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INTEGRATED EFFECTS OF FERTILIZERS IN COMBINATION WITH RHIZOBIUM AND MICRONUTRIENTS (ZN AND B) ON THE GROWTH, PRODUCTIVITY, AND ECONOMICS OF CHICKPEA

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ABSTRACT

A field experiment was carried out during the *Rabi* season of 2024 at the Instructional Farm, School of Agricultural Science, Renaissance University (Madhya Pradesh) to evaluate the combined influence of chemical fertilizers, Rhizobium inoculation, and micronutrients (zinc and boron) on the growth, yield, and economic returns of chickpea (*var.* RVG 202). The study employed a randomized block design comprising six treatment combinations, each replicated three times. The treatments included the recommended dose of NPK fertilizers (100% RDF) applied alone and in combination with Rhizobium (600 ml/ha), zinc (25 kg/ha), and boron (2 kg/ha) resulted in significantly superior performance across all measured parameters. This treatment recorded the highest plant height (44.06 cm), number of branches per plant (13.63), dry matter accumulation (14.28 g/plant), nodulation (27.67 nodules/plant), pod formation (31.78 pods/plant), seeds per pod (2.09), seed index (14.81 g), seed yield (1986 kg/ha), haulm yield (2970 kg/ha), and harvest index (40.08%). Economically, the same treatment yielded the highest gross return (Rs. 1,24,087/ha), net return (Rs. 91,504/ha), and benefit-cost ratio (3.81), indicating its profitability and agronomic advantage over other nutrient combinations.

***Keywords* :** Chickpea, Rhizobium, Zinc, Boron, Yield.

Introduction

Chickpea (*Cicer arietinum* L.), a member of the Leguminosae family and sub-family Papilionaceae, is one of the most important pulse crops globally. It is a diploid, self-pollinated annual legume cultivated since 7000 BC, primarily in semi-arid regions across South Asia, the Middle East, and Mediterranean countries (Singh *et al.*, 2009). The crop is grown in over 50 countries, with India continuing to lead in both area and production. As per the latest estimates, India contributes approximately 71.23% to global acreage and 70.14% to total output (DES, Ministry of Agriculture & Farmers Welfare, 2024-25). Despite this dominance, India's chickpea productivity remains lower than countries like Ethiopia (2075 kg/ha), Mexico (1942 kg/ha), and Australia (1898 kg/ha), highlighting a persistent gap in yield optimization (FAOSTAT, 2024).

Chickpea is predominantly cultivated under irrigated conditions, making it vulnerable to nutrient deficiencies and soil degradation. The rising cost of cultivation and stagnant yields have intensified the need for sustainable nutrient management. Conventional reliance on inorganic fertilizers, while effective in boosting short-term productivity, often leads to soil health deterioration and reduced microbial activity (Kumar *et al.*, 2003). To address these challenges, integrated nutrient management (INM) strategies combining chemical fertilizers with biofertilizers and micronutrients have gained prominence.

Biofertilizers such as *Rhizobium* enhance biological nitrogen fixation, enabling chickpea to meet up to 85% of its nitrogen requirement through symbiosis (Ahlawat *et al.*, 2007). They also improve root development, nodulation, and overall plant vigor. Micronutrients like zinc and boron play vital roles in plant metabolism. Zinc acts as a co-factor in enzymatic processes related to photosynthesis, respiration, and protein synthesis (Patel *et al.*, 2009), while boron regulates hormone levels, nutrient uptake, and reproductive growth, directly influencing seed set and yield (Ahlawat *et al.*, 2007).

Considering these facts, the present investigation entitled "Integrated effects of fertilizers in combination with rhizobium and micronutrients (Zn & B) on the growth, productivity, and economics of chickpea" was undertaken to identify the most effective nutrient combination for enhancing chickpea performance. The study aims to evaluate the synergistic effects of chemical fertilizers, *Rhizobium* inoculation, and micronutrient supplementation on growth parameters, yield attributes, and economic returns under field conditions. This integrated approach is expected to improve productivity, reduce input costs, and promote sustainable pulse cultivation in India.

