



Response of Different Level of Phosphorus, Zinc and Rhizobium Inoculation on Growth Yield Attributes and Yield of Chickpea (*Cicer aretinum* L.)

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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 present field experiment was conducted during the 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. The experiment comprised of 18 treatment combinations in Factorial randomized block design with three replications. The result shown among the growth parameters the following assessed data: maximum plant height (48.56 cm) at 90 DAS, the number of nodules (31.27) at 60 DAS, dry weight of nodules (185.77 mg) at 60 DAS and the number of branches (18.12), similarly among yield attributes and yield viz. number of pod plant⁻¹ (69.54), number of grains pod⁻¹ (1.78), 100 grain weight (20.19 gm), grain yield (20.89 q ha⁻¹) and stover yield (25.26 q ha⁻¹) were recorded under T₁₈ (P₆₀+Zn_{2.5}+ rhizobium) during the second year (2021-22) of experimentation. The application of phosphorous, zinc and rhizobium inoculation significantly increase growth, yield and yield attributes of chickpea during the both years of experiments. The present study shown that application of phosphorus, zinc and rhizobium inoculation along with recommended nitrogen and potassium could be an effective option for enhancing the chickpea growth parameters, yield attributes and yield of chickpea.

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1. INTRODUCTION

Pulses are the predominated crop after the cereal crop in India. It is an easily available source of dietary protein in the rural heart of India and the best crop for sustainable and restoring soil fertility of soil. Pulses provide significant nutritional and health benefits and are known to reduce several non-communicable diseases such as colon cancer and cardiovascular diseases [1]. India is the largest producer and consumer of pulses in the world. Major pulses grown in India include chickpea, pigeon pea, lentil, urd bean, mung bean, pea, lablab bean, moth bean, and horse bean. Among the pulses, chickpea is the most important growing in every part of India. Chickpea (*Cicer arietinum* L.) is one of the pre-dominant *Rabi* crop in pulse-growing areas in India. It is originated in south eastern Turkey [2]. Chickpea is mainly cultivated in the cool, dry season of the semi-arid tropical region. The plant is well adapted to tropical climates with moderate temperatures and is successfully cultivated under irrigation in the cool season of many tropical countries [3]. It is a major legume crop cultivated for its edible seeds legume of the family *Fabaceae* (*leguminaceae*), and subfamily *Papilionaceae*. It provides a protein-rich diet to the vegetarian of the Indian and complement the stable cereals in the diet with proteins, essential amino acids, vitamins and minerals [4]. Many attractive dishes viz.,– sweets, snacks and namkeen are also prepared from its flour called besan which can be eaten either as whole fried or boiled and salted. Fresh green leaves (sag) are used as vegetables and green grains as hare chhole or chholia. The straw of gram is an excellent fodder while both husk and bits of 'Dal' are valuable cattle feed. Leaves consist of mallic and citric acid and are very useful for stomach ailments and blood purifiers. Nutritive value Chickpea grain contains Protein – 18-22%, Calcium – 280 mg/100 g, Carbohydrate – 61-62%, Iron–12.3 mg/100 g, Fat – 4.5 %, Phosphorus–301 mg/100 g Calorific value –396 kcal/100gm (The Nutritive value of Indian Foods & the planning satisfactory Diets, ICMR).

India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. India ranks first in the world in terms of pulse production (25% of total worlds production) [5]. In India chickpea occupies 10.17 million ha area, with a production of 11.35 million tonnes

registering the productivity of 1116 kg/ha. In Uttar Pradesh, chickpea crop occupied 0.62 million hectares area, 0.85 million tonnes production and 1371 kg/ha productivity [6].

Phosphorus also plays an important role in the build-up and maintenance of soil productivity by legumes through its effect on host plant growth and through its specific effect on the *Rhizobium* growth, survival, and nodulation capability. Phosphorus is one of the essential nutrients for legume growth and BNF [7]. Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy [8] and energy generating metabolism strongly depends upon the availability of P [9]. Moreover, it plays a key role in various physiological processes of some particular plants as growth factors for root development, vigorous stem, enhanced flower formation and seed production, earlier and more uniform crop maturity, increase nitrogen fixing capacity of legumes, improvement in crop quality and resistance to plant diseases [10]. Nodules themselves are strong sinks for P and nodulation and Nitrogen fixation are strongly influenced by P availability.

