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Effect of Phosphorus, and Zinc on Growth, Yield and Economics of Chickpea (*Cicer aritinum* L.)

Kuldeep Balai[1], Y. Sharma[1], M. Jajoria[2], P. Deewan[2] and R. Verma[2*]

[1]College of Agriculture, S. K. R. A. U., Bikaner, Rajasthan, India
[2]SKN College of Agriculture, S. K. N. A. U., Jobner, Rajasthan, India
**Corresponding author:*

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A B S T R A C T

A field experiment was conducted at Agronomy farm, College of Agriculture, Bikaner during *Rabi*, 2009-10. The experiment was laid out in factorial randomized block design with three replications, assigning twelve treatments consisting of four levels of phosphorus (control, 20, 40 and 60 kg ha^{-1}) and three levels of zinc (control, 3.0 and 6.0 kg ha^{-1}). The results indicated that the application of phosphorus up to 40 kg ha^{-1} significantly increased the plant growth (plant height at 60, 90, at harvest, dry matter accumulation at 60, 90 and 120 DAS and nodules per plant), yield attributes (grain pod^{-1}, pods plant^{-1}), yield (grain, straw and biological yield), net returns (Rs. 21006.58 ha^{-1}), B:C ratio (2.58) whereas, dry matter accumulation at 30 DAS, primary and secondary branches at 60 DAS and at harvest, increasing dose of zinc up to 6 kg ha^{-1} significantly increased the plant growth (Primary and secondary branches plant^{-1} at 30 DAS and at harvest, dry matter accumulation at 60, 90 and 120 DAS, chlorophyll content, nodules plant^{-1}), yield attributes (grains pod^{-1}, pods plant^{-1}), yield (grain, straw and biological yield), net returns (Rs. 21810.83 ha^{-1}), B:C ratio (2.62) whereas, phosphorus content in grain and straw decreased with the increasing level of zinc. Dry matter accumulation at 30 DAS and plant height at different stages significantly increased only up to application of zinc 3 kg ha^{-1}. The combined effect of phosphorus x zinc were found significant for nodules per plant, pods per plant, grain yield.

Introduction

Chickpea (*Cicer aritinum* L.), rich in protein and vital mineral nutrients, is an important component of diet in developing countries, which grown in rainfed areas in semiarid/arid climate of world. It contributes significantly to soil fertility through biological nitrogen fixation. However, its productivity remains low in India and, therefore, it is great concern to achieve desired production of chickpea (Siddiqui *et al.*, 2015). Its requirement in India is projected to be around 10.22 million tones by the year 2030 that's needs a 4% increase in the annual growth rate (IIPR, 2011). The current average global yield of chickpea is 0.9 t ha-1, which is much lower than its estimated potential of 6 t ha^{-1} under the optimum cultivation conditions (FAO, 2012). Plant nutrients are the main source for improving the quality and quantity of chickpea. The non-availability of nutrients is a major constraint of crop productivity and soil fertility, which imbalanced use of plant nutrients markedly affects the crop growth and yield (Siddiqui *et al.*, 2015).

Phosphorus fertilizers seem to be an important constraint in bumper harvest of the crop in most of the chickpea growing areas which are deficient in phosphorus. The supply of phosphorus to legumes is more important than of nitrogen because, later being fixed by symbiosis with *Rhizobium* bacteria. Phosphorus stimulates nodulation, early root development, plant growth, yield and quality of grains etc. It gives rapid and vigorous start to plants, strengthens straw and decreases lodging tendency. Phosphorus application to legumes not only benefits the current crop but also favorably affects the succeeding non-legume crop. It also improves the crop quality and resistance against plant diseases. Availability of soil P is critical for growth and development of chickpea, and a poor P availability limits its productivity. Phosphorus deficiency is a critical nutrient-deficiency problem in the Indian soils and may cause up to 29-45% yield losses in chickpea (Ahlawat *et al.*, 2007).

