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Comprehensive research on nutrient management in chickpeas (*Cicer arietinum* L.)

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Abstract
A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to assess the Comprehensive research on nutrient management in chickpeas (*Cicer arietinum* L.). The soil was normal in pH of 7.66, electrical conductivity (EC) of 0.28 dSm^{-1}, organic carbon content of 0.41%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 216.5.0, 19.4, and 148.50 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24. The experiment consisted of 8 treatment combinations, was laid out in Randomized Block Design (RBD) with three replications.

Keywords: Nutrients, chickpea, RDF, rhizobium

Introduction
The most significant winter season (Rabi) grain legume in India is the chickpea (*Cicer arietinum* L.), which is primarily grown on residual moisture after Kharif crop harvesting under rainfed conditions. Insufficient soil moisture in the seedbed is a significant obstacle to the development of the chickpea crop. This is due to the fact that insufficient soil moisture in rainfed crops can decrease yield, slow down seedling growth, and reduce seed germination (Sharma 1985). Crop productivity is increased by protective irrigation or pre-sowing irrigation during critical stages of crop growth. 90% of the world's chickpea crop is grown in rainfed environments, where it suffers severe yield losses from terminal drought stress.

A significant source of protein for diets, chickpeas are especially crucial for vegetarian diets. The majority of the time, this protein is eaten as dal and as dal flour, as well as processed whole seeds (boiled, roasted, fried, steamed, etc.). It's used to make condiments, sweets, and snacks. As a green vegetable, fresh green seeds are also eaten. It is a great source of vitamins, minerals (such as calcium, phosphorus, and iron), fat (4–10%), carbohydrates (52–70%), and protein (18–22%). Its straw has good forage value and makes an excellent animal feed (Prasad 2012) [1].

In India, 10.56 mha of chickpea crop yields 11.37 m tons annually at an average of 1077 kg ha^{-1}. The entire area of Uttar Pradesh is
5.01 lakh hectares, 5.78 lakh tons of output, and 1155 kg ha^{-1} of productivity. Anonymous (2018–19) [2]. This makes up roughly 70% of the entire world's land area and 67% of its total production (Ministry of Agriculture, 2018) [2]. The states that produce the most chickpeas are Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, and Andhra Pradesh.

As per the Ministry of Agriculture (2018), India's per capita net availability of pulses is 56 g per day [2], despite the World Health Organization's (WHO) recommendation of at least 80 g capita-1. (Verma and others, 2013) [3]. The current state of agriculture's sustainability is a major global concern due to the detrimental effects of intensive chemical input use on the environment and soil fertility (Laranjo *et al*., 2014) [4].

By optimizing the benefits from all available plant nutrient resources in an integrated manner, integrated nutrient management primarily aims to maintain or adjust soil fertility as a result of nutrient supply to an optimal level for sustaining the desired crop productivity (Roy and Ange, 1991) [5]. The fundamental idea of integrated nutrition management (INM) is to maintain soil fertility, promote sustainable agriculture, increase productivity, and increase farmer profitability by using crop residue, organic manures, green manures, biofertilizers, and mineral fertilizers sparingly and effectively.

Farm Yard Manure (FYM) is a valuable source of nutrients and organic matter for the soil that becomes available to plants when it breaks down due to microbial activity. (Qureshi and others, 2008) [6]. It is well known that bacteria that solubilize phosphorus, such as Bacillus polymyxa, Pseudomonas striata, and Pseudomonas fluorescence, can change phosphorus from its fixed form to an ionic form. According to Bhavya *et al*. (2018), the production of organic acids in soil systems, such as citric acid, fumaric acid, mallic acid, and succinic acid, decreased the pH in the area around them, causing the phosphate in the soil to become soluble.

