Research Article

Efficacy of Phosphorus Application on Yield in Different Chickpea (*Cicer arietinum* L.) Genotypes

Hera Gul Mohmmand[1], Rozina Gul[1], Hamayoon Khan[2], Sheraz Ahmed[1*], Laila Fayyaz[1], Ajmalud Din[1] and Imtiaz Ali[1]

[1]Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar, Pakistan; [2]Department of Agronomy, The University of Agriculture, Peshawar, Pakistan.

Abstract | Phosphorus (P) is one of the essential nutrients needed for plant growth and development. The P has a significant ecological and economic importance; therefore, its application is considered to maximize the yield of various crops, including chickpea. The current experiment was performed to assess the impact of phosphorus application on yield of 15 chickpea genotypes during the growing season of 2017-18 at the University of Agriculture, Peshawar. A randomized complete block design was used with three replications under two treatments. One treatment was a control without phosphorous application, while the second treatment was application of phosphorous at a rate of 35.3 kg (P_2O_5) ha^{-1}. Data were documented on plant height, pod number $plant^{-1}$, seed number pod^{-1}, seed number $plant^{-1}$, 100-seed weight, seed yield and harvest index. Amongst genotypes, highly significant variation was observed for the studied characters. Similarly, significant results were obtained for genotype by environment (GE) interaction for all traits except plant height. Application of phosphorus enormously improved seed yield in all chickpea genotypes. Based on mean data, chickpea plants with P application produced more seed number $plant^{-1}$ (60.9), pods $plant^{-1}$ (57.3) and seed yield (557.2 kg ha^{-1}). Higher seed yields were produced by genotypes NDC-4-20-1 (1004 kg ha^{-1}) and NKC-5-S-15 (851 kg ha^{-1}). Seed yield had significantly negative phenotypic correlation with plant height. Similarly at genotypic level, it was significantly correlated with seed number pod^{-1} while negatively with 100-seed weight. Among the tested genotypes, NDC-4-20-1 and NKC-5-S-15 were identified as better performing with phosphorus application while genotype NKC-5-S-12 followed by NDC-4-20-1 performed well in both environments. Therefore, the screened lines could be used in various chickpea breeding programs for higher seed yield. Considering current findings, this study suggests that application of phosphorus to chickpea fields is recommendable for higher seed yield and hence is justified from economic perspective.

Received | February 17, 2021; **Accepted** | November 09, 2021; **Published** | February 03, 2022
***Correspondence** | Sheraz Ahmed, Department of Plant Breeding and Genetics, The University of Agriculture, Peshawar, Pakistan; **Email**: drsheraz@aup.edu.pk
Citation | Mohmmand, H.G., R. Gul, H. Khan, S. Ahmed, L. Fayyaz, A. Din and I. Ali. 2022. Efficacy of phosphorus application on yield in different chickpea (*Cicer arietinum* L.) genotypes. *Sarhad Journal of Agriculture,* 38(2): 439-447.
DOI | https://dx.doi.org/10.17582/journal.sja/2022/38.2.439.447
Keywords | Chickpea, Phosphorus, Yield, Correlation, Fertilizer

Introduction

Pulses are considered as the second most important crop after cereals fulfilling dietary requirements for humans in many parts of the world (Maphosa and Jideani, 2017). Chickpea (*Cicer arietinum* L.) is valuable for its cheapest source of protein and an inexpensive meat alternative. Various types of chickpeas are commonly known as gram, garbanzo or garbanzo bean. Chickpea has a great nutritional value. Their seeds provide proteins and carbohydrates, together constituting ~ 80% of the total dry seed mass. Comparative to common beans (*Phaseolus vulgaris* L.) and field peas (*Pisum sativum* L.) chickpea has higher carbohydrate content (~63%) (Serrano *et al*., 2017). However, protein content of chickpea varies in cultivars *i.e*., 12.4–31.5% as reported by Canadian Grain commission (Wang and Daun, 2004) or 17-22% (Jukanti *et al*., 2012), which is most likely double than the protein content of wheat and thrice than that of rice (Shukla *et al*., 2013). During 2019-20, chickpea was cultivated on an area of 13.7 million hectares of the world with a total production of 14.24 million tones averaging 1038 kg ha^{-1} (FAO, 2019). During the same year in Pakistan, chickpea was grown on an area of 0.94 million hectares which produced 0.44 million tones with an average yield of 473 kg ha^{-1} (FAO, 2019).

Sensitivity to different levels of fertilizers, water application and certain biotic and abiotic factors are the considerable limitations resulting in chickpea`s low yield. The imbalance of nutrients has a great negative effect on chickpea production. The pulse crop can meet their nitrogen requirement from the mechanism of nitrogen fixation via biological mean and so per hectare only15-20 kg nitrogen is sufficient. However, deficiency of phosphorus is widespread in soils and pulse crops revealed varying reaction to 20-80 kg P_2O_5 application of phosphorus per hectare, reliant on status of nutrients in the soil, availability of water and system of cropping (Ali *et al*., 2008). Appropriate crop and nutrient management are the major and important factors promoting higher productivity. Judicious usage of suitable varieties along with plant nutrients and fertilizers consumption have a significant impact upon yield and other related components which in turn leads towards high yield.

