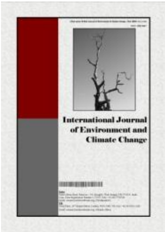

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Studies on the Root Architecture with Nodulation of the Chickpea (*Cicer arietinum* L.) as Influence by Different Moisture Management Practices along with Seed Inoculation and Level of Zinc

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The current field experiment was carried out during *Rabi* season of 2020-21 and 2021-22 at the Student's Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh to assess the Studies on the root architecture with nodulation of the chickpea (*Cicer arietinum* L.) as influence by different moisture management practices along with seed inoculation and level of zinc. The experiment was laid out in split-split plot design with 27 treatment combination comprising three moisture conservation practices namely, flat bed with 2.5 t/ha crop residue, narrow bed and furrow with 2.5 t/ha crop residue, broad bed and furrow with 2.5 t/ha crop residue in main plot and three seed inoculation (control, *rhizobium* and *PSB*) in sub-plots and three zinc level (control, 2.5 kg zinc/ha and 5.0 kg zinc/ha) in sub- sub plot with three

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replication. Results showed that among the different moisture management practices, used of broad bed and furrow with 2.5 t/ha crop residue were significantly enhanced root architecture, nodulation and grain yield, over the flat bed with 2.5 t/ha crop residue, respectively. Among the different Biofertilizers treatments seed inoculation with *Rhizobium* had significantly improved the root architecture, nodulation and yield, over control. Application of increasing levels of zinc up to 5.0 kg Zn/ha has significant influences on root architecture, nodulation and yield, over control. The combined application broad bed and furrow with 2.5 t/ha crop residue with *Rhizobium* and 5.0 kg/ha zinc resulted in significantly higher root architecture, nodulation and seed yield of chickpea during both the years of experimentation.

Keywords: Broad bed and furrow; chickpea; narrow bed and furrow; nodule; rhizobium and zinc.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) occupies prominent position among the various pulse crop grown in India. India ranks first in the world in respect of production as well as acreage and produces 11.23 million tons chickpea grains from 10.56 million hectare area with an average productivity of 1063 Kg ha^{-1} during 2017-18. India contributes 71 per cent of chickpea production of the world [1]. It is commonly used for human consumption as well as for feeding animals. Chickpea is considered to have medicinal effects and it is used for blood purification. Chickpea is free from various anti-nutritional factors and has high protein (18-22%), total carbohydrates (52-70%) and fat (4-10%). It is also a rich source of minerals (calcium, phosphorus, iron, niacin) and vitamins. Being a leguminous crop it has unique property of maintaining and restoring soil fertility through biological nitrogen fixation and also improve soil organic matter by addition of ample amount of residue due to shedding of their leaves at maturity.

Chickpea mostly grown on stored or residual soil moisture after harvest of *kharif* crops faces moisture stress throughout the life cycle. Nitrogen fixation by leguminous plants is reduced by moisture stress due to reduction in leghaemoglobin in nodules, specific nodule activity and number of nodules. The risk factor can be minimized through *in situ* moisture conservation, adoption of suitable crops and their varieties [2]. *In-situ* application of crop residues and division of field into beds and furrows could be used as low-cost input technology, which helps to conserve more rainwater in soil by minimizing runoff of water from soil surface under water scarcity situations [3]. Application of crop residue on soil surface as a mulch reduces the loss of water through evaporation and moderate the soil profile temperature [4].

Seed inoculation with *Rhizobium* increase the nodulation through better root development and improves nutrient availability which is beneficial in improving the grain yield. Phosphorus solubilizing bacteria is a cheapest source of phosphorus availability particularity in legume crops, it possess the ability to bring sparingly insoluble organic and inorganic phosphate into soluble forms by secreting organic acid [5-7]. Use of biofertilizer such as *rhizobium* can reduce the need for chemical fertilizer and decrease adverse environmental effects. Biofertilizers provide an economically judicious, attractive and ecologically sound means of fertilization [8]. Chickpea Inoculated with *Rhizobium* significantly increased the nodulation and its dry weight, root length, root dry weight and grain yield [9]. Rhizobium and phosphate solubilizing bacteria (PSB) assume a great importance on account of their vital role in N_2 fixation and P solubilization [10-12].