Zinc deficiency in agricultural soils is also a wide-spread constraint for chickpea production in India (Ahlawat *et al.*, 2007; Singh, 2008). P and Zn facilitate the availability of each other for crop plants (Ryan *et al.*, 2012). Similarly zinc is also an important micro nutrient element which increases resistance to disease in plant. Now days, wide spreads deficiency of zinc is observed in various part of country which limit to the production of crops. Zn application has been noticed in chickpea grown on zinc deficient soil. A field study was under taken to assess the effect of zinc on yield of chickpea under rainfed condition; the Zn application improved the efficiency of applied phosphorus as higher grain yield in chickpea. Zinc is involved in the channelization of photosynthesis during reproductive stage by way of its involvement in electron transfer (Baker *et al.*, 1982) it can also be more serious on calcareous, organic matter deficient, arid and semi arid soil. Among micronutrient disorder, soil of arid and semi arid region may often test below the critical level of zinc availability (1.2 ppm). Rajasthan has wide variations in micronutrients content. Chattopadhyay *et al.*, (1997) observed that about 34.83 per cent area of Rajasthan suffer from deficiency of zinc. Thus, the study of P and Zn behaviour becomes pertinent because these two nutrients will lead to achieve optimum growth, chemical composition and yield of the crop either individually or in combination. These aspects on chickpea cultivation have received very little attention particularly in light textured soils of this locality.

Materials and Methods

A field experiment using chickpea as test crop was conducted at Agronomy farm, College of Agriculture, Bikaner during *Rabi*, 2009-10. The experimental site is located in north direction at 28.01^{o} N latitude and 73.22^{o} E longitude with an altitude of 234.70 meters above sea level. This region falls under agroclimatic zone I-C [Hyper Arid Partially Irrigated Western Plain Zone] of Rajasthan and agroclimatic zone XIV [Western Dry Region] of India. The soil of experiment site was loamy sand in texture containing 87.72, 20.72 and 164.14 kg ha^{-1} available nitrogen, phosphorus and potassium, respectively in 0-30 cm depth with pH 8.15, EC 0.15 dS m^{-1} and organic carbon 0.08 per cent. The experiment was laid out in factorial randomized block design with three replications, assigning twelve treatments consisting of four levels of phosphorus (control, 20, 40 and 60 kg ha^{-1}) and three levels of zinc (control, 3.0 and 6.0 kg ha^{-1}). The treatments were allotted to various plots with the help of random table as advocated by Fisher (1950). The net plot size 3.0 m x 1.8 m was used for yield and other related studies. Crop variety GNG – 663 developed from a cross between GNG-16x GNG- 146 and identified for North West Plain Zone by varietal evaluation committee during rabi pulses group meet in 1994. The fertilizer applied as nitrogen @ 20 kg ha^{-1} through urea as basal, phosphorus as per treatment through di ammonium phosphate (DAP) and zinc as per treatment through zinc sulphute.

The growth attributes observed as plant stand per row length (25 DAS and at harvest), dry matter accumulation (30, 60, 90 DAS and at harvest), plant height (30, 60, 90 DAS and at harvest), Primary and secondary branches per plant (60 DAS and at harvest), no. of nodules per plant and chlorophyll content at flowering stage. Also at harvest, plant yield and yield component data (the number of pods per plant, the number of seeds per pod, and the 1,000-seed weight) were collected. The yield and economics were calculated from the yield components. Initial soil samples were collected from 0-30 cm depth soil collected from chickpea grown field and brought to laboratory. Air dried soil samples were ground to pass through 2.0 mm mesh sieve. Processed soil samples were then subjected to electro-chemical. The results obtained and analyzed standard procedures have been presented in table 1. Data were analyzed statistically as per Panse and Sukhatme (1985), using the statistical computer programme MSTAT, version 5.

