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Effect of Different Doses of Phosphorus on the Growth and Yield of Mung Bean (Vigna)

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Abstract

Phosphatic fertilizers play a vital role in enhancing mung bean production by not only improving crop yield but also increasing the quality of the produce. A field trial was done at the Nepal Polytechnic Institute research field to determine the effect of different levels of phosphorus on yield of Mung bean at Bharatpur, Chitwan during the summer season 2024. The test was carried out as per Randomized Complete Block Design with three replicates. There were eight level of phosphorous i.e. P0 (T1), P30 (T2), P40 (T3), P50 (T4), P60 (T5), P70 (T6), P80 (T7), and P90 (T8) taken as treatment. Nitrogen and potash @ 20 kg/ha each were given through Urea and Muriate of potash and phosphorus through single super phosphate as a dose applied in treatments. Findings revealed that the application of different level of phosphorus significantly enhanced the grain yield. The maximum grain yield was obtained from P90 (1.53 t/ha) followed by P70 (1.33 t/ha) and P80 (1.27 t/ha) which are statistically similar to P60 and P50, whereas the minimum grain yield (0.79 t/ha) was obtained from P0 applied plot. The test weight was maximum (37.21 gm) in P90, which statistically is at par with all treatments except control. It is concluded that P2O5 at 40 to 90 kg/ha has no significant difference increased productivity of Mung bean under rainfed conditions of Chitwan.

Keywords: Mung bean, phosphorus fertilization, grain yield, agronomic performance

INTRODUCTION

Mung bean (Vigna radiata L.) also known as a green gram is an important pulse that can be grown twice a year i.e. spring and autumn. It belongs to the family Leguminosae and sub-family Papilionaceae [1]. In Southeast Asian nations, these legumes play a crucial role in ensuring food security and sustaining agricultural output [2]. India is the world's largest producer of mung bean. In Nepal, the crop is gaining recognition as a valuable legume due to its high nutritional content. As one of the most important pulse crops in Asia, mung bean is cultivated on approximately 24,500 hectares in Nepal, yielding 21,633 tonnes with an average productivity of 883 kg ha^{-1} [3].

Effective nutrient management plays a vital role in ensuring successful and profitable mung bean production. With significant potential for commercial cultivation, more than 75% of Nepal's mung bean production is concentrated in the eastern and central Terai regions, particularly in areas with adequate irrigation [4]. In recent years, there has been a growing emphasis on optimizing the efficiency of phosphorus (P) fertilizer use rather than merely increasing its application [5]. Phosphorus is a fundamental nutrient in soil, serving as a key component of sustainable food production, environmental stewardship, and agricultural productivity. It is essential for various biological processes in plants, including energy transfer, photosynthesis, nucleic acid synthesis, and root development, all of which contribute to overall plant growth and productivity [6]. Mung bean

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exhibits a positive response to phosphorus fertilization, as phosphorus is the second most essential macronutrient after nitrogen. It plays a vital role in various physiological and developmental processes, including root development, stalk and stem strengthening, flower and seed formation, crop maturity, and overall productivity [7]. Additionally, phosphorus is crucial for nitrogen fixation in legumes, enhances crop quality, and improves resistance to plant diseases.

Mung bean is an important catch crop in Nepal with significant production potential. However, despite its potential, a substantial quantity of mung bean is imported to meet domestic demand. In cereal-based countries, particularly in South Asia, mung bean serves as a crucial source of protein. It is popular among farmers as it fits well into the regions' rice-based farming system because of its short duration, low fertilizer requirement, and better performance under heat and drought stresses [8]. The declining productivity of mung bean can be attributed to inadequate agronomic practices, phosphorus-deficient soils, and limited attention to its cultivation. Research on phosphorus dynamics is essential for assessing soil fertility and developing effective nutrient management strategies. However, limited studies have been conducted on phosphorus fixation in Nepal's acidic soils [9]. The key challenges associated with soil phosphorus in Nepal include uneven fertilizer application, soil degradation leading to reduced phosphorus availability, and limited fertilizer use due to high costs and low farmer awareness [10]. This study aims to identify the optimal phosphorus levels required to enhance mung bean productivity, thereby enabling smallholder farmers to make informed decisions regarding phosphorus application. By improving nutrient management strategies, the research seeks to maximize yield potential and promote sustainable mung bean cultivation.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted during the summer season of 2024 at the research block of Nepal Polytechnic Institute, Bharatpur, Chitwan. The experimental site is situated 5 km from Bharatpur, the administrative headquarters of the Chitwan district, at a latitude of 27°37'25" N and a longitude of 84°34'00" E in central Nepal. Representing the Inner Terai region, the site experiences a subtropical climate and is located at an altitude of 168 meters above sea level. The research farm was well-equipped with the necessary physical facilities to support the experiment. The soil at the experimental site was classified as sandy loam.

