Research Article

Phosphorus Application on Grain Yield, Uptake and P Utilization Efficiency of Mungbean (*Vigna radiata* L.)

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Abstract | Mungbean represents second largest crop after chickpea which mostly grow without nutrients. Among leguminous pulse food grain, phosphorus application shows an important part in enhancing plant productivity of the crop. Keeping in view the role of plant nutrition, research trial was led to determine various rates of P 0, 25, 38, 50, 75, 100, 125, 150 P_2O_5 kg ha $^{-1}$ on yield, uptake, P utilization efficiency of Mungbean. For this, randomized complete block design was arranged with three times. The outcome showed that Phosphorus application 50 kgha^{-1} P_2O_5 with nitrogen (N), and potassium (K) (15 kg ha^{-1} N and K_2O) had significant effect on mungbean growth parameters, 75 kg ha^{-1} P_2O_5 gave highest result of yield related parameters. The maximum plant height (70 cm), number of plant/ treatment (82), number of fruits bearing branches (23), number of pods plant^{-1} (88), 1000 grain weight (45.3 g), biomass yield (2478 kg ha^{-1}), yield of grain (2986 kg ha^{-1}), yield of straw (509 kg ha^{-1}), protein (22%), leaves P (0.46 %) content, P uptake (11.49 kg ha^{-1}) and P utilization efficiency (10.3 %) were noted by P application with N and K applied treatment. However, the lowest values were recorded where no P was applied. The highest yield had 100% increase in mungbean yield with combined nutrient application of N:P: K (15:75:15 kg ha^{-1}) compared the control plot through this study. Increasing the P application levels from 100 to 150 P_2O_5 kg ha^{-1} with N and K application (both 15 kg ha^{-1}) did not express any vital outcome on yield and yield contributing parameters. It is recommended that P application is essential for mungbean; however, further studies may be conducted on various types of soil. The relationship was found positive among all yield parameters. Hereafter, it was suggested that P application with N and K mineral are important for mungbean growth and production enhancement.

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Introduction

Mungbean (*Vigna radiata* L.) is a key annual herbaceous, short duration; tropical leguminous pulse crop belongs to the family phaseoleae (Patel *et al*., 2014; Aziz-Ur-Rehman *et al*., 2019). It is used as a cereal based humanoid food grain, cuisine, beverage source, vegetal, green manure, livestock feed and medication in Pakistan (Cheng, 2016). Mungbean is also an energetic rich source of digestible vegetarian protein and lysine (GOP, 2019). Its seed contains protein (24.7-28.5%), fat (0.65%), fiber (0.95 %), ash (3.75 %) (Monem *et al*., 2012) and vitamin A (74.37 mg), C (4.8 mg), foliate (625 mg), Ca (132 mg/100g), P (367 mg/100g) and Zn (2.7 mg/100g), respectively (Mbeyegala *et al*., 2017). In Pakistan, Mungbean represents the second largest crop among pulse food grain and cultivated twice in a year in spring and summer seasons (Raina *et al*., 2016; Amin *et al*., 2019).