Zinc is also involved directly in the biosynthesis of plant hormones including indole acetic acid and in maintaining normal auxin concentration in tissues. It plays a vital role in the synthesis of protein and nucleic acid and helps in the utilization of nitrogen and phosphorus in plants. It also promotes nitrogen fixation through the nodulation in leguminous crops. Zn solubility decreases markedly above pH 6.065 and thus Zn deficiencies can be encountered in neutral to alkaline soils. Phosphorus and Zinc application improved the fertility status of soil and produce higher grain yield of chickpea. In agriculture it can be improved by inoculation of legume crops with suitable *Rhizobium*. Knowledge of the biodiversity of *Rhizobia* and of local populations is important for the design of successful inoculation strategies [11]. The formation of an effective symbiosis requires the existence of specific rhizobia in the soil that can nodulated host legume or inoculation of with effective rhizobia, and suitable environmental factors. The major abiotic factors that affect effective symbiosis includes the following ones nutrient, pH, temperature, water holding capacity, water stress, salinity and the nitrogen level are the major factors affecting the BNF [12]. The *Rhizobium* legume symbiotic relationship is

highly specific and most legume plants form an association with only a limited number of the *Rhizobium* strain [13]. There is a good possibility to increase its production by exploiting better colonization of the roots and rhizospheres through application of the effective nitrogen fixing bacteria to the seed or to the soil. Microbial inoculants are cost effective, eco-friendly, and renewable sources of plant nutrients [14].

The objective of this research to evaluate the Response of different level of phosphorus, zinc and rhizobium inoculation on growth and yield attributes of chickpea (*Cicer arietinum* L.).

2. METHODS AND MATERIALS

The experiment was carried out in at the SIF Farm of CSAUA&T, Kanpur, Uttar Pradesh. It is located on 25°18' N latitude, 83° 03' E longitude and at an altitude of 80.71 meters above mean sea level. The experimental site area, Kanpur is situated in the central part of U.P. and has sub-tropical climate, characterized by hot summer and cool winters. Total rainfall received during the crop growing period was 15.90 mm during the period from 2020-21 and 2021-22 to study the effect of phosphorus, zinc and rhizobium on growth and yield attributes of chickpea and the improvement of soil health of the research area. The experiment was consisted of three factors: Factor A: Phosphorus (3 levels); P₀: 0 kg (Control), P₁: 30 kg, and P₂: 60 kg P₂O₅; Factor Zn: (3 levels): Zn₀: 0 kg (Control), Zn₁: 2.5 kg and Zn₂: 5 kg Zn ha⁻¹. The experiment was carried out in the Factorial Randomized Complete Block Design (FRBD) with the three replications. A full dose of nitrogen and potash were applied at the time of sowing homogeneously. Phosphorus, zinc and *rhizobium* were applied as per treatments. N, P, K and Zinc were applied through urea, SSP, Murate of potash and zinc

sulphate respectively. The crop received two uniform irrigations (pre sowing and pre flowering). The crop was grown by adopting the standard agronomic practices. The crop was harvested in the last week of March in both the years. Growth process and growth attributes were recorded at harvest. The nutrient status of the initial soil prior to fertilization is presented in Table 1.

The soil samples were analysed for pH, EC by [15] and organic carbon by the method described in previous works [16]. The available N was determined by alkaline per magnate method as described by Subbiah and Asija [17]. The available phosphorus was extracted with 0.5 M NaHCO₃ [18]. The available K was determined by flame photo meter [19]. The available sulphur was determined by Turbidimetric method [20]. The available zinc was determined by DTPA extraction [21].

2.1 Observation Recorded

The observations for evaluation of the treatment effects were recorded on various plant characters during the course of investigation. In the present investigation, the plants were selected randomly in each plot and tagged with a level for recording various observations on growth and yield parameters. The plant height, number of nodules plant⁻¹, dry wt. of nodules plant⁻¹, grain, straw and biological yield were recorded following standard procedures.

2.2 Harvesting and Threshing

The crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually.

Table 1. Analytical data of the experimental soils (pre-sowing)

S. No.	Soil characters	Value	
		2020-21	2021-22
	Texture	Sandy loam	Sandy loam
1.	pH (1:2.5 soil water suspension)	8.00	7.98
2.	EC (dsm ⁻¹) (1:2.5 soil water suspension)	0.47	0.46
3.	Organic carbon (%)	0.31	0.32
4.	Available N (kg ha ⁻¹)	201.12	202.59
5.	Available P (kg ha ⁻¹)	11.78	12.09
6.	Available K (kg ha ⁻¹)	153.15	154.31
7.	Available S (kg ha ⁻¹)	0.43	0.45
8.	Available Zinc (mg kg ⁻¹)	11.84	12.49

