

Original Research Article

Effect of Zinc, Iron and Biofertilizer on physical property of soil under chickpea cultivation

ABSTRACT

The research was conducted at the Central Research Farm of the Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS) in Prayagraj during the Rabi season of 2022-23. The experimental design employed was a Randomized Block Design (RBD), with application of Zn, Iron along with standard fertilizer dose (RDF). This design aimed to systematically assess the combined effects of these factors on the specified parameters, providing valuable insights into the potential benefits of using micronutrients in the cultivation of chickpea, particularly the "Sadabahar" variety. In the study, Bulk density (Mg-mg m^{-3}); Particle density (Mg-mg m^{-3}); Pore Space (%); Water holding capacity (%) was calculated by methods suggested by Muthuvel *et al.*, 1992. The details of nano mixed micronutrients treatment given are T₁ (Absolute control); T₂ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹); T₃ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 5 kg ha⁻¹); T₄ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹); T₅ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 0 kg ha⁻¹); T₆ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹); T₇ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 5 kg ha⁻¹); T₈ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹); T₉ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 0 kg ha⁻¹); T₁₀ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹); T₁₁ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 5 kg ha⁻¹); T₁₂ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹); T₁₃ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹); T₁₄ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹) and T₁₅ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹). Zinc and Iron improve root development and microbial activity, enhancing soil structure and porosity. Rhizobium further promotes root nodulation and organic matter decomposition, increasing soil aggregation and moisture retention. This balanced nutrient and microbial application optimizes soil physical properties, leading to superior water holding capacity and pore space.

Keywords: *Cicer arietinum*, pH, Zinc, Biofertilizers.

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Introduction

Chickpea (*Cicer arietinum* L.) also known as Bengal gram is a self-pollinated pulse crop which is grown in all the parts of India. It is the most important pulse crop grown. Chickpea followed by Pigeon pea and green gram. It accounts 29.60% of the total pulse acreage. Botanically Chickpea is known as *Cicer arietinum* (L.) belongs to family Leguminosae, sub-family Papilionaceae. Chickpea probably originated from Near East. It is mainly cultivated in China, India, Burma, and other parts of south-east Asia. Madhya Pradesh ranks first in area and production of chickpea in year 2021-22 followed by Uttar Pradesh and Rajasthan. The area under production of chickpea in Uttar Pradesh is 6.11 thousand hectares and the production is 75.59 tonnes for year 2021-22 (Source: DES, Ministry of Agriculture & Farmers Welfare, Government of India, 2022-23). Chickpea is considered as quality pulses due to its excellent digestibility and rich protein (25-28%) content. It is also used as fodder for livestock and incorporated in soil for enrichment of organic matter. Chickpeas are usually rapidly boiled for 10 minutes and then simmered for longer. Chickpeas are a popular ingredient in vegetarian dishes, such as chana masala and chole. Chickpeas are also used to make a popular snack called chana chaat, which consists of boiled chickpeas, chopped onions, tomatoes, and spices, in India (Kadam, 2019). Chickpea is well adapted crop for many diversified cropping systems and rotations. It grown as sole crop and fodder crop as well as mixed crop in *Rabi* seasons in India. It has high capacity of nitrogen fixation. It is well suited to cold climate with annual rainfall of 60-75 cm. Chickpea is grown in all types of well-drained soil but is sensitive to water logging.

Zinc is one of the 17 essential elements necessary for the normal growth and development of plants. Zinc plays a key role in plants with enzymes and proteins involved in carbohydrate metabolism, protein synthesis, gene expression, auxin (growth regulator) metabolism, pollen formation, maintenance of biological membranes, protection against photo-oxidative damage and heat stress and resistance to infection by certain pathogens (Alloway, 2008). Zinc deficiency in plants retards photosynthesis and nitrogen metabolism, reduces flowering and fruit development, prolongs growth periods (resulting in delayed maturity), decreases yield, quality and results in sub-optimal nutrient-use efficiency. Micronutrient deficiency Zn and Fe is major problem of now days because of use of high yielding varieties, intensive cropping system, inadequate supply of micronutrient and loss of organic matter content by erosion and pollution. Iron involved in chlorophyll and thylakoid synthesis and development of chloroplast and important element for plant growth and development. Zn application influence on synthesis of auxin, nodulation and nitrogen fixation which enhance the plant growth and development of crop and ultimately influence the seed yield (Kasthurikrishna and Ahlawat, 2000). Balanced fertilization is the key to soil as well as plant health and it refers to the use of inorganic and

