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Effect of rhizobium inoculation with ZN and B on growth and yield of chickpea (*Cicer arietinum* L.)

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Abstract
A study with 9 different therapies, including the experiments used a randomized block design (RBD) with three replications and consisted of nine treatments: control (T_1) 100% RDF (T_2), 100% RDF + Zn (0.5%) (T_3), 100% RDF + B (0.5%) (T_4), 100% RDF + Rhizobium (20 g kg^{-1}) (T_5), 100% RDF + Zn (0.5%) + B (0.5%) (T_6), 100% RDF + Rhizobium (20 g kg^{-1}) + Zn (0.5%) (T_7), 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) (T_8), and 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) + Zn (0.5%) (T_9). Based on the findings of the current study, it is possible to draw the conclusion that the application of 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) + Zn (0.5%) applied to chickpea significantly increases plant height, number of branches per plant, accumulation of dry matter, and yield attributes such as number of grains per pod, number of pods per plant, and test weight (g). Additionally, the results demonstrated that, among the various fertility levels, the application of 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) + Zn (0.5%) considerably improved productivity metrics, including grain yield, stover yield, and biological output, over the control, except for harvest index. Higher economic values were observed for chickpea when 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) + Zn (0.5%) were applied, with the exception of the B:C ratio (2.74) which is maximum when 100% RDF + Rhizobium (20 g kg^{-1}) were applied. Gross return was Rs. 110810.10 ha^{-1}, net return was Rs. 69121.10 ha^{-1}, and cultivation cost was Rs. 41689.

Keywords: Chickpea, Rhizobium, Zn, B, productivity and net return

Introduction
The chickpea is one of the most widely grown pulses worldwide. *Cicer arietinum* L. is the scientific name for this plant, and it belongs to the Leguminosae family. It is popularly known as Chana in Uttar Pradesh. Pulses and food legumes are grown all over the world because of their excellent nutritional value. The southern part of Turkey and neighbouring Syria are credited as the birthplace of the chickpea. Both the Desi and Kabuli kinds of chickpea are widely farmed for industrial purposes around the globe. Over fifty countries cultivate chickpeas, with India, Turkey, Pakistan, Iran, Mexico, Australia, Ethiopia, Canada, Myanmar, and Iraq among the top producers. With a total output of 14.77 M tonnes, a total area of 14.56 M ha, and a productivity of 1.01 tonnes ha^{-1}, It is the third-most significant grain and legume crop worldwide (FAO STAT 2019). India is the world's leader in chickpea production and cultivation, accounting for 70 percent of the global total. It produces 11.35 million tonnes and is grown on 10.17 million hectares of land in India, yielding an average of 1116 kg per ha (GOI, 2020). The nutritional breakdown of a serving of chickpeas is as follows: 18-22% protein, 280 mg calcium per 100g, 61-62g carbohydrates, 12.3 mg iron per 100 g, 4.5 g fat, 301mg phosphorus per 100 g, and 396 calories (ICMR).

Zinc
Certain metabolic processes need zinc to be promoted. It is required for the synthesis of carbohydrates and chlorophyll. Numerous enzyme systems, aux in and protein synthesis, seed formation, and maturation rate are all dependent on zinc, either directly or indirectly. Zinc is thought to encourage the synthesis of RNA, which is necessary for the formation of proteins. Micronutrients play an important role in increasing legume yield through their effects on the plant itself, on the nitrogen fixing symbiotic process and the effective use of the major and secondary nutrients, resulting in high legume yields. Zinc is the main micronutrient that limits chickpea productivity (Ahlawat *et al.*, 2007) [1].

Boron

Boron is a crucial trace element for higher plants to operate physiologically. Plant B deficiency is regarded as a nutritional disease that negatively impacts plant growth and metabolism. It is essential for chickpea growth, particularly for flowering, fruit and seed production, and yields (Ahlawat *et al*., 2007) [1].

Rhizobium

Rhizobia are a special class of bacteria that live as symbionts with legumes and fix inert air nitrogen. The major contributions of fixed nitrogen to farming systems come from symbiotic partnerships between legumes and rhizobia, which are among the microorganisms that fix N_2. Rhizobium is found in soil and aids in the nitrogen fixation process in leguminous plants. It grows nodules and affixes to the leguminous plant's roots. These nodules capture nitrogen from the atmosphere and transform it into ammonia, which the plant can use to thrive and expand. BNF is the biochemical mechanism where rhizobia bacterial symbiont of legumes fixes inert atmospheric nitrogen into a plant usable form under the presence of enzyme nitrogenase (Mohammadi and Sohrabi, 2012) [2].

