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RESEARCH ARTICLE

Effect of biofertilizer and micronutrients on the growth of chickpeas (*Cicer arietinum* L.)

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Abstract

A field experiment was carried out in the Rabi seasons 2017-18 and 2018-19 at Agronomy Research Farm, CSA University of Agriculture and Technology, Kanpur, to investigate the influence of integrated nutrient management (INM) on the growth of chickpea. The treatments consisted of three fertility levels: 100 % RDF (20:60:20 NPK kg/ha), 50 % RDF + vermicompost (2.5 t/ha) and 50 % RDF + FYM (5 t/ha), along with seven micronutrient and biofertilizer treatments, i.e., control, PSB, Zn, B, PSB+Zn, PSB+B and PSB+Zn+B. Growth characteristics like plant population, root length, number of primary, secondary and tertiary branches and fresh and dry biomass were noted at 60 DAS and harvest. Treatment with 100 % RDF yielded very high values of plant population, root development, branch development and biomass than integrated organic treatment. Among organic amendments, 50 % RDF + vermicompost gave higher growth than 50 % RDF + FYM, which confirms the efficacy of vermicompost in promoting growth when supplemented with inorganic fertilizers. Micronutrient management greatly contributed and PSB + Zn + B (M7) was the most optimal treatment, followed by PSB + B (M6). The control registered the lowest growth values. In general, balanced fertilization by 100 % RDF (together with appropriate micronutrient management, especially M7) was most effective in enhancing chickpea growth, resource-use efficiency and sustainability under the Indo-Gangetic plains.

Keywords: chickpea; micronutrient; Phosphorus Solubilizing Bacteria (PSB); Recommended Dose of Fertilizers (RDF); split plot design

Introduction

Chickpea (*Cicer arietinum* L.) belongs to the Fabaceae family and is an ancient self-pollinated diploid annual legume with a chromosome number of 2n=16, grown in various regions since 7000 BC in semi-arid climates. Gram is also widely grown in Southeast Asia, India, the Middle East and Mediterranean countries (1). It is one of the earliest grain legumes to have been domesticated by humans and ranks second in the area cultivated and third in production among pulses (2). INM (Integrated Nutrient Management) represents the integrated application of organic and inorganic fertilizers, further supplemented by other agronomic practices that increase crop yields, improve crop quality and enhance soil fertility (3). The application of INM to chickpea production can significantly improve both productivity and quality, resulting in farming practices that are more sustainable, resilient and economically viable. However, some variability in efficiency may result from differences in soil type, climate, crop variety and the specific combination and timing of nutrient inputs (4). Hence, there is a need to develop INM strategies according to the regional conditions and the needs of crops for better outcomes. The goal of the research was to enhance crop productivity without degradation to soil fertility. Simultaneously with the improvement of nutrient availability, the replenishment of soil fertility was done using biofertilizers and micronutrients without harming the environment (5). As biofertilizers are made of beneficial microorganisms, they increase the availability and uptake of nutrients for the roots. The trace application of micronutrients is, however, necessary for several physiological and biochemical operations in the plants. The application of both biofertilizer and micronutrient integrated systems supports healthier growth of plants with higher production of biomass and, ultimately, yields better results with better crop performance.

Materials and Methods

The experiment was conducted at the Agronomy Research Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The site is situated on the Indo-Gangetic plains in central Uttar Pradesh, between latitudes 25° 26' to 26° 58' North and longitudes 79° 31' to 80° 34' East, at an altitude of 125.9 m above sea level.

Treatment details

The experiment is carried out on a split-plot design. Treatments in the main plot included 100 % RDF (20:60:20 NPK kg/ha) (F_1), 50 % RDF + vermicompost at 2.5 t/ha (F_2) and 50 % RDF + FYM at 5 t/ha (F_3). In the sub-plots, the treatments were M_1 Control (without micronutrients), M_2-Biofertilizers (PSB at 6 kg/ha) as basal, M_3-micronutrients (Zn at 5 kg/ha) as basal, M_4-Boron (B at 6 kg/ha) as basal, M_5-PSB + Zn as basal, M_6-PSB + B as basal and M_7-PSB + Zn + B as basal. The traits measured during the experiment included initial plant population, number of branches/plant, fresh weight/plant (g), dry weight/plant (g) and root length/ plant (cm). The data collected on these aspects were analyzed using the analysis of variance (ANOVA) technique as given by previous researchers (6). The critical difference at the 5 % level of probability was deliberate to test the significance of differences between treatment means wherever the F-test was significant (7).

