Response of different level of phosphorus, zinc and rhizobium inoculation on growth yield attributes and yield of chickpea(*Cicer aretinum* L.)

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 deign 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 T_{18} (P_{60}+$Zn_{2.5}$+ *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 been an effective option for enhancing the chickpea growth parameters, yield attributes and yield of chickpea.

Key Words: Chickpea, Phosphorous, Rhizobium, Yield and Zinc

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 **(Jukanti *et al.* 2012)**. India is the largest producer and consumer of pulses in the world. Major pulses grown in India include chickpea, pigeonpea, lentil, urd bean, mung bean, pea, lablab bean, moth bean, and horse bean. Among the pulses, chickpea is the most important growingin every part of India.Chickpea (*Cicer arietinum* L.) is one of the pre-dominant *Rabi* crop in pulse-growing areas in India. It isoriginated in south eastern Turkey **(Redden *et al.* 2007).** 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 **(Bejiga and Van der Maesen, 2006)**. 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 **(Pingoliya *et al.* 2013).** Many attractive dishes viz.,– sweets, snacks and namkeen are also prepared from its floor 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 bloodpurifiers**.** 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) **(FAOSTAT, 2017).**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 **(Anonymous, 2021).**

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 **(Mhango *et al.*, 2008).**Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy **(Schulze *et al.*, 2006)** and energy generating metabolism strongly depends upon the availability of P **(Plaxton, 2004).**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 **(Rehan *et al.* 2018).** 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. Inagriculture 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 **(Lindstrȍm *et al.*, 2010)**. 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 **(Panchali, 2011)**. The *Rhizobium* legume symbiotic relationship is highly specific and most legume plants form an association with only a limited number of the *Rhizobium* strain **(Subba Rao. 1999).** 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 costeffective, eco-friendly, and renewable sources of plant nutrients **(Khan *et al.* 2007).**

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

Methods& 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^{0} 03′ E longitude and at an altitude of 80.71 meters above meansea 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); P_0: 0 kg

(Control), P_1: 30 kg, and P_2: 60 kg P_2O_5; Factor Zn: (3 levels): Zn_0: 0 kg (Control), Zn_1 : 2.5 kg and Zn_2: 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.

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

The soil samples were analysed for pH, EC by **(Jackson, 1973)**and organic carbon by the method described in previous works**(Walkley and Black, 1934).**The available N was determined by alkaline per magnate method as described by**Subbiah and Asija (1956).**The available phosphorus was extracted with 0.5 M $NaHCO_3$**(Olsen *et al.* 1954).** The available K was determined by flame photo meter (**Hanwey and Heidel, 1952**). The available sulphur was determined by Turbidimetric method **(Chesnin and Yien 1950).**The available zinc was determined by DTPA extraction **(Lindsay and Norvell 1978).**

Table -2: Detail of the treatment combinations/:

S. N.	Treatment combination	Symbol
1.	0 kg P+0 kg Zn without *rhizobium*	$P_0 Zn_0 Rh_0$
2.	0 kg P+2.5 kg Zn without *rhizobium*	$P_0 Zn_{2.5} Rh_0$
3.	0 kg P+5 kg Zn without *rhizobium*	$P_0 Zn_5 Rh_0$
4.	30 kg P+0 kg Zn without *rhizobium*	$P_{30} Zn_0 Rh_0$
5.	30 kg P+2.5 kg Zn without *rhizobium*	$P_{30} Zn_{2.5} Rh_0$
6.	30 kg P+5 kg Zn without *rhizobium*	$P_{30} Zn_5 h_0$
7.	60 kg P+0 kg Zn without *rhizobium*	$P_{60} Zn_0 Rh_0$
8.	60 kg P+2.5 kg Zn without *rhizobium*	$P_{60} Zn_{2.5} Rh_0$
9.	60 kg P+5 kg Zn without *rhizobium*	$P_{60} Zn_5 Rh_0$
10.	0 kg P+0 kg Zn with *rhizobium*	$P_0 Zn_0 Rh_1$
11.	0 kg P+2.5 kg Zn with *rhizobium*	$P_0 Zn_{2.5} Rh_1$
12.	0 kg P+5 kg Zn with *rhizobium*	$P_0 Zn_5 Rh_1$
13.	30 kg P+0 kg Zn with *rhizobium*	$P_{30} Zn_0 Rh_1$
14.	30 kg P+2.5 kg Zn with *rhizobium*	$P_{30} Zn_{2.5} Rh_1$
15.	30 kg P+5 kg Zn with *rhizobium*	$P_{30} Zn_5 Rh_1$
16.	60 kg P+0 kg Zn with *rhizobium*	$P_{60} Zn_0 Rh_1$
17.	60 kg P+2.5 kg Zn with *rhizobium*	$P_{60} Zn_{2.5} Rh_1$
18.	60 kg P+5 kg Zn with *rhizobium*	$P_{60} Zn_5 Rh_1$