Materials and Methods

Experiment site

The field experiment took place at the Rama University's Agricultural Research Farm in Mandhana, Kanpur Nagar (U.P.), which is located in the alluvial tract of the Indo-Gangetic Plain in the central part of Uttar Pradesh between $25^0 26'$ and $26^0 58'$ North latitude and $79^0 31'$ to $31^0 34'$ East longitude at an altitude of 125.9 meters, during the rabi season of 2020-2021. On this property, there are sufficient irrigation facilities. The farm is located on the university's main campus.

Soil of Experimental Field

The experimental field is sandy loam in texture, neutral in reaction (pH 7.18), low in organic carbon (0.39%), EC (0.32 dSm^{-1}), available N (208.40 kg ha^{-1}), medium in available P (11.72 kg ha^{-1}), and low in available K (198.50 kg ha^{-1}).

Study Design

The experiment was laid out in a randomized block design (RBD) assigning treatment combinations *viz*. control (T_1) 100% RDF (T_2), 100% RDF + Zn (0.5%) (T_3), 100% RDF + B (0.5%) (T_4), 100% RDF + Rhizobium (20 g kg^{-1}) (T_5), 100% RDF + Zn (0.5%) + B (0.5%) (T_6), 100% RDF + Rhizobium (20 g kg^{-1}) + Zn (0.5%) (T_7), 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) (T_8), and 100% RDF + Rhizobium (20 g kg^{-1}) + B (0.5%) + Zn (0.5%) (T_9) with three replications. Each treatment was randomly allocated within them. The row-to-row and seed-to-seed distance were 30 and 15 cm, respectively.

Harvest Index

With the use of the Singh and Stockopf (1971) formula, the harvest index was computed.

$$Harvest\ Index = \frac{Economic\ Yield\ (kg/ha)}{Biological\ Yield (kg/ha)} \times 100$$

Net Profit (ha^{-1}):

Each treatment's potential net profit was determined independently by applying the methodology presented in the next paragraph.

Net profit (ha^{-1}) = Gross return - Cost of cultivation

Benefit: Cost ratio (B: C)

The ratio B:C was determined by utilizing the formula that is presented here below:

$$B: C = \frac{Gross\ monitary\ retern (Rs./ha)}{Total\ cost\ of\ cultivation\ (Rs./ha)}$$

Statistical analysis

In order to determine the statistical significance of treatment effects, a technique called SPSS was utilized for the analysis of variance. At a probability threshold of five percent, the importance of treatment effects was evaluated. In addition, the crucial difference (CD) method, which was introduced by Gomez and Gomez (1984), was used to analyse the 'F' test results and determine whether or not there was a significant difference between the treatments.

Results and Discussion

Growth parameters:

The application of 100% RDF + Rhizobium (20 g/kg) + Zinc (0.5%) and Boron (0.5%) led to a considerable increase in plant height across all phases of crop development (Table-1). At the stage of harvest, there was a 19.05 percent increase in plant height as a result of this treatment compared to the control. It is abundantly obvious that the synergistic effect of all microorganisms on plant height may be due to boosting the crop's availability of nitrogen and phosphorus. The increased plant height in the Rhizobium-treated plot in comparison to the control plot may be the result of an improvement in the physicochemical qualities of the soil, which may have influenced the population of microorganisms. Singh and Pareek (2003) [3] reported findings that were very similar to what we found.

In the current study, it was discovered that the application of 100% RDF + Rhizobium (20 g/kg) + Zinc (0.5%) + Boron (0.5%) inoculation resulted in a considerably higher number of branches per plant (Table-1) compared to the application of any other treatment. The application of fertiliser and bio-fertiliser inoculation resulted in an increase in the metabolic activity of the plant, which led to an increase in total foliage, which included an increase in the number of branches. This increase was caused by an increase in the number of branches per plant. Jarande *et al*. (2006) [4] and Lavanya and Ganapathy (2010) [5] both reported findings that were very similar to our own.

With the application of 100% RDF + Rhizobium (20 g/kg) + Zinc (0.5%) + Boron (0.5%) inoculation, the dry matter accumulation was determined to be 15.56 percent greater than with the control. This was found in Table-1. Because of the addition of Rhizobium and Zn inoculation, there was a greater amount of protein synthesis, which enabled the plant leaves to grow larger, which resulted in a greater amount of dry weight production and a higher surface area available for photosynthesis. Mathur *et al*. (2008) [6] also reported findings that were comparable to these.

The height of the plant, the number of branches per plant, and the accumulation of dry matter increased gradually at first, but after that, they increased at a quicker pace up to 90 DAS before beginning a downward trend. It's possible that a lower absorption rate and a slower photosynthetic rate are to blame for the slow growth rate of dry matter accumulation in the early stages of crop development. Because of the combined effect of increased plant height and a greater number of branches, there has been a rise in the amount of dry matter that has accumulated. Singh and Pareek (2003) [3] also observed that the application of biofertilizers led to an increase in the growth parameters of chickpea.