Table 2. Detail of the treatment combinations

S. N.	Treatment combination	Symbol
1.	0 kg P+0 kg Zn without <i>rhizobium</i>	P ₀ Zn ₀ Rh ₀
2.	0 kg P+2.5 kg Zn without <i>rhizobium</i>	P ₀ Zn _{2.5} Rh ₀
3.	0 kg P+5 kg Zn without <i>rhizobium</i>	P ₀ Zn ₅ Rh ₀
4.	30 kg P+0 kg Zn without <i>rhizobium</i>	P ₃₀ Zn ₀ Rh ₀
5.	30 kg P+2.5 kg Zn without <i>rhizobium</i>	P ₃₀ Zn _{2.5} Rh ₀
6.	30 kg P+5 kg Zn without <i>rhizobium</i>	P ₃₀ Zn ₅ Rh ₀
7.	60 kg P+0 kg Zn without <i>rhizobium</i>	P ₆₀ Zn ₀ Rh ₀
8.	60 kg P+2.5 kg Zn without <i>rhizobium</i>	P ₆₀ Zn _{2.5} Rh ₀
9.	60 kg P+5 kg Zn without <i>rhizobium</i>	P ₆₀ Zn ₅ Rh ₀
10.	0 kg P+0 kg Zn with <i>rhizobium</i>	P ₀ Zn ₀ Rh ₁
11.	0 kg P+2.5 kg Zn with <i>rhizobium</i>	P ₀ Zn _{2.5} Rh ₁
12.	0 kg P+5 kg Zn with <i>rhizobium</i>	P ₀ Zn ₅ Rh ₁
13.	30 kg P+0 kg Zn with <i>rhizobium</i>	P ₃₀ Zn ₀ Rh ₁
14.	30 kg P+2.5 kg Zn with <i>rhizobium</i>	P ₃₀ Zn _{2.5} Rh ₁
15.	30 kg P+5 kg Zn with <i>rhizobium</i>	P ₃₀ Zn ₅ Rh ₁
16.	60 kg P+0 kg Zn with <i>rhizobium</i>	P ₆₀ Zn ₀ Rh ₁
17.	60 kg P+2.5 kg Zn with <i>rhizobium</i>	P ₆₀ Zn _{2.5} Rh ₁
18.	60 kg P+5 kg Zn with <i>rhizobium</i>	P ₆₀ Zn ₅ Rh ₁

2.2.1 Grain yield (q ha⁻¹)

After threshing the grain yield from each plot was separately weighed and recorded following the converting into quintals per hectare.

2.2.2 Stover yield (q ha⁻¹)

After subtracting the grain yield was stoved per plot from the total biological yield. After converting the yields into quintals per hectare, yields were recorded.

2.3 Statistical Analysis

The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) with tested 5% level of significance to interpret the significant differences.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Generally, growth has a genetically controlled character. But several studies found that growth can be increased by the use of appropriate doses of fertilization. Significantly increased growth characteristics include plant height, number of branch plant⁻¹, number of nodules plants⁻¹ and dry weight of nodule plant⁻¹ use of different level (0, 30 and 60 kg ha⁻¹). The number of increasing level of various doses of phosphorus with *rhizobium* inoculation significantly enhanced plant height, number of branch plant⁻¹, number of nodules plants⁻¹ and dry wt. of nodule plant⁻¹ except plant population during both of the years. The maximum level of

these growth parameters is owing to the supply of essential plant nutrients in use of appropriate amount of fertilizer. This resulted in preferential growth and the development of chickpea plants while, minimum growth parameters were recorded with control. The use of phosphorus may be due to increasing photosynthetic activity, efficient translocation and utilization of photosynthesis causing rapid cell elongation and cell division at entire period of chickpea crop. By the use of *rhizobium* we found the enhanced formation of number of root nodules which fixed the free nitrogen of the atmosphere. This has a better effect on the growth parameters of chickpea plants. These results are in accordance to the findings of Kumar et al. [22], Sharma et al. [23], Tiwari et al. [24], Ram and Dixit [25], Rao and Shaktawat [26], Thenua et al. [27], Zaman et al. [28], Singh et al. [29], Singh et al. [30].

Application of zinc also enhanced growth parameters viz. plant height, number of branch plant⁻¹, number of nodules plants⁻¹ and dry weight of nodule plant⁻¹. Significant increase in the growth characters was recorded upto 2.5 kg Zn ha⁻¹ while plant population effect was found to be non-significant in all level of Zn during both years. Zinc plays pivotal role in regulating the auxin concentration in plant and nitrogen metabolism and might have improved the above stated growth characters. All the interaction effect were found non-significant. These results are in close conformity with those of Pathak et al. [31], Karwasra and Kumar [32], Khan et al. [33], Das et al. [34], Straw [35], Surendra R. [36], Woldearegay et al. [37] and Pal et al. [38].

