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Response of chickpea cultivars to phosphorus application

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Abstract

Low soil P levels pose major limitation in realizing optimal growth and development of grain legumes and yet the suitable P levels of common chickpea cultivars (i.e. Black gram and Benazir) are not on the record. Effect of various P application levels (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) on two chickpea cultivars was evaluated in a field study using randomized complete block design. All the treatments received recommended dose of N and K_2O (each at 30 kg ha^{-1}) in the form of urea and SOP, respectively. Application of P resulted in significant increase in plant height (102.4 cm), number of branches (31.1 $plant^{-1}$) and grain yield (1058 kg ha^{-1}), shoot P (0.49%), P uptake (5.18 kg ha^{-1}) and protein content (17.4%) over control. Increasing the P levels from 50 to 75 kg P_2O_5 ha^{-1} did not have any significant effect on number of branches (30.4 to 31.1 $plant^{-1}$). As for cultivars, a significant effect was observed for grain yield ($p<0.06$) and P uptake ($p<0.001$) and the differences were prominent when the P level was increased from 50 to 75 kg P_2O_5 ha^{-1}. The P in shoot (0.50%) and plant uptake (5.71 kg ha^{-1}) were significantly affected by the interaction between P fertilizer and the cultivars in Benazir at the P level of 75 kg P_2O_5 ha^{-1}. The shoot P content gave a positive relationship with grain yield (R^2 0.67) and protein content (R^2 0.73) and grain yield with P uptake (R^2 0.89). Growth, yield, shoot P, P uptake and protein content of chickpea cultivars enhanced with phosphorus levels with highest at 75 kg P_2O_5 ha^{-1}. Chickpea cultivar Benazir responded better with regard to grain yield and P uptake.

Introduction

Chickpea is an important pulse crop and is assessed next to cereals due to its high protein content (18-27%), which is much higher compared to wheat (10.50-16.02%) (Sial *et al.,* 2012) and rice (7.00-7.56%) (Shabir, 2009). In human diet, it is an economical source for carbohydrates, oil, considerable amounts of vitamin (A, B and C), Fe, P, Ca in addition to quality vegetable protein (Aslam *et al.,* 2010; Rashid *et al.,* 2013; Uddin *et al.,* 2014). With huge population, the country requires more and more quantities of food and chickpea is the low cost available source for the poor people of the country in addition to some health benefits (Jukanti *et al.,* 2012). Pakistan produces 0.571 Mt of chickpea from 0.992 million hectares with an average grain yield of 757 kg ha^{-1} (GOP, 2014) against the potential yield of 2000 kg ha^{-1} (Ali *et al*., 2010). The country generally grows chickpea on marginal lands without any or little fertilizer application with general perception that being a legume crop it does not require any nutrients.

Phosphorus is a major nutrient element required for proper growth and yield of grain legumes. It is essential in efficient and early root development, enhanced nodulation, leaf size, tillering, flowering, grain yield, and fastens maturity. It plays an important role in photosynthesis process and storage and transfer of energy and sugar and starch utilization by being constituent of energy rich compounds viz. adenosine triphosphate (ATP) and adenosine diphosphate (ADP). Due to symbiotic nitrogen fixation, the energy requirement of leguminous crops is much higher and therefore the phosphorus. Many biochemical reactions cannot be carried out unless the phosphate in high energy compounds (ATP, ADP) is transferred to other energy requiring molecules in the plant (Memon, 1996; Green and Sharma, 2012).

Considering the low phosphorus status of Pakistani soils (80-90% soils are deficient) (Ahmad and Rashid, 2004), it is of basic importance not only to make phosphorus application compulsory but this expensive input may be used efficiently and effectively to overcome yield gaps. So far, the work carried out pertains to genotypes 90261, 93127, 97086, 98004, 98154 and Bittal-98 (Ali *et al.,* 2004, Ali *et al.,* 2010; Aslam *et al.,* 2010), Paidar-91 (Aslam *et al.,* 2000), Balkassar-2000 (Islam *et al.,* 2012; Islam *et al.,* 2013), Punjab-91, Punjab-2000 and Piadar-91 (Rashid *et al.,* 2013) belonging to northern Pakistan, except DG-89 and DG-92 (Badini *et al.,* 2015). There is a dire need to conduct research related to

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phosphorus requirement of local cultivars of the area for achieving higher yield and grain quality.