Materials and Methods

A field experiment was conducted during *Rabi* season of 2024 at Student Instructional Farm, School of Agricultural Science, Renaissance University, Indore (M.P.). The soil of the experimental plot was silty clay in texture, nearly neutral in soil reaction (pH 7.57), medium in organic carbon (0.467 %), low in available Nitrogen (183.5 kg/ha), medium in available Phosphorous (14.77 kg/ha) and high in available Potash (249.6 kg/ha). he treatments comprised the application of 100% Recommended Dose of Fertilizers (RDF) at the rate of 22.5:60:40 kg/ha of $N:P_2O_5:K_2O$, with the entire quantity of nitrogen, phosphorus, and potassium incorporated as basal. Biofertilizers, specifically *Rhizobium* at 600 ml/ha, were applied as seed treatment. Additionally, micronutrients Zinc at 25 kg/ha and Boron at 2 kg/ha were supplied in powdered form. whose effect is observed on chickpea (*var.* RVG 202). The experiment was laid out in Randomized Block Design with six treatments replicated thrice. The experiment comprising six treatment possible combination of above factor, *viz.,* T1: Absolute Control, T2: 100 % RDF + Zinc, T3: 100 % RDF + Zinc + Rhizobium, T4: 100 % RDF + Boron, T5: 100 % RDF + Boron + Rhizobium and T6: 100 % RDF + Zinc + Boron + Rhizobium observations regarding growth, yield and economics was recorded during the field experiment. Crop growth parameters, yield attributes, and final yield were recorded at various growth stages following standard agronomic protocols. The effectiveness of root nodules can be determined by examining their internal colour. Nodules showing a pink or reddish tint indicate the presence of active leghaemoglobin, signifying efficient nitrogen fixation. In contrast, nodules that appear white or pale lack leghaemoglobin and are considered ineffective (Subba Rao, N.S. 1999). The experimental data were subjected to statistical analysis using analysis of variance (ANOVA), applying the F-test as outlined by Gomez and Gomez (1984). Treatment means were compared using the Critical Difference (CD) at a 5% level of significance to determine statistical validity.

Result and Discussion

Growth

Plant growth parameters were assessed across distinct developmental stages and summarized in Table-1. A marked increase in growth was observed during the early crop phase, from establishment to vegetative development. Subsequently, growth stabilized across treatments, indicating a plateau phase irrespective of nutrient or biofertilizer inputs. Among all treatments, the application of 100% RDF + Zinc (25 kg/ha) + Boron (2 kg/ha) + Rhizobium (600 ml/ha) as seed treatment (T6) recorded significantly superior performance. This treatment achieved the highest plant height (47.1 cm), number of branches per plant (13.63), and dry biomass (14.28 g/plant) at harvest. In terms of nodulation, T6 also exhibited the highest total number of nodules (27.67 nodules/plant) and effective nodules, with an effectiveness rate of 80.42%. Treatments T5 and T3, which also included Rhizobium inoculation, showed comparable results. In contrast, treatments relying solely on native soil rhizobia recorded lower nodule effectiveness. These findings are illustrated in Table-1 & Figure-1. The enhanced growth and nodulation in Rhizobium-treated plots may be attributed to improved nutrient availability and microbial synergy. The integrated use of biofertilizers and micronutrients likely facilitated better root development and nutrient uptake, reducing inter-plant competition. "Additionally, the soil application of zinc and boron may have enhanced physiological processes such as cell division and elongation by improving micronutrient availability in the rhizosphere, thereby promoting overall plant vigor and productivity." Similar findings were reported by Kumar *et al.* (2020) and Reddy *et al.* (2022), Rawat *et al*. (2024).

Yield attributes

The study revealed significant improvements in chickpea yield attributes and overall productivity due to seed inoculation with biofertilizers and foliar application of micronutrients. Notably, the treatment comprising 100% RDF + Zinc (25 kg/ha) + Boron (2 kg/ha) + Rhizobium (600 ml/ha) recorded the highest values for key yield parameters pods per plant (31.78), seeds per pod (2.09), and seed index (14.81 g). This enhanced performance is attributed to the synergistic effects of biofertilizers and micronutrients, which promoted biological nitrogen fixation, improved nutrient uptake, and accelerated vegetative and reproductive growth phases. These physiological enhancements translated into superior yield attributes, aligning with findings reported by Singh and Gandhi (2019) and Sahil *et al.* (2003).