Table 3. The effects of treatment combinations on growth parameters of chickpea

Treatments	Plant height at 90 DAS			No. of nodules plant ⁻¹			Wt. of root nodules			No. of branch		
	2020-21	2021-22	pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁	31.45	32.45	31.95	17.69	18.05	17.87	118.9	120.35	119.63	13.30	13.47	13.38
T ₂	32.87	33.84	33.36	19.72	20.38	20.05	132.57	142.05	137.31	13.94	14.21	14.08
T ₃	35.12	35.76	35.44	21.87	22.53	22.20	140.25	142.55	141.4	14.36	14.52	14.44
T ₄	34.86	35.12	34.99	21.78	22.21	22.00	139.78	140.98	140.38	14.08	14.59	14.34
T ₅	39.07	39.75	39.41	25.46	26.39	25.93	158.34	159.71	159.03	15.21	15.75	15.48
T ₆	41.94	42.59	42.27	26.35	27.11	26.73	167.45	169.11	168.28	16.1	16.56	16.33
T ₇	39.16	40.06	39.61	25.72	26.47	26.10	160.48	162.63	161.56	15.72	15.86	15.79
T ₈	44.05	45.16	44.61	28.34	28.86	28.60	174.65	175.98	175.32	16.81	16.92	16.87
T ₉	45.35	46.10	45.73	29.03	29.56	30.00	178.51	180.22	179.37	17.12	17.23	17.18
T ₁₀	32.21	33.17	32.69	19.25	20.23	19.74	126.18	127.98	127.08	13.65	13.95	13.8
T ₁₁	35.98	36.84	36.41	22.13	22.87	22.5	144.29	146.74	145.52	14.67	14.72	14.7
T ₁₂	36.85	37.15	37	22.58	23.16	22.87	149.78	151.75	150.77	14.98	15.06	15.02
T ₁₃	38.02	38.69	38.36	23.25	24.08	23.67	155.79	157.32	156.56	14.89	15.06	14.98
T ₁₄	42.21	43.65	42.93	26.47	27.57	27.02	169.54	171.88	170.71	16.54	16.77	16.66
T ₁₅	44.98	46.18	45.58	28.89	29.33	29.11	176.64	178.22	177.43	16.99	17.1	17.05
T ₁₆	43.32	44.75	44.04	27.99	28.15	28.07	172.25	173.44	172.85	16.68	16.81	16.74
T ₁₇	45.98	47.24	46.61	29.46	30.12	29.79	181.48	183.05	182.27	17.39	17.51	17.45
T ₁₈	46.72	48.56	47.64	30.89	31.27	31.08	184.29	185.77	185.03	17.85	18.12	17.99
Overall mean	39.45	40.39	39.92	24.83	25.46	25.14	157.29	159.43	158.36	15.57	15.79	15.68
SEm±	P 0.67	P 0.73	P 0.50	P0.40	P0.45	P 0.30	P1.94	P2.06	P 1.42	P0.18	P0.22	P 0.14
	Zn 0.67	Zn0.73	Zn 0.50	Zn0.40	Zn0.45	Zn 0.30	Zn1.94	Zn2.06	Zn 1.42	Zn0.18	Zn0.22	Zn 0.14
	Rh 0.55	Rh0.60	Rh0.40	Rh0.33	Rh0.36	Rh 0.24	Rh1.59	Rh1.68	Rh 1.16	Rh0.15	Rh0.18	Rh0.12
C.D. at 5%	P 1.92	P 2.09	P 1.36	P1.14	P1.28	P 0.84	P5.59	P5.91	P 4.07	P0.53	P0.64	P0.40
	Zn 1.92	Zn2.09	Zn1.39	Zn1.14	Zn1.28	Zn 0.84	Zn5.59	Zn5.91	Zn 4.07	Zn0.53	Zn0.64	Zn0.40
	Rh 1.57	Rh1.71	Rh1.13	Rh0.93	Rh1.04	Rh 0.68	Rh4.46	Rh4.83	Rh3.32	Rh0.43	Rh0.52	Rh0.33

