**Growth and Yield Response of Mungbean (*Vigna radiata* L.) to Different Rates of Phosphorous and Potassium Application**

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ABSTRACT

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| This study investigated the effects of phosphorus (P) and potassium (K) fertilization rates on the growth, yield attributes, and seed yield of mungbean (*Vigna radiata* L.) under pre-monsoon and monsoon seasons in Myanmar. Field experiments were conducted using a two-factor randomized complete block design with three replications, comprising four P levels (P0, P20, P40, P60: 0, 20, 40, 60 kg P ha-1) and four K levels (K0, K20, K40, K60: 0, 20, 40, 60 kg K ha-1). Results demonstrated that combined P and K application significantly enhanced mungbean productivity compared to single-nutrient treatments. During the pre-monsoon season, the optimal treatment was 60 kg P ha-1 with 40 kg K ha-1 (P₆₀K₄₀), yielding 1,126.87 kg ha-1, which was statistically comparable to P₆₀K₆₀. In the monsoon season, 60 kg P ha-1 with 40 kg K ha-1 (P₆₀K₄₀) produced the highest yield (1,561.17 kg ha-1), showing no significant difference from P₆₀K₂₀ or P₆₀K₆₀. In both seasons, the combined application of P and K fertilizers significantly enhanced yield and yield components, including pods per plant and seeds per pod . While P₆₀K₄₀ is recommended for pre-monsoon cultivation, reduced K input (P₆₀K₂₀) is sufficient during the monsoon, likely due to increased nutrient solubility under wetter conditions. The findings highlight the combined application of P and K in optimizing mungbean yields compared to the single application. Therefore, to optimize mungbean production, growers should consider the combined application of P and K fertilizers rather than single applications. However, to reach a precise conclusion and recommendation, more research work on mungbean should be conducted in different agro ecological zones. |

*Keywords: Mungbean, Phosphorus, Potassium, Growth and Yield*

1. INTRODUCTION

Mungbean (*Vigna* *radiata*) plays a crucial role in human and animal nutrition, particularly in tropical and subtropical regions, where it is recognized as a valuable source of protein and energy [1]. From a nutritional perspective, mungbean is often considered one of the most beneficial pulses available due to its rich nutrient profile [2]. Additionally, its short growth cycle and ability to enhance soil fertility through atmospheric nitrogen (N) fixation make it a valuable crop in diverse agricultural systems [3]. As a N-fixing legume, the production of mungbean is relatively independent of N fertilizers; however, the availability of phosphorus (P) and potassium (K) remains critical for achieving optimal yields per hectare [4].

Globally, P deficiency is a major limiting factor in crop productivity [5]. P is an integral component of essential biomolecules, including nucleic acids, phospholipids, and ATP, making its presence vital for the growth and development of crops [6]. In legumes such as mungbean, P is particularly important for promoting root development, enhancing nutrient uptake, facilitating energy conversion in root nodules, and supporting overall plant growth [7].

Potassium (K), the third most important macronutrient after N and P, is key for plant physiological processes. Unlike N and P, K does not form part of cellular structures; instead, it is involved in protein synthesis and a variety of critical functions such as enzyme activation, photosynthesis, and nutrient transport [8]. Moreover, K plays a pivotal role in the regulation of stomatal movements, thereby enhancing plant resilience against abiotic and biotic stresses [9]. K deficiency increases plant susceptibility to environmental stresses, which is particularly relevant in rainfed agricultural systems where leguminous crops like mungbean are extensively cultivated [10].

Increasing cropping intensity has led to a gradual decline in soil fertility, resulting in nutrient shortages, particularly of P and K, for mungbean crops [11]. Effective nutrient management, especially focusing on P and K, is essential for maximizing crop productivity and quality [12]. Therefore, this study aims to examine the growth and yield responses of mungbean to varying rates of P and K fertilizer applications, ultimately identifying optimal application strategies to enhance mungbean yield.