Plants need various nutrients for their healthy and vigorous growth. Phosphorus is one of these which improve formation of flowers, seed production, early maturity, elevated fixation of nitrogen, quality improvement and disease resistance (Zeid *et al*., 2015). The application of phosphorus among other aspects is of critical significance in influencing production of chickpea. As a measurable amount of applied phosphorus to the soil more likely remains unavailable and thus could not be used by the crop. Phosphorus is getting deficient after nitrogen in agricultural soils globally (Vance *et al*., 2003). In plants, deficiency of phosphorus ruins several biochemical and physiological processes (Wu *et al*., 2005). Even in more fertile soils, phosphorus availability is scarce for plants because Ca in alkaline soils (Rahmatullah *et al*., 1994), while in acidic soils Al and Fe make precipitates with phosphorus (Plaxton and Carswell, 1999). Phosphorus application helps in hardiness of shoots, regulation of photosynthesis, improvement of grain quality governing physio-biochemical processes and also imparts in elongation of roots, maximization of nodule growth and thus increases the chances to fix nitrogen (Chowdhury *et al*., 1975).

The response of phosphorus application was noticed to be quite well in legume crops. From various studies it has been observed that the application of phosphorus had a positive effect on yield of chickpea (Johansen and Sahrawat, 1991) though, Chen *et al*. (2006) stated that during different conditions of growth, the amount of required phosphorus changes accordingly. Among various major constraints poor fertility of the soil, especially phosphorus scarcity, is one of the main limitations in productivity of chickpea (Srinivasarao *et al*., 2003).

Different genotypes respond differently to varying environments. It has been reported by Gul *et al*. (2014) that 0-195% increase in yield of chickpea genotypes was associated with the environment where nitrogen was applied. Similarly, Ali *et al*. (2008) also noticed an increased performance of chickpea genotypes in terms of seed yield under phosphorus application. This shows that GE interaction plays a fundamental role in the yield of chickpea. Considering the prior facts, the current test was accomplished while aiming the yield response of chickpea genotypes to the implementation of phosphorus, determination of phosphorus interaction with different chickpea genotypes for yield and its attributing parameters and to determine genotypic and phenotypic correlation amidst various parameters of different chickpea genotypes.

Materials and Methods

Experimental material and layout

The current experiment was devised to study phosphorous effect on various genotypes of chickpea. A field experiment was performed at The University of Agriculture, Peshawar located between 358 02" N latitude, 731 46" E longitudes with an altitude of 360 ft. during the growing season in 2017-18. Two treatments, *i.e*., E1 with no phosphorous implementation and E2 with phosphorus application of 35.3 kg P_2O_5 ha^{-1} in the form of diammonium phosphate (P_2O_5) were prepared for this experiment. The planting materials,

Table 1: *Pooled mean squares for various traits of 15 chickpea genotypes grown under E1 (control) and E2 (P applied) at the University of Agriculture, Peshawar during 2017/18.*

SOV	df.	Plant height	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100-seed weight	Seed yield	Harvest index
Environment (E)	1	0.11	1925.31**	0.01	39.04**	1.79*	8146615.53**	1.66
Reps w/n (E)	4	41.07	109.34	0.01	31.10	0.18	2895.70	31.06
Genotype (G)	14	61177.62**	5214.24**	4.15**	8034.93**	995.40**	481026.32**	3556.86**
G×E	14	0.94	200.91**	0.02*	2.18**	0.55**	136132.30**	16.58**
Pooled Error	56	38.35	64.04	0.02	1.11	1.41	4641.02	10.43

, = significant at 5% and 1% probability level, respectively.*

comprised of 15 genotypes of chickpea, were planted in the respective environments in randomized complete block design with three replications. A single experimental unit constituted of four 4 m rows with 0.30 m distance between rows with a plant density of about12 plants/m^2.

Statistical analysis

Data were collected for plant height (cm), pod number plant^{-1}, seed number pod^{-1}, seed number plant^{-1}, 100-seed weight (g), seed yield (kg ha^{-1}) and harvest index (%). Data for the aforementioned traits were taken on five randomly selected plants at each plot. Using the procedure of Gomez and Gomez (1984), analysis of variance (ANOVA) test was carried out to analyze all the data. Furthermore, phenotypic and genotypic correlations among various plant traits were also assessed for separate experiment adopting SAS (Statistical Analysis System) software (Kwon and Torrie, 1964; SAS Institute, 2009).