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.

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.

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.

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.

Statistical analysis: The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) with tested5% level of significance to interpret the significant differences.

Result and discussion

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 includeplant 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.* (2000), Sharma *et al.* (2002)**, **Tiwari *et al.* (2000), Ram and Dixit (2001), Rao and Shaktawat (2001), Thenua *et al.* (2010), Zaman *et al. (*2011), Singh *et al.* (2014), Singh *et al.* (2018).**

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.* (2003)**, **Karwasra and Kumar (2007), Khan *et al.* (2007), Das *et al.* (2012), Straw (2014), Surendra R. (2018), Woldearegay *et al.* (2020) and Pal *et al.* (2021).**

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 Zn 0.67 Rh 0.55	P 0.73 Zn0.73 Rh0.60	P 0.50 Zn 0.50 Rh0.40	P0.40 Zn0.40 Rh0.33	P0.45 Zn0.45 Rh0.36	P 0.30 Zn 0.30 Rh 0.24	P1.94 Zn1.94 Rh1.59	P2.06 Zn2.06 Rh1.68	P 1.42 Zn 1.42 Rh 1.16	P0.18 Zn0.18 Rh0.15	P0.22 Zn0.22 Rh0.18	P 0.14 Zn 0.14 Rh0.12
C.D. at 5%	P 1.92 Zn 1.92 Rh 1.57	P 2.09 Zn2.09 Rh1.71	P 1.36 Zn1.39 Rh1.13	P1.14 Zn1.14 Rh0.93	P1.28 Zn1.28 Rh1.04	P 0.84 Zn 0.84 Rh 0.68	P5.59 Zn5.59 Rh4.46	P5.91 Zn5.91 Rh4.83	P4.07 Zn4.07 Rh3.32	P0.53 Zn0.53 Rh0.43	P0.64 Zn0.64 Rh0.52	P0.40 Zn0.40 Rh0.33

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.* (2000), Vimla and Natarajan (2000), Tiwari *et al.* (2001), Yadav *et al.* (2002), Bicer (2014), Badini *et al.* (2015),Pegoraro *et al. (20*18), Singh *et al.* (2021) and Pal *et al.* (2021)**

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.* (2003), Yadav *et al.* (2010), Valenciano *et al.* (2011), Kumari *et al.* (2019), Raj *et al.* (2019**), **Singh *et al.* (2022)Patel *et al.* (2022) and Yadav *et al.* (2022)**

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

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 T_{18} [60 kg P+ 5.0 kg ha^{-1} Zn with *Rhizobium*] is a best option for improving the productivity of chickpea crop.

References-

Anonymous. (2021). Agricultural Statistics at a Glance 2020. Directorate of Economics & Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Govt. of India, New Delhi, p. 63.

Badini, S.A., Khan, M., Baloch, S.U., Baloch, S.K., Baloch, H.N., Bashir, W., Badini, A.R. Badini, M.A.(2015). Effect of Phosphorus Levels on Growth and Yield of Chickpea (*Cicer aretinum* L.) Varieties. *Journal of Natural Sciences Research*. 5 (3): ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online).