Material and Methods

A field experiment was conducted during rabi season of 2022-23 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh Comprehensive research on nutrient management in chickpeas (*Cicer arietinum* L.). The soil was normal in pH of 7.66, electrical conductivity (EC) of 0.28 dSm^{-1}, organic carbon content of 0.41%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 216.0, 19.4, and 148.50 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24. The experiment consisted of 8 treatment combinations, was laid out in Randomized Block Design (RBD) with three replications. T_1 100% RDF, T_2 75% RDF, T_3 50% RDF, T_4 75% RDF + *Rhizobium*, T_5 75% RDF + *Rhizobium* + PSB, T_6 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25kg ha^{-1}, T_7 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25kg ha^{-1} + Sulphur @ 30 kg ha^{-1}, T_8 Control data were gathered on five plants chosen from each plot.

Results and Discussion

Growth Parameters

The results showed that at all growth stages—30, 60, 90 DAS, and harvest—the maximum plant heights (15.80, 33.51, 45.09, and 40.75 cm), respectively, were recorded with the application of T_7 (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulfur @ 30 kg ha^{-1}) The plants' heights were found to be comparable across all treatments at 30 DAS. Plant height did not significantly differ across treatments at 30 or 60 days after seeding, but did significantly differ at 90 days after seeding and during the harvest stage. In treatment T_8 (control), the minimum plant heights (14.50, 24.90, 33.62, and 30.38 cm) at 30, 60, 90, and harvest stage were noted. Gupta *et al*. (2016) and Dinesh *et al*. (2015) have also reported results similar to these [8, 9]. Based on various fertilizer management practices at 30, 60, 90 DAS, and harvest, the data showed that the dry matter accumulation/plant was recorded in the range of 0.58 to 0.63, 3.74 to 5.01, 7.42 to 16.92, and 9.28 to 21.15 g/plant. The application of treatment T_7 (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 30 kg ha^{-1}) at harvest resulted in the maximum dry matter accumulation (21.15 g/plant), which was found to be significantly superior over control and at par with T_1 (100% RDF) T_5 (75% RDF + Rhizobium + PSB) T_6 (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1}) with the treatments. Singh *et al*. (2007) [10] also report similar results. Treatment T_8 showed the lowest dry matter accumulation/plant (control). Different fertilizer management practices at 30, 60, 90 DAS, and harvest stage resulted in a range of nodules/plant recorded (2.9 to 3.16, 14.94 to 20.04, 10.45 to 14.028, and 3.7 to 5.01), according to the data. T_7 (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulfur @ 30 kg ha^{-1}) was found to have the highest number of nodules/plant across all growth stages. The number of nodules per plant was found to be at par at the 30 DAS initial growth stage. From 30 DAS to 60 DAS, it increased gradually, and from 60 DAS to harvest stage, it declined. T_7 produced the greatest number of nodules per plant during all growth stages, whereas the control group produced the fewest nodules during all growth stages. Similar findings are also documented by Bandyoupadhay (2002) and Tagore *et al*. (2014) [11, 12]. The information showed that owing to various fertilizer management techniques at 30, 60, 90 DAS, and at harvest, respectively, a range of branches/plant were recorded (2.18 to 2.37, 7.72 to 10.35, 26.15 to 35.07, and 26.95 to 35.10). Across all chickpea growth stages, the number of branches/plant gradually increases under all treatments. Throughout all growth stages (30, 60, 90, and harvest), the maximum number of branches/plant was recorded with T_7 (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulfur @ 30 kg ha^{-1}) and the minimum number of branches/plant was recorded with T_8 (control). T_7 (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 30 kg ha^{-1}) had the highest number of branches (35.10)/plant at harvest stage, which was significantly more than T_8 (control), T_2 (75% RDF alone), T_3 (50% RDF), and T_4 (75% RDF + Rhizobium), but on par with T_6, T_5, and T_1. With the exception of T_2 (75% RDF alone) and T_3 (50% RDF alone), the minimum number of branches/plant recorded with T_8 (control) was significantly lower than that of all other treatments. Comparable results were found by Imayavarmbani *et al*. (2002) and Hussain *et al*. (2011) [13, 14].