Results and Discussion

Seed yield and harvest index

Analysis demonstrated highly significant (P ≤ 0.01) differences amongst the tested genotypes, GE interaction and environments for seed yield (Table 1). Similar results were also documented by past researchers Macil *et al.* (2017) for seed yield in chickpea genotypes. Across environments, the most productive genotype for seed yield was NKC-5-S-12 while the least productive was NDC-5-S-10 (Table 4). Generally, E2 (P applied) was the most productive environment for seed yield where highest production was obtained from genotyped NDC-4-20-1 which was 1004.2 kg ha^{-1} thus making this environment more favorable for seed yield (Table 4). The drastic decline in seed yield under control environment suggested that seed yield was heavily affected by limited availability of phosphorus in the soil. Therefore, phosphorus application could be recommended to achieve higher productivity in chickpea. Correlation analysis unveiled significant positive relationship of seed yield with seeds pod^{-1} (r_g = 0.73) at genotypic level however it had negative association with 100-seed weight (Table 5). Phenotypically, seed yield and plant height were negatively correlated (Table 5). The current results confirmed the findings of Islam *et al.* (2011) that seed yield was correlated with seeds pod^{-1} in chickpea genotypes.

For harvest index, mean squares were significantly (P ≤ 0.01) different among genotypes and GE interaction (Table 1). However, environments were non-significantly different for harvest index (Table 1). Desai *et al.* (2016) also published same results for genotypes and their interaction in chickpea for the said trait. Overall, mean data for harvest index ranged between 37.2 and 51.5 % (Table 4). Overall, highest harvest index (51.47 %) was noted for genotype NKC-5-S-12 and lowest harvest index (37.2 %) was noted for genotype NDC-5-S-10. In E2, highest harvest index (50.9%) was recorded for genotype NKC-5-S-12 (Table 4). Overall, mean harvest index values in both environments were close to each other which is expected by their non-significant environments. The correlation results determined between 100-seed weight and seeds pod^{-1} were negative both genotypically and phenotypically (r_g = -0.47, r_p = -0.25) but significant at genotypic and non-significant at phenotypic level (Table 5). Similar results for genotypic and phenotypic correlation of harvest index (r_g = 0.01, r_p = 0.05) was recorded with 100-seed weight i.e. non-significant and positive (Table 5). Hussain *et al.* (2018) however, reported a negative and significant association between 100-seed weight and harvest index which could be due to differences in experimental material used in the studies.

Similarly, between seeds plant^{-1} and pods plant^{-1} (r_g = 0.55,) the correlation coefficient was significant and

Table 2: *Mean performance of different chickpea genotypes for plant height, pods plant^{-1} and seeds pod^{-1} under E1 (control) and E2 (P applied) environments evaluated at the University of Agriculture, Peshawar during 2017/18.*

Genotypes	Plant height (cm)				Pods plant^{-1}				Seeds pod^{-1}			
	E1 (control)	E2 (P appl.)	Diff.	Mean	E1 (control)	E2 (P appl.)	Diff.	Mean	E1 (control)	E2 (P appl.)	Diff.	Mean
NDC-4-20-5	71.3	54.2	-17.1	62.7	36.5	61.4	24.9	49.0	1.49	1.48	-0.01	1.48
NDC-4-20-3	81.1	56.3	-24.8	68.7	40.7	54.4	13.7	47.5	1.43	1.45	0.02	1.44
NKC-5-S-14	76.4	58.7	-17.7	67.5	50.1	51.3	1.2	50.7	1.38	1.23	-0.15	1.3
NKC-5-S-16	78.8	54.2	-24.6	66.5	31.4	43.9	12.5	37.7	1.62	1.59	-0.03	1.6
NKC-5-S-15	77.8	54.3	-23.5	66.1	37.0	58.1	21.1	47.6	1.66	1.73	0.07	1.69
NDC-122	70.6	59.2	-11.4	64.9	41.7	58.9	17.2	50.3	1.54	1.53	-0.01	1.54
NDC-4-20-4	73.9	50.3	-23.6	62.1	44.4	54.4	10.0	49.4	1.47	1.38	-0.09	1.42
NDC-15-1	77.3	53.1	-24.2	65.2	54.1	60.1	6.0	57.1	1.68	1.4	-0.28	1.54
NKC-5-S-12	81.3	49.7	-31.6	65.5	61.9	52.6	-9.3	57.2	1.49	1.61	0.12	1.55
NDC-4-20-2	81.9	53.8	-28.1	67.8	57.4	55.5	-1.9	56.5	1.48	1.32	-0.16	1.4
NDC-15-4	83.4	57.9	-25.5	70.6	42.3	58.9	16.6	50.6	1.61	1.66	0.05	1.64
NDC-4-20-1	70.7	45.7	-25.0	58.2	39.5	48.3	8.8	43.9	1.44	1.62	0.18	1.53
NDC-5-S-10	62.4	46.0	-16.4	54.2	62.0	63.9	1.9	62.9	1.39	1.32	-0.07	1.35
KARAK-1	67.7	51.5	-16.2	59.6	45.1	63.6	18.5	54.3	1.4	1.39	-0.01	1.39
KARAK-2	71.2	50.3	-20.9	60.7	51.4	74.3	22.9	62.9	1.47	1.46	-0.01	1.47
Mean	75.0	53.0	-22.0	64.0	46.4	57.3	10.9	51.8	1.5	1.48	-0.02	1.49
LSD (0.05)	G = 8.3	E = ns	-	G×E = ns	G = 6.3	E = 1.4	-	G×E = 5.8	G = 1.71	E = ns	-	G×E = 0.8

positive at genotypic level. However, between seed yield (r_g = 0.14, r_p = 0.29) and seeds plant^{-1}, phenotypic correlation was significant and positive (Table 4). Neenu *et al.* (2017) also reported the same results for the associations of these traits in chickpea genotypes while studying the impact of sowing dates on up taking of nutrients and yield of chickpea under different climatic conditions.