Bejiga, G. and van der Maesen, L. J. G. (2006).*Cicer arietinum* L. *Plant Resources of Tropical Africa*, **1**, 42-46.

Bicer, B.T. (2014). The effect of phosphorus doses on chickpea cultivars under rainfall conditions. *Cercetari Agronomice in Moldova*, Vol. XL VII, No. 2 (158): 89- 95.

Chesnin, L. and Yien, C.H. (1950). Turbidimetric determination of available sulphate, *Soil sci. Am. Proc.*15: 149-151.

Das, S., Pareek, N., Raverkar, K. P., Chandra, R., & Kaustav, A. (2012). Effectiveness of micronutrient application and Rhizobium inoculation on growth and yield of Chickpea. *International Journal of Agriculture, Environment and Biotechnology*, *5*(4), 445-452.

FAOSTAT, (2017). Database of Food and Agriculture Organization of the United Nations-http://www.fao.org/faostat/en/ (accessed 10 March 2017).

Hanway, J.J; and Heidel, H. (1952). Soil analysis methods as used in Iowa State College, Soil Testing Laboratory. *Iowa Agriculture* **54**: 1-31.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd, New Delhi.

Jukanti, A.K., Gaur, P.M., Gowda, C.L.L. and Chibbar, R.N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.). *A Review British J. Nutr*. **108**:S11-S26.

Karwasra, R.S., Kumar, Y. and Yadav, A.S. (2007). Effect of phosphorus and sulphur on greengram (Phaseollus radiatus). *Haryana Journal of Agronomy* 22 (2): 164-165.

Khan, M. S., Zaidi A., and Wani, P. A., (2007). Role of phosphate solubilizing microorganisms in sustainable agriculture. *Agronomy for Sustainable Development*, **27**: 29–43.

Khan, M. U., & Qasim, M. (2007). Effect of Zn fertilizer on rice grown in different soils of Dera Ismail Khan. *Sarhad Journal of Agriculture*, *23*(4), 1033.

Kumar, A., Lai, S.B. and Roy, U.K. (2000). Effect of Rhizobium culture and different levels of phosphorus on nodulation, growth and yield of groundnut (Arachis hypogaea L.). *New Agric*. 11: 113-117.

Kumari, N., Mondal, S., Mahapatra, P., Meetei, T.T. and Devi, Y.B. (2019). Effect of Biofertilizer and Micronutrients on Yield of Chickpea, *InternationalJournal of Current Microbiology and Applied Sciences***8**(1): 2389-2397.

Lindsay, W. L., & Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal*, *42*(3), 421-428.

Lindstrỏm, K., Murwira, M., Willems, A. and Altier, N. (2010). The biodiversity of beneficial microbe-host mutualism: the case of *Rhizobia*. *Research in Microbiology* **161**: 453-463.

Mhango, W.G., Mughogho, S.K., Sakala, W.D. and Saka A.R. (2008). The effect of phosphrous and sulphur fertilizers on grain Legumes and maize productivity in Northern Malawi. *Bunda Journal of Agriculture, Environmental Science and Technology* **3**: 20-27.

Mali, G. C., Sharma, N. N., Acharya, H. K., Gupta, S. K., & Gupta, P. K. (2003). Response of pigeonpea to S and Zn fertilization on vertisols in south-eastern plain of Rajasthan. *Advances in arid legumes research*, 267-271.

Olsen, S.R, Cole, C.V., Watanable, F. S. and Dean, L. A. (1954). Estimation of available phosphorous in soil by extraction with sodium bicarbonate. *USDA, Cric*. **930**:19- 23

Pal, S., Pandey, S. B., Singh, A., Singh, S., Sachan, R., & Yadav, A. (2021). Effect of Phosphorus, Boron and Rhizobium inoculation on productivity and profitability of chickpea.

Pal, S., Pandey, S. B., Kumar, R., Singh, D., Singh, A., & Singh, S. (2021). Response of phosphorus, boron and rhizobium inoculation on growth attributes and productivity of chickpea.