Table 4. The effects of treatment combinations on yield attributes of chickpea

Treatments	No. of pod plant ⁻¹			No. of grain pod ⁻¹			100 grain weight (gm)		
	2020-21	2021-22	Pooled	2020-21	2020-22	Pooled	2020-21	2021-22	Pooled
T ₁	47.36	48.02	47.49	1.23	1.25	1.24	17.02	17.05	17.04
T ₂	51.53	51.64	51.59	1.41	1.43	1.42	17.24	17.26	17.25
T ₃	52.47	52.75	52.61	1.48	1.49	1.49	17.43	17.45	17.44
T ₄	51.84	52.12	51.98	1.45	1.46	1.46	17.41	17.43	17.42
T ₅	58.89	60.45	59.67	1.57	1.59	1.58	18.3	18.4	18.35
T ₆	63.05	65.15	64.1	1.62	1.65	1.64	18.96	19.07	19.02
T ₇	59.24	61.05	60.15	1.58	1.59	1.59	18.32	18.35	18.34
T ₈	64.13	65.52	64.83	1.68	1.69	1.69	19.06	19.21	19.14
T ₉	65.57	66.09	65.83	1.71	1.73	1.72	19.34	19.48	19.41
T ₁₀	50.62	51.47	51.05	1.39	1.4	1.4	17.13	17.15	17.14
T ₁₁	55.68	56.42	56.05	1.5	1.52	1.51	17.64	17.68	17.66
T ₁₂	56.96	57.78	57.37	1.51	1.53	1.52	17.96	18.07	18.02
T ₁₃	58.67	59.87	59.27	1.54	1.56	1.55	18.09	18.11	18.1
T ₁₄	63.84	65.28	64.56	1.65	1.67	1.66	18.98	19.12	19.05
T ₁₅	65.03	65.95	65.49	1.7	1.71	1.71	19.32	19.45	19.39
T ₁₆	63.97	65.39	64.68	1.67	1.68	1.68	19.03	19.16	19.1
T ₁₇	67.94	68.11	68.03	1.73	1.74	1.74	19.58	19.64	19.61
T ₁₈	68.64	69.54	17.04	1.76	1.78	17.04	19.94	20.19	17.04
Overall mean	59.19	60.14	17.25	1.57	1.58	17.25	18.38	18.46	17.25
SEm±	P 0.58 Zn 0.58 Rh 0.47	P 0.62 Zn 0.62 Rh 0.50	P 0.42 Zn 0.42 Rh 0.35	P 0.03 Zn 0.03 Rh 0.02	P 0.03 Zn 0.03 Rh 0.02	P 0.02 Zn 0.02 Rh 0.02	P 0.17 Zn 0.17 Rh 0.14	P 0.18 Zn 0.18 Rh 0.15	P 0.13 Zn 0.13 Rh 0.10
C.D. at 5%	P 1.67 Zn 1.67 Rh 1.36	P 1.78 Zn 1.78 Rh 1.45	P 1.19 Zn 1.19 Rh 0.97	P 0.08 Zn 0.08 Rh 0.07	P 0.09 Zn 0.09 Rh 0.07	P 0.06 Zn 0.06 Rh 0.05	P 0.50 Zn 0.50 Rh 0.41	P 0.52 Zn 0.20 Rh 0.42	P 0.36 Zn 0.36 Rh 0.29

Table 5. The effect of treatment combinations on productivity parameters

Treatments	Grain yield (q ha ⁻¹)			Stover yield (q ha ⁻¹)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁	12.26	12.52	12.39	17.16	17.79	17.48
T ₂	13.79	14.02	13.91	18.72	18.86	18.79
T ₃	14.68	14.86	14.77	19.68	19.94	19.81
T ₄	14.51	14.61	14.56	19.16	19.36	19.26
T ₅	17.19	17.42	17.31	21.59	21.84	21.72
T ₆	18.05	18.47	18.26	22.05	22.37	22.21
T ₇	17.36	17.68	17.52	21.87	22.03	21.95
T ₈	18.93	19.03	18.98	23.79	23.99	23.89
T ₉	19.25	19.51	19.38	24.08	24.27	24.18
T ₁₀	13.65	13.87	13.76	18.02	18.28	18.15
T ₁₁	14.80	15.10	14.95	20.11	20.61	20.36
T ₁₂	16.39	16.82	16.61	20.79	21.07	20.93
T ₁₃	16.84	17.04	16.94	21.02	21.58	21.30
T ₁₄	18.25	18.63	18.44	22.89	23.10	23.00
T ₁₅	19.12	19.38	19.25	23.97	24.13	24.05
T ₁₆	18.75	18.86	18.81	23.24	23.68	23.46
T ₁₇	19.86	20.11	19.99	24.32	24.59	24.46
T ₁₈	20.58	20.89	20.74	24.95	25.26	25.11
Overall mean	16.90	17.16	17.03	21.52	21.82	21.67
SEm±	P 0.34 Zn 0.34 Rh 0.27	P 0.39 Zn0.39 Rh0.32	P 0.26 Zn 0.26 Rh0.21	P 0.41 Zn 0.41 Rh 0.33	P 0.45 Zn 0.45 Rh 0.37	P 0.30 Zn 0.30 Rh 0.25
C.D. at 5%	P 0.96 Zn 0.96 Rh 0.79	P 1.12 Zn1.12 Rh0.91	P 0.72 Zn0.72 Rh0.59	P 1.17 Zn 1.17 Rh 0.95	P 1.30 Zn 1.31 Rh 1.06	P 0.85 Zn 0.85 Rh 0.70