The soils, specifically in Khyber Pakhtunkhwa (KP) province of Pakistan, have become seriously lacking in N, P and K which in turn results in low yield on farmer fields than potential yield. This should also be taken into consideration that the pattern of cropping in the province is not balanced very well and only a marginal land is allocated for cultivation of pulses. Phosphorus plays a vital role in plant growth and development of seeds thus making itself an essential nutrient. Considering the above facts, a field experiment was directed to look over the impact of phosphorus on growth and seed yield of chickpea. From this study it was obvious that yield and growth of chickpea were greatly influenced due to phosphorus application.

Plant height

Taller plants have usually good survival chance in any environmental conditions. Table 1 shows the differences among the chickpea genotypes for the plant height with high statistical significance. Nath *et al.* (2013) reported the same results regarding genotypes, environments and interaction due to GE whereas observing the impact of phosphorous and measures of controlling weeds on yield and growth of chickpea. Plant height and branches play important functions in plant development and growth (Kumar *et al.*, 2020). Across environments, highest plant height of 70.6 cm was noted for NDC-15-4 genotype (Table 2). Genotypes NDC-15-4 also exhibited highest (83.4 cm) plant height under control environment (E1), whereas NDC-122 produced taller plants under phosphorus applied environment. Generally, under phosphorus applied environment, shorter plants were observed. This suggested that phosphorus application may have negatively affected the plant height of chickpea genotypes. Ullah *et al.* (2018) reported that 35 kg ha^{-1} of P_2O_5 had negligible effect on plant height of chickpea. This could be due to the fixation of P to soil surface and making it unavailable for plant uptake. Hence, biological growth of plant is retarded. In such case, sufficient dose of P is required. Ullah *et al.* (2018) suggested that P_2O_5 at 70 kg ha^{-1} was sufficient and significantly enhanced the biological

Table 3: *Mean performance of different chickpea genotypes for seeds plant^{-1} and 100-seed weight under E1 (control) and E2 (P applied) environments evaluated at the University of Agriculture, Peshawar during 2017/18.*

Genotypes	Seeds plant^{-1}				100-seed weight (g)			
	E1 (control)	E2 (P appl.)	Diff.	Mean	E1 (control)	E2 (P appl.)	Diff.	Mean
NDC-4-20-5	76.7	79.0	2.3	77.9	21.7	20.8	-0.9	21.2
NDC-4-20-3	47.6	49.3	1.7	48.4	22.4	21.9	-0.5	22.1
NKC-5-S-14	51.7	52.7	1.0	52.2	25.8	26.3	0.5	26.0
NKC-5-S-16	31.3	33.3	2.0	32.3	22.6	22.2	-0.4	22.4
NKC-5-S-15	61.9	64.0	2.1	62.9	22.0	21.9	-0.1	22.0
NDC-122	35.0	35.5	0.5	35.3	25.2	25.1	-0.1	25.2
NDC-4-20-4	50.4	52.3	1.9	51.4	28.9	27.5	-1.4	28.2
NDC-15-1	77.5	79.1	1.6	78.3	21.9	21.8	-0.1	21.9
NKC-5-S-12	85.2	86.0	0.8	85.6	20.6	20.1	-0.5	20.4
NDC-4-20-2	72.3	75.0	2.7	73.7	26.0	24.8	-1.2	25.4
NDC-15-4	63.6	66.3	2.7	64.9	22.0	22.1	0.1	22.1
NDC-4-20-1	54.8	54.9	0.1	54.9	13.7	13.2	-0.5	13.5
NDC-5-S-10	60.6	61.0	0.4	60.8	19.1	18.4	-0.7	18.7
KARAK-1	57.8	59.3	1.5	58.6	25.5	26.1	0.6	25.8
KARAK-2	64.4	66.3	1.9	65.3	20.7	20.8	0.1	20.7
Mean	59.4	60.9	1.5	60.2	22.5	22.2	-0.3	22.4
LSD (0.05)	G = 6.2	E = 3.3	-	G×E = 4.1	G = 2.9	E = 1.2	-	G×E = 3.9

growth and development of chickpea. Overall, shortest plants were observed for genotypes NDC-4-20-1 and NDC-5-S-10 (54.2 cm). Between plant height and 100-seed weight, there was highly significant genotypic correlation (r_g = 0.60). At phenotypic level, the correlation of plant height with pods plant^{-1} was significant and positive whereas, it was negative and non-significant at genotypic level (r_g = -0.36, r_p = 0.34) (Table 5). For plant height`s correlation with other traits, the same results were documented by Aulakh *et al*. (2003) in chickpea genotypes.