Cultural practices

After the harvesting of the previous Kharif season crop, before ploughing pre pre-sowing irrigation was given to the experimental field. First cross ploughing was done by tractor-drawn disc harrow, followed by planking and then one cross ploughing with cultivator, followed by planking, was done properly to make the soil firm, friable and level the field to ensure proper germination. The seed of the chickpea variety KWR-108 was developed by CSAUniv. Department of Agriculture and Technology, Kanpur, was used in the experiment. The sowing of chickpea was done on 22th October, 2017-18 and 21th October, 2018-19 at a row spacing of 45 cm apart was treated with rhizobium culture. Sowing of crop was done behind country plough @ 100 kg seed ha^{-1} . To provide proper space to each plant, extra plant were removed and wide gap spaces were filled by resowing the seed at each vacant place. The experimental crop was fertilized according to treatments by supplying the nitrogen, phosphorus and potash through Urea, single super phosphate and muriate of potash at the time of sowing as a basal dressing.

Growth parameters

Since it is not possible to study all plants for the population at its successive stage of growth; therefore, three plants were selected randomly in each plot, which were labelled for successive observations on growth and other characters.

Plant population (m^{-2})

The initial plant population per running meter was counted after complete germination and the final plant population per running meter was recorded at maturity of the crop.

Root length (cm)

The data pertaining to plant root length at 60 DAS (cm) and at the harvest stage. The average was used for statistical analysis.

Number of branches

Numbers of branches (Primary, secondary and tertiary) of the tagged plant were counted at 60, 90 DAS and at the harvest of the crop. The average was used for statistical analysis.

Fresh and dry weight/Plant (g)

For this purpose, three plants from each plot were taken at 60 DAS and at the harvest stage of the crop and weighed. The average fresh weight per plant was calculated. For dry weight, plants were dried in the sun and after sun drying, the bulk was dried in an oven at 70 °C for 24 hr and weighed. The average was used for statistical analysis.

Results and Discussion

Initial plant population

Table 1 presents the initial plant population under different treatments based on fertility levels and micronutrient management practices for the years 2017-18 and 2018-19, along with pooled data.

For fertility and micronutrient Levels

In the fertility level, the highest plant population in the pooled data was observed in F_1, representing 100 % RDF with a specific NPK ratio, reporting 14.46. This was followed by F_2, which combines 50 % RDF with vermicompost, reporting 14.12. The lowest population was recorded in F_3, which combines 50 % RDF with Farm Yard Manure (FYM), at 13.86. While in micronutrients, the highest initial plant population was recorded in M_7 (14.99), followed by M_6, with a value of 14.76. The lowest population was observed in M_1 (control), with a value of 12.77closed results were reported earlier (7-9).

Root length/plant (cm) at 60 days

Fertility and micronutrient levels

Table 2 showed that fertility level that the highest root length per plant at 60 days in pooled data was for F_1 (100 % RDF 20:60:20 NPK kg/ha) with 15.05 cm. F_2 (50 % RDF + Vermicompost 2.5 t/ha) recorded a root length of 13.78 cm. The lowest root length was observed in F_3 (50 % RDF + FYM @ 5 t/ha) with 13.40 cm, similar findings were reported earlier (10, 11). In micronutrients that the highest root length per plant at 60 days in pooled data was for M_7 (PSB+Zn+Bo) with 15.13 cm. M_6 (PSB+Bo as a basal dose) recorded a root length of 14.77 cm. The minimum root length was observed in the control group, M_1, with 13.16 cm (12).