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organic fertilizers in coordination and equal proportions so that plant will get more and more benefit out of it. Hence, the inoculation of biofertilizers with inorganic fertilizer acts as a boon to crop growth. The inoculation of Rhizobium can increase grain yield in pulse crop from 10 to 15% (Ali and Chandra, 1985). The application of biofertilizers also exerts a positive effect on the physical and biological properties of the soil including increase in bulk density, particle density, macropore space, soil pH, microbial population, and soil enzyme activities. Biofertilizers are cost effective and eco-friendly source of plant nutrition. Biofertilizers such as Rhizobium culture and phosphorus solubilizing bacteria (PSB) help in enhancing the productivity and profitability of pulse crops by fixing atmospheric nitrogen and by solubilizing insoluble soil phosphates and discharging plant growth substances in the soil (Bajracharya and Rai, 2009). Therefore, the present investigation with aim to study the impact of Zn, Fe and Biofertilizer on Physical properties of soil.

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Commented [H2]: Use new resources for the introduction section
1-Effects of Iron on Crops and Availability of Iron in Soil: A Review
2- INTERACTIVE EFFECT OF ZINC AND IRON ON PHYSICO- CHEMICAL PROPERTIES OF SOIL OF FIELD PEA
2-Influence of zinc and iron on Physico-chemical properties of soil in cluster bean

Materials and Methods

The research was conducted at the Central Research Farm of the Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS) in Prayagraj during the Rabi season of 2022-23 and 2023-24. The experimental design employed was a Randomized Block Design (RBD), with application of Zn, Iron along with standard fertilizer dose (RDF). This design aimed to systematically assess the combined effects of these factors on the specified parameters, providing valuable insights into the potential benefits of using micronutrients in the cultivation of chickpea, particularly the "Sadabahar" variety. The Fisher and Yates, 1963 method was used to statistically analyse the data. The software used for analysis was OPSTAT. In the study, Bulk density (Mg m^{-3}); Particle density (Mg m^{-3}); Pore Space (%); Water holding capacity (%) was calculated by methods suggested by Muthuvel *et al.*, 1992. The details of nano mixed micronutrients treatment given are T₁ (Absolute control); T₂ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹); T₃ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 5 kg ha⁻¹); T₄ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹); T₅ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 0 kg ha⁻¹); T₆ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹); T₇ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 5 kg ha⁻¹); T₈ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹); T₉ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 0 kg ha⁻¹); T₁₀ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹); T₁₁ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 5 kg ha⁻¹); T₁₂ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹); T₁₃ (RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹); T₁₄ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹) and T₁₅ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹).

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The method of data analysis should also be fully described

Results and Discussion

The present paper discusses the influence of zinc, iron and biofertilizers application on soil physical properties under chickpea cultivation for first year (*rabi*-2022-23). The pre sowing soil sampling values for bulk density, particle density, pore space and water holding capacity is given in table 1.

Bulk density and Particle density

A critical perusal of data pertaining to bulk density and particle density (table 2) revealed that effect of different levels of Zn, Fe and biofertilizers on the bulk density of soil in the years 2022-23 was found to be non-significant at both depths *viz.*, 0-15 cm and 15-30 cm.

Post harvesting of chickpea soil bulk density was increasing according to the depth which was found to be maximum 1.307 Mg m^{-3} at 0-15 cm and 1.319 Mg m^{-3} at 15-30 cm in 2022-23 in treatment T₁ (Absolute control) followed by 1.300 Mg m^{-3} at 0-15 cm and 1.306 Mg m^{-3} at 15-30 cm in 2022-23 in treatment T₈ (RDF 100 % + Zinc @ 6.67 kg ha^{-1} + Iron @ 7.5 kg ha^{-1}) and minimum 1.248 Mg m^{-3} at 0-15 cm in treatment T₁₃ (RDF 100 % + Zinc @ 0 kg ha^{-1} + Iron @ 2.5 kg ha^{-1} + Rhizobium 20 g kg^{-1}) and 1.243 Mg m^{-3} at 15-30 cm in 2022-23 in treatment T₁₅ (RDF 100 % + Zinc @ 13.34 kg ha^{-1} + Iron @ 7.5 kg ha^{-1} + Rhizobium 20 g kg^{-1}). Similar results were also reported by Hussain *et al.*, 2022 and Yadav *et al.*, 2021 for bulk density remaining non-significant by application of zinc and iron fertilizers.