Panchali, K. (2011). 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, Dalhousie University, Nova Scotia.

Patel, K. K., Pandey, A. K., Baheliya, A. K., Rai, R., Bhadauria, S., & Sachan, R. (2022). Production and Economic Feasibility of Chickpea (*Cicer arietinum* L.) by the Diverse Bioinputs and Soil Nutrients Amendments.

Pathak, Satyajit; Namdeo, K. N.; Chakrawarti, V. K. and Tiwari, R. K. (2003). Effect of biofertilizers, diammonium phosphate and zinc sulphate on nutrient contents and uptake of chickpea (*Cicer arietinum* L.). *Crop Research*, **26**(1): 47-52.

Pegoraro, R. F., Almeida Neta, M. N. D., Costa, C. A. D., Sampaio, R. A., Fernandes, L. A., & Neves Rodrigues, M. (2018). Chickpea production and soil chemical attributes after phosphorus and molybdenum fertilization. *Ciência e Agrotecnologia*, *42*, 474-483.

Pingoliya, K, K., Dotaniya, M, L., Mathur, A, K. (2013). Role of phosphorus and iron in chickpea (Cicer arietinum L.). *Lap Lambert Academic Publisher,Germany*.

Plaxton, W.C. (2004). Plant response to stress: biochemical adaptations to phosphate deficiency. *In:* Goodman R (eds.) *Encyclopedia of Plant and Crop Science*. New York: Marcel Dekker. pp.976-980.

Raj, B.A. and Sheeja, K.R. (2019). Zinc and boron nutrition in pulses: A review**,** *Journal of Applied and Natural Science***11**(3): 673-679.

Ram, S.N. and Dixit, R.S. (2001). Growth, yield attributing parameters and quality of summer green gram as influenced by dates of sowing and phosphorus. *Indian Journal of Agriculture Research*, 35: 275-277.

Rao, S.S. and Shaktav, M.S. (2001). Effect of organic manure, phosphorus and gypsum on growth, yield and quality of groundnut {Arachis hypogaea L.). *Indian J. Plant Physiol*. 6: 306-311.

Redden, B., furman, B, J., Upadhyaya, H, D., Pundir R, P, S., Gowda, C, L, L., Coyne, C., Enne King, D., (2007). Biodiversity Management in Chickpea. In: Yadav, S, S., Redden R., Chen, W., Sharma, B., editors. Chickpea Breeding & Management. CABI, Walling ford, UK. Pp355-368.

Rehan, W., Jan, A., Liaqat, W., Jan, F.M., Ahmadzai, M.D., Ahmad, H., Haroon, J., Anjum, M.M. and Ali, N. (2018). Effect of phosphorous, rhizobium inoculation and residue types on chickpea productivity. *Pure Appl. Biol.,* **7**(4):1203-1213.

Schulze, J., Temple, G., Temple, S.J., Beschow, H., and Vance, C.P. (2006). Nitrogen fixation by white lupin under phosphorus deficiency. *Annals of Botany* **98**: 731-740.

Sharma, S.C, Vyas, A.K. and Shakawat, M.S. (2002). 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.* 36(2): 123-127.

Singh, V.V.; Singh, D.K., Sharma, P.K., Singh, R.K. and Singh, Priyanka (2014). Interaction effect of phosphorus and sulphur on growth, yield and mineral composition of mungbean (*Vigna radiata* L. Wilzeck). *Journal of the Indian Society of Soil Science,* 62 (2): 179-183.

Singh, A. K., Dimree, S., Kumar, A., Sachan, R., Sirohiya, A., & Nema, S. (2022). Effect of Rhizobium Inoculation with Different Levels of Inorganic Fertilizers on Yield, Nutrient Content & Uptake of Chickpea (*Cicer arietinum* L.).

Singh, A., Singh, D., Kumar, R., Chandel, R. S., Pal, S., & Singh, S. (2021). Impact of organic, inorganic and biofertilizers on yield attributing parameters and quality of chickpea (*Cicer arietinum* L.).