With this thought in mind, this study was planned to evaluate the effect of various P levels (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) on growth, yield and protein content of two local chickpea cultivars (Black gram and Benazir) of Sindh, Pakistan.

Materials and Methods

The experimental field Pulses Research Sub-station, Tandojam Sindh, a subtropical region of the country is located at latitude 25º25ˈ35.60˝N, 68º32ˈ35.76˝E, and an elevation of 25 m above sea level in the south of Pakistan. The area is characterized by hot summers and mild cold winters having average temperature of 32ºC, which normally rises to 48ºC during the months June-August with average rainfall of 15-18 cm. The silty clay loam soil (0-15 and 15-30 cm) had EC of 0.23 and 0.26 dS m^{-1}, pH 7.70 and 7.75, organic matter 0.46 and 0.40 % and AB-DTPA P 2.80 and 2.30 mg L^{-1} at respective depths.

The field trial carried out during winter (2014-15) included two local cultivars Black gram and Benazir grown at four P levels i.e. 0, 25, 50 and 75 kg P_2O_5 ha^{-1}. The study followed a randomized complete block design with three replications totalling to 24 sub-plots, each having a size of $35m^2$ (5m x 7m). In addition to P, the crop also received uniform levels of N and K (30 kg each N and K_2O ha^{-1}). All the N, P and K, were given at the time of soil preparation. Chickpea field was ploughed with disc harrow, followed by irrigation as a soaking dose and planting of chickpea cultivars in rows by means of single coulter hand drill. Further, the crop followed all the agronomic practices, irrigation schedule, weed removal as per recommended production practices.

The crop matured in 120 days when it was harvested. The data for plant height, number of branches and seed index was recorded. The seed index (1000 grains) data were converted to grain yield by using the formula: Grain yield (kg ha^{-1}) = [grain yield (kg $plot^{-1}$)/plot size (m^{-2})] x 10000 and the grain samples obtained from each treatment were reserved for analysis. Whole shoots of six randomly selected plants from each plot were taken at flowering stage as given in Grain Legume Hand Book (1998). The shoots and grain samples were separately air (in shade) and oven dried (68ºC). The dried shoots and grains were ground to fine mesh size. Phosphorus content in plant shoots and grains was carried out by acid digestion (Rashid, 1986), followed by developing a yellow coloured complex (Cottenie, 1980) quantified at 470 nm wavelength using spectrophotometer (Shimadzu UV-1800, Japan). Protein content in grains was tested as given by Lowry *et al*. (1951). Phosphorus uptake was calculated by using the formula: P uptake (kg ha^{-1}) = [P contents (%) in plant part (dry matter) x yield (kg ha^{-1})]/100.

The analysis of variance and regression analysis for various parameters were carried out using Statistix 8.1. The means were compared by using Tukey's Honestly Significant Difference Test ($HSD_{0.05}$).

Results

Phosphorus levels significantly ($p<0.05$) affected the growth parameters, plant height, number of branches, grain yield, shoot P content, P uptake, and grain protein content of chickpea cultivars under study. The chickpea cultivars and the interactive effect between P levels and the cultivars was significant ($p<0.05$) for grain yield ($p<0.06$) and P uptake. Whereas, the shoot P content was only significant ($p<0.05$) in case of interaction as presented in Table 1.