Results and Discussion

Growth attributes

A perusal of data showed that plant stand per plot recorded at 20 DAS and at harvest were not influenced significantly due to different treatments of phosphorus and zinc. The dry matter accumulation at 30 DAS significantly increased dry matter accumulation up to 60 kg P_2O_5 ha^{-1} and also at 60, 90 and 120 DAS significantly increased the dry matter accumulation up to 40 kg P_2O_5 ha^{-1} to the tune of 25.48 and 9.63, 22.83 and 9.28 and 20.25 and 8.06 per cent over control and 20 kg P_2O_5 ha^{-1}, respectively. However it was remained at par with 60 kg P_2O_5 ha^{-1}. However Plant height at 30, 60, 90 DAS and at harvest significantly increased in the same manner of dry matter accumulation. Application of 60 kg P_2O_5 ha^{-1} produced significantly superior primary and secondary branches per plant at 60 DAS and at harvest over rest of treatments. Application of 40 kg P_2O_5 ha^{-1} significantly increased the total chlorophyll content of leaves by 26.47 and 8.86 per cent over control and which was also produced significantly higher number of root nodules per plant over control, 20 kg P_2O_5 ha^{-1} by 24.66, 11.01 per cent, respectively. However it was remained at par with of 60 kg P_2O_5 ha^{-1} treatment. The probable reasons might be the stimulating effect of phosphorus on plant processes as phosphorus is a major constituent of plant cell nucleus and growing root tips which helped in cell division and root elongation. P involved in photosynthesis which is directly related with production of root biomass of plant and caused vigorous growth of plants and extensive root system leading to increased growth parameters. Similar results were also reported by Meena *et al.,* (2005) Deo and Khaldewal (2009) and Dotaniya *et al.*, (2014).

The application of zinc up to 6.0 kg ha^{-1} significantly increased dry matter accumulation at 60, 90 and 120 DAS by the per cent of 18.15 and 6.75, 18.92 and 6.52 and 14.10 and 6.08 over control and 3 kg Zn ha^{-1} respectively. The application of 3.0 kg Zn ha^{-1} increased plant height significantly at all the stages by the by the tune of 7.28, 6.94, 6.76 and 5.91 per cent over control. However it was remained at par with 6.0 kg Zn ha^{-1} respectively. An appraised of data further revealed that application of 6 kg Zn ha^{-1} significantly increased primary and secondary branches per plant control and 3.0 kg Zn ha^{-1}, respectively. The number of root nodules per plant at 60 DAS increased significantly due to application of 6 kg Zn ha^{-1} over control and 3 kg Zn ha^{-1} by with 17.23 and 6.00 per cent, respectively. However 6.0 Kg Zn ha^{-1} significantly increase chlorophyll content by the 37.31 and 13.58 per cent over control and 3.0 Kg Zn ha^{-1}, respectively. This might be due to its enzymatic role in starch formation and in protein synthesis. The increase in the availability of zinc to plant might have stimulated the metabolic and enzymatic activities thereby increasing the growth of the crop. Similar findings were also reported by Singh and Sharma (2005) and Sammuriya (2007) and Siddiqui *et al.,* (2015).

Yield attributes and yield

It is evident from the data given in table 4 indicated that phosphorus levels had significant effect on number of pods per plant. The phosphorus up to 40 kg ha^{-1} significantly increased the number of pods per plant over just preceding level. The phosphorus level 40 kg P_2O_5 ha^{-1} significantly produced more number of pods per plant over control and 20 kg P_2O_5 ha^{-1} to the tune of 54.69and 20.80 per cent, respectively over control and it was found to be at par with 60 kg P_2O_5 ha^{-1} treatments. The number of seeds per pod was increased significantly in the same tuning of no. of pods per plant. The yield parameters as seed yield (1372.11 kg/ha), straw yield (2282.44 kg/ha) and biological yield (3654.56 kg/ha) of chickpea were increased significantly with successive increase of phosphorus application up to 40 kg P_2O_5 ha^{-1}. It was remained at pat with 60 kg P_2O_5 ha^{-1}. The test weight was not significant due to application of different levels phosphorus and zinc. The increase in seed yield due to phosphorus application is attributed to source and sink relationship. It appears that greater translocation of photosynthates from source to sink (seed) might have increased the seed yield. It might also be due to improvement in yield attributes which ultimately increased the seed yield as evident by existence in strong positive correlation between seed yield and pods per plant, seeds per pod and 1000-seed weight (Table 4). These findings clearly suggest profound role of phosphorus fertilization in exploiting inherent potential of vegetative and reproductive growth which ultimately resulted in increased productivity of chickpea crop. These results are in line with that reported by Khorgamy and Farnia (2009), Kumar *et al.,* (2009) and Dotaniya *et al.,* (2014).