Yield attributes and Yield

The table-2 showed that the T_9 with 100% RDF + Zn (0.5%) + Rhizobium + B (0.5%) was the most effective treatment. Accordingly, the maximum pods per plant were 57.03, with 1.67 seeds per pod and a 1000-seed weight of 163.62 g. In terms of pods/plant, T_7 (100% RDF + Rhizobium (20 g/kg) + Zn (0.5%) and 1000 seed weight, T_8 (100% RDF + Rhizobium (20 g/kg) + B (0.5%) were the next-best treatments. T_6 (100% RDF + Zn (0.5%) + B (0.5%)) therapies were administered after T_5 (100% RDF + Rhizobium (20 g/kg) treatments. The control treatment had the lowest pod counts- 45.36 per plant, 1.26 seeds per pod, and 142.65 g of test weight- by a wide margin. Both Ram *et al.* (2008) and Mathur *et al.* (2008) [6] reported findings that are similar.

Compared to the other INM treatments, the application of 100% RDF + Zn (0.5%) + Rhizobium (20 g/kg) + B (0.5%) as in T_9 produced a grain yield that was much higher (20.67 kg/ha). T_7 (100% RDF + Rhizobium (20 g/kg) + Zn (0.5%), with a grain yield of 19.56, came in second. Contrarily, the control treatment, which did not apply fertiliser, produced the lowest grain yield (13.17 q/ha). The INM treatments also had a similar impact on the biological and stover yields, with T_9 having maximum yields of 24.60 and 45.27 q/ha, respectively.

Treatment T_8 was then applied to both parameters. The crop's harvest index was found to be non-significant and to be at its highest for treatment T_6: 100% RDF + Zn (0.5%) + B (0.5%) (47.50). Singh and Gupta (2006) [11], Kide and Pathak (2008) [9], and Dhyani *et al.* (2011) [8] found similar results.

Economics of crop

Cost of cultivation (Rs./ha)

The cost of cultivation information was provided in Table-3. The 100% RDF + Rhizobium (20g/kg) + Zn (0.5%) + B (0.5%) treatment had the highest cultivation cost, followed by the 100% RDF + Zn (0.5%) + B (0.5%) treatment. The control treatment had the lowest cultivation cost.

Gross return (Rs./ha)

The information in Table-3 showed that the application of 100% RDF + Rhizobium (20 g/kg) + Zn (0.5%) + B (0.5%) followed by 100% RDF + Rhizobium (20 g/kg) + Zn (0.5%) treatment boosted gross return and the observed maximum (Rs. 110810.1 ha^{-1}). The control treatment showed the lowest gross return.

Net return (Rs/ha)

The information pertaining to net return was displayed in table-3. The treatment consisting of 100% RDF + Rhizobium (20 g/kg) + Zn (0.5%) + B (0.5%) produced the highest net return (Rs. 69121.10/ha), followed by the treatment consisting of 100% RDF + Rhizobium (20 g/kg) + Zn (0.5%). The control treatment showed the lowest net return.

Benefit: Cost ratio

The information in Table-3 showed that the 100% RDF + Rhizobium (20 g/kg) treatment had the highest benefit-to-cost ratio (2.74). The second-highest benefit was provided by the 100% RDF + Rhizobium + Zn + 0.5% treatment, with a cost ratio of 2.72. The control treatment showed the lowest benefit-to-cost ratio. Gupta and Sharma (2006) [7] observed a similar finding as well.

Table 1: The growth parameters of chickpea as influenced by different INM treatments