Table 1: F values and significance from analysis of variance for various growth parameters i.e. seed yield and grain protein content at various P levels for chickpea cultivars

Parameter	P levels (P)	Cultivars (C)	P x C
Plant height	20.49***	0.90 ^{NS}	1.15^{NS}
Number of branches	25.99***	3.35^{NS}	0.79 ^{NS}
Grain yield	34.49***	4.15*$^{(@ 0.06)}$	3.22*$^{(@ 0.06)}$
Shoot P content	296.87***	0.59^{NS}	5.64**
Grain protein content	5.75**	0.18 ^{NS}	0.80 ^{NS}
P uptake	143.36***	6.16*	3.37*

NS - non significant; *, ** and *** - significant at 0.05, 0.01 and 0.001 probability level according to honestly significant difference (HSD) test

Plant height

The plants grew as tall as 102.4 cm with phosphorus application of 75 kg P_2O_5 ha^{-1} and as short as 86.1 cm against no phosphorus application (Fig. 1a), thus enhancing the plant height by 18.8%. Plant heights at the P levels of 0 (86.1 cm) and 25 (91.2 cm) kg P_2O_5 ha^{-1} were statistically similar in performance. Same was the case at 25 (91.2 cm) and 50 (94.1 cm) kg P_2O_5 ha^{-1}. Increasing the P level from 50 to 75 kg P_2O_5 ha^{-1} increased the plant height by 8.7% (94.1 to 102.4 cm). Plant height, with respect to cultivar differences and the interactive effects of cultivars and phosphate fertilizer was although non-significant with no difference in cultivars.

Number of branches

Chickpea plants produced around 50% more branches when supplied with 75 kg P_2O_5 ha^{-1} over those treatments where no phosphorus was applied (Figure 1b) with respective branches of 20.6 and 31.1 in control and 75 kg P_2O_5 ha^{-1}. Nonetheless, increasing the P level from 50 to 75 kg P_2O_5 ha^{-1} did not bring any significant improvement in number of branches (30.4 to 31.1) and same was case at two lower P levels (i.e. 25 and 50 kg P_2O_5 ha^{-1}) where the branches increased from 20.6 to 26.9. Statistically, there was no variation in number of branches among two cultivars.

Grain yield

In contrast to plant height and number of branches, grain yield was significantly ($p<0.06$) affected by cultivars and the interaction in addition to P fertilizer ($p<0.05$). Maximum chickpea yield (1151.8 kg ha^{-1}) was achieved at highest P level (75 kg P_2O_5 ha^{-1}). The data (Figure 1c) explicitly highlights the importance of each additional doze and relevant increase in yield. There was 24% increase in yield with 25 kg P_2O_5 ha^{-1}, which further increased with the level of P. The yield increased by 19% when the P level was enhanced from 50 to 75 kg P_2O_5 ha^{-1}. Cultivar means show dominance of Benazir (868.4 kg ha^{-1}) over the Black gram (805.3 kg ha^{-1}) producing 7.8% more yield.