2. material and methods

Field experiments were conducted at the Yezin Agricultural University (YAU) during the pre-monsoon (February to April 2024) and monsoon (June to September 2024) seasons. The experimental design employed was a randomized complete block design (RCBD) with two factors, consisting of three replications. Factor A comprised four levels of P application: P0, P20, P40, and P60, representing 0, 20, 40, and 60 kg P ha-1, respectively. Similarly, Factor B included four levels of K: K0, K20, K40, and K60, corresponding to 0, 20, 40, and 60 kg K ha-1. Each experimental block contained a total of sixteen treatment combinations. The size of each plot was 10 m² (2.5 m × 4 m), with a spacing of 1.00 m between blocks and 0.50 m between unit plots. In the second season, the same treatments were applied to the corresponding plots as utilized in the first season.

Before the initiation of the experiments, soil samples were collected to analyze various physicochemical properties; the results are presented in Table 1. A uniform N application of 20 kg ha⁻¹ in the form of urea was allocated to all plots. P was supplied through Triple Super Phosphate, while K was provided via Muriate of Potash. During land preparation, all plots were treated with complete doses of fertilizers, which were applied uniformly by hand. Seeds of the mungbean variety Yezin (15) were sown in the morning, arranged in continuous rows spaced 45 cm apart, and planted at a depth of approximately 1.5 cm. Cultural practices, including irrigation, weed control, and pest and disease management, were carried out as needed throughout the growing season.

**2.1 Data Collection**

The height of the plant was assessed by measuring the distance from the base to the uppermost growing point. Additionally, the number of branches per plant, total dry matter, number of pods per plant, and number of seeds per pod were recorded from five randomly selected plants. The 100-seed weight and grain yield were calculated in kilograms per hectare (kg ha-1) based on the total yield from the experimental plots.

**Table 1. Measurement of some physicochemical properties of initial soil before experiment**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristics** | **Analytical**  **Result** | **Rating** | **Analytical Methods** |
| Soil Texture class  (USDA classification system) | | Sandy loam | Pipette method |
| Sand (%) | 76.50 |  |  |
| Silt (%) | 15.76 |  |  |
| Clay (%) | 7.74 |  |  |
| Soil pH | 5.70 | Moderately acid | 4A1- 1:5 soil: water suspension |
| EC (dSm-1) | 0.04 | Non- saline | 3A1- 1:5 soil: water suspension |
| Organic matter (%) | 0.88 | Low | Walkley-Black method |
| Total N (%) | 0.07 | Very low | Kjaldehl distillation method |
| Available P (mg.kg-1) | 5.00 | Low | 9C-Olsen’s P-Malachite green |
| Available K (mg kg -1) | 23.00 | Low | 15A1 1N Ammonium acetate extraction |

**2.2 Statistical Analysis**

All experimental data were analyzed by using the Analysis of Variance (ANOVA) with Statistix (Version 8) software. The differences in treatment means were separated by Least Significant Difference (LSD) at 5% significant level.

3. results

**3.1 Plant height**

The application of P and K significantly influenced plant height across both experimental seasons, as presented in Tables 2 and 3. Notably, the treatment with P at a rate of 60 kg ha-1 (P₆₀) resulted in the tallest plants, measuring 36.66 cm during the pre-monsoon season and 103.43 cm throughout the monsoon season. These heights were statistically superior to those obtained under all lower P application rates, with a significant level of p < 0.01. Similarly, K at 60 kg ha-1 (K₆₀) also cultivated the tallest plants, recording heights of 34.49 cm pre-monsoon and 98 cm monsoon. However, this effect was not significantly different when compared to the K application at 40 kg ha**-1** (K₄₀). The combination between P and K (P×K) was determined to be non-significant; nevertheless, the combination treatment of P₆₀ and K₄₀ (60 kg P + 40 kg K ha-1) consistently resulted in the tallest plants across both seasons, as shown in tables 4 and 5.

**3.2 Number of branches plant****-1**

The results indicated a significant effect of P and K on the number of branches plant-1 (p < 0.01). The P₆₀ treatment maximized branching, yielding 1.65 branches pre-monsoon and 2.80 branches during the monsoon. This effect was statistically distinct from lower P treatments. Correspondingly, K₆₀ also produced the highest number of branches, with 1.53 branches pre-monsoon and 2.58 branches in the monsoon, comparable to the K₄₀ treatment results. The combined treatment of P₆₀K₄₀ showed the highest branching levels, although not statistically significant from other treatment combinations, as outlined in Tables 2–5.

