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Effect of rhizobium, different levels of NPK & micronutrient (Zn, Fe) on soil health, growth and yield attributes of chickpea (*Cicer arietinum* L.)

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Abstract
The Research Entitled **"**Effect of Rhizobium, different levels of NPK & Micronutrient (Zn, Fe) on Soil Health, growth, and yield attributes of Chickpea (*Cicer arietinum* L.)" aimed to evaluate the influence of different combinations of different levels of N, P, K, Zinc, and iron on the soil health, growth, and yield attributes of the chickpea variety Pusa-362. The study was conducted at the Research Farm, Department of Soil Science, Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, Uttar Pradesh, during the Rabi season of 2024-2025, using a Randomized Block Design (RBD).The experiment included nine treatments: T_1- Control, T_2- (Rhizobium Inoculation + @50% RDF + Zn @ 50%), T_3- (Rhizobium Inoculation + @50% RDF + Fe@ 50%), T_4- (Rhizobium Inoculation + @ 50% RDF + Zn @ 50% +Fe @ 50%), T_5- (Rhizobium Inoculation + @ 75% RDF + Zn@ 75%), T_6- (Rhizobium Inoculation + @ 75% RDF + Fe @ 75%), T_7- (Rhizobium Inoculation + @ 100% RDF + Zn @ 100%), T_8- (Rhizobium Inoculation + @ 100% RDF + Fe @100%), T_9 (Rhizobium Inoculation + @100% RDF + Zn @ 100%+ Fe @100%).Significant differences were observed across treatments for growth and yield parameters. Treatment T_7 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100%) showed the best performance in terms of plant height and no. of branches, with the highest plant height of 10.72 cm at 30 DAS, 23.82 cm at 60 DAS, 34.01 cm at 90 DAS, and 42.23 cm at harvest, number of branches per plant (2.87, 5.80, 7.6., 9.47). On the other hand, Treatment T_9- (Rhizobium Inoculation + @ 100% RDF + Zn @ 100%+ Fe @100%) excelled in yield and yield attributes parameters, recording the highest no. of pods/plant (89.60), no. of seeds/pod (2.20), 100 seed index (28.87), yield kg/plot (0.516), yield q/ha. (12.90). It is also shown that the highest quantity of Available N (252.53 kg/ha), Available P (17.37 kg/ha), Available K (215.12 kg/ha), Zinc (0.445 mg), Iron (8.82 mg), pH (7.93), EC (0.438 dSm-1), and O.C (0.525%) was observed in Treatment T_9 (Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%).

Keywords: Rhizobium, Zinc, Iron, pH, E.C., OC., Chickpea

Introduction
The first studies on Indian soils were conducted by Voelcker in 1893 and Leather in 1898. They classified the soils of India into four main types: Indo-Gangetic alluvium, black cotton soil (regur), red soil, and laterite soil (Bhattacharyya *et al.*, 2013) [3]. Nutrient deficiencies in soil-crop systems and poor management practices are major contributors to low crop yields, lower nutritional quality of agricultural products, and widespread malnutrition in animals and humans worldwide. The Green Revolution has enabled food production to become self- sufficient, meeting the needs of an expanding population. However, the continued extraction of nutrients from soil reserves has decreased soil nutrient levels (Niu *et al.*, 2024) [19]. This decline poses a significant risk to food security. High-yielding cultivars, intensive cropping, increased crop yields, reliance on high-analysis fertilizers, and decreased use of crop residues, animal manures, and composts have all contributed to growing concerns about micronutrient deficiency in crops. These deficiencies have had a significant impact on crop performance, lowering food grain output and affecting the food chain (Hashmi *et al.*, 2024) [10]. The scientific name for chickpea is (Cicer arietinum L.). It belongs to the papilionaceae subfamily of the Fabaceae family and is a member of the Cicereae tribe. This is one of the most important legume crops in the world and