Mungbean was grown of 163,200 hectares area with production raised at 118,000 tons and an average yield of 723 kg ha^{-1} (GOP, 2019). In Pakistan, there were 186.7 thousand hectares, 132.7 thousand tonnes, and 711 kg ha^{-1} of mungbean area, output, and yield (GOP, 2020). The production was increased by 12.6 % over last year. But in general, average Mungbean yield is far below the level of potential yield (2650 kg ha^{-1}) compared to other countries. Among the important of plant nutrient, Phosphorus (P) is the second major nutrient and performs various physiological functions such as photosynthesis, storage, carbohydrates utilization, seed formation, fruiting and root development, respiration (Anwar, 2016). Nearly 98 percent of farmers in Sindh do not apply P fertilizer on their mungbean crops since it is commonly accepted that as a leguminous crop, it does not require fertilizers. In the rest of Pakistan, 90 percent of soils are poor in available P. Despite the fact that most soils are alkaline and calcareous in nature, the efficacy of applied P is poor, ranging from 15-20 percent at best (Mehta *et al*., 2014). Since, P adsorption and precipitation with $CaCO_3$ and Ca ion in soil with high pH, P inadequacy is a ubiquitous concern in Pakistan soils (Smith and Schindler, 2009). To overcome production gaps, consider the balance and required usage of P fertilizer with N and K application efficiently and effectively (Sahai, 2004). Currently, the farmers ignored fertilizer application due to its high prices. Nevertheless, P application has valuable outcome on crop production. Review of the local work demonstrated combine effect of P with N and K fertilization on yield of Mungbean as well as other leguminous crop (Malik *et al*., 2002; Shah *et al*., 2006; Memon *et al*., 2016; Rajput, 2018). Fageria *et al*. (1997) described that the dry bean grain yield increased with the addition P fertilizer application. Similarly, Higgs *et al*. (2000) conducted that world grain production enhanced 30-50% with the addition of fertilizer including P since 1950s. So far, many researchers depicted that the, combine application of NPK are essential nutrient and responsible for increased plant height, nodulation pattern, growth, yield and quality of Mungbean (Ali *et al*., 2010; Awomi *et al*., 2012; Meena, 2013; Meena and Yadve, 2015). Additionally, the combined of P with N resulted maximum yield, number of fruit bearing branches plant^{-1}, protein content and highest net income (Malik *et al*., 2003; Sadeghipour and Tajali, 2010; Razzaque *et al*., 2017). Also, application of different P levels with various methods (broadcast, banding and fertigation) of mungbean crop gave highest yield, uptake and agronomic efficiency with increasing P levels with fertigation methods (Shah *et al*., 2006). Similarly, NPK with rhizobacterium depicted positive response for enhancing growth and productivity of mungbean crop (Figueiredo *et al*., 2008). Malik *et al*. (2002) conducted field experiment to determine the effect of various P levels (0, 30, 50, 90 and 110 kg ha^{-1}) on Mungbean variety NM-98. Maximum yield was obtained with P levels applied 50 kg ha^{-1}. Maximum yield (2626.7 and 1500.2 kg ha^{-1}) were found with 84 kg ha^{-1} P_2O_5 applied treatment at 2007 and 2008 years, respectively. Sadeghipour and Tajali (2010) concluded the maximum productivity (224.2 gm^{-2}) with 120 kg P_2O_5 ha^{-1} with N 90 kg ha^{-1}. Whereas, Kumar *et al*. (2012) concluded the highest productivity (10.78 q ha^{-1}) and straw yield (26.63 q ha^{-1}) was found at 45 kg ha^{-1} P_2O_5. Furthermore, mostly higher yield was achieved at higher rate of P application (Meena and Varma, 2016; Kaysha *et al*., 2020). This study was planned to conduct research phosphorus application requirement with N and K for getting higher yield with minimum rate of application at irrigated field area in Sindh Pakistan.

Materials and Methods

Description of the experimental site

Tandojam Sindh is a semitropical area in Pakistan's southernmost province. Tandojam's Agriculture Research Sindh did a field trial. It is at a height of 56 feet (17 metres) above sea level. The experimental site had climatic conditions with yearly temperatures ranging from 27.7 to 38 degrees Celsius and annual rainfall ranging from 150 to 200 millimeters. The data of physico-chemical parameters of experimental soil provided in Table 1.

Table 1: *Soil analysis before P application.*

Soil parameters										
EC	pH	O.M	$CaCO_3$	Soil N	Available P	Available K	Sand	Silt	Clay	Textural class
dSm^{-1}	(1:2)	(%)	(%)	(%)	(mg kg^{-1})	(mg kg^{-1})	(%)	(%)	(%)	
7.8	0.38	0.66	12.54	0.03	7.48	77	25	35	45	Clay loam

Table 2: *Environmental data during experiment.*

Dates	Rainfall month^{-1}	Temperature °C		Relative humidity	Cloudiness	Sun-shine	Wind/ Speed	Direc-tions	Evapora-tion
	(mm)	Min.	Max.	%	Octas	Hrs	Km/hr	S	mm/day
June 2015	22.5	28	45	30	1.0	14	4.0	S	6.8
July 2015	45.2	26	40	35	1.0	13	3.8	S	5.9
August 2015	55.7	27	39.3	40	6.8	12	3.5	S	5.1
September 2015	17.5	22	36.6	48	3.7	10	3.5	SN	3.9

Climate and weather conditions

Averagely, highest and lowest temperature were 41.9 and 23.3 (May and September 2015) respectively. May is the hottest month of the summer having maximum temperature up to 41.90. The climatological data viz. rainfall, temperature, relative humidity, evaporation and cloudiness were recorded at meteorological observatory. The data depicted in Table 2. The rainfall of 0.3 and 4.2 mm was noted in the month of June and July with a mean relative humidity of 58 and 70%. During the month of August, mean relative humidity was 68.66%, while, in September with mean relative humidity of 70.8% and in October it was recorded 69.72%.

