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Research Article

Phosphorus nutrition and its effect on the growth, yield attributes and seed yield of Mungbean

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ABSTRACT

Phosphorus has a crucial role in the growth and development of mungbean to improve the quality as well as its grain yield. Therefore, to investigate the effect of varying phosphorus levels on growth and yield attributes under different mungbean varieties, a field experiment was conducted at Agronomic Research Farm, University of Agriculture Faisalabad. The experiment was carried out using a randomized complete block design with a split-plot arrangement and replicated thrice. Four phosphorus levels i.e. 0, 30, 60 and 90 kg ha^{-1} in main plots while three varieties viz. AZRI Mung-2018, PRI Mung-2018 and Chakwal Mung-2006 in subplots were maintained. The data related to phenology, growth, yield, and various yield-related traits were recorded following standard procedures. The results depicted that growth and yield parameters such as leaf area index, total dry matter, grain yield and biological yield were recorded highest for AZRI Mung-2018. This variety produced 14% more seed yield than Chakwal Mung-2006, and it was followed by PRI Mung-2018 which resulted in 6% more seed yield than Chakwal Mung-2006. Regarding different phosphorus levels, phosphorus supplementation at the rate of 30, 60, and 90 kg ha^{-1} produced 16%, 37%, and 27% more seed yield as compared to control (0 kg ha^{-1}), respectively. The interaction effect of different cultivars and phosphorus levels was non-significant. Our study highlighted that maximum seed yield (1862 kg ha^{-1}) was recorded under 60 kg ha^{-1} phosphorus application rate across different varieties, and this dose can be adopted to enhance the productivity of mungbean on sustainable basis.

Keywords: Crop Nutrition, Legume cultivars, Macronutrients, Phosphorus, *Vigna radiata.*

INTRODUCTION

The achievement of sustainable development goals (SDGs) worldwide, particularly in relation to zero hunger and alleviating poverty, is closely related to the availability of nutritious food at reasonable price (Iqbal et al., 2023). Green gram *Vigna radiata* (L.) R. Wilczek], also known as mungbean, constitutes a vital source of dietary protein and thus strategically contributes to ensuring the nutritional security (Rehman et al., 2022) of the rapidly increasing population in South Asia (Mahmood et al., 2022; Mohammed, 2007). Mung bean is a member of family *Fabaceae* and grown as an important summer pulse crop in many Asian countries like Pakistan due to its magnificent flavor, valuable market price, excellent digestibility and capability for biological nitrogen fixation. Essentials nutrients such as proteins (24.7 %,), fiber (0.9%), ash (3.7%) and fats (0.6%) are present in mung bean seed (Ali et al., 2014; Amin et al., 2014). However, in Pakistan average yield of mung bean is about 1.1 tons ha^{-1} which is very low than its potential yield. There are several factors for low production of mung bean such as varieties selection, insect attack, poor resistance to pathogens, low soil fertility, nutrient deficiency and inappropriate use of fertilizers.

Crop growth and production in affected by many factors out of which nutritional management gains significant importance (Fatima et al., 2021; Saleem et al., 2020). Phosphorus falls among macronutrients

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required by plants, deficiency of which causes grain yield losses and lower productivity (Ismail et al., 2024). As the human population increases, the demand for the quality food increases correspondingly, whereas intensive agricultural practices have resulted in significant soil degradation (Saleem et al., 2023). Therefore, crop nutrition must be managed to escalate crop yields (Ahmad et al., 2018). The nutrients are classified into macronutrients and micronutrients based on their requirement by plants. Each nutrient has a distinct role in the plant's structure, growth and development. Phosphorus is essential for cell division and photosynthesis, and it is crucial for producing high-quality crops (Maqsood et al., 2001) and root development (Kabir et al., 2013). Most of these nutrients are absorbed by plants through their roots from the soil, and this uptake is facilitated by specific transporters (Kimura et al., 2019).