It is clear that application of 6.0 kg Zn ha^{-1} significantly increase number of pods per plant over control and 3 kg Zn ha^{-1} to the tune of 48.82 and 15.73 per cent, respectively. The numbers of seed per pod increase significantly in same manner of pods per plant due to application of 6.0 kg Zn ha^{-1} over control and 3.0 kg Zn ha^{-1} by 21.16 and 7.79 per cent, respectively. Data of chickpea yield in table 4 reveals that the graded levels of zinc up to 6.0 kg Zn ha^{-1} significantly increased seed, straw and biological yield over their preceding levels. Application of 6.0 kg Zn ha^{-1} produced significantly higher seed yield (1409.92 kg/ha), straw yield (2335.00 kg/ha) and biological yield (3744.92 kg/ha), which was significantly superior of the rest of treatments. The application of zinc significantly increased the yield attributing characters in chickpea. Hence on account of their physiological roles, their increase the growth and yield. Increased availability of zinc have shown marked improvement in growth attributes and directly increase grain and straw yield. Biological yield is the function of grain and straw yield. These findings are in confirmation to the earlier reporter by Singh and Mann (2007) and Khorgamy and Farnia (2009) and Akay (2011) and Siddiqui *et al.,* 2015.

Interactive effect of zinc and phosphorus

The interactive combined effect of phosphorus and zinc significantly enhanced the grain yield, nodules per plant and pods per plant. The data relating to the combined effect phosphorus and zinc on nodules per plant has been (Table 3) showed that the maximum (20.26) and minimum (13.19) nodules per plant was recorded with application of 40 kg P_2O_5 + 6 kg Zn ha^{-1} and control, respectively while it was remained at par with 60 kg P_2O_5 + 6 Kg Zn ha^{-1}. The interactive combined effect on seed yield was also found to be significant (Table 6). The significantly higher seed yield (1588.0 kg ha^{-1}) was recorded under 40.0 kg P_2O_5 ha^{-1} in combination with 6.0 kg Zn ha^{-1}, which was at par with other treatment combination 60.0 kg P_2O_5 ha^{-1} + 6.0 kg Zn ha^{-1}. Minimum pods per plant (450.0 kg ha^{-1}) was recorded when neither phosphorus nor zinc was applied. The combined interactive effect of phosphorus and zinc on pods per plant was found in same manner of seed yield of chickpea (Table 5). This might be due to synergistic effect between these two nutrients at desired concentration in soil. Plants are responsive to better nutritional environment in terms of increased nitrogen fixation and plant growth. Higher grain yield may be attributed to the cumulative effect of plant growth parameter and yield attributes such as number of pods per plant and branches per plant. Physiological role of different nutrients enhanced the yield and yield attributes. Similar results were also found by Bishat and Chandel (1996); and Choudhary *et al.*, (1998); Das *et al.*, (2005) and Das (2015).