Pod number and seed number

Highly significant (P ≤ 0.01) results were depicted by pooled ANOVA among genotypes, GE interaction and environments for pods plant^{-1} (Table 1). Keneni *et al*. (2015) also reported same findings during estimation of phosphorous uptake efficiency in different chickpea accessions. Across environments, genotypes NDC-5-S-10 and Karak-2 produced highest pods plant^{-1} *i.e.*, 62.9 (Table 2). In E1, the range for pods plant^{-1} was between 31.4 and 62 (Table 2). Genotype NKC-5-S-16 produced lowest pods in a plant whereas, highest pods plant^{-1} were produced by genotype NDC-5-S-10. Similarly, in E2 (P applied), pods plant^{-1} ranged between 43.9 and 74.3 wherein NKC-5-S-16 produced lowest pods plant^{-1} whereas Karak-2 produced highest pods plant^{-1}. In this case, phosphorus application significantly improved pods production of chickpea genotypes and hence, higher values were observed in E2. There was significant genotypic correlation between pods plant^{-1} and seeds plant^{-1} (Table 5). The correlation of harvest index and pods plant^{-1} at genotypic and phenotypic level was positive but could not reach to the level of significance (Table 5). Yadav *et al*. (1990) studied correlation among yield traits in chickpea genotypes and reached to the same conclusions regarding correlation of pods plant^{-1} in relation with other discussed traits.

For seeds pod^{-1}, significant (P ≤ 0.01) differences were observed from pooled analysis of variance amongst genotypes and GE interactions (Table 1). However, environments were non-significantly different for seeds pod^{-1}. Keneni *et al*. (2015) also found significant (P ≤ 0.01) differences amongst the tested chickpea genotypes, whereas non-significant GE interaction. Across environments, the highest mean value for seeds pod^{-1} was recorded for genotype NKC-5-S-15 which was 1.69. Highest mean value for seeds pod^{-1} in E2 was 1.73 and was marked by genotype NKC-5-S-15 (Table 2). Overall, mean values for seeds pod^{-1} under both environments were close which is evident by non-significant environments. Similarly, it

Table 4: *Mean performance of different chickpea genotypes for harvest index and seed yield under E1 (control) and E2 (P applied) environments evaluated at the University of Agriculture, Peshawar during 2017/18.*

Genotypes	Harvest index (%)				Seed yield (kg ha^{-1})			
	E1 (control)	E2 (P appl.)	Diff.	Mean	E1 (control)	E2 (P appl.)	Diff.	Mean
NDC-4-20-5	53.3	48.2	-5.1	50.8	335.9	383.3	47	359.6
NDC-4-20-3	46.5	46.8	0.3	46.7	273.2	400.0	127	336.6
NKC-5-S-14	36.5	40.3	3.8	38.4	192.7	393.1	200	292.9
NKC-5-S-16	37.5	37.7	0.2	37.6	95.8	600.0	504	347.9
NKC-5-S-15	48.9	47.1	-1.8	48.0	132.9	851.4	719	492.1
NDC-122	43.8	42.6	-1.2	43.2	233.8	497.2	263	365.5
NDC-4-20-4	45.8	46.2	0.4	46.0	358.6	281.9	-77	320.3
NDC-15-1	41.8	42.0	0.2	41.9	601.8	497.2	-105	549.5
NKC-5-S-12	52.0	50.9	-1.1	51.5	529.0	706.9	178	618.0
NDC-4-20-2	36.7	38.5	1.8	37.6	338.4	708.3	370	523.4
NDC-15-4	38.2	36.8	-1.4	37.5	366.3	594.4	228	480.4
NDC-4-20-1	41.4	40.1	-1.3	40.7	126.3	1004.2	878	565.3
NDC-5-S-10	33.5	40.9	7.4	37.2	135.3	180.6	45	157.9
KARAK-1	50.0	43.1	-6.9	46.5	497.5	597.2	100	547.4
KARAK-2	43.0	42.6	-0.4	42.8	317.8	662.5	345	490.2
Mean	43.3	42.9	-0.4	43.1	302.3	557.2	255	429.8
LSD (0.05)	G = 5.6	E = ns	-	G×E = 7	G = 1.1	E = 2.9	-	G×E = 6

could be inferred that seeds pod^{-1} were sensitive to phosphorus application and performance of genotypes was significantly altered as indicated by significant GE interaction (Table 1). For seeds pod^{-1} the correlation results were negative but non-significant at both genotypic and phenotypic levels (r_g = -0.47, r_p = -0.25) with 100-seed weight (Table 5). However, seeds pod^{-1} (r_g = 0.73) has significant association with seed yield at genotypic level only (Table 5). Siddiqui *et al*. (2015) reported similar outcomes for correlation of seeds pod^{-1} with seed yield in chickpea genotypes.