3.2 Yield and Yield Attributes

Application of phosphorus enhanced all yield and yield attributes viz. the number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield, biological yield and harvest index. Significant increase in all level of phosphorus with rhizobium yield parameters was detected during both of the years except harvest index during second years. This includes for instance, number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield and biological yield. The enhancement in yield attributes due to phosphorus may be due to the enriched nutritional conditions of the plants. It may also owing to the all metabolic processes, such as photosynthesis, glycolysis and respiration are based on action of co-enzymes like NAD and NADP which are dependent on phosphorus. Similar observations were also reported by Sinha et al. [39], Vimla and Natarajan [40], Tiwari et al. [41], Yadav et al. [42], Bicer [43], Badini et al. [44], Pegoraro et al. [45], Singh et al. [46] and Pal et al. [47].

The application of different level of Zn considerably enhanced all characters of yield attributes viz., number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield, biological yield and harvest index while significantly increased yield characters viz. number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield and biological yield except for harvest index during the both years of chickpea crop. Similar findings were also reported by Mali et al. [48], Yadav et al. [49], Valenciano et al. [50], Kumari et al. [51], Raj et al. [52], Singh et al. [53] Patel et al. [54] and Yadav et al. [55]

4. CONCLUSION

The current study demonstrate the benefit of phosphorus, zinc and *rhizobium* alone with recommended N, K for achieving higher growth parameters and productivity by chickpea crop. Application of phosphorus, zinc and rhizobium inoculation increased yield attributes and yield of chickpea crop. Finally it can be concluded that the treatment T₁₈ [60 kg P+ 5.0 kg ha⁻¹ Zn with *Rhizobium*] is a best option for improving the productivity of chickpea crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Jukanti AK, Gaur PM, Gowda CLL, Chibbar RN. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.). A review British J. Nutr. 2012;108:S11-26.
- Redden B, furman BJ, Upadhyaya HD, Pundir RPS, Gowda CLL, Coyne C, Enne King D. Biodiversity Management in Chickpea. In: Yadav, S, S., Redden R, Chen, W., Sharma, B., editors. Chickpea Breeding & Management. CABI, Wallingford, UK. 2007:355-368.
- Bejiga G, van der Maesen LJG. *Cicer arietinum* L. Plant resources of tropical Africa. 2006;1:42-6.
- Pingoliya K, K, Dotaniya M, L, Mathur A, K. Role of phosphorus and iron in chickpea (*Cicer arietinum* L.). Germany: Lap Lambert Academic Publisher; 2013.
- FAOSTAT. Database of Food and Agriculture Organization of the United Nations. Available:<http://www.fao.org/faostat/en/>; 2017 [accessed Mar 10 2017].
- Anonymous. Agricultural statistics at a glance 2020. Directorate of economics & statistics, department of agriculture, cooperation and farmers welfare. New Delhi: Ministry of Agriculture & Farmers Welfare, Govt of India. 2021:63.
- Mhango WG, Mughogho SK, Sakala WD, Saka AR. The effect of phosphorous and sulphur fertilizers on grain Legumes and maize productivity in Northern Malawi. Bunda journal of agriculture. Environ Sci Technol. 2008;3:20-7.
- Schulze J, Temple G, Temple SJ, Beschow H, Vance CP. Nitrogen fixation by white lupin under phosphorus deficiency. Ann Bot. 2006;98(4):731-40.
- Plaxton WC. Plant response to stress: biochemical adaptations to phosphate deficiency. In: Goodman R, editor Encyclopedia of plant and crop science. New York: Marcel Dekker. 2004:976-80.
- Rehan W, Jan A, Liaqat W, Jan FM, Ahmadzai MD, Ahmad H et al. Effect of phosphorous, rhizobium inoculation and residue types on chickpea productivity. Pure Appl Biol. 2018;7(3): 1203-13.
- Lindström K, Murwira M, Willems A, Altier N. The biodiversity of beneficial microbe-