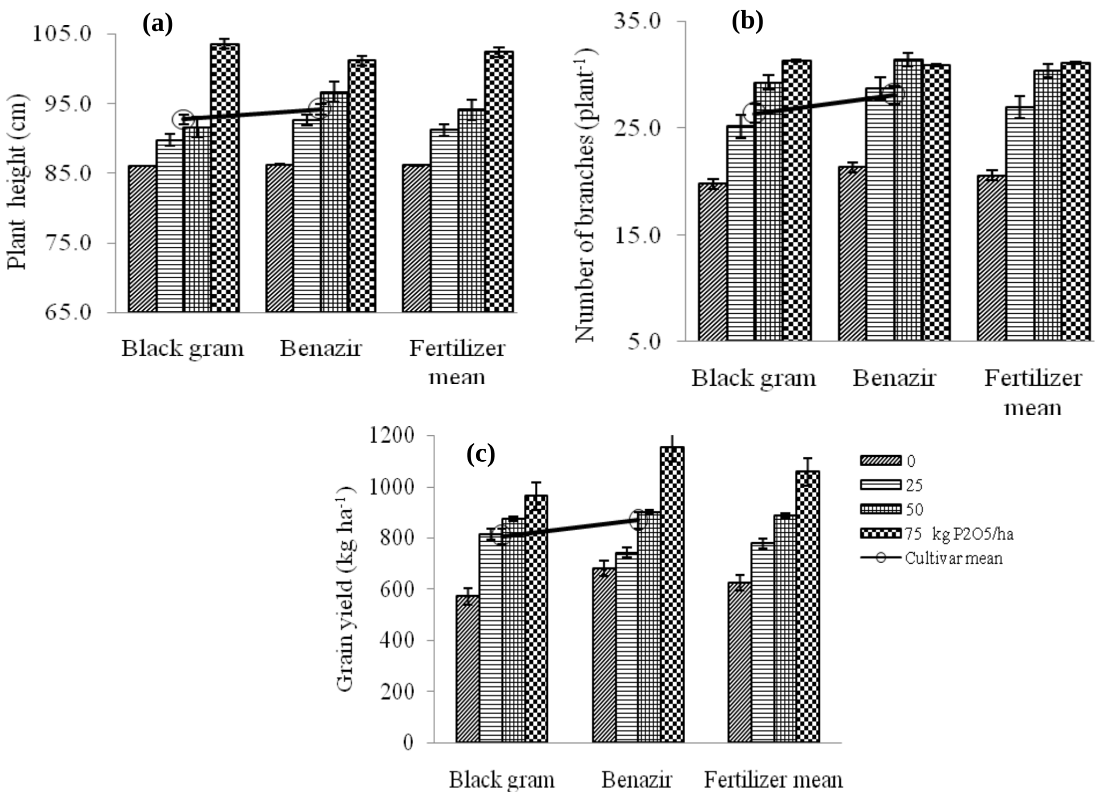

Figure 1: Effect of P fertilizer levels on two chickpea cultivars (Benazir and Black gram) in addition to mean fertilizer P on plant height (a), number of branches (b) and grain yield (c)

Shoot P content

The enhancement in shoot P content data (Fig. 2a) with each addition of 25 kg P_2O_5 ha^{-1} proves the importance of P fertilizer application. Phosphorus content almost doubled (0.23-0.49 %) from control (0.23%) to the treatment having P application level of 75 kg P_2O_5 ha^{-1}. There was 27% increase in shoot P content when P level increased from 50 to 75 kg P_2O_5 ha^{-1} and both values (0.38 and 0.49 %) were above the critical P value of 0.34% as given in Grain Legume Hand Book (1998) for flowering stage. These results indicate that the fertilizer treatments played major role and that the effect of fertilizers was not same for each variety in the study.

23 % increase in yield and P uptake of Benazir over Black gram.

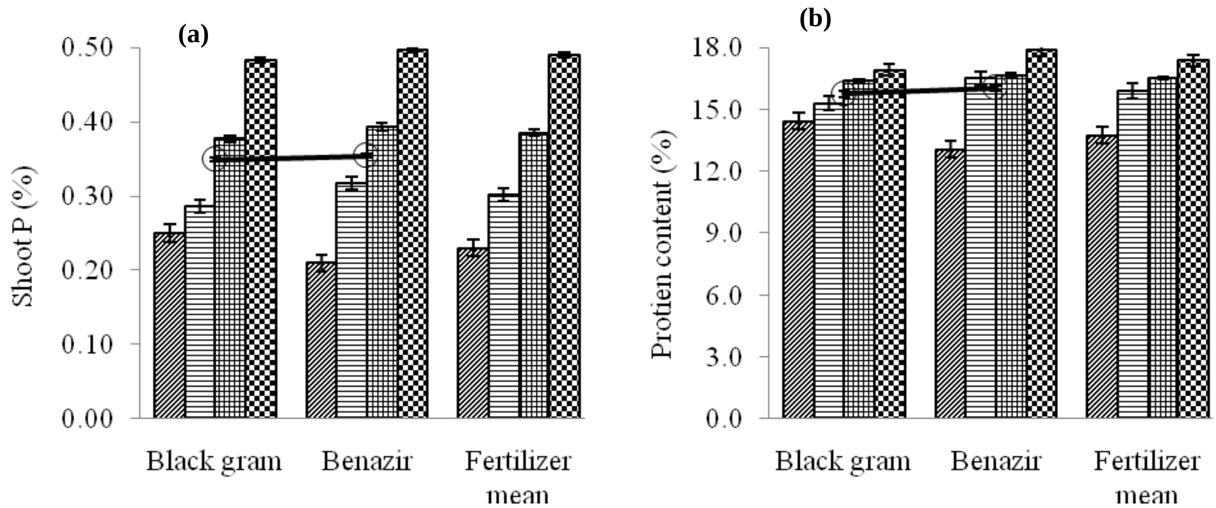

Figure 2: Effect of P fertilizer levels on two chickpea cultivars (Benazir and Black gram) in addition to mean fertilizer P on shoot P content (a) and protein content (b)