Among genotypes, environments and their interaction in terms of seeds $plant^{-1}$, pooled ANOVA revealed highly significant (P ≤ 0.01) variation (Table 1). Badini *et al*. (2015) also described same results while studying the effect of different phosphorous levels on yield of chickpea. In E2, the range for seeds in a single plant was between 33.3 and 86.0 (Table 3). Genotype NKC-5-S-12 produced highest seeds $plant^{-1}$ at both environments suggesting its stability across diverse environments (Table 3). This also indicated that NKC-5-S-12 was insensitive to phosphorus application therefore, the genotype is expected to produce similar results in phosphorus deficient soil as well. Analysis of correlation revealed significant association of seeds $plant^{-1}$ with pods $plant^{-1}$ at genotypic level only while non-significant association was observed with seed yield at both genotypic and phenotypic levels (Table 5). This indicated that plants that produce more pods are likely to bear more seeds in them.

100-seed weight

Pooled analysis of variance for 100-seed weight revealed significant (P ≤ 0.01) differences amongst genotypes and GE interaction while significant at P ≤ 0.05 among environments (Table 1). Mansur *et al*. (2009) also reported similar findings for 100-seed weight while determining the impact of densities of plants as well as phosphorous levels upon seed yield and protein content of chickpea genotypes. Highest 100-seed weight of 27.5 g in E2 was exhibited by genotype NDC-4-20-4 which happened to be top in E1 as well for 100-seed weight (Table 3). Although, 100-seed weight was non-significantly associated with any other trait at phenotypic level however, it had strong positive association with plant height while negative association with seed yield at genotypic level (Table 5).

Application of phosphorus at the rate of 35.3 kg ha^{-1} resulted in overall short plants of chickpea genotypes. Nevertheless, NDC-122 attained highest height (59.2 cm) in E2. Highest pods $plant^{-1}$ was depicted for

Table 5: *Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among various traits of 15 chickpea genotypes under E1 (control) and E2 (P applied) environments evaluated at the University of Agriculture, Peshawar during 2017/18.*

Traits	Plant height	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100-seed weight	Seed yield	Harvest index
Plant height	-	-0.36	0.02	-0.26	0.60**	-0.16	-0.14
Pods plant^{-1}	0.34*	-	-0.55	0.55*	-0.01	-0.20	0.05
Seeds pod^{-1}	0.09	-0.16	-	-0.01	-0.47	0.73**	0.24
Seeds plant^{-1}	-0.05	0.30	0.01	-	-0.20	0.14	0.37
100-seed weight	0.17	0.01	-0.25	-0.20	-	-0.44*	0.01
Seed yield	-0.47*	-0.26	0.24	0.29	-0.12	-	-0.11
Harvest index	0.08	0.12	0.03	0.29	0.05	0.10	-

, = significant at 5% and 1% probability level, respectively.*

genotype Karak-2 i.e., 74.3 in P applied environment. Genotype NKC-5-S-15 produced maximum seeds pod^{-1} which was 1.73 in E2. Frossard *et al*. (2000) reported that phosphorus application at higher levels resulted in improved crop growth, specifically positive effect was determined on seeds pod^{-1}, pods per plant, seed yield and harvest index. In the current study, P application also improved pods production in plants which is another important yield determining factor in chickpeas. However, it seems that higher pods production was not truly reflected in seed yield. As a matter of fact, genotypes (NDC-15-1 and NKC-5-S-12) with modest pods plant^{-1} (57.1 and 57.2, respectively) produced higher seed yield. This could be due to the fact that higher pods formation in chickpea reduced seed size and weight which ultimately declined overall seed yield. This suggested that plants with optimum number of pods would be a better selection criterion to increase seed yield in chickpea. A positive effect of P application on chickpea performance in terms of seed yield has also been reported by Fairhurst *et al*. (2007). The genotype NDC-4-20-1 was superior line in terms of seed yield and thus it can be suggested for direct and general cultivation by farmers. The mentioned line can also be used in various breeding programs to improve seed yield in chickpea genotypes. The obtained results indicated that significantly higher values were noted specifically for seed yield due to phosphorus application in chickpea genotypes.

In the present study, as GE interaction was significant for all the studied traits except plant height. This confirmed that the effect of phosphorus application brought significant changes in these parameters of chickpea genotypes which forced genotypes to respond differently across environments.

Conclusions and Recommendations

Among 15 chickpea genotypes tested, Genotype NDC-4-20-4 exhibited the highest 100-seed weight which was 28.2 g whereas, genotype NDC-4-20-1 outyielded the rest of the genotypes for seed yield (1004.2 kg ha^{-1}) in the environment having phosphorous application whereas it was only 126 kg h^{-1} in the control treatment. On the other hand, some genotypes such as NDC-15-1 yielded lower in P treatment compared with the control. Plant heights of all genotypes treated with P were lower than those of control plants. The highest yielding genotype was NDC-4-20-1; hence it can be used for improvement of seed yield and its attributing traits in different chickpea breeding programs. This experiment revealed that phosphorus application forced chickpea genotypes to respond differently and hence produce different mean performance for various traits. This study suggests sufficient phosphorus application to achieve higher seed yield in chickpea genotypes.

Novelty Statement

Phosphorus is one of the essential fertilizers for crop plants which plays a crucial role in plant growth and development. Imbalance application of phosphorus adversely affects the performance of chickpea resulting in lower seed yield. However, efficiency of chickpea genotypes to phosphorus application is different which is determined by its genetic makeup. Therefore, chickpea genotypes must be assessed in varying phosphorus applications to reduce the cost of production.