**3.3 Total dry matter**

The accumulation of total dry matter was significantly enhanced by treatment with P at 60 kg ha-1 (P₆₀), resulting in dry matter yields of 3082.80 kg ha-1 for the pre-monsoon season and 5633.28 kg ha-1 during the monsoon season. Similarly, K₆₀ demonstrated a significant effect, yielding 2604.30 kg ha-1 pre-monsoon and 4863.79 kg ha-1 monsoon. In contrast, K₄₀ generated similar dry matter yields. Importantly, the combination of P₆₀ and K₄₀ yielded the highest dry matter, recording values of 3433.49 kg ha-1 in the pre-monsoon and 6030.25 kg ha-1 in the monsoon. These results were not statistically different to those of the P₆₀K₆₀ and P₆₀K₂₀ combinations, as illustrated in tables 2–5.

**3.4 Number of pods plant-1**

The number of pods plant-1 was maximized under the P₆₀ treatment, yielding 21.56 pods during the pre-monsoon season and 23.37 pods in the monsoon. Similarly, the K₆₀ treatment resulted in a higher number of pods, with 18.31 pods pre-monsoon and 20.27 pods monsoon, while K₄₀ showed comparable results. The combined effect was statistically significant (p < 0.01), with the P₆₀K₄₀ combination producing the highest pod numbers, recorded at 24.03 pods during the pre-monsoon and 25.60 pods during the monsoon seasons (Tables 6, 7; Figure 1).

**3.5 Number of seeds pod-1**

The number of seeds pod-1 showed a significant increase with the application of P₆₀ (11.97 seeds pre-monsoon, 13.68 seeds monsoon) and K₆₀ (11.64 seeds pre-monsoon, 13.38 seeds monsoon). During the pre-monsoon season, the highest number of seeds pod-1 was produced by the P₆₀K₄₀ and P₆₀K₆₀ treatments, with values of 12.37 and 12.30, respectively. In the monsoon season, the P₆₀K₄₀ treatment yielded the highest number of seeds pod-1 (14.30) which significantly surpassed the other treatment combinations, as detailed in Tables 6, 7, and Figure 2.

**3.6 100-Seed weight**

The weight of seeds was maximized under the P₆₀ treatment, registering weights of 6.96 g pre-monsoon and 5.70 g monsoon, while K₆₀ provided weights of 6.90 g pre-monsoon and 5.56 g monsoon. The P₆₀K₄₀ treatment yielded the heaviest seeds during the pre-monsoon season (7.03 g), whereas the optimal weight in the monsoon was observed in the P₆₀K₆₀ treatment (5.87 g), although not statistically significant from other treatment combinations (Tables 6, 7).

**3.7 Seed yield**

Maximum seed yields were recorded at P₆₀, with values of 1053.11 kg ha-1 for the pre-monsoon and 1395.44 kg ha⁻¹ for the monsoon. Similarly, K₆₀ treatment resulted in significant yields of 928.26 kg ha⁻¹ pre-monsoon and 1238.39 kg ha⁻¹ during the monsoon. The combined effect was significant (p < 0.01), with the combination of P₆₀K₄₀ recording the highest overall yield of 1126.87 kg ha-1 pre-monsoon and 1561.17 kg ha-1 monsoon. This yield was statistically comparable to those obtained from P₆₀K₆₀ in pre-monsoon and P₆₀K₆₀, P₆₀K₂₀ in the monsoon season, as discussed in Tables 6, 7; and Figure 3.