Particle density for soil sample collected post-harvest of chickpea was reported to be maximum in T₁ (Absolute control) with value of 2.627 Mg m^{-3} followed by T₂ (RDF 100 % + Zinc @ 0 kg ha^{-1} + Iron @ 2.5 kg ha^{-1}) with value of 2.608 at depth of 0-15 cm. Similar pattern was observed at depth of 15-30 cm with value of 2.644 Mg m^{-3} for T₁ and 2.621 Mg m^{-3} for T₂. Minimum particle density was reported in sample from treatment T₁₅ (RDF 100 % + Zinc @ 13.34 kg ha^{-1} + Iron @ 7.5 kg ha^{-1} + Rhizobium 20 g kg^{-1}) with 2.427 and 2.436 Mg m^{-3} at 0-15 cm and 15-30 cm depth respectively. Hussain *et al.*, 2022 reported similar conclusions for particle density remaining non-significant by application of zinc and iron fertilizers.

Pore space and Water Holding capacity

After carefully examining data on pore space and water holding capacity (table 3), it was determined that the impact of varying Zn, Fe, and biofertilizer levels on soil bulk density in the years 2022–2023 was significant at CD. of 5%.

Following the harvesting of chickpea soil, the pore space decreased with depth, reported to be maximum with 49.66% at 0-15 cm and 47.59% at 15-30 cm in 2022-23 and in treatment T₁₅ (RDF 100 % + Zinc @ 13.34 kg ha^{-1} + Iron @ 7.5 kg ha^{-1} + Rhizobium 20 g kg^{-1}). This was

followed by 49.43% at 0-15 cm and 47.49% at 15- 30 cm in 2022-23 in treatment T₁₄(RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹). While minimum pore space was reported by treatment T₇ (RDF 100 % + Zinc @ 6.67 kg ha⁻¹ + Iron @ 5 kg ha⁻¹) being 47.19% at depth of 0-15 cm and for treatment T₁ (Absolute control) being 45.15% at 15-30 cm depth.

Because of the synergistic effects of these components, the treatment with 100% RDF, 13.34 kg ha⁻¹ of zinc, 7.5 kg ha⁻¹ of iron, and 20 g kg⁻¹ of rhizobium increases the amount of pore space in the soil. Better microbial health and root development are facilitated by zinc and iron, which also enhance soil structure and aggregation. By fixing nitrogen and producing root exudates, rhizobium improves soil organic matter even more and encourages the development of stable soil aggregates. The combination increases the macropores and micropores in the soil, which are vital for the movement of water and air. This ideal balance might not be reached by other treatments at different doses, which would lead to less improved pore space. Because deeper soil layers (15–30 cm) are typically more compacted and less impacted by root activity and organic matter accumulation than the surface layer (0–15 cm), pore space decreases with depth. Deeper soil layers experience limited air and water movement due to this compaction, which also decreases the total porosity and number of macropores. Similar results were also reported by Dangi *et al.*, 2020 and Vasava *et al.*, 2020.

On the other hand, water holding capacity increased with depth. Soil sample from plot of T₁₅ (RDF 100 % + Zinc @ 13.34 kg ha⁻¹ + Iron @ 7.5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹) reported to have maximum water holding capacity being 47.23% and 47.89% at depth of 0-15 cm and 15-30 cm respectively. This was followed by 47.18% at 0-15 cm and 47.78% at 15- 30 cm in 2022-23 in treatment T₁₃(RDF 100 % + Zinc @ 0 kg ha⁻¹ + Iron @ 2.5 kg ha⁻¹ + Rhizobium 20 g kg⁻¹). While minimum pore space was reported by treatment T₁ (Absolute control) being 45.04% at 0-15 cm and 45.10% at 15-30 cm depth. The treatment combining RDF 100%, Zinc at 13.34 kg ha⁻¹, Iron at 7.5 kg ha⁻¹, and Rhizobium at 20 g kg⁻¹ enhances soil water holding capacity through synergistic effects. Zinc and Iron improve root development and microbial activity, enhancing soil structure and porosity. Rhizobium further promotes root nodulation and organic matter decomposition, increasing soil aggregation and moisture retention. This balanced nutrient and microbial application optimizes soil physical properties, leading to superior water holding capacity compared to other treatments with varied doses of these elements, which might not achieve the same level of soil structure improvement and microbial activity enhancement. Water holding capacity increases with depth because deeper soil layers, such as those at 15-30 cm, typically have higher clay content and organic matter accumulation, enhancing their ability to retain water. Additionally, these layers are less disturbed by surface evaporation and plant

uptake, allowing them to maintain higher moisture levels compared to the 0-15 cm depth. Findings were also reported by Dangi *et al.*, 2020 and Vasava *et al.*, 2020.