Table.1 Initial physico-chemical characteristics of the experimental soil

Soil properties	Value	Methods of analysis with reference
A. Mechanical Composition		
Sand (%)	84.25	Hydrometer method (Bouyoucos, 1962)
Silt (%)	7.70	
Clay (%)	7.84	
Texture	loamy Sand	Triangular method (Brady, 1983)
B. Physical properties		
Bulk density (Mg m^{-3})	1.58	Method No. 38, USDA HandBook No. 60 (Richards, 1954)
Particle density (Mg m^{-3})	2.65	Method No. 39, USDA HandBook No. 60 (Richards, 1954)
Field Capacity (%)	7.92	Method No. 30, USDA HandBook No. 60 (Richards, 1954)
Porosity (%)	37.30	Method No. 40, USDA Handbook No. 60 (Richards, 1954)
C. Chemical properties		
Soil pH (1:2 soil water suspension)	8.15	Method No. 21 b, USDA Handbook No. 60 (Richards, 1954)
EC (dS m^{-1}) (1:2 soil water suspension at 25^0C)	0.15	Method No.4 USDA Handbook No.60 (Richards, 1954)
Organic carbon (%)	0.08	Walkley and Black's rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	87.72	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	20.72	Olsen's method (Olsen *et al.*, 1954)
Available K_2O (kg ha^{-1})	164.14	Flame photometric Method (Jackson, 1973)

Table.2 Effect of phosphorus and zinc on growth attributes of chickpea

Treatment	Plant stand per row length		Dry matter accumulation (g plant^{-1})				Plant height (cm)				Branches per plant				No. of nodules plant^{-1} at flowering	Chlorophyll content in leaves at flowering
											Primary		Secondary			
	25 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest		
Phosphorus level																
P_0-Control	2.55	2.45	0.40	2.63	4.60	6.47	11.73	25.53	35.03	43.49	3.33	4.25	6.06	11.16	15.04	0.68
P_1-20 kg P_2O_5 ha^{-1}	2.56	2.49	0.50	3.01	5.17	7.20	13.02	27.84	38.28	47.11	3.79	4.76	6.86	12.54	16.89	0.79
P_2-40 kg P_2O_5 ha^{-1}	2.57	2.52	0.56	3.30	5.65	7.78	13.32	29.93	41.04	50.20	4.18	5.18	7.51	13.69	18.75	0.86
P_3-60 kg P_2O_5 ha^{-1}	2.58	2.53	0.61	3.38	5.79	8.05	13.56	30.18	41.37	50.71	4.53	5.54	8.10	14.71	19.09	0.88
S.Em±	0.06	0.05	0.01	0.08	0.13	0.17	0.34	0.66	0.90	1.04	0.11	0.12	0.20	0.34	0.14	0.02
CD (5%)	NS	NS	0.04	0.22	0.39	0.50	1.00	1.92	2.63	3.05	0.32	0.35	0.58	1.00	0.42	0.07
Zinc level																
Z_0-Control	2.55	2.49	0.48	2.81	4.81	6.88	12.22	26.93	36.79	45.82	3.54	4.57	6.43	11.84	15.96	0.67
Z_1-3 kg Zn ha^{-1}	2.56	2.49	0.53	3.11	5.37	7.40	13.11	28.80	39.28	48.53	4.00	4.95	7.23	13.13	17.65	0.81
Z_2-6 kg Zn ha^{-1}	2.58	2.52	0.55	3.32	5.72	7.85	13.38	29.38	40.72	49.29	4.32	5.28	7.74	14.10	18.71	0.92
S.Em±	0.05	0.04	0.01	0.07	0.12	0.15	0.30	0.57	0.78	0.90	0.09	0.10	0.17	0.30	0.12	0.02
CD (5%)	NS	NS	0.04	0.19	0.34	0.43	0.87	1.67	2.27	2.64	0.28	0.30	0.50	0.87	0.37	0.06

Table.3 Interaction effect between phosphorus and zinc on nodules per plant of chickpea

Treatments	P_0-Control	P_1-20 kg P_2O_5 ha^{-1}	P_2-40 kg P_2O_5 ha^{-1}	P_3-60 kg P_2O_5 ha^{-1}
Z_0-Control	13.19	15.63	16.79	18.24
Z_1-3 kg Zn ha^{-1}	15.31	17.03	19.22	19.07
Z_2- 6 kg Zn ha^{-1}	16.62	18.01	20.26	19.97
Mean	15.04	16.89	18.75	19.09
S.Em.±	0.25			
CD (5%)	0.73			