Singh, R., Pratap, T., Singh, D., Singh, G., & Singh, A. K. (**2018**). Effect of phosphorus, Sulphur and biofertilizers on growth attributes and yield of chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry, 7*(2), 3871-3875.

Sinha, B.N., Mehta, B.S. and Mandal, J. (2000). Quality and seed yield of garden pea (*Pisum sativum*) cultivars as influenced by date of planting and phosphorus levels. Indian J. Agric. Sci. 70: 248-249.

Straw, S. (**2014**). Response of chickpea to levels of zinc and phosphorus. *Annals of Plant and Soil Research*, *16*(2), 172-173.

Subba Rao, N.S. (1999). In: Soil microorganisms and plant growth soil microbiology. pp. 166- 217.

Subbiah, B.V. and Asija, C.L. (1956). A rapid procedure for the estimation of available N in Soil. *Curr. Sci.* **25**:259-260.

Surendra R. (2018). 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 Archives* Vol. 18, Special Issue (ICAAAS-2018), 2018 pp. 177-181.

Thenua, O. V. S.; Singh, S. P. and Shivakumar, B. G. (2010). Productivity and economics of chickpea (*Cicer arietinum*)-fodder sorghum (Sorghum bicolour) cropping system as influenced by P sources, bio-fertilizers and irrigation to chickpea. *Indian Journal of Agronomy*, **55**(1): 22-27.

Tiwari, V.N., Upadhyay, R, M. and Pandey RK (2001). Associate effect of diazotrophs and phosphorus on chickpea. *Indian J. Pulse Res.* 14:129 132.

Tiwari, V. N., Hari Singh, R. M. Upadhyay, R. K. Pandey and S. K. Mishra (2000). Relative efficiency of phosphatic fertilizers for BNF yield and quality of chickpea and pea. *Annals of Plant and Soil Res.*, 2(2): 180-186.

Valenciano, J.B., Boto, J.A. and Marcelo, V. (2011). Chickpea (*Cicer arietinum* L.*)* response to zinc, boron and molybdenum application under field conditions, *New Zealand Journal of Crop and Horticultural Science Vol.***39**(4), 217-229.

Vimla, B. and Natarajan, S. (2000). Effect of nitrogen, phosphorus and biofertilizers on pod characters, yield and quality in pea (Pisum sativum L. spp. hortense). *South Indian Horticulture*, 48: 60-63.

Walkley, A. and Black, C. S.A. (1934). Old piper, S.S. soil and plant analysis. Soil Sci. 37:29- 38.

Woldearegay, B. S., Argaw, A., Feyisa, T., Abdulkadir, B., & Wold-Meskel, E. (2020). Response of Chickpea (*Cicer ariteinum* L.) to Sulphur and Zinc Nutrients Application and Rhizobium Inoculation in North Western Ethiopia. *Turkish Journal of Agriculture-Food Science and Technology*, *8*(10), 2040-2048.

Yadav, M. K., Singh, B. H. A. G. W. A. N., Singh, A. K., Mahajan, G. A. U. R. 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.

Yadav, P.S., Kameria, P.R. and Rathore, S. (2002). Effect of phosphorus and iron fertilization on yield, protein content and nutrient uptake in gram (*Cicer arietinum* L.) on loamy sand soil. *Journal of the Indian Society of Soil Science* 50: 225-226.

Yadav, P., Yadav, D. D., Pandey, H. P., Yadav, A., Sachan, R., & Yadav, S. (2022). Effect of Fertility Levels and Biofertilizers on Growth Parameters, Root Architecture and Quality of Chickpea (*Cicer arietinum* L.).

Zaman S., M. Abdul Mazid and Golam Kabir (2011). Effect of Rhizobium inoculant on nodulation, yield and yield traits of chickpea (*cicer arietinum* L.) in four different soils of greater rajshahi, Bangladesh. *J. of Life Earth Sci*, 6: 45-50.