- host mutualism: the case of Rhizobia. Res Microbiol. 2010;161(6):453-63.
12. Panchali K. Symbiotic nitrogen fixation and seed development of genetically modified soyabean in relation to Bradyrhizobium inoculation and nitrogen use under acidic and saline dykeland and soil conditions [MSc thesis]. Nova, Scotia: Dalhousie University; 2011.
 13. Subba Rao NS. Soil microorganisms and plant growth soil microbiology; 1999. p. 166-217.
 14. Khan MS, Zaidi A, Wani PA. Role of phosphate solubilizing microorganisms in sustainable agriculture. Agron Sustain Dev. 2007;27(1):29-43.
 15. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd; 1973.
 16. Walkley A, Black IA. Old piper, S.S. soil and plant analysis. Soil Sci. 1934;37(1): 29-38.
 17. Subbiah BV, Asija CL. A rapid procedure for the estimation of available N in Soil. Curr Sci. 1956;25:259-60.
 18. Olsen SR, Cole CV, Watanable FS, Dean LA. Estimation of available phosphorous in soil by extraction with sodium bicarbonate. USDA Cric. 1954;930: 19-23.
 19. Hanway JJ, Heidel H. Soil analysis methods as used in Iowa State College, Soil Testing Laboratory. Iowa Agric. 1952;54:1-31.
 20. Chesnin L, Yien CH 1950. Turbidimetric determination of available sulphate, Soil sci. Am. Proc.15: 149-51.
 21. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci Soc Am J. 1978;42(3):421-8.
 22. Kumar A, Lai SB, Roy UK. Effect of Rhizobium culture and different levels of phosphorus on nodulation, growth and yield of groundnut (*Arachis hypogaea* L.). New Agric. 2000;11:113-7.
 23. Sharma SC, Vyas AK, Shakawat MS. Effect of levels and sources of phosphorus under the influence of farmyard manure on growth determinants and productivity of soybean (*Glycine max* (L.) Merrill). Indian! Agric Res. 2002;36(2):123-7.
 24. Tiwari VN, Singh Hari, Upadhyay RM, Pandey RK, Mishra SK. Relative efficiency of phosphatic fertilizers for BNF yield and quality of chickpea and pea. Annals Plant Soil Res. 2000;2(2):180-6.
 25. Ram SN, Dixit RS. Growth, yield attributing parameters and quality of summer green gram as influenced by dates of sowing and phosphorus. Indian J Agric Res. 2001; 35:275-7.
 26. Rao SS, Shaktav MS. Effect of organic manure, phosphorus and gypsum on growth, yield and quality of groundnut (*Arachis hypogaea* L. Indian J Plant Physiol. 2001;6:306-11.
 27. Thenua OVS, Singh SP, Shivakumar BG. Productivity and economics of chickpea (*Cicer arietinum*)-fodder sorghum (*Sorghum bicolor*) cropping system as influenced by P sources, bio-fertilizers and irrigation to chickpea. Indian J Agron. 2010;55(1):22-7.
 28. Zaman S, Mazid MA, Kabir Golam. Effect of Rhizobium inoculant on nodulation, yield and yield traits of chickpea (*Cicer arietinum* L.) in four different soils of greater rajshahi, Bangladesh. J Life Earth Sci. 2011;6: 45-50.
 29. Singh VV, Singh DK, Sharma PK, Singh RK, Singh P. Interaction effect of phosphorus and sulphur on growth, yield and mineral composition of mungbean (*Vigna radiata* L. Wilzeck). J Indian Soc Soil Sci. 2014;62(2):179-83.
 30. Singh R, Pratap T, Singh D, Singh G, Singh AK. Effect of phosphorus, sulphur and biofertilizers on growth attributes and yield of chickpea (*Cicer arietinum* L.). J Pharmacogn Phytochem. 2018;7(2): 3871-5.
 31. Pathak S, Namdeo KN, Chakrawarti VK, Tiwari RK. Effect of biofertilizers, diammonium phosphate and zinc sulphate on nutrient contents and uptake of chickpea (*Cicer arietinum* L.). Crop Res. 2003;26(1):47-52.
 32. Karwasra RS, Kumar Y, Yadav AS. Effect of phosphorus and sulphur on greengram (*Phaseollus Radiatus*). Haryana J Agron. 2007;22(2):164-5.
 33. Khan MU, Qasim M. Effect of Zn fertilizer on rice grown in different soils of Dera Ismail Khan. Sarhad J Agric. 2007;23(4): 1033.
 34. Das S, Pareek N, Raverkar KP, Chandra R, Kaustav A. Effectiveness of micronutrient application and Rhizobium inoculation on growth and yield of