Treatment Details and Agronomic Practice

The field test was carried out with three replicates using Randomized Complete Block Design (RCBD). Experimental design consisted of individual plots measuring 3 m × 3 m (9 m^2) in a gross total experimental area of 302.5 m^2. There were 60 cm × 20 cm spacing and one plant per hill with one plant per hill. Fertilizer treatment involved phosphorus basal at different levels, nitrogen 20 kg ha^{-1} through urea, and potassium 20 kg ha^{-1} through muriate of potash (MOP) and well-decomposed farm yard manure at 6 t ha^{-1}. Bavistin at 2.5 g kg^{-1} was treated to the seeds 2 h prior to sowing, and seeds were sown at 30 kg ha^{-1} at 3–4 cm depth. Gap filling and thinning at 15 DAS were done to maintain the optimal plant population. Irrigation was administered three times at 3 DAS, 6 DAS, and 14 DAS using the basin method. Against diseases and pests, SAAF fungicide was sprayed at 16 and 35 DAS, and insecticides (Chlorpyrifos 5% and Cypermethrin 50% EC, and then Emidacloprid 30% EC) were sprayed at 20 DAS and 15 days from the first spray. Weeds were controlled manually at 30 DAS and 40 DAS in order to control the infestation of weeds due to natural rain and excessive moisture. The mung bean variety 'VC-6372,' was used for the experiment Table 1.

Table 1. Details of treatments used in the field experiment Bharatpur Chitwan, 2024.

Treatments	Dose
T_1	P_0 Control (0 kg P_20_5 ha^{-1})
T_2	P_{30} (30 kg P_20_5 ha^{-1})
T_3	P_{40} (40 kg P_2O_5 ha^{-1})

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T_4	P_{50} (50 kg P_2O_5 ha^{-1})
T_5	P_{60} (60 kg P_2O_5 ha^{-1})
T_6	P_{70} (70 kg P_2O_5 ha^{-1})
T_7	P_{80} (80 kg P_2O_5 ha^{-1})
T_8	P_{90} (90 kg P_2O_5 ha^{-1})

Weather Condition of the Research Site

The agro-meteorological data presented in the bar graph illustrate the monthly fluctuation of maximum temperature, minimum temperature, rainfall, and relative humidity in April, May, and June. The maximum temperature is relatively stable for the three months, ranging between 37°C and 39°C. Similarly, the minimum temperature rises gradually, ranging from approximately 18°C in April to 24°C in June. Rainfall is also on the rise, with minimal rainfall in April, slightly more in May, and maximum in June. Relative humidity too follows the same pattern, rising steadily month by month to mark the beginning of the monsoon season. These trends suggest that while temperature is relatively consistent, the increase in rainfall and humidity is an indication of seasonal climatic variations, namely the onset of the monsoon season Figure 1.

