***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, insightful information about the potential advantages of using micronutrients in cultivation of chickpea, particularly the "Sadabahar" variety. 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 $T_1$ (Absolute control); $T_2$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$); $T_3$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$); $T_4$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$); $T_5$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 0 kg $ha^{-1}$); $T_6$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$); $T_7$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$); $T_8$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$); $T_9$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 0 kg $ha^{-1}$); $T_{10}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$); $T_{11}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$); $T_{12}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$); $T_{13}$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$+ Rhizobium 20 g $kg^{-1}$); $T_{14}$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$+ Rhizobium 20 g $kg^{-1}$) and $T_{15}$ (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: Organic, Iron, Zinc, Rhizobium, Randomized Block Design

**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 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"[11-13]. 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. Chickpea 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.Iron is crucial for crop growth, aiding chlorophyll synthesis and enzyme function. Deficiency causes chlorosis and stunted growth, while excess iron can be toxic. Soil pH, organic matter, and moisture influence iron availability. Chelates and soil amendments enhance iron uptake. Understanding soil-iron interactions is vital for optimizing crop yields and ensuring balanced nutrient management. Balanced fertilization is crucial for both soil and plant health. It involves the coordinated and equal use of inorganic and organic fertilizers to maximize plant benefits. Therefore, combining biofertilizers with inorganic fertilizers significantly enhances crop growth. For instance, inoculating pulse crops with Rhizobium can boost grain yields by 10 to 15%. **(Ali and Chandra, 1985)**.The application of biofertilizers also exerts a positive effect affect the soil's biological and physical characteristics, such as changes in the pH, bulk density, particle density, and macropore space 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) work to increase the yield and profitability of pulse crops by releasing plant growth chemicals into the soil, solubilizing insoluble soil phosphates, and fixing atmospheric nitrogen.

(**Bajracharya and Rai, 2009).**Therefore, the present aim is to study the impact of Zn, Fe and Biofertilizer on Physical properties of soil.

**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 offering insightful information on 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 $T_1$ (Absolute control); $T_2$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$); $T_3$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$); $T_4$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$); $T_5$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 0 kg $ha^{-1}$); $T_6$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$); $T_7$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$); $T_8$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$); $T_9$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 0 kg $ha^{-1}$); $T_{10}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$); $T_{11}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$); $T_{12}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$); $T_{13}$ (RDF 100 % + Zinc @ 0 kg $ha^{-1}$ + Iron @ 2.5 kg $ha^{-1}$+ Rhizobium 20 g $kg^{-1}$); $T_{14}$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 5 kg $ha^{-1}$+ Rhizobium 20 g $kg^{-1}$) and $T_{15}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$+ Rhizobium 20 g $kg^{-1}$).

**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 response of different levels of Zn, Fe as well as 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 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 $T_1$ (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 $T_8$ (RDF 100 % + Zinc @ 6.67 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$)and minimum1.248 Mg $m^{-3}$ at 0-15 cm in treatment $T_{13}$ (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 $T_{15}$ (RDF 100 % + Zinc @ 13.34 kg $ha^{-1}$ + Iron @ 7.5 kg $ha^{-1}$+ Rhizobium 20 g $kg^{-1}$)". [14] 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 $T_1$ (Absolute control) with value of 2.627 Mg $m^{-3}$ followed by $T_2$ (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 $T_1$ and 2.621 Mg $m^{-3}$for $T_2$. Minimum particle density was reported in sample from treatment $T_{15}$ (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 with49.66% at 0-15 cm and 47.59% at 15- 30 cm in 2022-23 and in treatment $T_{15}$ (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 $T_{14}$(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 $T_7$ (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$T_1$ (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 $T_{15}$ (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 $T_{13}$(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 $T_1$ (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. Similar resultss 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.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Details of the AI usage are given below:

1.

2.

3.

**Table1** Pre sowing analysis of physical parameters of Soil

| S.No. | Soil Parameters | Year 2022-23 |
|---|---|---|
| **1.** | Bulk Density (Mg $m^{-3}$) | 1.20 |

| | | |
|---|---|---|
| **2.** | **3.** | **4.** |
| Particle Density (Mg $m^{-3}$) | Pore Space (%) | Water Holding Capacity (%) |
| 2.61 | 46.66 | 44.11 |

**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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