Zinc has an important metabolic role in plant growth and development and therefore, called an essential trace element or micronutrient [13,14]. Zinc is involved in various host plant metabolic processes, nodule growth and N_2 fixation process. Zn nutrient is receiving substantial attention as application of zinc in many legumes has also been found to increase root growth, nodulation and yield [15]. In addition to having an important role in activating plants enzymatic systems. Zinc is essential for the synthesis of chlorophyll and carbohydrates. This element plays an important role in increasing plant resistance to fungal disease and expanding plant roots [16]. Many area of the world suitable for chickpea have widespread zinc deficiency. Zinc deficiency affect plant water relation, induce stomata closure and decreases transpiration in plant. Chickpea is generally considered sensitive to zinc deficiency compared to various crop species. Zinc deficiency reduces not only the grain yield but also nutritional quality of the grain.

2. MATERIALS AND METHODS

The experiment was conducted at "Students Instructional Farm" of Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur-208002 (U.P.) during the *Rabi* season of 2020-21 and 2021-22. The experiment was laid out in spit-split plot design with three replication. The experiment was conducted in with 27 treatment combination comprising three moisture conservation practices namely, flat bed with 2.5 t/ha crop residue, narrow bed and furrow with 2.5 t/ha crop residue, broad bed and furrow with 2.5 t/ha crop residue in main plot and three seed inoculation (control, *rhizobium* and PSB) in sub-plots and three zinc level (control, 2.5 kg zinc/ha and 5.0 kg zinc/ha) in sub- sub plot. The chickpea variety RVG 202 was used for field experiment during both the year. The crop was fertilized as per the treatment. The recommended dose of nitrogen, phosphorus and potassium @ Recommended dose of fertilizers were applied to the crops during both the years in all plots. 20 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha were applied in all the plots as basal dose at the time of sowing. Urea, DAP, Murate of potash were used as the source of nitrogen, phosphorus and potassium. After field preparation and before sowing of crop, the narrow beds of 70 cm wide with furrows of 30 cm width and broad beds of 90 cm wide with furrow of 30 cm width were prepared manually in respective plots. Paddy straw residue was applied in chickpea crop as per treatments just after sowing as moisture management treatments during both the years of study. Zinc was applied as per treatments through zinc sulphate ($ZnSO_4.7H_2O$) containing 21% Zn and 10% S at the time of sowing as basal dose. seeds of chickpea are inoculated with *Rhizobium* and PSB as per treatments one day before sowing treated seeds are spread in shades for 8-10 hours then after used for sowing.

3. RESULT AND DISCUSSION

3.1 Root Architecture and Root Length

It is visualized from the data given in Table 1, higher values of root length at nodulation and flowering stage of chickpea was observed under broad bed and furrow with 2.5t/ha crop residue in both the years and in pooled data. sowing of chickpea under broad bed and furrow with 2.5t/ha crop residue resulted into significantly higher root length (7.12 and 28.32 cm) at nodulation and flowering stage as compared to other moisture conservation practices in pooled data study with percent increment 13.37, 34.98 over flat bed with 2.5 t/ha crop residue at nodulation and flowering stage, respectively. The results of present investigation are also in agreement with the findings of Rathore et al. [2], Mishra et al. [17], Lal et al. [18], Kumar et al. [19], Chavan et al. [20] and Gupta et al. [21].

The data presented in Table 1 clearly indicate that response of seed inoculation to root length show significant variation in length of root was increased in rhizobium as compare to control and PSB. The percentage increment over control of 3.35, 9.41 and PSB of 1.49, 4.21 at nodulation and flowering stage in pooled analyzed data of experimentation, respectively. These results also confirms of the findings of Shahzad et al. [9], Chandra and Pareek [22], Gyandev et al. [23], Khaitov et al. [24], Chauhan and Singh [25], Singh et al. [26], Katiyar et al. [27], Benjelloun et al. [28] and Yadav et al. [29].