Treatment No.	Treatments	Plant height				No. of branches/plant				Dry matter accumulation			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At Harvest
T_1	Control	15.12	30.69	40.69	40.67	3.30	19.35	25.38	25.36	0.63	5.34	14.07	15.03
T_2	100 % RDF (inorganic)	16.07	31.62	43.62	43.61	3.42	22.02	28.05	28.04	0.66	6.03	14.76	15.69
T_3	100 % RDF + Zn (0.05%)	16.95	32.94	44.94	44.93	3.45	22.29	28.32	28.30	0.70	6.18	14.91	15.84
T_4	100 % RDF + B (0.05%)	16.65	32.46	44.46	44.45	3.43	22.41	28.44	28.43	0.69	6.21	14.94	15.87
T_5	100 % RDF + Rhizobium (20 g/kg)	18.03	34.23	46.23	46.21	3.60	24.33	30.36	30.33	0.72	7.35	16.08	17.01
T_6	100 % RDF + Zn (0.05%) + B (0.05%)	17.40	33.06	45.06	45.05	3.51	23.07	29.1	29.0	0.68	6.27	15.00	15.93
T_7	100 % RDF + Rhizobium (20 g/kg) + Zn (0.05%)	18.24	34.86	46.86	46.84	3.69	24.03	30.06	30.05	0.72	7.53	16.26	17.19
T_8	100 % RDF + Rhizobium (20 g/kg) + B (0.05%)	18.09	34.38	46.38	46.37	3.96	25.02	31.05	31.03	0.71	7.41	16.14	17.07
T_9	100 % RDF + Rhizobium (20 g/kg) + Zn (0.05%) + B (0.05%)	19.08	35.43	48.43	48.42	4.03	25.41	31.44	31.41	0.75	7.71	16.44	17.37
S.Em ±		0.45	0.86	1.18	1.17	0.09	0.60	0.76	0.75	0.75	0.18	0.17	0.40
C.D. (P= 0.05)		1.35	2.62	3.56	3.54	0.28	1.81	2.29	2.29	2.291	0.06	0.52	1.21

Table 2: Yield attributes and yield parameters of chickpea as influenced by different INM treatments

Treatment No.	Treatments	No. of pods/plant	No. of grains/pod	Test weight (g)	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index
T_1	Control	45.36	1.26	142.65	13.17	17.43	30.60	43.03
T_2	100 % RDF (inorganic)	50.22	1.47	147.33	17.46	19.56	37.02	47.16
T_3	100 % RDF + Zn (0.05%)	52.41	1.49	149.58	18.33	20.55	38.88	47.14
T_4	100 % RDF + B (0.05%)	51.90	1.46	147.42	17.91	19.92	37.83	47.34
T_5	100 % RDF + Rhizobium (20 g/kg)	55.06	1.56	153.03	19.23	21.33	40.56	47.41
T_6	100 % RDF + Zn (0.05%) + B (0.05%)	53.43	1.59	151.71	18.84	20.82	39.66	47.50
T_7	100 % RDF + Rhizobium (20 g/kg) + Zn (0.05%)	56.12	1.62	158.61	19.56	22.20	41.76	46.83
T_8	100 % RDF + Rhizobium (20 g/kg) + B (0.05%)	55.92	1.60	159.96	19.35	23.01	42.36	45.67
T_9	100 % RDF + Rhizobium (20 g/kg) + Zn (0.05%) + B (0.05%)	57.03	1.67	163.62	20.67	24.60	45.27	45.65
S.Em ±		1.38	0.04	3.97	0.47	0.54	1.02	1.22
C.D. (P= 0.05)		4.17	0.12	11.99	1.43	1.65	3.08	NS

Table 3: Monetary gain Rs. /ha from chickpea as influenced by different integrated nutrient management treatments

Treatment No.	Treatments	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B: C Ratio
T_1	Control	33237	70796.40	37559.40	2.13
T_2	100 % RDF (inorganic)	37301	93467.40	56166.40	2.50
T_3	100 % RDF + Zn (0.05%)	38276	98126.40	59850.40	2.56
T_4	100 % RDF + B (0.05%)	40489	95860.50	55371.50	2.36
T_5	100 % RDF + Rhizobium (20 g/kg)	37526	102952.20	65426.20	2.74
T_6	100 % RDF + Zn (0.05%) + B (0.05%)	41464	100823.40	59359.40	2.43
T_7	100 % RDF + Rhizobium (20 g/kg) + Zn (0.05%)	38501	104740.80	66239.80	2.72
T_8	100 % RDF + Rhizobium (20 g/kg) + B (0.05%)	40714	103574.70	62860.70	2.54
T_9	100 % RDF + Rhizobium (20 g/kg) + Zn (0.05%) + B (0.05%)	41689	110810.10	69121.10	2.66

Conclusion

Based on the discussion above, it can be seen that among the various integrated nutrient management techniques, T_9 (having 100% RDF + Rhizobium (20 g/kg) + Zn (0.5%) + B (0.5%)) produced higher yield attributes, including more pods per plant (57.03), seeds per pod (1.67), seed yield (163.62 q ha^{-1}). On evaluating several integrated nutrient management strategies, it was discovered that 100% RDF + Rhizobium (20 g/kg) + Zn (0.5%) was more lucrative in terms of highest gross income (Rs. 110810.1/ha), net income (Rs. 69121.1/ha), and B:C ratio (2.66).

In comparison to their individual treatments, it was discovered that the use of fertiliser, zinc, boron, and rhizobium together was the best. Furthermore, it is important to note that the agro-climatic conditions of central U.P. were shown to be the best for these treatments' effects.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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