Protein content

The protein content of chickpea grain progressively improved with each level of P fertilizer. The values increased from 13.75% in control (0P) to 17.38% in treatment applied with 75 kg P_2O_5 ha^{-1} corresponding to 26% increase in protein content of chickpea grain. Even the treatment (50 kg P_2O_5 ha^{-1}) next to maximum performed better by accomplishing 20% increase over control (Figure 2b). This way, the P fertilizer application of 25 g added 5.2% increase in protein content. With non-significant differences among cultivars, the protein content of Benazir was slightly higher than the Black gram.

Grain yield and P uptake of two cultivars in relation to various P levels

Interactive effects of cultivars with fertilizer levels show a regular increase in the grain yield (Figure 3a) and P uptake (Figure 3b). Both of these traits show supremacy of Benazir at maximum P application levels in the study. Both yield and uptake have performed in the same way with no differences in cultivars. When the level was increased from 50 to 75 kg P_2O_5 ha^{-1}, the grain yield increased by 28% and uptake by 61% in case of Benazir and the same respective increase was 10 and 41% for Black gram. There was 20 and

Relationship of shoot P content and grain yield with various plant characteristics

Grain yield and protein content of chickpea was separately regressed against shoot P contents in addition to grain yield with plant uptake of chickpea to find out the type of relationship. Figure 4 shows increase in grain yield (Fig. 4a) and protein content (Fig. 4b) with the increase in shoot P content, which is illustrated by significant ($p<0.01$) relationship with corresponding coefficient of determination (R^2) of 0.67 and 0.72. Similarly, the grain yield when regressed with chickpea uptake gave positive, linear and significant ($p<0.01$) relationship (Fig. 4c).

Discussion

Phosphorus is an essential plant nutrient required for the growth of chickpea. In leguminous crops, the requirement of P as ATP or ADP compounds is not only vital but much higher due to symbiotic fixation of N (Bildirici and Yilmaz, 2005; Walley *et al.*, 2005 and Uddin *et al.*, 2014). With P application, the yield and protein content of chickpea is improved (Shukla *et al.*, 2010). Majority of the chickpea growers in Sindh, Pakistan do not consider the application of phosphorus fertilizer in spite of the reality that majority of the soils of this area are deficient (<0.4 mg kg^{-1}) in AB-DTPA extractable P. Under these conditions, the crop completely relies on the applied P. Phosphorus efficiency of chickpea may also be cultivar dependent. Limited studies have been carried out for local cultivars of chickpea in Sindh with regard to P application.

This study illustrated significant improvements in growth, yield and protein content (Figures 1-4) of chickpea