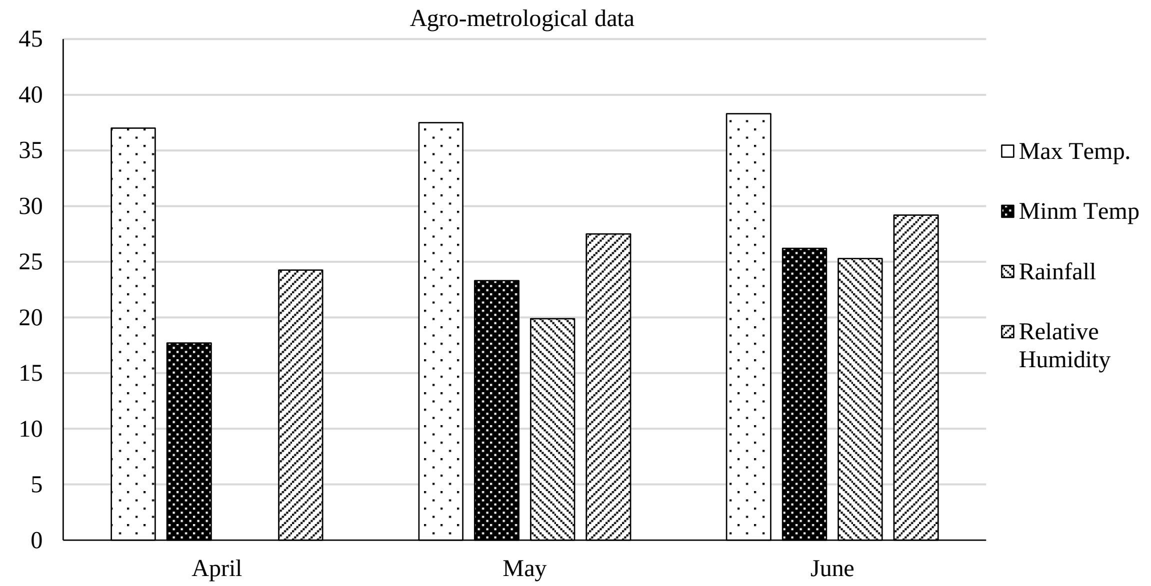

Figure 1. Climate conditions of the study location throughout the research period at Bharatpur, Chitwan (2024)
Source: *National Maize Research Program (NMRP)*

Data Collection

The experiment involved regular observations and recording of data into phenological, biometrical, and yield-contributing traits. Phenological observations were recorded at 2–3-day intervals, and each growth phase was completed when 50% of the plants exhibited the respective trait. Key parameters were days to 50% emergence of seedlings, flowering, pod formation, and harvest maturity. These were recorded on the second, third, and fourth rows of the net plot for each treatment. Biometric observations were taken on five randomly chosen plants per plot, and values were averaged. Plant height was taken every 15 days starting from 25 DAS up to 55 DAS from the ground to the plant tip at the time of its greatest vegetative development. The overall number of leaves per plant was counted at 25, 40, and 55 DAS. Leaf width was measured at three points: base, middle, and tip while leaf length was measured from the base to the tip. Leaf area index (LAI) was calculated by multiplying leaf length and width, and measurements were made at 25, 40, and 55 DAS. LAI was calculated by the following formula:

$$LAI = \text{Land Area } (cm^2) / \text{Leaf Area } (cm^2)$$

Yield-attributing characteristics were taken from five tagged plants per plot. Harvest plant population per square meter was taken at the final harvest, except for border plants. Plant clusters per plant were counted at the first harvest, and pods per plant were taken from the same sample plants. Pod length was measured on three randomly selected pods per plant and the seeds per pod were counted from the same pods that were used for pod length measurement. Thousand seed weight (TSW) was determined by weighing 1,000 seeds of the net plot yield using an electronic balance. Grain yield was measured after the net plot was harvested, dried, threshed, and cleaned seeds. The final seed yield per hectare was adjusted to 10% moisture using the formula used by [11] :

$$\text{Grain yield (kg/ha)} = \frac{(100 - \text{MC}) \times \text{Plot yield (kg)} \times 10000(\text{m2})}{(100 - 10) \times \text{net plot area (m2)}}$$

Where, MC = grain moisture content (%)

The biological yield was determined by harvesting all above-ground biomass (stems, leaves, and husks), drying them, and calculating the yield in hectare. Finally, the harvest index (HI), indicating the efficiency in converting biological to economic yield, was calculated from the equation used by [12]:

$$\text{Harvest index (HI)} = \frac{\text{Economic (Grain) yield}}{\text{Biological (Grain + Stover) yield}}$$

Statistical analysis

Data entry was performed using Microsoft Excel 2016, while data analysis was conducted using R Studio (version 4.1.2). Statistical interpretation was carried out utilizing the Agricolae package for mean separation. Analysis of variance (ANOVA) was performed using R Statistics, and mean comparisons were conducted using Duncan's Multiple Range Test (DMRT) at a 5% level of significance ($p \leq 0.05$).

RESULT AND DISCUSSION

The analysis of data indicates that the effect of different levels of phosphorus fertilizer on days to 50% germination was not statistically significant. However, P90 treatment took the longest time to 50% germination, averaging 7 days, as compared to the other phosphorus treatments. In spite of this numerical difference, days to 50% germination under all treatments were statistically equal to one another, suggesting that the level of phosphorus did not significantly affect this phenological stage.