Application of increasing levels of zinc up to 5.0 kg Zn/ha did not influences the root length at nodulation stage whereas it significantly influenced at flowering stage in 2020-21 and 2021-22 (Table 1). However, direct application of chickpea with 5.0 Zn/ha enhanced the root length by 0.59, 1.38 and 1.05, 2.42 percent at nodulation and flowering stage, respectively, over 2.5 kg/ha zinc and control in pooled data of experimentation. Similar result was reported by Gupta et al. [30], Yadav et al. [31] and Singh and Bhati [32].

3.2 Dry Weight of Root

Data revealed that higher values of root dry weight at nodulation and flowering stage of chickpea was observed under broad bed and furrow with 2.5t/ha crop residue (Table 1) in 2020-21 and 20221-22 as well as in pooled. Sowing of chickpea under broad bed and furrow with 2.5t/ha crop residue resulted into significantly higher root dry weight (0.924 and 2.48 g) at nodulation and flowering stage as compared to other moisture conservation practices with percent improvement 62.67 and 16.98 over flat bed with 2.5 t/ha crop residue at nodulation and flowering stage. These results also confirms of the findings of Rathore et al. [2], Mishra et al. [17], Lal et al. [18], Kumar et al. [19], Chavan et al. [20] and Gupta et al. [21].

The data clearly indicate that response of seed inoculation to dry weight of root show significant variation, dry weight of root was increased in *rhizobium* as compare to control and PSB. The percentage increment over control of 16.76, 4.91 and PSB of 8.16, 2.62 at nodulation and flowering stage in both the years of studies, respectively. Similar result was reported by Verma et al. [33], Verma et al. [34], Abisha and Singh [35] and Yadav et al. [29].

Application of increasing level of zinc up to 5.0 kg Zn/ha has significant influences on dry weight of root at nodulation while it became at par at flowering in pooled analyzed data (Table 1). However, direct application of chickpea with 5.0 Zn/ha enhanced the root dry weight by 2.52, 0.86 and 6.34, 2.20 percent at nodulation and flowering stage, respectively, over 2.5 kg/ha zinc and control in both the years of pooled data, respectively. The results of present investigation are also in agreement with the findings of Gupta et al. [30], Yadav et al. [31] and Singh and Bhati [32].

3.3 Number of Nodule

Data presented in Table 2 revealed that sowing of chickpea under broad bed and furrow with 2.5 t/ha crop residue proved significantly superior over narrow bed and furrow with 2.5 t/ha crop residue and flat bed with 2.5 t/ha crop residue in both the years of study. The significantly higher number of root nodules per plant (17.39, 17.48) were observed under broad bed and furrow with 2.5 t/ha crop residue during 2020-21 and 2021-22 over rest of the treatment with The percentage increment over flat bed with 2.5 t/ha crop residue of 24.30 in study of pooled data. The consequences of the current investigation are additionally in concurrence with the investigation of Mishra et al. [17], Lal et al. [18], Kumar et al. [19], Chavan et al. [20] and Gupta et al. [21].

The data clearly indicate that response of number of nodule per plant of chickpea to used seed inoculation was increased in *rhizobium* compare to control and PSB during both year of study (Table 2). The significantly higher number of root nodules per plant (16.23, 16.34) were observed under rhizobium. The results of present investigation are also in agreement with the findings of Khaitov et al. [24], Chauhan and Singh [25], Singh et al. [26], Verma et al. [33], Katiyar et al. [27], Verma et al. [34] and Benjelloun et al. [28].

Number of root nodules per plant were also affected significantly due to zinc level treatments directly applied to chickpea (Table 2). Application of 5.0 kg Zn/ha to chickpea being statistically at par with 2.5 kg Zn/ha, recorded significantly higher number (15.96 and 16.05) over control during both the years of experimentation with percent increment of 1.20 in pooled study. These results also confirms of the findings of Singh and Bhati [32], Chaudhary et al. [36], Thenua et al. [37] and Yadav et al. [38].