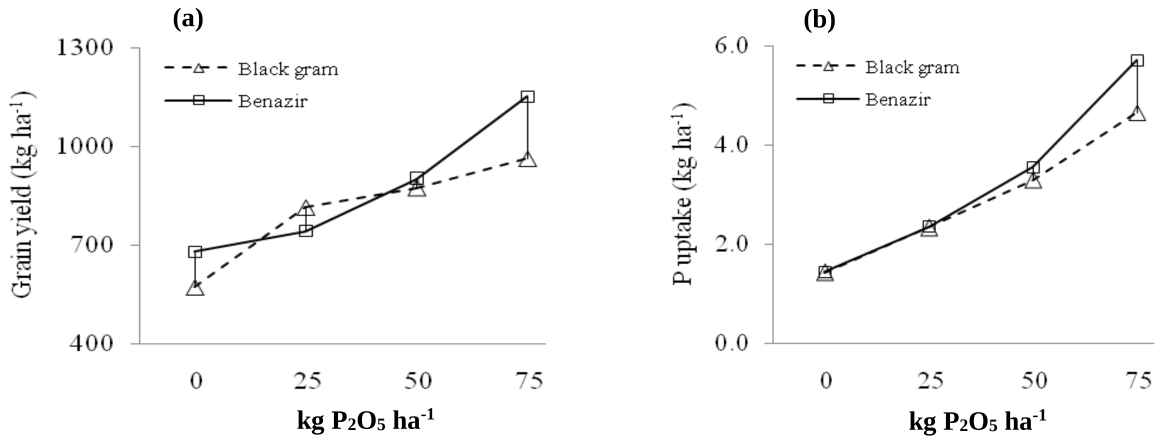

Figure 3: Grain yield (a) and P uptake (b) of two cultivars under different P levels.

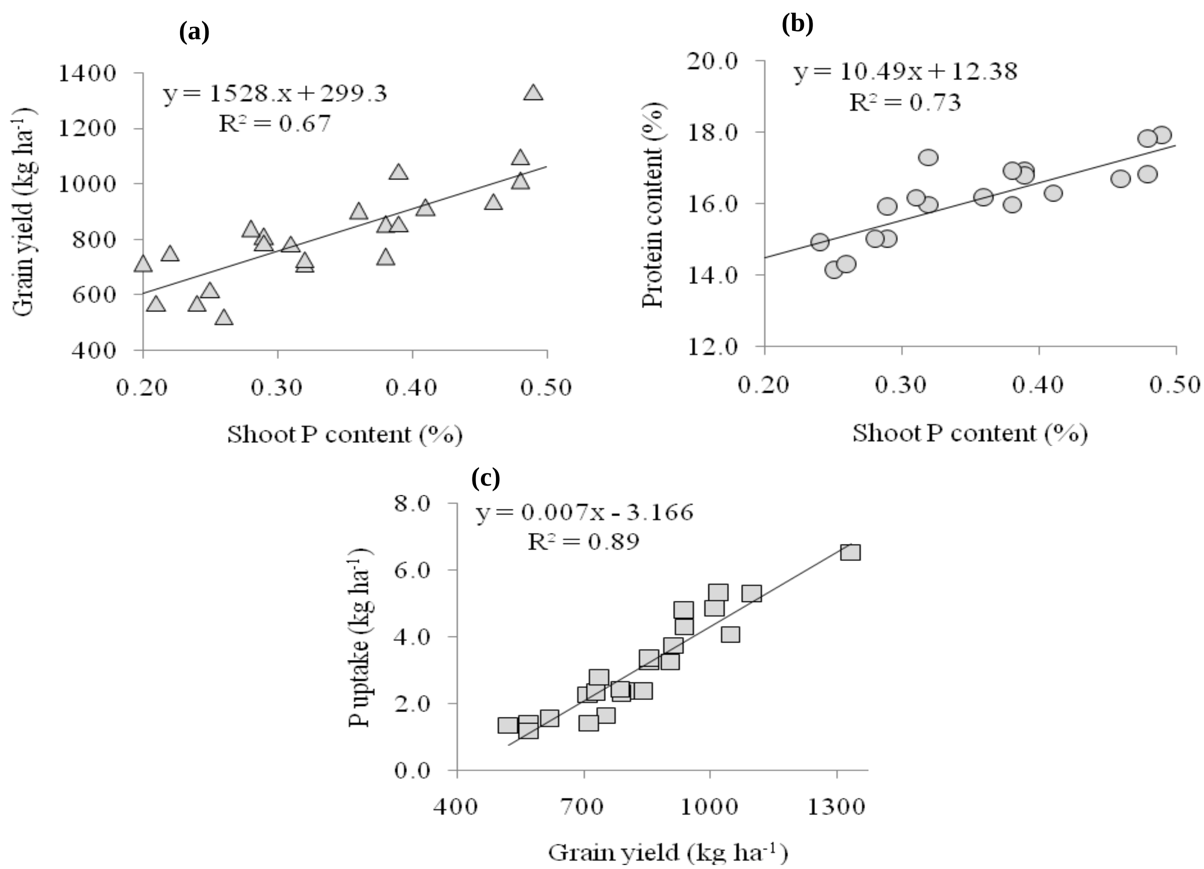

Figure 4: Relationship between shoot P and grain yield (a), shoot P and protein content (b) and grain yield and uptake (c) of two chickpea cultivars Black gram and