an ancient pulse crop (Zhang *et al.*, 2024) [27]. Chickpea is a significant pulse crop cultivated and consumed globally, particularly in Afro-Asian regions. It is also one of the primary pulse crops grown and consumed in India, where it is commonly known as Bengal gram. In India, chickpea represents approximately 45% of the total pulse production. Like other pulses, India is the leading producer of chickpeas, contributing over 75% of the global chickpea production (Maurya *et al.*, 2018) [16]. According to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), chickpea seeds, on average, consist of 21.1% protein and 64% total carbohydrates (with 47% being starch and 6% soluble sugar). They also contain 5% fat, 6% crude fibre, and 3% ash. Chickpeas are rich in minerals, with phosphorus at 340 mg per 100 g, calcium at 190 mg per 100 g, magnesium at 140 mg per 100 g, iron (Fe.) at 7 mg per 100 g, and zinc (Zn.) at 3 mg per 100 g (Sahu *et al*., 2020) [25] additional nitrogen fertilization at specific stages of growth can further enhance its establishment, biomass accumulation, and yield potential. Proper nitrogen management ensures early vigor, better root development, and efficient nodulation, leading to improved biological nitrogen fixation and overall plant productivity (Kebede, 2021) [12]. The CRISPR/Cas9 genome editing technology offers a precise and efficient method to modify specific genes involved in the nitrogen fixation process (Rasheed *et al*., 2022) [24]. However, excessive nitrogen application can suppress nodulation and is therefore carefully regulated. Integrating minimal doses of starter nitrogen with biofertilizers optimizes chickpea performance, making it a sustainable cultivation practice under various soil and environmental conditions (Arora & Bhan, 2017) [1]. Chickpeas need a balanced supply of nutrients to thrive and yield at their best since they are a deep-rooted plant with a prolonged growth cycle. Phosphorus (P), one of the key macronutrients, is vital to chickpea production. Energy transmission, nodulation, and root growth all depend on it and have a direct impact on the crop yield and biological nitrogen fixation (Dikr & Abayechaw, 2022) [6].

2. Material and Methods

The experiment was carried out in naturally ventilated polyhouse at Agriculture Research Field, Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, Uttar Pradesh. The soil of the experimental field was sandy loam in texture, with soil pH 7.8, low level of organic carbon (0.47%), available N (228 Kg/ha), P (22.9 kg/ha), K (236.1 kg/ha). The experiment was laid out in RBD with 7 treatments each replicated thrice. The treatment combinations are T_1 - [Control], T_2 - [Rhizobium Inoculation + @50%RDF + Zn@ 50%], T_3 - [Rhizobium Inoculation + @50%RDF + Fe@ 50%], T_4 - [Rhizobium Inoculation + @50%RDF + Zn @50%+Fe@ 50%], T_5 - [Rhizobium Inoculation + @75%RDF + Zn@ 75%], T_6 - [Rhizobium Inoculation + @75%RDF + Fe@ 75%], T_7 - [Rhizobium Inoculation + @100%RDF + Zn@ 100%], T_8 - [Rhizobium Inoculation + @100%RDF + Fe@100%], T_9 - [Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%]. Data recorded on different aspects of crop, *viz*., growth, quality attributes and yield were subjected to statistically analyzed by analysis of variance method as described by Gomez and Gomez (1976) [9].

3. Results and Disccusion

3.1 Growth Attribute

3.1.1 Plant height (cm)

The data on plant height (cm) as affected by different treatments recorded at 30, 60,90DAS, and at harvest as presented in Table 1. At 30 DAS, all fertilized treatments significantly outperformed the control (T_1), having the value 8.78 cm, which recorded the lowest height. The highest plant height was observed in T_7 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100%) at (10.72 cm), followed by T_9 (Rhizobium Inoculation + @ 100%RDF + Zn @ 100% + Fe @ 100%) at (10.49 cm) and T_8 (Rhizobium Inoculation + @ 100%RDF + Fe @ 100%) at (10.17 cm). At 60 DAS, the highest plant height (cm) was observed in T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) recorded the highest value at 23.82 cm, followed closely by T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) at (23.34 cm) and T_4 (Rhizobium Inoculation + @ 50% RDF + Zn @ 50% + Fe @ 50%) at (22.89 cm). Control plants (T_1) were still the shortest (21.61 cm).