Experimental details

Field experiment was conducted with Mungbean included local variety C-95 to know various levels of phosphorus (0, 25, 38, 50, 75, 100, 125 and 150 P_2O_5 kgha^{-1}) on the yield, uptake, and P recovery of mungbean. The experiment was laid out in RCBD with three time replications totaling to 24 sub-plots, each have a size of 15 m^2 (3 m x 5 m). The sowing was done in the month of June and harvesting was completed in initial dates of September 2015.The variety was sown with the help of a single row hand drill on a well-prepared soil. With a disc harrow, the field was prepared for sowing. Mungbean seeds were then sown in rows using a single coulter hand drill. After seeding, row to row (40 cm) and plant to plant (10 cm) distance was maintained by thinning manually. In addition to P fertilizer, the crop was given consistent amounts of 15 kg of NK_2O ha^{-1}. During land preparation, the entire quantity of P, K, and N (1/3) in the farm of single super phosphate, potassium sulphate, and urea were given according to treatment. The remaining N was applied during the first and second irrigations after planting. Three modest (2-3 cm) irrigations were applied to the crop and first irrigation was applied after 21 days of seeding. Agronomical procedures such as weeding, hoeing, watering, and plant protection are also important. The crop was developed and harvested after 120 days. Various observations for instance Plant height, number of plants per treatment, number of fruits producing branches, and 1000 grain weight were all measured as growth characteristics. Grain productivity was determined with the following equation: grain weight (kg ha^{-1})/area size (m^{-2}) 10000. Straw yield, on the other hand, was calculating by deducting productivity from biomass (biological) output. Harvest index was calculated by = Productivity (kg ha^{-1})/biological yield (kg ha^{-1}) 100.

Physico-chemical properties of experimental field

Representative 10 soil samples from the experimental region were collected and composted on a single sample to determine the fertility level. Prior to seeding mungbean, soil samples were assembled at the depths of 0-20 cm using an auger. The materials were air dried before being sieved through a 2 mm sieve and analyzed. The hydrometer technique (Bouyoucos, 1962) was used to measure soil texture, pH, and EC in a 1:2 soil-water extract.

The Walkley Black technique (Jackson, 1962) was used to determine soil organic matter, lime by acid neutralization method (Jackson, 1969) and total soil N by Kjeldahl's distillation. The available P was assessed using 1 N ammonium acetate (NH_4OAc), followed by colour development using the Murphy and Riley (1962) ascorbic acid technique. Available K was determined by same extract of NH_4OAc by Knudsen *et al*. (1982) on flame photometer.

Plants leave sampling and analysis

Ten plants per treatment were selected at random, tagged and numbered separately. Plant leaves were taken at the time of flowering initiate stage (Grain Legume Hand Book, 1998). Third leaves from top were selected, clean with distilled water, dried at 70°C in an oven, and then ground in Wiley's mill. Nitric acid and perchloric acid (HNO_3:$HCLO_4$) were prepared with 5:1 ratio and poured 10 ml in grind plant leaves. After digestion, total nitrogen was determined by Kjheldahl's method, total P by metavanadate yellow color method (Jackson, 1962) and total P and K by (Soltanpour and Schwab, 1977). For calculation of protein content, N (%) in grain was multiplied by 6.25 (Hiller *et al*., 1948). However, further, parameters of P uptake and P use efficiency (Fageria *et al*., 1977) by using following formulae:

$$\text{P uptake (kg ha}^{-1}\text{)} = \text{Productivity (kg ha}^{-1}\text{)} \times \text{P content (leaves) (\%)} / 100$$

$$\text{P use efficiency (\%)} = \text{P uptake (fertilized)} - \text{P uptake (Control)} \times 100 / \text{P applied (kg ha}^{-1}\text{)}$$

Statistical analysis

Data was statistically examined, and treatment means were compared using Statistix 8.1's Duncan's multiple range tests at a 5% level of probability (Anonymous, 2005).

Results and Discussion

Soil properties

The texture of soil was a clay loam containing 25% sand, 35% silt and 45% clay (Table 1) by USDA system. The soil had an EC value (7.8 dS m^{-1}), pH (0.38) and $CaCO_3$ content of 12.54%. The soil had low soil nitrogen (<0.05 %), low organic matter < 0.86 %), medium level of AB-DTPA P (<7 mg kg^{-1}) and low in NH_4OAc extractable K (>120 mg kg^{-1} soil) (Knundsen *et al*., 1982) with respective values of 0.66 %, 0.03 %, 7.48 mg kg^{-1} and 77 mg kg^{-1} soil (Table 1).

P application had significantly ($P< 0.05$) an impact the growth as well as productivity and its contributing characteristics such as number of fruits bearing branches plant^{-1}, 1000 grain weight in gram (g), productivity, yield of straw and biomass in kilogram per hectare (kg ha^{-1}), Total P content in leaves, protein content, P uptake, P recovery and P use efficiency of Mungbean except plant height, pods per plant and plants treatment^{-1} (Table 3).