Table 1. Effect of fertility levels and micronutrient management practices on initial plant population/m^2 of chickpea

Treatment	Initial plant population		
	2017-18	2018-19	Pooled
Fertility level			
F_1	14.39	14.53	14.46
F_2	14.01	14.24	14.12
F_3	13.75	13.90	13.83
SEm ±	**0.43**	**0.46**	**0.32**
CD at 5 %	**NS**	**NS**	**NS**
Micronutrient Management Practices			
M_1	12.65	12.89	12.77
M_2	13.39	13.51	13.45
M_3	13.91	13.98	13.95
M_4	14.34	14.50	14.42
M_5	14.56	14.70	14.63
M_6	14.66	14.84	14.76
M_7	14.83	15.14	14.99
SEm ±	**0.58**	**0.66**	**0.44**
CD at 5 %	**NS**	**NS**	**NS**

Whereas F1- 100 % RDF (20:60:20 NPK Kg/ha), F2-50 % RDF+Vermicompost@2.5 t/ha, F3-50 % RDF+FYM@5 t/ha, M1-Control, M2-Biofertilizers (PSB@6 Kg/ha) as basal, M3- Micronutrient (Zn@5kg/ha) as basal, M4-Boron (Bo @6 kg/ha) as basal, M5- PSB + Zn as basal, M6-PSB+Bo as basal and M7-PSB+Zn+Bo as basal.

Table 2. Effect of fertility levels and micronutrient management practices on root length/plant (cm) of chickpea

Treatment	Root length /Plant (cm)					
	60DAS			At harvest		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Fertility levels						
F_1	15.06	15.05	15.05	27.95	28.34	28.14
F_2	13.47	14.08	13.78	27.21	27.69	27.45
F_3	13.29	13.52	13.40	27.17	27.66	27.41
SEm ±	**0.21**	**0.21**	**0.14**	**0.28**	**0.25**	**0.19**
CD at 5 %	**0.83**	**0.81**	**0.48**	**NS**	**NS**	**NS**
Micronutrient Management						
M_1	13.24	13.08	13.16	24.87	25.27	25.07
M_2	13.29	13.65	13.47	27.25	27.48	27.37
M_3	13.67	14.07	13.87	27.51	27.92	27.71
M_4	13.85	14.22	14.03	27.65	28.13	27.89
M_5	13.95	14.29	14.12	27.95	28.40	28.17
M_6	14.65	14.88	14.77	28.12	28.73	28.42
M_7	14.94	15.33	15.13	28.76	29.35	29.06
SEm ±	0.21	0.31	0.22	0.38	0.44	0.29
CD at 5 %	**0.83**	**0.90**	**0.62**	**1.09**	**1.28**	**0.82**
F x M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Whereas F1- 100 % RDF (20:60:20 NPK Kg/ha), F2-50 % RDF+Vermicompost@2.5 t/ha, F3-50 % RDF+FYM@5 t/ha, M1-Control, M2-Biofertilizers (PSB@6 Kg/ha) as basal, M3- Micronutrient (Zn@5kg/ha) as basal, M4-Boron (Bo @6 kg/ha) as basal, M5-- PSB + Zn as basal, M6-PSB+Bo as basal andM7-PSB+Zn+Bo as basal.

Root length/plant (cm) at harvest stage

Fertility and micronutrient levels

Table 2 showed that Root length per plant at harvest, based on pooled data at maximum length, was presented in F_1 with 100 % RDF 20:60:20 NPK kg/ha; the length was 28.14 cm. F_2 with 50 % RDF + Vermicompost 2.5 t/ha had a root length of 27.45 cm and the minimum root length was found in F_3 having 50 % RDF + FYM @ 5 t/ha with 27.41 cm. The micronutrients, as well, showed that M_7 (PSB + Zn + Bo) had the longest length of the roots per plant at 29.06 cm. M_6 best was found in (PSB + Bo as a basal dose) with an average length of 28.42 cm. The control treatment, M_1, averaged 25.07 cm in root length, which is consistent with the findings reported previously (13).