Yield

In terms of final yield, the combination of 100% RDF + Zinc (25 kg/ha) + Boron (2 kg/ha) + Rhizobium (600 ml/ha) resulted in significantly higher seed yield (1986 kg/ha), haulm yield (5.70 t/ha), and harvest index (34.51%). The grain yield, being the cumulative outcome of metabolic and physiological processes, was notably enhanced by the integrated application of biofertilizers and micronutrients. These results corroborate earlier studies by Kumari. et al. (2019) and Gupta, & Sahu (2012) emphasizing the role of microbial inoculants and micronutrients in optimizing chickpea productivity.

Economics

The economic analysis of various treatment combinations revealed that the application of 100% recommended dose of fertilizers (RDF) supplemented with Zinc (25 kg/ha), Boron (2 kg/ha), and Rhizobium (600 ml/ha) resulted in the most favorable economic returns. This integrated nutrient management approach achieved the highest gross return of Rs. 1,24,087 per hectare, a net return of Rs. 91,540 per hectare, and a benefit-cost (B:C) ratio of 3.81. These figures indicate a substantial improvement in profitability compared to other treatment combinations. The enhanced economic performance can be attributed to the synergistic effects of micronutrients and biofertilizers. "These results are in line with the observations of Kumar et al. (2020), who also reported similar findings."

Conclusion

The integrated use of Rhizobium and micronutrients (Zn & B), particularly the combination of 100% RDF + Zinc (25 kg/ha) + Boron (2 kg/ha) + Rhizobium (600 ml/ha), significantly enhanced growth, yield traits, and economic returns in chickpea cultivation under western Madhya Pradesh conditions.

Table 1 : Growth parameters of Chickpea as influenced by RDF, Rhizobium and micronutrients.

S. No.	Treatments	Growth Parameters (100 DAS)			Nodules (No./Plant) 60 DAS	
		Plant height (cm)	**Branches (No./Plant)**	**Dry matter (g/Plant)**	**Total nodules**	**Effective nodules**
T1	Control	35.5^{d}	8.64^{d}	8.62^{e}	13.83^{d}	8.45^{d}
T2	100 % RDF + Zinc (25 Kg/ha)	40.2^{c}	9.90^{cd}	10.86^{cd}	19.67^{c}	13.59^{c}
T3	100 % RDF + Zinc (25 Kg/ha) + Rhizobium (600 ml/ha)	43.9^{b}	11.71^{b}	12.64^{b}	25.50^{ab}	19.87^{ab}
T4	100 % RDF + Boron (2 Kg/ha)	40.8^{c}	9.51^{d}	10.18^{d}	15.50^{d}	10.50^{b}
T5	100 % RDF + Boron (2 Kg/ha) + Rhizobium (600 ml/ha)	$42.5b^{c}$	11.12^{bc}	11.68^{bc}	23.67^{b}	18.63^{cd}
T6	100 % RDF + Zinc (25 Kg/ha) + Boron (2 Kg/ha) + Rhizobium (600 ml/ha)	47.1^{a}	13.63^{a}	14.28^{a}	27.67^{a}	22.25^{a}
SEm		**0.538**	**0.315**	**0.284**	**0.521**	**0.783**
C.D. at 5 %		**1.718**	**1.007**	**0.906**	**1.662**	**2.591**

Table 2 : Yield attributes & yield of Chickpea as influenced by RDF, Rhizobium and micronutrients.

S. No.	Treatments	No. of pods/plant	No. of seed/pod	Seed index (g)	Seed yield (kg/ ha)	Haulm yield (kg/ha)	Harvest index (%)
T1	Control	23.12^{d}	1.54^{c}	13.42	1297^{c}	2164^{d}	37.57
T2	100 % RDF + Zinc (25 Kg/ha)	25.74^{c}	1.75^{bc}	13.96	1555^{bc}	2440^{bcd}	38.99
T3	100 % RDF + Zinc (25 Kg/ha) + Rhizobium (600 ml/ha)	29.83^{ab}	1.94^{ab}	14.63	1762^{ab}	2876^{ab}	37.95
T4	100 % RDF + Boron (2 Kg/ha)	25.02^{cd}	1.71^{bc}	13.64	1509^{bc}	2343^{cd}	39.27
T5	100 % RDF + Boron (2 Kg/ha) + Rhizobium (600 ml/ha)	28.96^{b}	1.86^{ab}	14.04	1693^{ab}	2772^{abc}	37.97
T6	100 % RDF + Zinc (25 Kg/ha) + Boron (2 Kg/ha) + Rhizobium (600 ml/ha)	31.78^{a}	2.09^{a}	14.81	1986^{a}	2970^{a}	40.08
	SEm	**0.465**	**0.101**	**0.641**	**78.6**	**157.2**	**0.887**
	C.D. at 5 %	**1.483**	**0.321**	**NS**	**250.8**	**501.8**	**NS**