Similar to germination, the days to 50% flowering were also statistically non-significant under the different phosphorus levels. Although P70 treatment recorded the longest time to 50% flowering (44 days), there was no significant difference between the treatments. The findings indicate that while flowering time may slightly vary with changing phosphorus, these differences were not substantial enough to be considered statistically significant and indicate that phosphorus was not a factor for determining flowering time under the test conditions.

The plant height, measured at two growth stages (55 DAS and 75 DAS), was not affected by the phosphorus treatment. The highest plants (163.26 cm) at 55 DAS were in P90 treatment, while the shortest plants (149.28 cm) were in the P60 treatment. For the tallest plant height (164.25 cm), at 75 DAS it was again under the P90 treatment, while the shortest height (149.47 cm) was in the P60 treatment. Although they were quantitative differences, statistical differences could not prove differences in plant height among treatments, meaning phosphorus content had no influence on plant growth height-wise during the observation period Table 2.

The application of phosphorus fertilizer had no statistically significant impacts on pod length among the treatments. However, the maximum pod length (8.01 cm) was recorded in the P90 treatment, while the minimum pod length (6.79 cm) was recorded in the P40 treatment. The mean length of pods per plant was 7.19 with a range of 6.79 to 9.8 among the treatment. Similar to pod per plant, phosphorus application failed to yield any significant differences in seeds per plant. The highest number of seeds per plant occurred in the P40 treatment (9.78). The lowest number of seeds per plant occurred in P0 (8.65).

Table 2. Effect of different levels of phosphorus fertilizer on phonological and height parameters of mung bean in the experiment at Bharatpur,

Treatment	Days to 50%		Plant height (cm)	
	Germination	*Flowering*	*At 55 DAS*	*At 75 DAS*
P0	7	41	156.32	159.21
P30	6	42	157.26	161.39
P40	7	42	151.14	153.26
P50	7	43	150.23	152.34
P60	7	43	149.28	149.47
P70	7	44	152.16	152.68
P80	7	43	155.32	151.33
P90	8	43	163.26	164.25
CV (%)	4.07	1.24	5.3	6.23
F test (0.05)	NS	NS	NS	NS
LSD	2.1	2.21	15.2	15.77
Mean	7.0	42.6	154.35	155.49

Note: NS= Non-significant, CV= coefficient of variation, LSD= least significant difference, DAS= Days after seedling

The plant number of effective nodules was significantly influenced by different levels of phosphorus fertilizers at 35 DAS and 45 DAS. The highest number of effective nodules (8.56) at 35 DAS was found in the P50 treatment, which was statistically similar to the P30 treatments. At 45 DAS, a maximum effective nodal number (9.93) was observed in P40 and then followed by P90. Application of phosphorus enhanced the nutrient use efficiency, increased crop canopy growth, and improved rhizobial activity, hence observing a higher number of effective nodules. This augmented nodulation would have led to better nitrogen fixation, which ultimately endorsed overall plant growth. These findings are consistent with Masih et al., (2020) [13], who observed similar results regarding the role of phosphorus in improving nodule formation.

Unlike the previous characters, phosphorus significantly affected the thousand grain weight of mung bean. The average 1000-grain weight was 36.02 g and ranged from 35.37 g to 37.21 g. The maximum thousand grain weight was observed under the P90 treatment (37.21 g), which was statistically equal to all treatments other than the control (P0). Minimum thousand grain weight was noted for control treatment (35.37 g), where no phosphorus was applied. The findings show that phosphorus fertilization had a positive impact on seed weight, likely due to enhanced photosynthesis, respiration, and storage of energy, which resulted in increased seed production. Thousand grain weight enhancement by phosphorus application is also supported by Tahir et al., (2015) [14], who also observed the same pattern in their study.

Grain yield was influenced significantly by the application of phosphorus fertilizers. Overall mean grain yield was 1.12 t/ha and varied from 0.79 t/ha to 1.53 t/ha. P90 treatment produced the maximum grain yield (1.53 t/ha), which was statistically on par with P50, P60, P70, and P80 treatments. The lowest grain yield (0.79 t/ha) was obtained from the control treatment (P0) which was statistically on par with P30 and P40 treatments. The results suggest that phosphorus application enhanced the grain yield of mung bean by improving root growth, nutrient uptake, and dry matter accumulation. The greater availability of phosphorus also enabled reproductive measures such as improved branching, pod and seed development. This finding is also supported by the previous research studies of (Rani et al., 2016) and (Ahmad et al., 2018) [15, 16] who determined that phosphorus plays a significant role in maximizing seed yield.