Number of primary branches / Plant

As shown in Table 3, the fertility level created a significantly average number of primary branches per plant by F_1 (100 % RDF at 20:60:20 NPK kg/ha), which was 11.74 branches. Number produced by F_2 treatment, that is, 50 % RDF + Vermicompost at 2.5 t/ha, followed by the sequence with 11.38 branches. The lowest count was seen in F_3 treatment, that is, 50 % RDF + FYM at 5 t/ha and it averaged at 11.15 branches. Concerning micronutrients, the M_7 treatment had the highest mean of 12.15 main branches per plant, while M_6 recorded 11.90 shoots. Control (M_1) had the fewest number of primary branches at a mean of 10.30; therefore, there exists a critical positive effect through specific nutrient treatments regarding the enhancement of branching (14).

Number of secondary branches/Plant

Fertility levels were analysed by using ANOVA and it is clear from Table 3 that the maximum average number of secondary branches per plant under F_1 treatment stood at 36.51 number of branches. The second best was the F_2 treatment with 50 % RDF + Vermicompost @ 2.5 t/ha, which reached 34.63 number of branches, while the least count was found in F_3, which was 50 % RDF + FYM @ 5 t/ha, with 34.41 number of branches. Tolerance to micronutrient treatment: M_7 (PSB+Zn+B) had the greatest value with an average of 37.82 secondary branches per plant. The second-highest average was noted with the application of PSB and a basal dose of B in M_6; that average being 36.99 branches. The control treatment, M_1, happened to have the lowest number of secondary branches-perhaps merely an average of 32.23-plus in this case, which proved the significance of nutrient treatment for the specific induction of branches (15).

Number of tertiary branches/Plant

From the table 3, it was noted an analysis of fertility levels was conducted, where the maximum average number of tertiary branches was found on a plant with F_1 treatment at a mean level of 15.28 branches. It was substantially higher in contrast to that in the F_2 treatment, which received 50 % RDF + Vermicompost at 2.5 t/ha, which had only 13.16 branches. The lowest count recorded was that of F_3, with a treatment of 50 % RDF + FYM at 5 t/ha, which had only 12.15 branches. In terms of micronutrients,

Table 3. Effect of fertility levels and micronutrient management practices on primary, secondary and tertiary branches /plants of chickpea at harvest

Treatment	No. of Primary Branches/plant			No. of Secondary Branches/plant			No. of Tertiary Branches/plant		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Fertility levels									
F_1	11.66	11.82	11.74	36.35	36.67	36.51	15.18	15.38	15.28
F_2	11.33	11.43	11.38	34.59	34.67	34.63	13.1	13.21	13.16
F_3	11.1	11.2	11.15	34.32	34.5	34.41	12.1	12.2	12.15
SEm ±	**0.12**	**0.11**	**0.08**	**0.33**	**0.29**	**0.22**	**0.14**	**0.12**	**0.09**
CD at 5 %	**0.46**	**0.45**	**0.25**	**1.32**	**1.13**	**0.68**	**0.54**	**0.49**	**0.29**
Micronutrient Management									
M_1	10.25	10.35	10.3	32.14	32.31	32.23	11.73	12.05	11.89
M_2	10.72	10.82	10.77	33.36	33.53	33.45	12.47	12.57	12.52
M_3	11.36	11.46	11.41	34.44	34.5	34.47	13.03	13.15	13.09
M_4	11.62	11.72	11.67	34.89	35.4	35.14	13.48	13.58	13.53
M_5	11.7	11.8	11.75	36.1	36.28	36.19	13.77	13.87	13.82
M_6	11.78	12.02	11.9	36.95	37.02	36.99	14.66	14.76	14.71
M_7	12.1	12.2	12.15	37.73	37.91	37.82	15.1	15.2	15.15
SEm ±	0.28	0.27	0.19	0.36	0.34	0.25	0.28	0.28	0.2
CD at 5 %	**0.8**	**0.79**	**0.55**	**1.04**	**0.98**	**0.7**	**0.82**	**0.8**	**0.56**
F x M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Whereas F1- 100 % RDF (20:60:20 NPK Kg/ha), F2-50 % RDF+Vermicompost@2.5 t/ha, F3-50 % RDF+FYM@5 t/ha, M1- Control, M2-Biofertilizers (PSB@6 Kg/ha) as basal, M3- Micronutrient (Zn@5kg/ha) as basal, M4-Boron (Bo @6 kg/ha) as basal, M5-- PSB + Zn as basal, M6-PSB+Bo as basal andM7-PSB+Zn+Bo as basal.