Phosphorus is the second most essential macronutrient, needs to be present in high concentrations for effective crop production. It is vital for plant growth and root development (Kabir et al., 2013), metabolism, and crop yield related traits (Cordell et al., 2009). In Pakistan, most soils have a high pH, which causes phosphorus to precipitate with calcium and magnesium ions in these soils (Albuquerque et al., 2016).

Globally, mungbean is getting significant attention due to its higher nutritional profile as it contains about 26% protein and 62% carbohydrates which is nutrient-rich food playing a vital role in human diets. Worldwide, mungbean is being cultivated on an area of around 7.3 million hectares and its production stands at about 5.3 million tons (Ademe, B. E., 2023).). While India and Myanmar are the leading suppliers, each exporting around 30% of the total global production. Like world, mungbean is also an important crop in Pakistan for its nutritional benefits, providing high protein content that helps combat malnutrition. It also plays a significant role in improving soil fertility, serving as animal fodder, and contributing to farmers' income, making it an essential crop in the agricultural landscape. In Pakistan, the area under cultivation of this crop was 0.201 million hectare and production remained at 0.152 million tons. Moreover, the average yield of our country stands just at 0.76 t ha^{-1} which is 37% lower than world average of 1.2 t ha^{-1} (Govt. of Pakistan, 2023; Ademe, B. E., 2023). owing to several constraints.

Phosphorus is essential for regulating physiological responses and improving abiotic stress tolerance in plants, including challenges such as heat, salinity, drought, waterlogging, elevated CO_2 levels, and heavy metal toxicity (Lambers, H., 2022). Plants can detect and respond to changes in phosphorus availability through specific signaling pathways, adjustments in root architecture, and modifications in stomatal morphology (George, et al., 2016). Additionally, by managing their phosphorus metabolism, plants can enhance their resilience to various abiotic stresses, including heat, drought, salinity, and heavy metal toxicity.

Fluctuation in climatic conditions, the development of new hybrids, and the uneven distribution of nutrients in the soil are negatively affecting the crop production. The requirements of crops, soil fertility, and nutrient efficiencies have evolved from the previously recommended levels. Different areas and soil conditions demand balanced nutrient management practices. Growth of root and timely maturity of crops is linked with phosphorus. It also effects nodulation and growth of root (Jinger et al., 2016; Kabir et al., 2013), enhance absorption of water and nutrients in seedling and raise resistance to disease, and drought tolerance (Jin et al., 2015) and as a result total dry matter production, seed yield and protein content of plant is increased (Imran et al., 2021). Rahman et al. (2015) reported increased growth and yield of mungbean in response to higher doses or P and Zn applied. Keeping the literature cited in focus, present study was conducted to find out the best phosphorus dose for different cultivars of mungbean in ecological conditions of Faisalabad, Punjab, Pakistan.

MATERIALS AND METHODS

Experimental Site

The present study was conducted at Student Research Area, University of Agriculture Faisalabad (31.4504o N, 73.1350 o E) during autumn season 2019. The mean maximum and minimum temperature were 42.4 and 27.4 ^{0}C during June, and 38 and 28 ^{0}C during July. The maximum rainfall of 35.5 mm during June, and 102.80 mm during July was received. Detail of weather data is shown in Figure 1. [(Source: Agromet Bulletin, Agricultural Meteorology Cell, University of Agriculture Faisalabad (UAF)]. ttps://web.uaf.edu.pk/Main/AgrometBuletin.