At 90 DAS, T_7 (Rhizobium Inoculation + @ 100%RDF + Zn @ 100%) maintained the lead in plant height at 34.01 cm, confirming its consistent benefit through all growth stages. T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) at (33.51cm) and T_2 (Rhizobium Inoculation + @ 50% RDF + Zn @ 50%) at (33.03 cm) also showed good performance, indicating a positive response to boron and zinc, respectively. The lowest plant height at this stage was observed in the control (T_1), at 31.34 cm, indicating the importance of nutrient supplementation. At harvest, the highest plant height was observed in T_7 (Rhizobium Inoculation + @100% RDF + Zn @ 100%) recorded the highest value at 42.23 cm, followed closely by T_9 (Rhizobium Inoculation + @ 100% RDF + Zn@ 100%+Fe @100%) at (41.53 cm) and T_8 (Rhizobium Inoculation + @100%RDF + Fe@100%) at (41.19 cm). Control plants (T_1) were still the shortest (38.15 cm). The result, however, is supported by another study by Virendra and others, which showed that the T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) treatment on Mungbean had the highest plant height (Kumar *et al*., 2020). This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. Zinc plays an important role in synthesizing plant growth regulators such as auxins, which play an active role in the enlargement and elongation of plant height. These findings are supported by Gupta and Sahu (2012) [8].

3.1.2 Number of branches

The data on the Number of branches were recorded and presented in Table 2. The recorded data on the number of branches on 30 DAS, all fertilized treatments significantly outperformed the control (T_1), which recorded the lowest number (1.47). The highest number of branches was observed in T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) at 2.87 cm, followed by T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) at 2.67 and T_6 (Rhizobium Inoculation + @ 75% RDF + Fe @ 75%) at 2.33.

At 60 DAS, the number of branches continued to increase. Again, T_7 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100%) recorded the highest value at 5.80, followed closely by T_9 (Rhizobium Inoculation + @ 100% RDF + Zn@ 100% + Fe @ 100%) at 5.53 and T_6 (Rhizobium Inoculation +@75% RDF + Fe @ 75%) at 5.27. Control plants (T_1) still have the lowest no. of branches at 3.40.

At 90 DAS, T_7 (Rhizobium Inoculation + @ 75% RDF + Fe @ 75%) maintained the lead in the growth of the number of branches at 7.60, confirming its consistent benefit through all growth stages. T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) at 7.20 and T_3 (Rhizobium Inoculation + @ 50% RDF + Fe @ 50%) at 6.87 also showed good performance. While Control plants (T_1) still have the lowest no of branches at 6.20.

At 120 DAS, the number of branches continued to increase. Again, T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) recorded the highest value at 9.47, followed closely by T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) aT9.27 and T_4 (Rhizobium Inoculation + @50%RDF + Zn @ 50% + Fe @ 50%) at 8.53. Control plants (T_1) still have the lowest no of branches at 7.73. The treatment combination involving T_7 (Rhizobium Inoculation + @100%RDF + Zn @ 100%) resulted in an increased number of branches in chickpea compared to other treatments. This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. Zinc plays an important role in synthesizing plant growth regulators such as auxins, which play an active role in the enlargement and increased no. of branches. These findings are supported by Balai *et al*. (2017) [2]; Pathak *et al*. (2024) [22].