No notable variance in biological yield due to the application of phosphorus fertilizer was recorded. The biological yield averaged at 2.47 t/ha ranging between 2.06 t/ha and 2.98 t/ha. The research demonstrates that there was no great effect of the application of phosphorus on the mean overall biological yield of mung bean, possibly to a lesser extent by some other factors that affect the overall production of biomass. The harvest index was not, also influenced by phosphorus fertilizer application. The mean harvest index was 32.95%, with a range of 27.24% to 38.56%. The highest harvest index occurred in treatment P70 (38.56%), and the lowest harvest index was in treatment P50 (27.24%). Despite these quantitative differences, statistical analysis revealed no appreciable effect of phosphorus application on the harvest index, and hence biomass partitioning between vegetative and reproductive organs was not appreciably affected by phosphorus fertilization.

Table 2. Effect of different levels of phosphorus fertilizer on yield and yield attributing parameters of mung bean at Bharatpur,

Treatment	Pod	Pod	Total pod	Effective Nodules					
	length	***per plant***	***number***	***At 35DAS***	***At 45DAS***	***TGW (gram)***	***GY (t/ ha)***	***BY (t /ha)***	***HI%***
P0	7.84	8.65	633.67	4.14^{cd}	7.21^{b}	35.37^{b}	0.79^{b}	2.42	29.33
P30	7.36	9.56	724.02	8.33^{ab}	6.54^{bc}	36.21^{ab}	0.83^{b}	2.54	33.21
P40	7.22	9.78	712.35	4.25^{cd}	9.93^{a}	35.19^{ab}	0.97^{b}	2.06	34.15
P50	7.54	9.67	687.45	8.56^{a}	3.53^{d}	36.46^{ab}	0.98^{ab}	2.16	27.24
P60	6.79	9.53	736.12	5.45^{bcd}	4.02^{cd}	35.82^{ab}	1.26^{ab}	2.40	36.32
P70	7.23	9.45	545.65	3.47^{d}	7.11^{b}	36.57^{ab}	1.33^{ab}	2.76	38.56
P80	7.74	8.83	647.49	5.41^{cd}	4.87^{cd}	35.37^{ab}	1.27^{ab}	2.49	28.71
P90	8.01	9.33	745.59	7.24^{abc}	8.25^{ab}	37.21^{a}	1.53^{a}	2.98	36.11
CV (%)	10.1	8.12	15.14	44.36	23.01	2.87	26.1	28.07	28.25
F test (0.05)	NS	NS	NS	**	***	*	*	NS	NS
LSD	2.06	1.84	156.24	3.33	1.76	1.74	0.47	1.1	10.3
Mean	7.48	9.35	679.04	5.85	6.43	36.02	1.12	2.47	32.95

Note: *NS= Non-significant, *, ** and *** indicates significant at 5%, 1% and 0.5% level of significance respectively, CV= coefficient of variation, LSD= least significant difference, DAS= Days after seedling, TGW= Thousand grain weight, GY= Grain yield, BY= Biomass yield and HI=Harvest Index*

CONCLUSION

Results from the field experiment indicate that applications of various levels of phosphorus fertilizer significantly enhanced the grain yield of mung bean. The highest grain yield (1.53 t/ha) in P90 was followed by P70 (1.33 t/ha) and P80 (1.27 t/ha), which were statistically on par with each other and also with P60 and P50. On the other hand, the minimum grain yield (0.79 t/ha) was observed in the control treatment (P0) when phosphorus was not used. In addition, the test weight was maximum (37.21 g) in P90 treatment and was statistically similar to all other treatments except the control. These findings reveal that phosphorus application at 40 to 80 kg P2O5 per hactare did not differ significantly from each other in their ability to improve mung bean productivity under the rainfed condition of Chitwan. However, further studies are recommended to validate these findings in other agro-climatic regions of the country. This would enable the comprehension of the broader applicability of phosphorus fertilizer application for mung bean cultivation under different environmental conditions.

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Conflicts of Interest

The authors declare no conflict of interest.

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