Table 3: *Analysis of variance for different parameters of Mungbean cultivar (C-26) as affected by P application.*

Parameters	F value	LSD (0.05)	S.E.
Plant height (cm)	0.49NS	11.85	5.52
No. of plant treatment^{-1}	0.55NS	16.25	7.57
No. of fruit bearing ranches plant^{-1}	0.57NS	5.03	2.35
No. of pods plant^{-1}	1.07NS	21.68	10.10
1000 grain weight (g)	37.28**	5.54	2.58
Grain yield (kg ha^{-1})	100.78**	214.43	99.98
Biomass yield (kg ha^{-1})	29.22**	252.4	117.7
Straw yield (kg ha^{-1})	7.55**	339.4	158.3
Harvest index	20.66	0.345	0.16
Total N (shoot content)	7.45**	0.34	0.16
Total P (shoot content)	331.3**	0.029	0.014
Protein %	735.3**	0.23	0.107
P uptake (kg ha^{-1})	580.5**	0.68	0.319
P recovery (%)	431.1**	0.899	0.419

NS: Non-significant and significant at 0.05 and 0,01 probability level according to least significant difference (LSD) test.

Growth parameters

Growth parameters plant height and number of plants treatment^{-1}were observed with the various phosphorus applications was non-significant whereas number of fruits bearing branches and number of pods plant^{-1} produced significantly 20% more fruit bearing branches and pods at the rate of 50 P_2O_5 in kilogram per hectare (kg ha^{-1}) with combine NK_2Oapplication (Figure 1).

Plant height (cm)

Plant height is among the most essential parameters of the crop. The findings shown in Figure 1 show that the plants height grew from 67 cm under control to 75 cm when 150 kg of P_2O_5 per hectare was applied. The application of various P levels showed increasing trend over control plot. However, data study using statistics revealed that the various P levels were non-significant with increasing P levels among them.

Number of plants per treatment

A key increase in number of plants per treatment over control was observed with various P levels (Figure 1).

The highest value was observed 23 when 50 kg of P_2O_5 per hectare was applied. There was increased by 35% over control plot. The treatments ranging from 75 to 150 kg ha^{-1} P_2O_5 functioned equally, with no statistically differences between them.

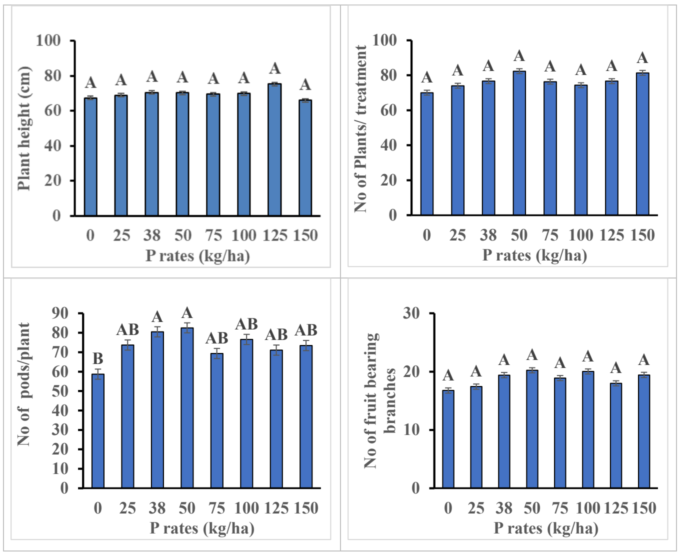

Figure 1: *Effect of P application on plant height (A), number of plants/treatment (B), pods/plant (C) and fruits bearing branches/ treatment (D) of mungbean.*

Number of fruits bearing branches plant⁻¹

The data in Figure 1 revealed significant influence of various P levels on fruit bearing branches. The maximum number of fruits bearing branches counted (32) at the P level of 50 kg P_2O_5 $ha^{-1}$and lowest (17) was obtained over control plot. Thus, there was increased 20% over control plot. Moreover, the remaining P levels from 75 to 150 kg ha^{-1} showed similar in performance and the differences between these treatments were statistically non-significant.

Number of small pods plant⁻¹

A significant enhance in number of pods $plant^{-1}$ was exhibited with various P rates. With the addition of (50 kg ha^{-1} P_2O_5), the maximum number of pods $plant^{-1}$ (88) was counted and the minimum value was found under control plot. There was 49% increase with 50 kg P_2O_5 ha^{-1}, which further enhanced with the increasing P levels. Number of pods $plant^{-1}$were recorded at the P levels of 75 (85), 100 (85), 125 (82) and 150 (83) kg P_2O_5 $ha^{-1}$and did not show any significant effect among each other. Similar case was noted at the 25 (74) and 38 (80) kg P_2O_5 ha^{-1} (Figure 1).