3.2 Yield and yield attributes

3.2.1 Number of pods/plant

The data on the Number of pods/Plant were recorded at harvest and presented in Table 2. Different fertilizer management strategies in different treatments had a significant effect on the number of pods/plants at harvest. At harvest, maximum pod/plant (89.60) was recorded when T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) was applied and it was found at par with the treatment T_7 with pod/plant of 88.07 which was applied with (Rhizobium Inoculation + @100%RDF + Zn@ 100%) DAS, whereas minimum Pod/plant (77.20) was recorded in treatment with T_1 Control. The treatment combination involving T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) resulted in an increased number of pods per plant in chickpea compared to other treatments. This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. Zinc plays a major role during the reproductive phase, especially during fertilization. Pollen grains also contain a higher amount of zinc. At the time of fertilization, there is a great translocation of zinc to the sink portion, which ultimately helps in grain formation. Iron has a structural role in cell elongation, which might lead to an increased number of pods per plant. These findings are supported by Patle *et al*. (2021) [21].

3.2.2 Number of seed/pods

The data for various treatments concerning seeds/pods were counted and recorded at harvest and presented in Table 4.6, and also depicted in Figure 4.6. The highest seeds/pod2.2 was recorded under the T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was succeeded by T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) at 2, T_5 (Rhizobium Inoculation + @ 75% RDF + Zn @ 75%) at 1.87and T_6 (Rhizobium Inoculation + @75%RDF + Fe@ 75%) at 1.80. However, the lowest (1.33) seeds/pod was recorded in the treatment T_1 control. The treatment combination involving T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) resulted in an increased No. of Seeds /pod in chickpea compared to other treatments. This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. Zinc plays a major role during the reproductive phase, especially during fertilization. Pollen grains also contain a higher amount of zinc. At the time of fertilization, there is a great translocation of zinc to the sink portion, which ultimately helps in grain formation. Iron has a structural role in cell elongation, which might have increased. of no. of Seeds /pod. Similar results were also reported by Nandan *et al*. (2018) [18]; Patle *et al*. (2021) [21].

3.2.3 Seed index

The data on 100 seed indexes were recorded at harvest and are presented in Table 3, as well as depicted in Figure 4.7. The results on 100 seed indexes showed that it had been significantly affected by different nutrient management strategies. At harvest, treatment T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) recorded the largest seed index (28.87 gm), which was significantly higher than to results obtained from treatment T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) at 26.23 gm, however, treatment T_1 with control resulted with lowest seed index of (19.4 gm). The treatment combination involving T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) resulted in an increased 100 Seed index in chickpea compared to other treatments. This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. Zinc plays a major role during the reproductive phase, especially during fertilization. Pollen grains also contain a higher amount of zinc. At the time of fertilization, there is a great translocation of zinc to the sink portion, which ultimately helps in grain formation. Similar findings are supported by Khorgamy & Farnia (2009) [15]; Drostkar *et al*. (2016) [7].

3.2.4 Yield q/plot

The Yield per q/hectare as influenced by different nutrient management practices has been presented in Table 3 and It is evident from the table, that the highest yield of 12.9 q/ha was obtained with T_9(Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was followed by 10.05 q/ha yield from T_3 (Rhizobium Inoculation + @50%RDF + Fe@ 50%) and T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) at 10.4 q/ha, whereas the lowest yield (7.1q/ha) was recorded in the treatment T_1 (control). The treatment combination involving T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) resulted in an increased Yield q/ha in chickpea compared to other treatments. This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. Zinc plays a major role during the reproductive phase, especially during fertilization. Pollen grains also contain a higher amount of zinc. At the time of fertilization, there is a great translocation of zinc to the sink portion, which ultimately helps in grain formation, which may lead to enhanced production. Iron has a structural role in cell elongation, which might have an increased Yield q/ha. These findings are supported by Kharol *et al*. (2014) [13]; Parimala *et al*. (2013) [20].