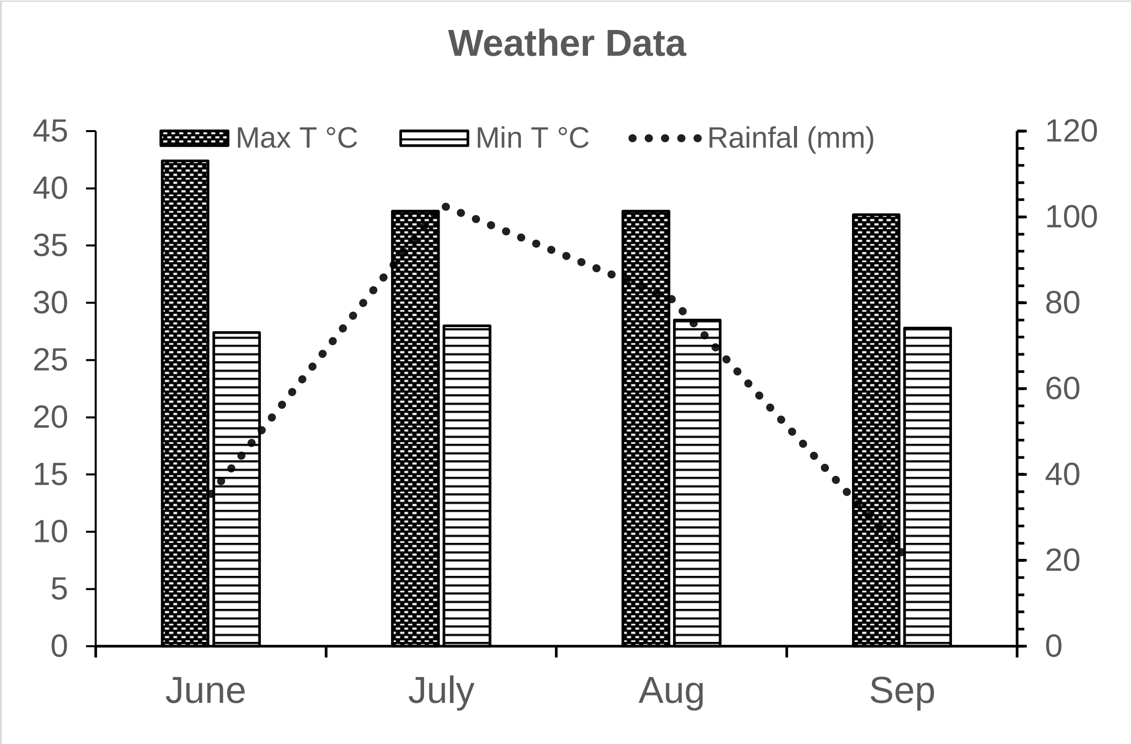

Figure 1. Weather data during the crop growth season.

Details of the Experiment

The experiment was conducted using a randomized complete block design with a split-plot arrangement using four phosphorus levels (0, 30, 60 and 90 kg ha^{-1}) in main plots and three mung bean varieties (AZRI Mung-2018, PRI Mung-2018 and Chakwal Mung-2006) in subplots. Each treatment was replicated thrice to reduce the experimental error. The dimension of each plot were 2.4 m×4 m, with rows and plants spacing of 30 and 10 cm, respectively. Half of the total nitrogen (25 kg ha^{-1}) was top dressed at the time of first irrigation, and the remaining half was applied at second irrigation. Furthermore, phosphorus was applied as per requirement of treatments, and other crop husbandry operations were kept uniform for all treatments. The phosphorus was applied by manual labour through broadcast method. Soil samples were taken from experimental site and analyzed for different parameters as given in Table 1. Statistical analysis of data was carried out by Fisher Analysis of Variance Technique and means of treatments was compared by using Tukey's LSD test at $p \leq 0.05$ (Steel et al., 1997).

Table 1. Soil physico-chemical properties

Parameter	**Value**
pH	7.73
Electrical conductivity (EC)	1.34 dSm^{-1}
Organic matter	1.3%

Available phosphorus	11.53 ppm
Nitrogen	0.07 ppm
Potassium	272 ppm

RESULTS

Phenological observations

It was observed that AZRI Mung-2018 took 8.25% more days to mature compared to PRI Mung-2018 and was statistically ($p\leq0.05$) on par with Chakwal Mung-2006. Regarding different phosphorus levels, plots supplemented with 60 kg ha^{-1} phosphorus took 15.54% more days to physiological maturity compared to those without phosphorus application. Additionally, the phosphorus doses at the rate of 30 kg ha^{-1} and 90 kg ha^{-1} took 5.54% and 9.71% more days, respectively, compared to control. It was observed that AZRI Mung-2018 required 3.74% more days to physiological maturity compared to PRI Mung-2018 and was statistically ($p\leq0.05$) on par with Chakwal Mung-2006. Regarding different phosphorus levels, plots supplemented with 60 kg ha^{-1} phosphorus took 3.66% more days to maturity compared to those without phosphorus application. Moreover, 30 kg ha^{-1} and 90 kg ha^{-1} plots took 0.97% and 1.92% more days, respectively, compared to control (Table 2).