Table.4 Effect of phosphorus and zinc on yield attributes, yield and economics of chickpea

Treatments	Number of pods per plant	Seeds per pod	Test weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Phosphorus Levels								
P_0-Control	28.98	1.28	121.00	829.67	1817.67	2647.33	9782.33	1.79
P_1-20 kg P2O5 ha^{-1}	37.11	1.50	121.82	1155.56	2087.44	3243.00	16489.44	2.27
P_2-40 kg P2O5 ha^{-1}	44.83	1.62	122.36	1372.11	2282.44	3654.56	21006.56	2.58
P_3-60 kg P2O5 ha^{-1}	47.30	1.68	123.24	1415.00	2389.22	3804.22	21784.67	2.59
S.Em±	1.25	0.03	2.07	26.98	63.37	79.58	650.11	0.05
CD (5%)	3.67	0.10	NS	79.13	185.86	233.40	1906.70	0.16
Zinc Levels								
Z_0-Control	31.44	1.37	121.68	939.08	1942.00	2881.08	11943.17	1.92
Z_1-3 kg Zn ha^{-1}	40.43	1.54	122.01	1230.25	2155.58	3385.83	18043.25	2.37
Z_2-6 kg Zn ha^{-1}	46.79	1.66	122.63	1409.92	2335.00	3744.92	21810.83	2.62
S.Em±	1.08	0.03	1.79	23.36	54.88	68.92	563.01	0.05
CD (5%)	3.18	0.09	NS	68.52	160.96	202.13	1651.25	0.14

Table.5 Interaction effect between phosphorus and zinc on number of pods per plant of chickpea

Treatments	P_0-Control	P_1-20 kg P_2O_5 ha^{-1}	P_2-40 kg P_2O_5 ha^{-1}	P_3-60 kg P_2O_5 ha^{-1}
Z_0-Control	26.23	27.78	35.39	36.35
Z_1-3 kg Zn ha^{-1}	29.60	38.10	44.75	49.27
Z_2-6 kg Zn ha^{-1}	31.10	45.46	54.35	56.27
Mean	28.98	37.11	44.83	47.30
S.Em.±	2.17			
CD (5%)	6.35			

Table.6 Interaction effect between phosphorus and zinc on seed yield of chickpea

Treatments	P_0-Control	P_1-20 kg P_2O_5 ha^{-1}	P_2-40 kg P_2O_5 ha^{-1}	P_3-60 kg P_2O_5 ha^{-1}
Z_0-Control	450.00	966.67	1122.33	1217.33
Z_1-3 kg Zn ha^{-1}	903.67	1177.33	1406.00	1434.00
Z_2-6 kg Zn ha^{-1}	1135.33	1322.67	1588.00	1593.67
Mean	829.67	1155.56	1372.11	1415.00
S.Em.±	46.728			
CD (5%)	137.05			

Economics

The application of 40 kg P_2O_5 ha^{-1} recorded higher net returns (Rs. 21006.58 ha^{-1}) and higher B:C ratio (2.58). This might be due to increase in seed yield in diminishing manner under the increasing levels of phosphorus. The application of 6 kg Zn ha^{-1} recorded higher net returns (Rs. 21810.83 ha^{-1}) and higher B: C ratio (2.62). This might be due to increase in seed yield in diminishing manner under the increasing levels of phosphorus. It may be concluded that significantly higher grain yield (1372.11 and 1409.92 kg ha^{-1}) and net return (21006.56 and 21810.83 ha^{-1}) could be obtained by application of 40 kg P_2O_5 ha^{-1} phosphorus and zinc level of 6.0 kg ha^{-1}, respectively under irrigated conditions of hyper arid irrigated tract of Rajasthan. The combined application of 40 kg P_2O_5 ha^{-1} + 6.0 kg Zn ha^{-1} gave maximum response of chickpea in terms of yield.

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