3.3 Chemical properties of soil

3.3.1 Available N, P, K

The available N content in soil at harvest, as influenced by different treatments, is presented in Table 3. Significantly highest N content in soil (252.53 kg ha-1) was observed in treatment T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) however the treatment T_8(Rhizobium Inoculation + @100%RDF + Fe@100%) was at par with (249.33 kg ha-1) and the lowest N content of soil was observed in the absolute control treatment T_1 (220.50 kg ha-1). Treatment T_7 also has the nearest value to T_8 with (246.30 kg ha-1).

The available P content in soil at harvest, as influenced by different treatments, is presented in Table 3. Significantly highest P content in soil was observed in treatment T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) with value (17.37kg ha-1) however the treatment T_8

(Rhizobium Inoculation + @100%RDF + Fe @100%) was at par with (16 kg ha-1) and the lowest P content of soil was observed in the absolute control treatment T_1 (13.59 kg ha-1). Treatment T_7 also has the nearest value to T_8 with (15.30 kg ha-1).

The available K content in soil at harvest, as influenced by different treatments, is presented in Table 3. The highest value of K content was observed in T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) with a value (215.12 kg ha-1); however, the treatment T_8 (Rhizobium Inoculation + @100%RDF + Fe@100%) was at par value with (212.10 kg ha-1), and the lowest K content of soil was observed in the absolute control treatment T_1 (193.22 kg ha-1). Treatment T_7 also has the nearest value to T_8 with (208.20 kg ha-1). The treatment combination involving T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) resulted in increased N, P, and Kin soil compared to other treatments. This might be attributed to enhanced nitrogen fixation by inoculation of chickpea with Rhizobium. A portion of this fixed nitrogen will remain in the root nodules and plant residues, enriching the soil. Zinc plays a major role during the reproductive phase, especially during fertilization. Zinc and iron play supportive roles in enzyme function and chlorophyll formation, which enhances nodule health and nitrogen fixation efficiency. Phosphorus is less mobile in the soil, so after application, it may lead to increased phosphorus levels in the soil. Potassium is relatively mobile, but after application with Zinc and Iron, some proportion of potassium remains in the soil. Applying Rhizobium and a full dose of NPK improves early nutrient availability and crop performance. After harvest, these findings are supported by Dhakal *et al*. (2016) [5]; Khatana *et al*. (2021) [14].

3.3.2 Available Zinc and Iron

Available Zn content in soil at harvest is influenced by the different treatments reported in 4. The data indicate a significant effect due to various treatments. The highest zinc (0.445 mg) was recorded in T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was at par with treatment T_7(Rhizobium Inoculation + @100%RDF + Zn@ 100%) with a value (0.443mg). The lowest available Zinc (0.290ppm) was recorded in the absolute control treatment T_1. In soil, available Fe content at harvest is influenced by the different treatments reported in Table 4.11 and Figure. 4.11. In the soil, available Fe content was significantly higher (8.82ppm) in the treatment T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was at par with treatment T_8 (Rhizobium Inoculation + @ 100%RDF + Fe@100%) with a value (8.57 ppm). The lowest available Fe content (4.31 ppm) was observed in the absolute control treatment T_1. The treatment combination involving T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) resulted in increased Zinc and iron in soil compared to other treatments. Zinc plays a major role during the reproductive phase, especially during fertilization. Chickpea crops take up Zn for enzyme activity, growth, and root development. Iron has a structural role in cell elongation, which might be due to increased Zinc and iron in the soil. Rhizobium indirectly increases Zn & Fe uptake in soil by improving root health and biomass. These findings are supported by Hossain *et al*. (2016) [11]; Pooja and Sarawad (2019) [23].

3.3.2 Soil pH, E.C., O.C.

The data for various treatments concerning average soil pH were recorded at harvest and presented in Table 4.

The highest (7.93 pH) was recorded in T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was at par with treatment T_8 (Rhizobium Inoculation + @ 100% RDF + Fe @ 100%) at value 7.57 pH. The Lowest pH was recorded in the absolute control T_1.

The data on E.C. of soil were recorded at harvest and presented in Table 4.