It was demonstrated that AZRI Mung-2018 acquired more days (77) as compared to PRI Mung-2018 and statistically at par with Chakwal Mung-2006 because PRI Mung-2018 is short duration variety and it required less number of days to pod formation as compared to AZRI Mung-2018 and Chakwal Mung-2006. Regarding different phosphorus levels, plots supplemented with 60 kg ha^{-1} phosphorus took 83 days to pod formation as compared to (P_0) without phosphorus application took 68.22 days . Moreover, 30 kg ha^{-1} and 90 kg ha^{-1} plots took 72.22 days to pod formation and 75.56 days, respectively.

Crop growth and agronomic observations

Among the varieties, AZRI Mung-2018 statistically ($p\leq0.05$) performed better compared to PRI Mung-2018 and Chakwal Mung-2006, with 5.02% more leaf area index compared to Chakwal Mung-2006. Similarly, PRI Mung-2018 had a 1.73% higher leaf area index than Chakwal Mung-2006 (Table 3). Regarding different levels of phosphorus, plants supplemented with 30, 60, and 90 kg ha^{-1} of phosphorus produced 4.00%, 4.41%, and 4.18% higher leaf area index, respectively, compared to the control (0 kg P ha^{-1}).

Among different varieties of mungbean, AZRI Mung-2018 statistically performed better ($p\leq0.05$) compared to PRI Mung-2018 and Chakwal Mung-2006 under Faisalabad conditions, yielding 13.68% more than Chakwal Mung-2006. Similarly, PRI Mung-2018 produced 6.04% more seed yield than Chakwal Mung-2006. Regarding different phosphorus levels, it was concluded from the Table 4 that plants supplemented with 0 kg ha^{-1} of phosphorus produced lowest yield, while those supplemented with 30, 60, and 90 kg ha^{-1} of phosphorus produced 16.25%, 36.79%, and 26.80% more seed yield compared to control (0 kg ha^{-1}), respectively. The comparison of means showed ($p\leq0.05$) that the highest yield was observed from plants where the recommended level (60 kg ha^{-1}) of phosphorus was applied, resulting in 36.79% more yield compared to control (0 kg ha^{-1}). However, the interaction effect of different cultivars and phosphorus levels was non-significant.

Table 2: Days to pod formation and days to physiological maturity in mungbean in response to different levels of phosphorus.

Days to pod formation					Days to physiological maturity			
Phosphorus Levels (kg ha^{-1})	**AZRI MUNG-2018**	**PRI MUNG-2018**	**CHAKWAL MUNG-2006**	**Means**	**AZRI MUNG-2018**	**PRI MUNG-2018**	**CHAKWAL MUNG-2006**	**Means**
0	72.33	64.33	68.00	68.22^{B}	91.67	88.33	92.33	90.78^{B}

30	75.00 (3.50)	69.00 (6.76)	72.67 (6.42)	72.22^{B} (5.54)	93.00 (1.43)	89.67 (1.49)	92.33 (0.00)	91.67^{B} (0.97)
60	83.00 (12.85)	77.00 (16.45)	82.33 (17.41)	80.78^{A} (15.54)	95.67 (4.18)	92.00 (3.99)	95.00 (2.8`)	94.22^{A} (3.66)
90	78.67 (8.05)	72.33 (11.06)	75.67 (10.13)	75.56^{AB} (9.71)	93.67 (2.14)	90.00 (1.85)	94.00 (1.77)	92.56^{AB} (1.92)
Means	77.25^{A} (8.52)	70.67^{B} (5.36)	74.67^{A}		93.50^{A} (3.74)	90.00^{B} (3.66)	93.42^{A}	

Table 2. Leaf area index, total dry matter, day to pod formation and days to physiological maturity in mungbean in response to different levels of phosphorus.