**Table 2. Mean effect of different rates of P and K on the** **plant height (63 DAS), number of branches plant-1, and total dry matter (at harvest) of mungbean during pre-monsoon season, 2024**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height**  **(cm)** | **No. of branches**  **plant-1** | **Total dry matter**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** |  |  |
| 0 | 28.38 ± 0.49 c | 1.03 ± 0.08 c | 1643.20 ± 36.71 d |
| 20 | 32.06 ± 0.12 b | 1.36 ± 0.05 b | 2050.80 ± 95.89 c |
| 40 | 34.26 ± 0.99 ab | 1.60 ± 0.02 a | 2606.00 ± 155.78 b |
| 60 | 36.66 ± 0.09 a | 1.65 ± 0.01 a | 3082.80 ± 35.60 a |
| LSD0.05 | 3.26 | 0.08 | 109.45 |
| **Potassium (kg ha-1)** |  |  |
| 0 | 29.95 ± 0.38 b | 1.21 ± 0.04 c | 1876.00 ± 118.33 c |
| 20 | 33.12 ± 1.75 ab | 1.41 ± 0.11 b | 2343.70 ± 398.54 b |
| 40 | 33.81 ± 1.71 a | 1.49 ± 0.12 a | 2558.90 ± 360.76 a |
| 60 | 34.49 ± 1.66 a | 1.53 ± 0.11 a | 2604.30 ± 331.61 a |
| LSD0.05 | 3.26 | 0.08 | 109.45 |
| Pr>F |  |  |  |
| P | \*\* | \*\* | \*\* |
| K | \* | \*\* | \*\* |
| P x K | ns | ns | \*\* |
| CV% | 11.92 | 6.70 | 5.61 |

In a column, means having the same letters are not significantly different at LSD 5% level.

\* Significant difference at 5% level, \*\* Significant difference at 1% level, ns non-significant difference, CV% Coefficient of Variation, Mean ± standard error of mean (n=3)

**Table 3. Mean effect of different rates of P and K on the plant height (63 DAS), number of branches plant-1 and total dry matter (at harvest) of mungbean during monsoon season, 2024**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height**  **(cm)** | **No. of branches**  **plant-1** | **Total dry matter (kg ha-1)** |
| **Phosphorus (kg ha-1)** |  |  |
| 0 | 88.50 ± 1.32 d | 1.82 ± 0.04 c | 3240.22 ± 113.38 d |
| 20 | 94.84 ± 0.49 c | 2.32 ± 0.08 b | 4131.39 ± 82.16 c |
| 40 | 99.90 ± 0.73 b | 2.63 ± 0.06 a | 5030.08 ± 302.11 b |
| 60 | 103.43 ± 0.59 a | 2.80 ± 0.02 a | 5633.28 ± 66.71 a |
| LSD0.05 | 2.08 | 0.17 | 115.88 |
| **Potassium (kg ha-1)** |  |  |  |
| 0 | 92.80 ± 1.47 c | 2.02 ± 0.08 b | 3992.13 ± 367.96 d |
| 20 | 96.66 ± 2.95 b | 2.43 ± 0.19 a | 4469.06 ± 484.69 c |
| 40 | 98.43 ± 3.12 ab | 2.53 ± 0.18 a | 4709.98 ± 462.71 b |
| 60 | 98.78 ± 2.50 a | 2.58 ± 0.12 a | 4863.79 ± 502.56 a |
| LSD0.05 | 2.08 | 0.17 | 115.88 |
| Pr>F |  |  |  |
| P | \*\* | \*\* | \*\* |
| K | \* | \*\* | \*\* |
| P x K | ns | ns | \*\* |
| CV% | 2.59 | 8.60 | 3.09 |

In a column, means having the same letters are not significantly different at LSD 5% level.

\* Significant difference at 5% level, \*\* Significant difference at 1% level, ns non-significant difference, CV% Coefficient of Variation, Mean ± standard error of mean (n=3)

**Table 4. Combined effect of different rates of P and K on the plant height** **(63 DAS), number of branches plant-1 and total dry matter (at harvest) of mungbean during pre-monsoon season, 2024**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height**  **(cm)** | **No. of branches**  **plant-1** | **Total dry matter**  **(kg ha-1)** |
| P0K0 | 26.43 | 0.90 | 1436.77 ± 196.22 h |
| P0K20 | 28.17 | 0.93 | 1641.86 ± 13.72 gh |
| P0K40 | 29.07 | 1.10 | 1728.08 ± 29.88 gh |
| P0K60 | 29.87 | 1.20 | 1765.93 ± 45.07 fg |
| P20K0 | 30.60 | 1.23 | 1787.10 ± 18.26 fg |
| P20K20 | 32.37 | 1.37 | 1953.92 ± 0.88 ef |
| P20K40 | 32.53 | 1.40 | 2186.92 ± 50.33 d |
| P20K60 | 32.77 | 1.43 | 2275.45 ± 25.42 cd |
| P40K0 | 30.90 | 1.37 | 2118.61 ± 18.14 de |
| P40K20 | 33.77 | 1.58 | 2459.73 ± 12.04 c |
| P40K40 | 35.20 | 1.70 | 2886.94 ± 60.94 b |
| P40K60 | 37.17 | 1.75 | 2958.87 ± 129.48 b |
| P60K0 | 31.87 | 1.33 | 2161.63 ± 150.69 d |
| P60K20 | 38.17 | 1.75 | 3319.31 ± 36.27 a |
| P60K40 | 38.43 | 1.79 | 3433.49 ± 32.52 a |
| P60K60 | 38.19 | 1.75 | 3416.78 ± 35.15 a |
| LSD0.05 | 6.51 | 0.16 | 109.45 |
| Pr>F | ns | ns | \*\* |
| CV% | 11.92 | 6.70 | 5.61 |