The largest value of EC (0.438 dSm-1) was recorded in T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was at par with treatment T_8 (Rhizobium Inoculation + @100%RDF + Fe @ 100%) with value (0.431 dSm-1). The lowest value of EC was recorded in the absolute control T_1.

The data for various treatments concerning the average Percentage of soil OC were recorded at harvest and presented in Table 4.

The highest O.C (0.525%) was recorded in T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%), which was at par with treatment T_8 (Rhizobium Inoculation + @100%RDF + Fe @100%) at value (0.522%). The Lowest percentage of O.C. was recorded in the absolute control T_1. The treatment combination involving T_9 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100% + Fe @ 100%) resulted in increased pH, EC, and O.C. because chickpea is a legume, and Rhizobium activity may help buffer soil pH slightly by increasing biological activity and root exudation. E.C. indicates soluble salt concentration in soil. Application of chemical fertilizers (NPK, $ZnSO_4$, $FeSO_4$) increases the soluble salt load in the root zone temporarily, which increases soil EC. Chickpea roots and crop residues, when decomposed, add organic matter to the soil. Crop residues are returned to the soil, and O.C. builds up further. These Findings are supported by Chintha *et al*. (2021) [4], Soheil Kobraee (2019) [26] and Mishra *et al*. (2011) [14].

Table 1: Effect of Rhizobium, Different levels of NPK & Micronutrient (Zn, Fe) on growth attributes of chickpea

		Plant height(cm)			
Sr. No.	**Treatment combinations**	**30DAS**	**60 DAS**	**90DAS**	**At harvest**
1.	Control (Absolute Control)	8.78	21.61	31.34	38.15
2.	Rhizobium Inoculation + @50%RDF + Zn@ 50%	9.70	22.39	33.03	39.31
3.	Rhizobium Inoculation + @50%RDF + Fe@ 50%	9.52	22.51	31.92	40.07
4.	Rhizobium Inoculation + @50%RDF + Zn @50%+Fe@ 50%	10.01	22.89	32.52	39.92
5.	Rhizobium Inoculation + @75%RDF + Zn@ 75%	9.41	21.88	32.07	39.56
6.	Rhizobium Inoculation + @75%RDF + Fe@ 75%	9.41	22.28	32.69	40.01
7.	Rhizobium Inoculation + @100%RDF + Zn@ 100%	10.72	23.82	34.01	42.23
8.	Rhizobium Inoculation + @100%RDF + Fe@100%	10.17	23.53	32.96	41.19
9.	Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%	10.49	23.34	33.51	41.53
	SEm (±)	0.65	0.72	0.24	0.30
	CD (p=0.05)	0.22	0.24	0.71	0.89

Table 2: Effect of Rhizobium, Different levels of NPK & Micronutrient (Zn, Fe) on growth attributes of Chickpea.

No. of branches					
Sr. No.	**Treatment combinations**	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
1.	Control (Absolute Control)	1.47	3.40	6.20	7.73
2.	Rhizobium Inoculation + @50%RDF + Zn@ 50%	2.07	4.33	6.53	8.07
3.	Rhizobium Inoculation + @50%RDF + Fe@ 50%	2.27	4.80	6.87	7.93
4.	Rhizobium Inoculation + @50%RDF + Zn @50%+Fe@ 50%	2.20	5.00	6.53	8.53
5.	Rhizobium Inoculation + @75%RDF + Zn@ 75%	1.60	5.13	6.73	8.13
6.	Rhizobium Inoculation + @75%RDF + Fe@ 75%	2.33	5.27	6.53	8.40
7.	Rhizobium Inoculation + @100%RDF + Zn@ 100%	2.87	5.80	7.60	9.47
8.	Rhizobium Inoculation + @100%RDF + Fe@100%	2.00	5.13	6.73	8.47
9.	Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%	2.67	5.53	7.20	9.27
	SEm (±)	0.25	0.33	0.36	0.39
	CD (p=0.05)	0.08	0.11	0.12	0.13