	Leaf Area Index				**Total Dry Matter**			
Phosphorus Levels (kg ha^{-1})	**AZRI MONG-2018**	**PRI MONG-2018**	**CHAKWAL MUNG-2006**	**Means**	**AZRI MONG-2018**	**PRI MONG-2018**	**CHAKWAL MUNG-2006**	**Means**
0	3.89	3.71	3.70	3.77^{C}	457.58	455.92	428.20	447.20^{C}
30	4.00 (2.55)	4.06 (8.52)	3.96 (6.64)	4.00^{BC} (5.91)	479.67 (4.61)	467.41 (2.46)	453.63 (5.63)	466.90^{BC} (4.22)
60	4.65 (16.27)	4.33 (14.32)	4.24 (12.74)	4.41^{A} (14.50)	564.89 (19.00)	529.22 (13.85)	524.90 (18.44)	539.67^{A} (17.13)
90	4.29 (9.25)	4.17 (11.03)	4.08 (9.31)	4.18^{AB} (9.86)	520.80 (12.14)	492.44 (7.42)	479.22 (10.67)	497.49^{B} (10.11)
Means	4.21	4.07	4.00		505.73^{A}	486.25^{AB}	471.46^{B}	

Table 4. Grain and biological yield of mung bean cultivars in response to different phosphorus levels.

	Grain Yield (kg ha^{-1})				**Biological Yield (kg ha^{-1})**			
Phosphorus Levels (kg ha^{-1})	**AZRI MONG-2018**	**PRI MONG-2018**	**CHAKWAL MUNG-2006**	**Means**	**AZRI MONG-2018**	**PRI MONG-2018**	**CHAKWAL MUNG-2006**	**Means**
0	1190.28	1092.78	22.33	1096.85^{D}	4575.79	4559.23	4280.93	4471.98^{C}
30	1428.58 (16.68)	1295.34 (15.64)	1205.05 (16.39)	1309.66^{C} (16.25)	4796.69 (4.61)	4674.09 (2.46)	4536.30 (5.63)	4669.03^{BC} (4.22)
60	1861.63 (36.06)	1707.67 (36.01)	1636.11 (38.42)	1735.13^{A} (36.79)	5648.87 (19.00)	5292.24 (13.85)	5248.97 (18.44)	5396.69^{A} (17.13)
90	1601.64 (25.68)	1491.94 (26.75)	1401.67 (28.12)	1498.41^{B} (26.80)	5208.02 (12.14)	4924.38 (7.42)	4792.15 (10.67)	4974.85^{B} (10.11)
Means	1520.53^{A}	1396.93^{AB}	1312.58^{B}		5057.49^{A}	4862.49^{AB}	4714.59^{B}	

Phosphorus application and varieties significantly affected the biological yield of the mung bean crop. Among the different varieties, AZRI Mung-2018 showed ($p \leq 0.05$) the best performance compared to PRI Mung-2018 and Chakwal Mung-06. AZRI Mung-2018 and PRI Mung-2018 produced 6.78% and 3.04% more biological yield, respectively, than Chakwal Mung-06 (Table 4). In the case of different phosphorus levels, the maximum biological yield was produced by the second level (60 kg ha^{-1}) of phosphorus, which was 17.13% higher than the control. Similarly, 30 and 60 kg ha^{-1} of phosphorus produced 4.22% and 10.11% more yield than the control (0 kg ha^{-1}). The interaction effect of different cultivars and phosphorus levels was non-significant. These findings are similar to those reported by Ali et al. (2014).

