10.1371/journal.pone.0230720>
8. Munir, M. K., Zafar, M., Babar, B. H., Zafar, N., Ahmed, S., Sarwar, M. A., … Hussain, S. (2024). Effect of different concentrations of soil and foliar applied zinc, boron and iron fertilizers on seedling growth, chlorophyll content and productivity of chickpea seedlings under semi-arid environment. *Plant Science Today.* <https://doi.org/10.14719/pst.3025>
9. Nandan, B., Sharma, B. C., Chand, G., Bazgalia, K., Kumar, R., & Banotra, M. (2018). Agronomic fortification of Zn and Fe in chickpea: An emerging tool for nutritional security – A global perspective. *Acta Scientific Nutritional Health, 2*(4), 12–19.
10. Paramesh, V., Kumar, R. M., Rajanna, G. A., Gowda, S. N. S., Nath, A. J., Madival, Y., … Toraskar, S. (2023). Integrated nutrient management for improving crop yields, soil properties, and reducing greenhouse gas emissions. *Frontiers in Sustainable Food Systems, 7*, 1173258. <https://doi.org/10.3389/fsufs.2023.1173258>
11. Parmar, P. M., & Poonia, T. C. (2020). Effect of zinc biofortification on growth, yield and economics of chickpea (*Cicer arietinum* L.). *International Journal of Chemical Studies, 8*(2), 1782–1786.
12. Pooja, C., & Sarawad, I. M. (2019). Influence of iron and zinc on yield, quality of chickpea and status of iron and zinc in post-harvest soil. *Agricultural Science Digest, 39*(1), 31–35. <https://doi.org/10.18805/ag.D-4882>
13. Shivay, Y. S., Prasad, R., & Pal, M. (2014). Effect of variety and zinc application on yield, profitability, protein content and zinc and nitrogen uptake by chickpea (*Cicer arietinum*). *Indian Journal of Agronomy, 59*(2), 317–321.
14. Sohu, I. A., Gandahi, A. W., Bhutto, G. R., Sarki, M. S., & Gandahi, R. (2015). Growth and yield maximization of chickpea (*Cicer arietinum*) through integrated nutrient management applied to a rice-chickpea cropping system. *Sarhad Journal of Agriculture, 31*(2), 131–138. <https://doi.org/10.17582/journal.sja/2015/31.2.131.138>
15. Zhang, J., Wang, J., Zhu, C., Singh, R. P., & Chen, W. F. (2024). Chickpea: Its origin, distribution, nutrition, benefits, breeding, and symbiotic relationship with *Mesorhizobium* species. *Plants, 13*(3), 429. <https://doi.org/10.3390/plants13030429>
16. Thalooth, A. T., Tawfik, M. M., & Mohamed, H. M. (2006). A comparative study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mungbean plants grown under water stress conditions. *World Journal of Agricultural Sciences, 2*(1), 37–46.
17. Rout, R. G., & Sahoo, S. (2015). Role of iron in plant growth and metabolism. *Reviews in Agriculture Sciences, 3*, 1–24.
18. Hassan, M. U., Aamer, M., Chattha, M. U., Haiying, T., Shahzad, B., & Barbanti, L. (2020). The critical role of zinc in plants facing the drought stress. *Agriculture, 10*(9), 396. https://doi.org/10.3390/agriculture10090396
19. Shukla, U. N., & Mishra, M. L. (2018). Biofortification: Golden way to save life from micronutrient deficiency—A review. *Agricultural Reviews, 39*(3), 202–209.
20. Panse, V. G., &amp; Sukhatme, P. V. (1985). Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.