Table 4.1: Effect of various treatments on plants height at different growth stages of chick pea crop

Treatments	Plants height (cm)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1: 100% RDF	15.50	31.50	42.53	38.43
T_2: 75% RDF	14.70	27.40	36.99	33.43
T_3: 50% RDF	14.60	26.90	36.32	32.82
T_4: 75% RDF + *Rhizobium*	15.00	27.70	37.40	33.79
T_5: 75% RDF + *Rhizobium* + PSB	15.20	28.60	38.61	34.89
T_6: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1}	15.60	31.20	42.12	38.06
T_7: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 30 kg ha^{-1}	15.80	33.51	45.09	40.75
T_8: Control	14.50	24.90	33.62	30.38
SEm $\pm$	0.78	1.31	1.95	1.97
CD at 5%	2.37	3.96	5.90	5.99

Table 4.2: Effect of various treatments on Dry matter accumulation at different growth stages of chick pea crop

Treatments	Dry matter accumulation/Plant			
	30 DAS	60 DAS	90 DAS	At harvest
T_1: 100% RDF	0.62	4.73	13.76	17.20
T_2: 75% RDF	0.59	4.11	10.76	13.46
T_3: 50% RDF	0.58	4.04	7.97	9.96
T_4: 75% RDF + *Rhizobium*	0.60	4.16	11.94	14.93
T_5: 75% RDF + *Rhizobium* + PSB	0.61	4.30	12.54	15.67
T_6: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1}	0.62	4.68	13.60	17.00
T_7: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 30 kg ha^{-1}	0.63	5.01	16.92	21.15
T_8:*Control*	0.58	3.74	7.42	9.28
SEm ±	0.03	0.20	0.66	0.59
CD at 5%	0.09	0.62	2.00	1.79

Table 4.3: Effect of various treatments on number of nodules/plant in chickpea

Treatments	Number of nodules/plant			
	30 DAS	60 DAS	90 DAS	At harvest
T_1: 100% RDF	3.1	18.9	13.23	4.72
T_2: *75%* RDF	2.94	16.44	11.50	4.11
T_3: *50%* RDF	2.92	16.14	11.29	4.03
T_4: 75% RDF + *Rhizobium*	3.00	16.62	11.63	4.15
T_5: 75% RDF + *Rhizobium* + PSB	3.04	17.16	12.01	4.29
T_6: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1}	3.12	18.72	13.10	4.68
T_7: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 30 kg ha^{-1}	3.16	20.04	14.02	5.01
T_8:*Control*	2.9	14.94	10.45	3.73
SEm ±	0.12	0.73	0.45	0.19
CD at 5%	0.36	2.20	1.38	0.58

Table 4.4: Effect of various treatments on number of branches/plant in chickpea

Treatments	number of branches/plant			
	30 DAS	60 DAS	90 DAS	At harvest
T_1: 100% RDF	2.33	9.77	33.08	33.10
T_2: 75% RDF	2.21	8.49	28.77	29.77
T_3: 50% RDF	2.19	8.34	28.25	28.50
T_4: 75% RDF + *Rhizobium*	2.25	8.59	29.09	30.55
T_5: 75% RDF + *Rhizobium* + PSB	2.28	8.87	30.03	32.95
T_6: *75%* RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1}	2.34	9.67	32.76	33.33
T_7: 75% RDF + *Rhizobium* + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + Sulphur @ 30 kg ha^{-1}	2.37	10.35	35.07	35.10
T_8:Control	2.18	7.72	26.15	26.95
SEm ±	0.09	0.38	1.21	1.02
CD at 5%	0.26	1.14	3.68	3.08

Conclusion

The application of biofertilizer (Rhizobium + PSB) in conjunction with (75% RDF + Rhizobium + PSB + $ZnSO_4$ @ 25 kg ha^{-1} + sulphur @ 30 kg ha^{-1}) may be advantageous for the growth and yield of chickpeas, according to the experimental results.

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