Yield and yield contributing parameters

The increasing effect of P application got to an edge over no P application by producing significantly higher 1000 grain weight, productivity, biomass yield and yield of straw. The highest 1000 grain weight of (45.3 g) was counted at P level of 75 kg P_2O_5 $ha^{-1}$and (39 g) was noted at 50 kg P_2O_5 ha^{-1}. The lowest 1000 grain weight was counted where fertilizer was not applied. This was 99% increased at the 75 kg P_2O_5 $ha^{-1}$and 72 % at the 50 kg P_2O_5 ha^{-1}over control plot. Although, increasing P levels from 75 to 150 kg ha^{-1} P_2O_5 contributed to increase 1000 grain weight but the treatment differences were non-significant.

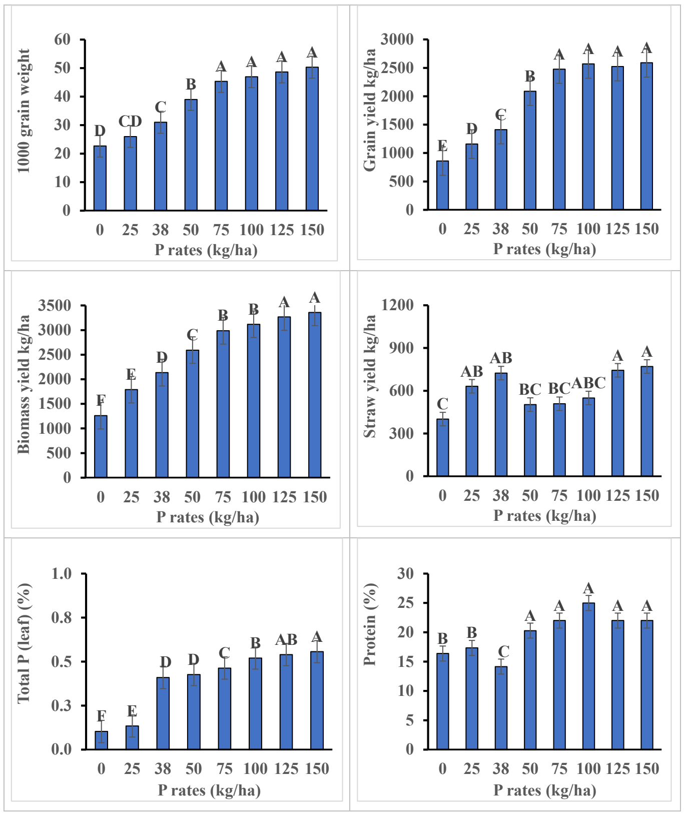

Figure 2: *Effect of P fertilizer application on 1000 grain weight (A), grain yield (B), biomass yield (C), straw yield, (D) leave P content (E) and protein % (F) of mungbean.*

The data in Figure 2 revealed significant increases in grain yield with increasing P level. Minimum yield (859 kg ha^{-1}) was recorded where P fertilizer was not applied; only N and K was applied. The data elaborated that the highest productivity was found where 75 kg ha^{-1} P_2O_5 was applied with N and K application as well as maximum grain yield (2089 kg ha^{-1}) was recorded at the rate of 50 P_2O_5 kg ha^{-1}. Thus, this was increased by more than 100%. Similarly, yield showed increasing trend in but the treatment differences from 75 to 150 kg ha^{-1} were not large enough to be significant.

The biomass and yield of straw enhanced from 1260 and 401 kg ha^{-1} where not receiving of P application rate and 2986 and 508 kg ha^{-1} were obtained at 75 kg ha^{-1} P_2O_5 with N and K application, respectively. Thus, these were increased by >100% biomass yield and 26% straw yield at 75 P_2O_5 kg ha^{-1} over those having no P application. There was no variation statistically among remaining treatment against no P application (Figure 2).

Total P content and protein content

Total P content data (Figure 2D) increased gradually from 0.103 % under control plot to 0.46, 0.52, 0.54 and 0.56% at the treatment having P application levels (75, 100, 125 and 150 kgha^{-1}). Thus, this was increased by more than 100% in total P content. Increasing trend of P levels proves the importance of P fertilizer application. Further, increasing application levels from 75 to 150 kg ha^{-1} contributed to increase P content in leaves but the treatment differences were not large enough to be significant and statistically was non-significant.

Protein content increased from 16% control plot (having no P application) to 20% under 50 kgha^{-1} treatment corresponding to 25% increase in protein content in mungbean crop. The protein content was progressively improved with increasing level of P application. With non-significant difference among treatment of 75, 100, 125 and 150 kg ha^{-1}.