Table 3 : Economics of Chickpea as influenced by RDF, Rhizobium and micronutrients

S.No.	Treatments	Total COC (Rs. ha^{-1})	GMR (Rs. ha^{-1})	NMR (Rs. ha^{-1})	B:C
T1	Control	26850	81935	55085	3.05
T2	100 % RDF + Zinc (25 Kg/ha)	31373	97637	66264	3.11
T3	100 % RDF + Zinc (25 Kg/ha) + Rhizobium (600 ml/ha)	31493	111057	79564	3.53
T4	100 % RDF + Boron (2 Kg/ha)	29913	94632	64719	3.16
T5	100 % RDF + Boron (2 Kg/ha) + Rhizobium (600 ml/ha)	30033	106743	76710	3.55
T6	100 % RDF + Zinc (25 Kg/ha) + Boron (2 Kg/ha) + Rhizobium (600 ml/ha)	32583	124087	91504	3.81

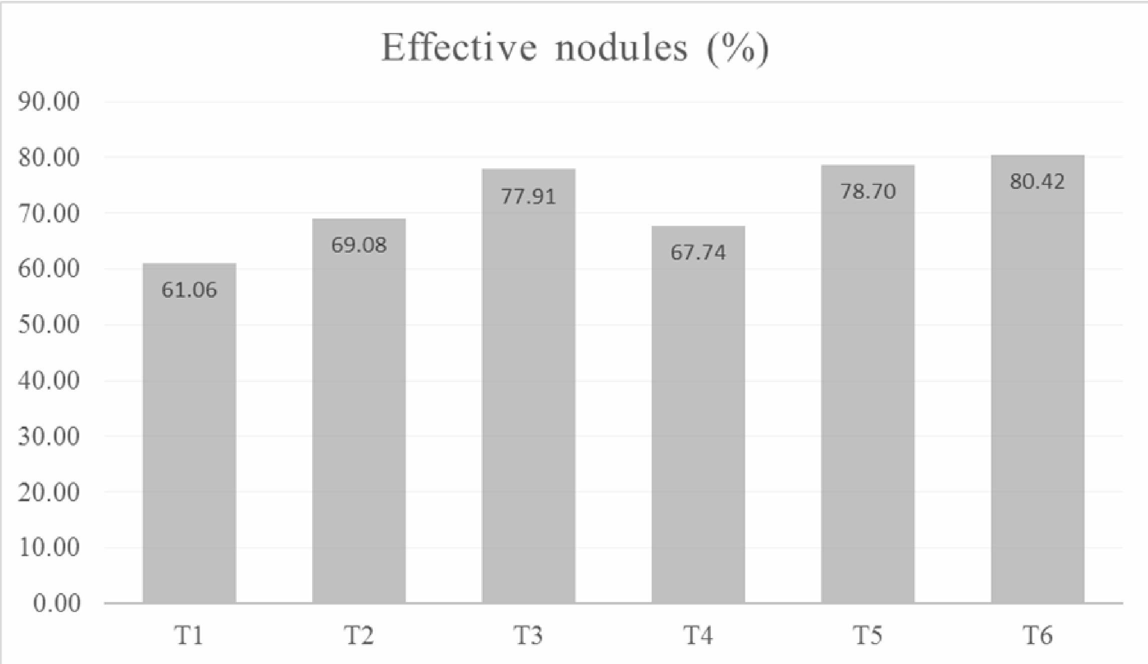

Fig. 1 : Effective nodules (%) influenced by RDF, Rhizobium and micronutrients.

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