3.4 Nodule Dry Weight

A perusal of data presented in Table 2 revealed that sowing of chickpea under broad bed and furrow with 2.5 t/ha crop residue produces significantly higher dry weight of root nodules per plant (208.24, 214.60 mg) during 2020-21 and 2021-22. The percent improvement in broad bed and furrow with 2.5 t/ha crop residue13.34 over flat bed with 2.5 t/ha crop residue on pooled basis. These results also confirms of the findings of Mishra et al. [17], Lal et al. [18], Kumar et al. [19], Chavan et al. [20] and Gupta et al. [21].

The data clearly indicate that response of dry weight of root nodule to used seed inoculation was increased in *rhizobium* compare to control and PSB during both year of study. *Rhizobium* treated seed show significantly higher dry weight of root nodules per plant (199.08 and 206.02 mg) with percent improvement over control 3.75, 3.85 and PSB 1.77, 1.98 during both the years of experimentation, respectively (Table 2). The consequences of the current investigation are additionally in concurrence with the investigation of Khaitov et al. [24], Chauhan and Singh [25], Singh et al. [26], Verma et al. [33], Katiyar et al. [27], Verma et al. [34] and Benjelloun et al. [28].

Dry weight of root nodules per plant were also affected significantly due to zinc level treatments directly applied to chickpea. Application of 5.0 kg Zn/ha to chickpea being statistically at par with 2.5 kg Zn/ha and control in first years while in second year it was only at par with 2.5 kg Zn/ha, recorded significantly higher dry weight of root nodules per plant (196.80 and 204.43 mg) over control during both the years of experimentation, respectively (Table 2). The results of present investigation are also in agreement with the findings of Singh and Bhati [32], Chaudhary et al. [36], Thenua et al. [37] and Yadav et al. [38].

Table 1. Root length and root dry weight as influenced by Moisture conservation practices, Seed inoculation and Zinc level

Treatments	Root length (cm)						Dry weight of root g/plant					
	Nodulation stage			Flowering stage			Nodulation stage			Flowering stage		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
A. Moisture conservation practices												
Flat bed + 2.5 t/ha crop residue	5.82	6.74	6.28	20.51	21.44	20.98	0.559	0.577	0.568	2.11	2.13	2.12
NBF + 2.5 t/ha crop residue	6.13	7.11	6.62	24.07	25.00	24.53	0.744	0.766	0.755	2.28	2.30	2.29
BBF + 2.5 t/ha crop residue	6.62	7.60	7.12	27.86	28.77	28.32	0.917	0.932	0.924	2.46	2.49	2.48
S.Em. ±	0.023	0.030	0.013	0.068	0.094	0.089	0.004	0.003	0.004	0.010	0.006	0.006
CD at 5%	0.089	0.118	0.049	0.265	0.367	0.347	0.017	0.010	0.014	0.037	0.023	0.023
B. Seed inoculation												
Control	6.08	7.03	6.56	23.03	23.93	23.48	0.686	0.699	0.692	2.23	2.26	2.24
Rhizobium	6.30	7.26	6.78	25.22	26.16	25.69	0.797	0.820	0.808	2.34	2.36	2.35
PSB	6.20	7.16	6.68	24.17	25.13	24.65	0.738	0.756	0.747	2.28	2.31	2.29
S.Em. ±	0.023	0.033	0.016	0.064	0.080	0.075	0.003	0.003	0.002	0.011	0.008	0.008
CD at 5%	0.069	0.100	0.051	0.198	0.245	0.230	0.010	0.009	0.007	0.035	0.023	0.025
C. Zinc level												
Control	6.16	7.11	6.64	23.87	24.79	24.33	0.719	0.731	0.725	2.26	2.28	2.27
2.5 kg Zn/ha	6.19	7.15	6.67	24.11	25.04	24.58	0.742	0.761	0.752	2.29	2.31	2.30
5.0 kg Zn/ha	6.22	7.19	6.71	24.45	25.38	24.92	0.759	0.782	0.771	2.30	2.33	2.32
S.Em. ±	0.034	0.038	0.026	0.085	0.091	0.077	0.003	0.004	0.004	0.012	0.009	0.008
CD at 5%	NS	NS	NS	0.243	0.260	0.220	0.010	0.012	0.010	0.033	0.027	0.024