P uptake and P use efficiency of mungbean crop

Considering the relevant P uptake (Figure 3A), a significant increase in P uptake was exhibited with various P levels. The highest value of P uptake (8.90, 13.35, 13.65, 11.49 and 14.42 kg ha^{-1}) was noted at (50, 75, 100, 125and 150 kg P_2O_5 ha^{-1}) as compared to control plot. There were > 100% increases with 50, 75, 100, 125 and 150 kg P_2O_5 ha^{-1}, which improved with the enhancing P levels. P uptake did not show any significant effect among each other (Figure 3A). Mungbean plant showing gradually increases in P recovery % from 0-150 kg P_2O_5 ha^{-1}due to the impact of P application. It is increased from 0.0 % in control to 10.30, 12.46, 12.91 and13.82 % in treatments applied highest P supplied in 75, 100, 125 and 150 kg ha^{-1} P_2O_5 (Figure 3B). The enhancement in P recovery data (Figure 3B) with increasing P levels demonstrates the importance of P fertilizer application. Phosphorus recovery 10.3% was recorded to the treatment having P application level 75 kg ha^{-1}. Increasing trend was showed from 0-150 kg ha^{-1}, whereas, decreasing trend was observed with decreasing P level application. These results indicate that the balanced P application with addition of N and K application made a criterion to establish balanced application with study of P recovery (use efficiency).

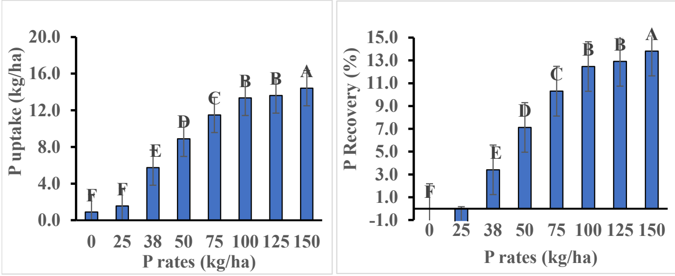

Figure 3: *Effect of P fertilizer application on (A) P uptake and (B) P recovery of mungbean.*

Correlation of grain yield with various parameters

The correlation indicates that the positive relative outcome of P application on grain productivity of all parameters, whereas, negative effect showed to straw yield, harvest index and total N leaves (Table 4).

Table 4: *Relationship of mungbean cultivar (C-26) with some growth, yield, uptake and P recovery as affected by P application.*

Parameters	values
Plant height (cm)	0.0787
No. of plant treatment^{-1}	0.2676
No. of fruit bearing branches plant^{-1}	0.2949
No. of pods plant^{-1}	0.1805
1000 grain weight (g)	0.1800
Biomass yield (kg ha^{-1})	0.9098
Straw yield (kg ha^{-1})	-0.8326
Harvest index	-0.9341
Total N (shoot content)	-0.0555
Total P (shoot content)	0.9051
Protein %	0.3347
P uptake (kg ha^{-1})	0.9785
P recovery (%)	0.9593

NS: Non-significant and significant at 0.05 and 0,01 probability level according to least significant difference (LSD) test.