Authors' Contribution

Hera Gul Mohammad: Performed the experiments

and wrote the first draft of the manuscript.
Hera Gul Mohammad and Rozina Gul: Formulated the research.
Hamayoon Khan and Sheraz Ahmed: Critically reviewed the first draft.
Ajmalud Din, Laila Fayyaz and Imtiaz Ali: Helped in data analysis and revised the first draft.

Conflict of interest
The authors have declared no conflict of interest.

References

Ali, M.A., N.N. Nawab, G. Rasool and M. Saleem. 2008. Estimates of variability and correlations for quantitative traits in *Cicer arietinum*. J. Agric. Soc. Sci., 4(4): 177–179.
Aulakh, M.S., N.S. Pasricha and G.S. Bahl. 2003. Phosphorus fertilizer response in an irrigated soybean–wheat production system on a subtropical, semiarid soil. Field Crops Res., 80(2): 99–109. https://doi.org/10.1016/S0378-4290(02)00172-7
Badini, S.A., M. Khan, S.U. Baloch, S.K. Baloch, H.N. Baloch, W. Bashir, A.R. Badini and M.A. Badini. 2015. Effect of phosphorus levels on growth and yield of chickpea (*Cicer arietinum* L.) varieties. J. Nat. Sci. Res., 5(3): 169–176.
Chen, C., G. Jackson, K. Neill and J. Miller. 2006. Spring pea, lentil and chickpea response to phosphorus fertilizer. Fertilizer Facts 38. Montana Agricultural Experiment Station, Montana State University, Bozeman.
Chowdhury, S.L., S. Ram and G. Giri. 1975. Effect of P, N and inoculum on root, nodulation and yield of gram. Indian J. Agron., 20(3): 290–291.
Desai, K., C.J. Tank, R.A. Gami and A.M. Patel. 2016. G × E interaction and stability analysis in chickpea (*Cicer arietinum* L.). Int. J. Agric. Environ. Biotechnol., 9(4): 479–484. https://doi.org/10.5958/2230-732X.2016.00063.2
Fairhurst, T., C. Witt, R. Buresh and A. Dobermann. 2007. Rice: A practical guide to nutrient management. Industriestrasse 31 CH-6300 Zug, Switzerland.
FAO. 2019. Food and Agriculture Organization of the United Nations (FAO), Statistics Division. Crops. (http://www.fao.org/faostat/en/#data/QC) (accessed 1 February 2021).
Frossard, E., L.M. Condron, A. Oberson, S. Sinaj and J.C. Fardeau. 2000. Processes governing phosphorus availability in temperate soils. J. Environ. Qual., 29(1): 15–23. https://doi.org/10.2134/jeq2000.00472425002900010003x
Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. 2nd ed. John Wiley & Sons Inc., New York, NY, USA.
Gul, R., H. Khan, N.U. Khan and F.U. Khan. 2014. Characterization of chickpea germplasm for nodulation and effect of rhizobium inoculation on nodules number and seed yield. J. Anim. Plant Sci., 24: 1421–1429.
Hussain, Q., N. Ahmad, M. Adnan, R. Mehbob and A. Sohail. 2018. Estimates correlation coefficient among yield and yield attributing traits in twenty chickpea genotypes. Int. J. Agric. Environ. Res., 4(2): 84–87.
Islam, M., S. Mohsan, S. Ali, R. Khalid, F. Ul-Hassan, A. Mahmood and A. Subhani. 2011. Growth, nitrogen fixation and nutrient uptake by chickpea (*Cicer arietinum*) in response to phosphorus and sulfur application under rainfed conditions in Pakistan. Int. J. Agric. Biol. 13(5): 725–730.
Johansen, C. and K.L. Sahrawat. 1991. Strategies for maximizing the efficiency of phosphorus utilization in cropping systems involving chickpea and pigeonpea. In: Johansen, C., Lee, K.K. and Sahrawat, K.L., (eds.), Phosphorus nutrition of grain legumes in the semi-arid tropics. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India. p. 227–241.
Jukanti, A.K., P.M. Gaur, C.L.L. Gowda and R.N. Chibbar. 2012. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): a review. Br. J. Nutr., 108(S1): S11–S26. https://doi.org/10.1017/S0007114512000797
Keneni, G., E. Bekele, F. Assefa, T. Debele, K. Dagne and E. Getu. 2015. Characterization of Ethiopian chickpea (*Cicer arietinum* L.) germplasm accessions for phosphorus uptake and use efficiency I. Performance evaluation. Ethiop. J. Appl. Sci. Technol., 6(2): 53–76.
Kumar, A., M. Kumar, P. Chand, S.K. Singh, P. Kumar and L.K. Gangwar. 2020. Studies on genetic variability and inter relationship among yield and related traits of parents and F1 population in Chickpea (*Cicer arietinum* L.). J. Pharmacogn. Phytochem., 9(3): 1434–1438.
Kwon, S.H. and J.H. Torrie. 1964. Heritability and interrelationship among traits of

two soybean populations. Crop Sci., 4(2): 196–198. https://doi.org/10.2135/cropsci1964.0011183X000400020023x