the highest average was also recorded for M_7, PSB+Zn+B, with 15.15 branches, while M_6 had the second highest, PSB+B as a basal dose, at 14.71 branches. The control treatment, M_1, had the fewest with an average of 11.89, which only strengthened findings on the benefits of specific nutrient treatments (15).

Fresh weight/plant (g) at 60 days

Fertility and micronutrient levels

Table 4 showed that fertility level highest fresh weight per plant in the pooled data was recorded for F_1 treatment, with a fresh weight of 20.63 g. F_2 (50 % RDF + Vermicompost 2.5 t/ha) followed with a fresh weight of 18.34 g. The minimum fresh weight was observed in F_3 (50 % RDF + FYM @ 5 t/ha), which recorded 18.11 g. In micronutrient reported that the highest fresh weight per plant in the pooled data was observed for M_7 (PSB+Zn+Bo) with 19.97 g. M_6 (PSB+Bo as a basal dose) recorded a slightly lower fresh weight of 19.77 g. The control group, M_1, had the lowest fresh weight of 16.03 g (16, 17).

Fresh weight/plant (g) at harvest stage

Fertility and micronutrient levels: At the harvest stage, in fertility level Table 4 showed that the highest fresh weight per plant in the pooled data was recorded for F_1 (100 % RDF 20:60:20 NPK kg/ha) with 56.20 g. F_2 (50 % RDF + Vermicompost 2.5 t/ha) had a fresh weight of 52.70 g. The lowest fresh weight was observed in F3 (50 % RDF + FYM at 5 t/ha), with a value of 51.71 g. Whereas recorded that the highest fresh weight per plant in the pooled data was observed for M_7 (PSB+Zn+Bo) with 59.29 g. M_6 (PSB+Bo as a basal dose) recorded a fresh weight of 57.16 g. The lowest fresh weight was observed in the control group, M_1, with 46.75 g, closed finding reported in previous studies (18, 19).

Dry weight/plant (g) at 60 days

Fertility and Micronutrient levels: Table 4 showed that the highest dry weight at 60 days in pooled data was for F_1 (100 % RDF 20:60:20 NPK kg/ha) with 6.36 g. F_2 (50 % RDF + Vermicompost 2.5 t/ha) followed by 5.60 g. The lowest dry weight was recorded for F_3 (50 % RDF + FYM @ 5 t/ha) with 5.43 g. While analyzing the micronutrient data, the highest dry weight per plant at 60 days was observed in pooled data for M7 (PSB+Zn+Bo), with 6.39 g. M_6 (PSB+Bo as a basal dose) recorded 6.16 g. The lowest dry weight was in the control group, M_1, which had 4.80 g.

Dry weight/plant (g) at harvest stage

Fertility and micronutrient levels: Table 4 showed that the fertility level highest dry weight per plant at the harvest stage in pooled data was recorded for F_1 (100 % RDF 20:60:20 NPK kg/ha) with 47.05 g. F_2 (50 % RDF + Vermicompost 2.5 t/ha) had a dry weight of 44.27 g. The lowest dry weight was recorded for F_3 (50 % RDF + FYM @ 5 t/ha) with 43.40 g, like the findings reported earlier (20). While in micronutrient recorded that the highest dry weight per plant at the harvest stage in pooled data was for M_7 (PSB+Zn+Bo) with 51.41 g. M_6 (PSB+Bo as a basal dose) recorded a dry weight of 49.25 g. The control group, M_1, had the lowest dry weight of 36.90 g, a similar result (21).