Plant nutrients in the form of synthetic fertilizer are measured as an important part of crop production for sustainable nutrient management. The primary nutrients for plant growth are nitrogen, phosphorus and potassium collectively known as NPK. Among the major nutrient (required in large amount) P is a basic component of plant growth and play highly significant effect on leguminous crop e.g., mungbean. Nitrogen was used more than P, K and micronutrients. The vegetative, reproductive and nutrient content of mungbean plant showed best performance in such way of following treatment order P0 < P1 < P2 < P3 < P4 < P5 < P6 < P7 with addition of N and K doses. The application of P with NK directly highlighted significant effect on the growth and yield of Mungbean. However, yield increased by >100% with addition of P (75 kg ha^{-1} P_2O_5) compared to control plot. This experiment highlighted significantly in growth, yield and protein content (Figures 1, 2) of Mungbean in response of P levels i.e., plant height (70 cm), number of plants treatment^{-1} (23), number of fruits bearing branches (82), 1000 grain weight (45.3), yield (2478 kg/ha) at the rate of 75 P_2O_5 kgha^{-1} over control plot. Malik *et al.* (2003) recorded similar plant height for mungbean cultivar NM-98 at the rate of 50 kg P_2O_5 ha^{-1} with N (25 kg ha^{-1}). In field study, Suryantini (2016) reported 1000grain weight (530 g) was much higher compared to this study. It may be due to higher P levels. i.e 100, 150 and 200 kg ha^{-1} P_2O_5 whereas, grain yield (1450 kg ha^{-1}) at the highest P rate (200 kg ha^{-1}) was lower compared to our study due to getting yield after soyabean and 1740 grain yield kg ha^{-1} was observed with application of PSB (5 g inoculant 1 kg seed) (10^9 CFU/g inoculant) and 200 kg ha^{-1} P_2O_5 with basal dose of N and K (50 and 75 N K_2O). In continuation of field work, Shah *et al.* (2003) conducted field study to compare the relative efficacy of three methods of P application broadcast, banding and fertigation technique using various P levels (0, 40, 0 and 120 kg P_2O_5 ha^{-1}) in mungbean crop. The data showed the highest grain yield and uptake (2.21 tons ha^{-1} and 14.96 kg ha^{-1}) were recorded at P level of 120 kg ha^{-1}whereas, highest recovery and P use efficiency of 10% and 13.69 kg kg^{-1} were recorded with the control plot. Further, a pot experiment was evaluated the ten mungbean genotypes for yield and Phosphorus use efficiency with and without phosphatic fertilizer by Irfan *et al.* (2017). Two level of P (i) deficient P (Native P under AB-DTPA extractable P) (ii) and adequate P addition of 30 mg kg^{-1} soil. The results showed variable data according to genotypes. Maximum plant height was observed (34.6 m) in genotypes "AEM-30/5/8/90" under P added application as well as P deficient level. Similarly, highest number of grains/pods showed in genotypes "AEM 20/3/87" with P added level. The genotypes 6601 showed maximum grain yield of 4.78 g/plant^{-1} at P added level whereas genotype "AEM-40/30" produced maximum grain yield of 3.72 g/plant at control plot (P deficient). Similarly, Rajput (2018) reported the maximum plant height (85.00 cm), pods plant^{-1} (43.8), seed index (455 g per 1000 grains), seed yield (1896.0 kg ha^{-1}), total biomass (5205 kg ha^{-1}), straw yield (3105 kg ha^{-1}), protein (15.77%), shoot N, P and K (2.1, 0.3 and 1.3 %) concentration and N, P and K uptake (95.3, 16.4 and 49.9 kg ha^{-1}) were recorded by combined application of 75 P_2O_5 kg ha^{-1} with N and K fertilizer. Further, Yin *et al.* (2018) concluded that the yield of Mungbean plant increased by 19.6% with optimal fertilizer rate of N: P_2O_5:K_2O = 1:0.5:1.59 (34.38-42.62 kg ha^{-1} N, 17.55-21.70 kg ha^{-1} P_2O_5 and 53.23-67.29 kg ha^{-1} K_2O. Further, Meena and Verma (2016) demonstrated that the significant improvement in seed yield (524 kg ha^{-1}, straw yield (1426 kg ha^{-1}) and biological yield (1449 kg ha^{-1}) with 100 % RDF (20:40:20 kg ha^{-1} $NP_2O_5K_2O$). Application of P levels of 40 kg ha^{-1} P_2O_5significantly increased the total number of nodules per plant (31.5), plant height (58.9cm), grain yield (1221 kg ha^{-1})and straw yield (2988 kg ha^{-1}by Venkalarao *et al.* (2014). Higher yield of mungbean have been reported by application of 90 kg ha^{-1} under field experiment by Lange *et al.* (2007). Maqsood *et al.* (2001) concluded P application 75 kg ha^{-1} gave significantly the highest yield of 1832 kg ha^{-1}. In contrast, Kaysha *et al.* (2020) gave maximum yield 1244 kg ha^{-1} for variety N-26 at the rate of 150 kg ha^{-1} NPS blended rate. In a field trial, Nawaz *et al.* (2021) investigated the efficacy of rhizobacteria seed priming in mungbean (AR1 mung-06). Seeds were treated. The treatment comprised two factors FA (control (dry seeds), hydro-priming, silicon (Si)-priming, and bio-priming) and FB (normal irrigation (IL+S+F+P) and terminal drought stress (IF+P). Result indicated that the bio priming significantly increased yield (8-12 %) and all yield components and regulated levels of antioxidants under drought stress compared with the control.

The value of P content in apical tissue of stylosanthes plant (0.26%) and entire plant tissue was (0.17%) at the pre-flowering stage reported by Moody and Edwards (1978). The production potential and sufficiency of nutrient supply are described by the critical nutrient concentration at particular growth stage and specific leaf place of plant. After that, another scientist Bell *et al.* (1990) depicted that the P content the values for the youngest fully expanded leaf blades (YFEL) at early flowering (0.3%) shows deficiency symptoms. A pot study was described by Venkatesh *et al.* (2014) to examined the outcome of various P rates (0, 10, 20, 30, 40, 50, 70 and 80 ppm P) on mungbean genotypes to determine the nutrient in leaf tissue at different growth stages for plant diagnostic. With the increasing rate of P levels (80 ppm) gave maximum leaf P (0.8, 0.6 and 0.39%) in 2nd leaf at 30, 45 and 60 days after sowing but in case of maturity after 60 days the P content was (0.46 %) in Samrat genotypes. Similarly, in NMI genotypes showed maximum leaf P (0.69, 0.62 and 0.46) at 30, 45 and 60 days after sowing and further P content was (0.37%) in NMI genotypes, respectively. It is concluded that the mature leaf showed decreasing trend in leaf tissue P content values as compared to young one. Further, it was concluded that the P content from 0.45 to 0.49 % in NMI mungbean cultivar and 0.45 to 0.57 % in urdbean at early growth stages. Improved P rates (0-150 kg P_2O_5 ha^{-1}) did develop the P content in 2nd leaf of mungbean (0.15 to 1.32%) is evidence from this study. Various plant parts show reflection of P status of the plant. However, local research related to fertilization to determine P shoot content or leaves content in mungbean and another leguminous crop is scarce and there was little work done by Memon *et al.* (2016) and Rajput (2018) in chickpea crop.