Table 2. No. of nodule/plant, Nodule dry weight and grain yield as influenced by Moisture conservation practices, Seed inoculation and Zinc level

Treatments	Number of nodule/plant			Nodule dry weight(mg/plant)			Grain yield (q/ha)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
A. Moisture conservation practices									
Flat bed + 2.5 t/ha crop residue	13.98	14.07	14.03	183.27	189.80	186.53	13.61	13.89	13.75
NBF + 2.5 t/ha crop residue	16.24	16.31	16.28	195.04	202.01	198.53	15.12	15.71	15.42
BBF + 2.5 t/ha crop residue	17.39	17.48	17.44	208.24	214.60	211.42	16.75	17.53	17.14
S.Em. ±	0.064	0.097	0.084	0.731	0.858	0.365	0.087	0.047	0.075
CD at 5%	0.251	0.379	0.329	2.856	3.348	1.427	0.338	0.184	0.291
B. Seed inoculation									
Control	15.48	15.53	15.50	191.87	198.37	195.12	14.62	15.15	14.89
Rhizobium	16.23	16.34	16.29	199.08	206.02	202.55	15.74	16.34	16.04
PSB	15.91	16.00	15.95	195.61	202.02	198.82	15.11	15.65	15.38
S.Em. ±	0.076	0.088	0.072	0.713	0.920	0.497	0.064	0.059	0.047
CD at 5%	0.235	0.271	0.221	2.198	2.834	1.530	0.198	0.181	0.146
C. Zinc level									
Control	15.77	15.85	15.81	194.42	199.98	197.20	14.63	15.15	14.89
2.5 kg Zn/ha	15.89	15.97	15.93	195.33	202.00	198.67	15.18	15.73	15.45
5.0 kg Zn/ha	15.96	16.05	16.00	196.80	204.43	200.62	15.68	16.27	15.97
S.Em. ±	0.053	0.054	0.052	0.989	1.083	0.784	0.070	0.082	0.074
CD at 5%	0.153	0.154	0.153	2.998	3.107	2.250	0.200	0.234	0.212

3.5 Grain Yield

The result revealed that grain yield was significantly increased at broad bed and furrow with 2.5 t/ha crop residue which was more than flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue in first year and second year Table 2 with percentage increment over flat bed with 2.5 t/ha crop residue of 24.65 and narrow bed and furrow with 2.5 t/ha crop residue of 11.15 in pooled analyzed data of experimentation, respectively. The consequences of the current investigation are additionally in concurrence with the investigation of Kumar et al. [39], Chavan et al. [20] and Gupta et al. [21].

The data clearly indicate that response of grain yield to used seed inoculation was increased in *rhizobium* compared to control and PSB during both year of study Table 2. The percentage increment over control of 7.72 and PSB of 4.29 in pooled analyzed data of experimentation, respectively. The results of present investigation are also in agreement with the findings of Chauhan and Singh [25], Singh et al. [40], Singh and Singh [41], Singh et al. [42], Verma et al. [33], Verma et al. [34], Katiyar et al. [27], Benjelloun et al. [28] and Yadav et al. [29].

It is clear from the Table 2 that zinc application exerted a positive effect on grain yield where the significantly response noted up to 5.0 kg Zinc/ha in both the years with percentage increment over control of 7.25 in pooled analyzed data. These results also confirms of the findings of Singh et al. [43], Shivay et al. [44], Parmar et al. [45] and Yadav et al. [38].

4. CONCLUSION

Based on the above result, it can be concluded that the broad bed and furrow with 2.5 t/ha crop residue is superior over the remaining moisture management practices with use of seed inoculation of *rhizobium* and dose of 5.0 kg zinc/ha in respect to root architecture, nodulation, and seed yield. Thus broad bed and furrow with 2.5 t/ha crop residue and *rhizobium* with 5.0 kg zinc/ha may be recommended to realize higher root architecture, nodulation and grain yields of chickpea.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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