cultivars in response to P application levels i.e. plant height (19%), number of branches (50%), grain yield (69%), shoot P (113%) and grain protein (26%) content. Ali *et al*. (2010) recorded similar plant height for chickpea genotypes 98004, however, the grain yield as reported by them (2476 kg ha^{-1}) and Badini *et al.* (2015) (1691 kg ha^{-1}) was much higher compared to this study. It may be due to higher P levels (i.e. 206 and 126 kg P_2O_5 ha^{-1}). It may also be due to low ABDTPA soil P (2.80 mg kg^{-1}) contents of the experimental soil in our study. Our results are very closely in line with widely held research works (Aslam *et al.*, 2000; Rashid *et al.*, 2013; Hussen *et al.*, 2013; Fatima *et al.*, 2013) where P levels between 50 to 60 kg P_2O_5 ha^{-1} were effective in enhancing growth and grain yield of different chickpea cultivars.

The critical limit for P content in whole shoot at flower initiation stage is 0.241%. Yahiya *et al*. (1995) reported P contents of 0.24-0.25% in Indian chickpea varieties (C-235, Pusa 408 and Pusa 417) at 40 kg P_2O_5 ha^{-1}. Enhanced P levels (i.e 0-70 kg P_2O_5 ha^{-1}) did improve the P contents in whole chickpea shoot (0.23-0.49%) is evidence from this study. Similar results were reported by Rashid and Din (1992) which were further supported by Mazid and Roychowdhury (2014) for nutrient composition for Bengal gram (cultivar DCP 92-3).

There are very few studies with regard to P application concerning the protein content. Protein content of the chickpea cultivars did improve significantly with the levels of P, however, the protein content obtained at three P levels (i.e. 25, 50 and 75 kg P_2O_5 ha^{-1}) was at par, which is in agreement with the findings of Uddin *et al*. (2014). Further the protein content of this study (14.1-17.9%) was exactly in line with the protein content of (11.3% to 17.6%) as given by Dragičević *et al*. (2015) for nineteen chickpea varieties. The protein content was also similar as reported by Rashid *et al.* (2013).

The data related to grain yield and P uptake additionally demonstrated cultivar and interactive (fertilizer and cultivar) differences (Table 1 and Figure 3). The interaction data depicted that the differences in these two parameters were not significant till a higher level of P (i.e. 75 kg P_2O_5 ha^{-1}) was supplied with Benazir being superior. These results are supported by Bhunia *et al.* (2006) and Ali *et al.* (2010).

The regression analysis depicted a positive, linear and significant relationship between shoot P and grain yield and protein content, and similarly grain yield with P uptake. Positive relations can be attributed to the fact that P plays a key role in pod filling, resulting into increased grain yield (Idris *et al*., 1989; Gupta *et al*., 1998). In addition, the graded application of P might have increased the root development, consequently enhanced absorption and availability of P (Yahiya *et al.*, 1995; Patel *et al.*, 2014) which ultimately increased the uptake in the study area. It is more likely in the study area where soils are P deficient (Memon *et al.*, 1992). Added P can also mobilize the availability of other nutrients such as N and S which in turn can affect the protein content (Williams and Singh, 1987). Since both nutrients are involved in protein metabolism and their relationships are always synergetic (Zhao *et al.*, 997). The relationships of shoot P and protein content in this study are closely linked to this fact.

Through this study, it was concluded that all the parameters plant height, number of branches, grain yield, P content in shoot, plant P uptake and protein content of chickpea cultivars increased with the increase in P level with highest at 75 kg P_2O_5 ha^{-1}. Chickpea cultivar Benazir responded better with regard to grain yield and P uptake in the study area. Further, research needs to be carried out at different areas of Sindh including more cultivars of the area at narrow gap between P levels. In addition, Chickpea cultivar Benazir may be considered for future breeding program since it is proved more P efficient cultivar than black gram.

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