Few studies were observed on P application related to the protein content. The value of protein percentage was varied in all applied P levels (0, 25, 38, 50, 75, 100, 125, 150 P_2O_5 kg ha^{-1}). It shows that protein content remains higher (20%) in 15:50:15 kg per ha N: P_2O: K_2O which is similar with the results of (Malik *et al.*, 2002; Rashid *et al.*, 2013; Uddin *et al.*, 2014; Dragicevie *et al.*, 2015; Meena and Verma, 2016; Memon *et al.*, 2016; Rajput, 2018). Protein content also performs as important factor in the plant growth under plant stress conditions. It is related to the N concentration in plants among the different legume varieties by Goud *et al.* (2014). Added P with N and K nutrients have synergistic effect that is elaborate in protein metabolism (Williams and Singh, 1987; Zhao *et al.*, 1997). The data related to P uptake and recovery % in (Figure 3). The maximum P uptake (11.49 kg ha^{-1}) and P recovery (10.30%) was observed. Shah *et al.* (2006) concluded that the highest grain yield (2.21 tons ha^{-1}) was recorded at the rate of 120 kg ha^{-1} by fertigation method. Further, highest P uptake (14.96 kg ha^{-1}), P recovery (10%) and agronomic efficiency (16.25 kg kg^{-1}) was recorded with application of (40 kg ha^{-1} P_2O_5). The increasing trend was followed with the enhancing P rates from 40-120 kg P ha^{-1} in grain productivity and uptake Whereas, P recovery and agronomic efficiency decrease with increasing P levels. Another scientist (Tahir *et al.*, 2015) concluded that the maximum FUE (7.30 kg kg^{-1}) was determined at 60 kg ha^{-1} P_2O_5 in various sources (DAP, TSP and SSP). Arsalan *et al.* (2020) noted the maximum yield (1410 kg ha^{-1}) and P uptake (12 kg ha^{-1}) with combine application of vermicompost (2 t ha^{-1}) and (75 kg P_2O_5 ha^{-1}). Whereas, economically significant yield (1282 kg) and P uptake (8.91 kg) per ha with P rate of (37.5 kg P_2O_5 ha^{-1}) and (2 t ha^{-1} vermicompost) over control.

It was observed that the highly significant effect on Mungbean growth and productivity, whereas non-significant relationship was established in grain productivity with plant height, number of plants/treatment and number of pods/treatments. It is fact that P is responsible to increase the root surface area which is enhanced availability of P for plant. Mostly, it is enhanced pod filling resulting into increased grain yield, uptake and P use efficiency (Idris *et al.*, 1989; Gupta *et al.*, 1998; Yahiya *et al.*, 1995; Patel *et al.*, 2014).

Similarly, Noor *et al.* (2003) showed pods number, seed size, seed weight, harvest index and biological yield have a direct impact on grain productivity, furthermore, Yin *et al.* (2018) showed regression equation for the correlation of P value highly significant (P <0.01) between N, P, K fertilization yield of mungbean crop. Rajput (2018) conducted field trial application of potassium on chickpea crop in an irrigated area showed highest significant positive correlation between all yield parameter except straw yield.

Conclusions and Recommendations

The consequence of this study depicted that among various rate of P applications from 0 to 75 kg ha^{-1} P_2O_5 enhanced growth, yield contributing parameters, leaves P content, protein content, uptake and P recovery (use efficiency). There was no variation statistically among remaining treatment from 100 to 150 kg ha^{-1}. Phosphorus recovery increased with increased addition of P levels. Generally, all the parameters of mungbean crop had minimum value at control plot. Hence, it is concluded that the recommendation of P (75 kg) with other nutrients N and K (15 and 15 kg) ha^{-1}in an irrigated area of locality Tandojam, Sindh, Pakistan. The phosphorus fertilizer significantly imperative for healthy growth and yield of mungbean crop.

Novelty Statement

In this study balanced phosphorus fertilizer application was used as an innovative approach to improve phosphorus recovery (use efficiency) of crop plants in an irrigated area of Tandojam.

Author's Contribution

Ambrin Rajput: Principal author, conducted research, analysis and write-up of the manuscript.
Mehrunisa Menmon: Provided technical guidelines.

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

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