Conclusion

Zinc and Iron improve root development and microbial activity, enhancing soil structure and porosity. Rhizobium further promotes root nodulation and organic matter decomposition, increasing soil aggregation and moisture retention. This balanced nutrient and microbial application optimizes soil physical properties, leading to superior water holding capacity and pore space.

UNDER PEER REVIEW

Table1 Pre sowing analysis of physical parameters of Soil

S.No.	1.	2.	3.	4.
Soil Parameters	Bulk Density ($Mg\ m^{-3}$)	Particle Density ($Mg\ m^{-3}$)	Pore Space (%)	Water Holding Capacity (%)
Year 2022-23	1.20	2.61	46.66	44.11

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UNDER PEER REVIEW

Table 2 Effect of different levels of Zn, Fe and Biofertilizer on bulk density and particle density of soil at different depth post-harvest of crop for year 2022-23

Treatment Notation	Treatment Details	Bulk density (Mg m ⁻³)		Particle density (Mg m ⁻³)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Absolute control	1.307	1.319	2.627	2.644
T ₂	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹	1.288	1.296	2.608	2.621
T ₃	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹	1.268	1.276	2.598	2.609
T ₄	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹	1.275	1.284	2.456	2.552
T ₅	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 0 kg ha ⁻¹	1.293	1.290	2.531	2.577
T ₆	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹	1.295	1.303	2.520	2.569
T ₇	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹	1.298	1.324	2.536	2.571
T ₈	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹	1.300	1.306	2.538	2.552
T ₉	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 0 kg ha ⁻¹	1.285	1.311	2.514	2.547
T ₁₀	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹	1.283	1.303	2.563	2.572
T ₁₁	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹	1.294	1.301	2.568	2.575
T ₁₂	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹	1.288	1.322	2.513	2.569
T ₁₃	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹ + Rhizobium 20 g kg ⁻¹	1.248	1.270	2.524	2.549
T ₁₄	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹ + Rhizobium 20 g kg ⁻¹	1.262	1.285	2.437	2.456
T ₁₅	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹ + Rhizobium 20 g kg ⁻¹	1.226	1.243	2.427	2.436
'F' test		NS	NS	NS	NS
SE m (±)		-	-	-	-
CD (5%)		-	-	-	-

Table 3 Effect of different levels of Zn, Fe and Biofertilizer on pore space and water holding capacity (%) of soil at different depth post-harvest of crop for year 2022-23

Treatment Notation	Treatment Details	Pore space (%)		Water holding capacity (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Absolute control	47.30	45.15	46.10	43.04
T ₂	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹	47.34	45.77	46.15	43.50
T ₃	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹	47.35	45.79	46.32	43.43
T ₄	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹	47.63	45.61	46.02	43.42
T ₅	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 0 kg ha ⁻¹	47.60	45.36	46.32	43.29
T ₆	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹	47.60	46.59	47.10	44.31
T ₇	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹	47.19	45.74	46.58	43.48
T ₈	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹	48.11	46.22	47.12	44.16
T ₉	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 0 kg ha ⁻¹	47.32	45.51	46.87	43.36
T ₁₀	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹	48.00	46.44	46.78	44.05
T ₁₁	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹	47.56	47.33	47.35	45.09
T ₁₂	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹	48.53	46.84	47.32	44.23
T ₁₃	RDF 100 % + Zinc @ 0 kg ha ⁻¹ + Iron @ 2.5 kg ha ⁻¹ + Rhizobium 20 g kg ⁻¹	49.32	47.37	47.78	45.18
T ₁₄	RDF 100 % + Zinc @ 6.67 kg ha ⁻¹ + Iron @ 5 kg ha ⁻¹ + Rhizobium 20 g kg ⁻¹	49.43	47.49	47.56	45.07
T ₁₅	RDF 100 % + Zinc @ 13.34 kg ha ⁻¹ + Iron @ 7.5 kg ha ⁻¹ + Rhizobium 20 g kg ⁻¹	49.66	47.59	47.89	45.23
'F' test		S	S	S	S
SE m (±)		0.38	0.33	0.40	0.29
CD (5%)		1.11	0.96	1.16	0.85

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