The data revealed that the total dry matter was significantly ($p \leq 0.05$) influenced by varying phosphorus application rates (Table 3). However, the interactive effect between different fertilizer rates and crop varieties was not found to be statistically significant at ($p \leq 0.05$). It has been found that treatments where 60 kg ha^{-1} of phosphorus were applied accumulated resulted in 17.13% more dry matter compared to control (0 kg ha^{-1}). The other phosphorus levels of 30 and 90 kg ha^{-1} produced 4.22% and 10.11% more dry matter than the control, respectively. In the case of varieties, AZRI Mung-2018 showed the best performance, accumulating 6.78% more dry matter compared to Chakwal Mung-06. PRI Mung-2018 also accumulated 3.04% more dry matter than Chakwal Mung-2006. The interactive effect of varieties and phosphorus levels was non-significant at $p \leq 0.05$.

DISCUSSION

Plant height is an important parameter that depends on seed quality, climatic conditions, genetic makeup, and the availability of fertilizers in the soil (Divito & Sadras, 2014; Quan et al., 2024). Significant effects of both varieties and phosphorus levels on plant height were observed. Phosphorus serves as a crucial element that plays a vital role in the growth and productivity of plants. The availability of P in soil is often limited due to fixation, which can hinder the optimal development and growth of plants. In cases of P deficiency, plants exhibit a range of morphological, physiological, and biochemical adaptations, while occurrences of P toxicity are relatively uncommon (Malhotra et al., 2018). Research findings demonstrate that the application of phosphate fertilizer significantly enhances growth parameters like plant population, height, leaf number, and branch number per plant, compared to control conditions. Similarly, the application of phosphorous leads to a notable increase in yield. Notably, the highest yield on mungbean was observed with the application of 60 kg P_2O_5 ha^{-1}, resulting in a 31.85% and 31.92% increase when compared to control (Dwivedi et al., 2018). Among the various production practices, fertilizer management stands out as a crucial agronomic approach for boosting crop yield and sustaining soil fertility (Langhans et al., 2022). Phosphorus (P) is one of the key elements among the three macronutrients essential for optimal plant growth and development (Wang et al., 2018). Phosphorus is a vital component of numerous enzymes that play a critical role in energy transformation during carbohydrate metabolism and respiration. It is also closely associated with cell division and development (Khan et al., 2023). The application of phosphorus fertilizer promotes root development, which enhances the availability of other nutrients and water to the growing parts of the plant. This results in increases the photosynthetic area, resulting in greater dry matter accumulation. Phosphorus also supports improved nodulation and the effective functioning of bacteria for nitrogen fixation, which plants utilize during the grain development stage, ultimately leading to higher grain yields (Singh et al., 2018).

Reason for differences is that an adequate amount of phosphorus increases leaf expansion, leaf surface area, and the number of leaves (Poorter et al., 2009). Overall, the comparison of means showed that the maximum leaf area index was obtained from plants where the recommended level (60 kg ha^{-1}) of phosphorus was applied, resulting in a 4.41% increase compared to the control. The interaction effect of different cultivars and phosphorus levels was non-significant.

The genetic variability among the performance of varieties might be the contributing factor for these differences in grain yield under different phosphorus levels. The genetic variability among the performance of varieties might be the contributing factor for producing such differences in biological yield under different phosphorus levels.

Phosphorus enhances the absorption of water and nutrients in seedlings, which increases disease resistance and drought tolerance. Consequently, total dry matter production significantly increased. Similar results were found by Singh and Yadav (2016). However, further increases in phosphorus and potassium levels did not result in increased plant height (Divito & Sadras, 2014). This may be due to the soil already having sufficient phosphorus and potassium levels, rendering higher doses ineffective in increasing plant height. The interaction effect of phosphorus levels and varieties on plant height was found to be non-significant.

CONCLUSION

Overall, the growth and yield parameters were highest for AZRI Mung-2018 as compared to other both varieties, and this cultivar resulted in 14% more seed yield than Chakwal Mung-2006, Under different phosphorus levels, phosphorus at the rate of maximum seed yield (37%) was recorded at 60 kg ha^{-1} as compared to control. Our study emphasizes that for getting higher seed yield, mentioned level can be adopted for any variety for enhancing mungbean production on a sustainable basis.

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