Conclusion

Finally concluded that on the Pooled data basis, 2017-18 and 2018-19 showed that the 100 % RDF (F1) application always performed better compared with other fertility treatments regarding plant population, root length, branching and fresh and dry biomass, illustrating the significance of balanced chemical fertilization. Out of the integrated methods, 50 % RDF with vermicompost (F2) performed better than 50 % RDF with FYM (F3), implying that vermicompost offers higher efficiency as an organic amendment when blended with inorganic fertilizers.

Management of micronutrients also played a critical role. Treatment M7 (PSB + Zn + B) exhibited the maximum growth and yield parameters, followed by M6, whereas the control (M1) was the poorest. In general, incorporating 100 % RDF together with management of micronutrients, particularly M7, guarantees greater productivity, increased resource-use efficiency and sustainable crop production.

Authors' contributions

AK designed the experiments, conducted the fieldwork and drafted the manuscript. RK, AC and YT contributed to the

Table 4. Effect of fertility levels and micronutrient management practices on fresh and dry weight/plant of chickpea

Treatment	Fresh weight/plant (g) 60DAS			Fresh weight/plant (g) At harvest			Dry weight/plant (g) 60 DAS			Dry weight/plant (g) At harvest		
	2017-18	2018 -19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Fertility levels												
F_1	20.35	20.92	20.63	55.26	57.15	56.2	6.33	6.39	6.36	46.9	47.2	47.05
F_2	18.3	18.38	18.34	51.66	53.75	52.7	5.58	5.62	5.6	44.25	44.3	44.27
F_3	17.96	18.26	18.11	51.08	52.34	51.71	5.41	5.44	5.43	43.19	43.61	43.4
SEm ±	**0.23**	**0.21**	**0.15**	**0.59**	**0.77**	**0.49**	**0.09**	**0.1**	**0.07**	**0.39**	**0.47**	**0.3**
CD at 5 %	**0.91**	**0.84**	**0.49**	**2.33**	**3.02**	**1.59**	**0.38**	**0.39**	**0.23**	**1.53**	**1.85**	**1**
Micronutrient Management												
M_1	15.94	16.13	16.03	46.06	47.45	46.75	4.79	4.82	4.8	36.45	37.35	36.9
M_2	18.76	18.93	18.85	48.9	50.48	49.69	5.4	5.44	5.42	40.86	40.91	40.88
M_3	19.34	19.45	19.41	51.18	52.86	52.02	5.72	5.75	5.73	42.97	43.16	43.06
M_4	19.37	19.63	19.48	52.5	54.21	53.36	5.97	6.01	5.99	45.51	46	45.76
M_5	19.46	19.89	19.67	55.49	57.52	56.51	6.05	6.12	6.08	47.07	47.11	47.09
M_6	19.56	19.97	19.77	56.25	58.08	57.16	6.13	6.19	6.16	49.21	49.29	49.25
M_7	19.65	20.29	19.97	58.29	60.3	59.29	6.38	6.41	6.39	51.39	51.44	51.41
SEm ±	0.43	0.56	0.35	0.88	0.96	0.65	0.18	0.19	0.13	0.63	0.75	0.49
CD at 5 %	**1.25**	**1.6**	**0.99**	**2.53**	**2.77**	**1.83**	**0.53**	**0.54**	**0.37**	**1.81**	**2.17**	**1.38**
F × M	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Whereas F1- 100 % RDF (20:60:20 NPK Kg/ha), F2-50 % RDF+Vermicompost@2.5 t/ha, F3-50 % RDF+FYM@5 t/ha, M1- Control, M2-Biofertilizers (PSB@6 Kg/ha) as basal, M3- Micronutrient (Zn@5kg/ha) as basal, M4-Boron (Bo @6 kg/ha) as basal, M5-- PSB + Zn as basal, M6-PSB+Bo as basal andM7-PSB+Zn+Bo as basal.

conceptualization of the research and provided guidance during the study. YT and PJ performed data analysis and interpretation. KKP, AK, AC and SKD were involved in the preparation of the final manuscript. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

Ethical issues: None

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