Table 3: Effect of Rhizobium, Different levels of NPK & Micronutrient (Zn, Fe) on yield and yield attributes of chickpea

Yield and yield attributes					
Sr. No.	**Treatment combinations**	**Number of pod/plant**	**Number of seeds/pod**	**seed index (g)**	**Seed yield (q/ha)**
1.	Control (Absolute Control)	77.20	1.33	19.40	7.10
2.	Rhizobium Inoculation + @50%RDF + Zn@ 50%	83.80	1.73	19.97	8.82
3.	Rhizobium Inoculation + @50%RDF + Fe@ 50%	82.20	1.67	20.28	10.05
4.	Rhizobium Inoculation + @50%RDF + Zn @50%+Fe@ 50%	85.00	1.73	20.87	9.67
5.	Rhizobium Inoculation + @75%RDF + Zn@ 75%	83.47	1.87	19.56	9.45
6.	Rhizobium Inoculation + @75%RDF + Fe@ 75%	85.27	1.80	22.10	9.03
7.	Rhizobium Inoculation + @100%RDF + Zn@ 100%	88.07	2.00	26.23	10.40
8.	Rhizobium Inoculation + @100%RDF + Fe@100%	85.13	1.66	21.74	8.60
9.	Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%	77.20	2.20	28.87	12.90
	SEm (±)	89.60	0.30	3.84	2.95
	CD (p=0.05)	3.95	0.10	1.27	0.98

Table 4: Effect of Rhizobium, Different levels of NPK & Micronutrient (Zn, Fe) on Soil Health of chickpea

Soil Properties						
Sr. No.	**Treatment combinations**	**Nitrogen**	**Phosphorus**	**Potash**	**Zinc (mg/kg)**	**Iron (mg/kg)**
1.	Control (Absolute Control)	220.50	13.59	193.22	0.290	4.31
2.	Rhizobium Inoculation + @50%RDF + Zn@ 50%	231.23	14.07	203.53	0.336	5.21
3.	Rhizobium Inoculation + @50%RDF + Fe@ 50%	233.47	14.90	201.83	0.328	4.41
4.	Rhizobium Inoculation + @50%RDF + Zn @50%+Fe@ 50%	235.10	13.77	204.67	0.335	4.62
5.	Rhizobium Inoculation + @75%RDF + Zn@ 75%	238.10	14.77	206.23	0.359	5.12
6.	Rhizobium Inoculation + @75%RDF + Fe@ 75%	241.97	15.17	206.10	0.411	6.34
7.	Rhizobium Inoculation + @100%RDF + Zn@ 100%	246.30	15.30	208.20	0.443	7.57
8.	Rhizobium Inoculation + @100%RDF + Fe@100%	249.33	16.00	212.10	0.428	8.57
9.	Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%	252.53	17.37	215.12	0.445	8.82
10.	Control (Absolute Control)	5.37	1.00	1.18	0.023	0.54
	SEm (±)	1.78	0.33	0.39	0.008	0.18
	CD (p=0.05)	220.50	13.59	193.22	0.290	4.31

Conclusion

- Based on the results of the present investigation, it can be concluded that the fertilizer application of T_7 (Rhizobium Inoculation + @100%RDF + Zn@ 100%) significantly enhanced vegetative growth, like plant height and no of branches. The treatment T_9 (Rhizobium Inoculation + @ 100%RDF + Zn @ 100% + Fe @ 100%) was found to be most effective in improving yield, soil properties, and recorded the highest cost-benefit ratio.
- Considering the superior performance in terms of growth, yield, soil properties, and economic returns, the fertilizer application of T_9 (Rhizobium Inoculation + @100%RDF + Zn@ 100%+ Fe @100%) and T_7 (Rhizobium Inoculation + @ 100% RDF + Zn @ 100%) along with the recommended dose of fertilizers (RDF), can be recommended for adoption by farmers cultivating chickpea cv. Pusa 362.

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