Macil, P.J., J.B. Ochanda Ogola, J.J. Owuor Odhiambo and S.G. Lusiba. 2017. The response of some physiological traits of chickpea (*Cicer arietinum* L.) to biochar and phosphorus fertilizer application. Legum. Res. Annu. Int. J., 40(2): 299–305. https://doi.org/10.18805/lr.v0i0.7290

Mansur, C.P., Y.B. Palled, S.I. Halikatti, P.M. Salimath and M.B. Chetti. 2009. Effect of plant densities and phosphorus levels on seed yield and protein content of Kabuli chickpea genotypes. Karnataka J. Agric. Sci., 22(2): 267–270.

Maphosa, Y. and V.A. Jideani. 2017. The role of legumes in human nutrition. In: Hueda, M.C., (ed.), Functional food - Improve health through adequate food. IntechOpen. https://doi.org/10.5772/intechopen.69127

Nath, P., J. Dev, A. Nath, S. Nath, S. Singh and R. Kathwal. 2013. Response of chickpea (*Cicer arietinum* L.) to phosphorus and weed control measures on yield and quality. 29: 340–345.

Neenu, S., K. Ramesh, S. Ramana and J. Somasundaram. 2017. Effect of cultivars and sowing dates on nutrient uptake and yield of chickpea under aberrant climatic conditions in black soils of central India. Adv. Res., 12(4): 1–11. https://doi.org/10.9734/AIR/2017/37624

Plaxton, W.C. and M.C. Carswell. 1999. Metabolic aspects of the phosphate starvation response in plants. In: Lerner, H.R., (ed.), Plant responses to environmental stresses: from phytohormones to genome reorganization. Marcel Dekker, New York, NY, USA. p. 349–372. https://doi.org/10.1201/9780203743157-16

Rahmatullah, M.A. Gill, B.Z. Shaikh and M. Salim. 1994. Bioavailability and distribution of phosphorus among inorganic fractions in calcareous soils. Arid L. Res. Manage., 8(3): 227–234. https://doi.org/10.1080/15324989409381397

SAS Institute. 2009. SAS/STAT ® User's Guide. 2nd ed. SAS Institute Inc., North Carolina, USA.

Serrano, C., B. Carbas, A. Castanho, A. Soares, M.C.V. Patto and C. Brites. 2017. Characterisation of nutritional quality traits of a chickpea (*Cicer arietinum*) germplasm collection exploited in chickpea breeding in Europe. Crop Pasture Sci., 68(11): 1031–1040. https://doi.org/10.1071/CP17129

Shukla, M., R.H. Patel, R. Verma, P. Deewan and M.L. Dotaniya. 2013. Effect of bio-organics and chemical fertilizers on growth and yield of chickpea (*Cicer arietinum* L.) under middle Gujarat conditions. Vegetos, 26(1): 183–187. https://doi.org/10.5958/j.2229-4473.26.1.026

Siddiqui, S., S. Umar, A. Husen and M. Iqbal. 2015. Effect of phosphorus on plant growth and nutrient accumulation in a high and a low zinc accumulating chickpea genotypes. Ann. Phytomedicine, 4(2): 102–105.

Srinivasarao, C., A.N. Ganeshamurthy and M. Ali. 2003. Nutritional constraints in pulse production. Indian Institute of Pulses Research, Kanpur, India.

Ullah, S., A. Jan, M. Ali, W. Ahmad, H.U. Rehman, M. Ishaq and B. Ahamd. 2018. Response of chickpea (*Cicer arietinum* L.) to phosphorus and zinc levels and their application methods. Sarhad J. Agric. 34(3): 575–582. https://doi.org/10.17582/journal.sja/2018/34.3.575.582

Vance, C.P., C. Uhde-Stone and D.L. Allan. 2003. Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. New Phytol., 157(3): 423–447. https://doi.org/10.1046/j.1469-8137.2003.00695.x

Wang, N. and J.K. Daun. 2004. The chemical composition and nutritive value of Canadian pulses. Canadian Grain Commission Report, Winnipeg, Manitoba. pp. 19–27.

Wu, C., X. Wei, H. Sun and Z. Wang. 2005. Phosphate availability alters lateral root anatomy and root architecture of Fraxinus mandshurica Rupr. seedlings. J. Integr. Plant Biol., 47(3): 292–301. https://doi.org/10.1111/j.1744-7909.2005.00021.x

Yadav, H.D., O.P. Yadav, O.P. Dhankar and V. Kumar. 1990. Response of chickpea (*Cicer arietinum* L.) to gypsum and phosphorus application in sodic soil. Annu. Arid Zone, 29(4): 275–278.

Zeid, H.A., H.M. Wafaa, I.I. Abou El Seoud and W.A.A. Alhadad. 2015. Effect of organic materials and inorganic fertilizers on the growth, mineral composition and soil fertility of radish plants (Raphine's sativus) grown in sandy soil. Middle East J. Agric. Res., 4(01): 77–87.