- Chickpea. Int J Agric Environ Biotechnol. 2012;5(4):445-52.
35. Straw S. Response of chickpea to levels of zinc and phosphorus. Annals Plant Soil Res. 2014;16(2):172-3.
 36. Surendra R. Response of sulphur and zinc nutrition on yield attributes, yield of mungbean (*Vigna radiata* L. Wilczek) under partially reclaimed saline-sodic soil in eastern U.P., India. Plant Arch. 2018;18;Special Issue (ICAAAS-2018), 2018:177-81.
 37. Woldearegay BS, Argaw A, Feyisa T, Abdulkadir B, Wold-Meskel E. Response of chickpea (*Cicer arietinum* L.) to sulphur and zinc nutrients application and rhizobium inoculation in North Western Ethiopia. Turkish JAF Sci.Tech. 2020;8(10):2040-8.
 38. Pal S, Pandey SB, Singh A, Singh S, Sachan R, Yadav A. Effect of phosphorus, Boron and Rhizobium inoculation on productivity and profitability of chickpea; 2021.
 39. Sinha BN, Mehta BS, Mandal J. Quality and seed yield of garden pea (*Pisum sativum*) cultivars as influenced by date of planting and phosphorus levels. Indian J Agric Sci. 2000;70:248-9.
 40. Vimla B, Natarajan S. Effect of nitrogen, phosphorus and biofertilizers on pod characters, yield and quality in pea (*Pisum sativum* L. spp. hortense). S Indian Hortic. 2000;48:60-3.
 41. Tiwari VN, Upadhyay R, M, Pandey RK. Associate effect of diazotrophs and phosphorus on chickpea. Indian J Pulse Res. 2001;14(129):132.
 42. Yadav PS, Kameeria PR, Rathore S. Effect of phosphorus and iron fertilization on yield, protein content and nutrient uptake in gram (*Cicer arietinum* L.) on loamy sand soil. J Indian Soc Soil Sci. 2002;50: 225-6.
 43. Bicer BT. The effect of phosphorus doses on chickpea cultivars under rainfall conditions. Cercet Agronom Moldova, Vol. XL VII. 2014;2(158):89-95.
 44. Badini SA, Khan M, Baloch SU, Baloch SK, Baloch HN, Bashir W et al.; 2015. Effect of phosphorus levels on growth and yield of chickpea (*Cicer arietinum* L.) varieties. Journal of Natural Sciences Research. Vol. 5(3): ISSN 2224-3186 [paper] ISSN 2225-0921 [online].
 45. Pegoraro RF, Almeida Neta MNd, Costa CA, Sampaio RA, Fernandes LA, Neves Rodrigues M. Chickpea production and soil chemical attributes after phosphorus and molybdenum fertilization. Ciênc. agrotec. 2018;42(5):474-83.
 46. Singh A, Singh D, Kumar R, Chandel RS, Pal S, Singh S 2021. Impact of organic, inorganic and biofertilizers on yield attributing parameters and quality of chickpea (*Cicer arietinum* L.).
 47. Pal S, Pandey SB, Kumar R, Singh D, Singh A, Singh S. Response of phosphorus, boron and rhizobium inoculation on growth attributes and productivity of chickpea; 2021.
 48. Mali GC, Sharma NN, Acharya HK, Gupta SK, Gupta PK. Response of pigeon pea to S and Zn fertilization on vertisols in south-eastern plain of Rajasthan. Adv Arid Legumes Res. 2003:267-71.
 49. Yadav MK, Singh, BHAGWA N. Singh, A.K., Mahajan, G. A. Univ Rev A:V., Kumar, R. A. K. E. S. H., Singh, M. K., & Balai, S. R. (2010). Response of Chickpea (*Cicer arietinum* L.) to Sowing Methods and Zinc Sulphate Levels under Rainfed Condition of Eastern Uttar Pradesh. Environment and Ecology, 28(3), 1652-1654.
 50. Valenciano JB, Boto JA, Marcelo V. Chickpea (*Cicer arietinum* L.) response to zinc, boron and molybdenum application under field conditions. N Z J Crop Hortic Sci. 2011;39(4):217-29.
 51. Kumari N, Mondal S, Mahapatra P, Meetei TT, Bijilaxmi Devi YB. Effect of biofertilizer and micronutrients on yield of chickpea. Int J Curr Microbiol Appl Sci. 2019;8(1):2389-97.
 52. Raj AB, Raj SK. Zinc and boron nutrition in pulses: a review. J Appl Nat Sci. 2019;11(3):673-9.
 53. Singh AK, Dimree S, Kumar A, Sachan R, Sirohiya A, Nema S. Effect of rhizobium inoculation with different levels of inorganic fertilizers on yield, nutrient content & uptake of chickpea (*Cicer arietinum* L.). IJPSS. 2022:262-8.
 54. Patel KK, Pandey AK, Baheliya AK, Rai R, Bhadauria S, Sachan R. Production and economic feasibility of chickpea (*Cicer arietinum* L.) by the diverse bioinputs and soil nutrients amendments. IJPSS. 2022:15-24.

55. Yadav P, Yadav DD, Pandey HP, Yadav A, Sachan R, Yadav S. Effect of fertility levels and biofertilizers on growth parameters, root architecture and quality of chickpea (*Cicer arietinum* L.). IJPSS. 2022:61-7.

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