In a column, means having the same letters are not significantly different at LSD 5% level.

\* Significant difference at 5% level, \*\* Significant difference at 1% level, ns non-significant difference, CV% Coefficient of Variation, Mean ± standard error of mean (n=3)

**Table 5. Combined effect of different rates of P and K on the plant height (63 DAS), number of branches plant-1 and total dry matter (at harvest) of mungbean during monsoon season, 2024**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height**  **(cm)** | **No. of branches**  **plant-1** | **Total dry matter**  **(kg ha-1)** |
| P0K0 | 84.80 | 1.48 | 2959.19 ± 28.94 l |
| P0K20 | 87.50 | 1.87 | 3141.13 ± 17.87 kl |
| P0K40 | 89.63 | 1.93 | 3326.85 ± 21.84 jk |
| P0K60 | 92.07 | 2.00 | 3533.71 ± 53.54 ij |
| P20K0 | 92.57 | 2.07 | 3619.73 ± 57.69 i |
| P20K20 | 94.67 | 2.27 | 4159.13 ± 44.15 h |
| P20K40 | 95.83 | 2.40 | 4443.74 ± 133.32 fg |
| P20K60 | 96.30 | 2.53 | 4302.96 ± 127.53 gh |
| P40K0 | 96.47 | 2.20 | 4550.20 ± 35.44 ef |
| P40K20 | 99.60 | 2.67 | 4758.86 ± 64.12 de |
| P40K40 | 101.63 | 2.80 | 5039.06 ± 223.26 c |
| P40K60 | 101.90 | 2.87 | 5772.19 ± 43.56 b |
| P60K0 | 97.37 | 2.33 | 4839.41 ± 10.93 cd |
| P60K20 | 104.87 | 2.93 | 5817.14 ± 35.77 ab |
| P60K40 | 106.63 | 3.00 | 6030.25 ± 27.03 a |
| P60K60 | 104.83 | 2.93 | 5846.32 ± 22.70 ab |
| LSD0.05 | 4.17 | 0.34 | 231.76 |
| Pr>F | ns | ns | \*\* |
| CV% | 2.59 | 8.60 | 3.09 |

In a column, means having the same letters are not significantly different at LSD 5% level.

\* Significant difference at 5% level, \*\* Significant difference at 1% level, ns non-significant difference, CV% Coefficient of Variation, Mean ± standard error of mean (n=3)

**Table 6. Mean effects of different rates of P and K application on number of pods plant-1, number of seeds pod-1, 100 seeds weight, seed yield and total dry matter of mungbean during pre-monsoon season, 2024**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **No. of pods plant-1** | **No. of seeds pod-1** | **100 seeds**  **weight (g)** | **Seed yield**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** | | | |
| 0 | 10.76 ± 0.72 d | 9.84 ± 0.43 d | 6.59 ± 0.06 b | 683.88 ± 15.96 d |
| 20 | 15.12 ± 0.22 c | 10.67 ± 0.30 c | 6.83 ± 0.01 a | 797.86 ± 4.83 c |
| 40 | 18.98 ± 0.95 b | 11.53 ± 0.06 b | 6.90 ± 0.02 a | 904.69 ± 61.15 b |
| 60 | 21.56 ± 0.20 a | 11.97 ± 0.11 a | 6.97 ± 0.01 a | 1053.11 ± 22.99 a |
| LSD0.05 | 0.66 | 0.23 | 0.15 | 14.41 |
| **Potassium (kg ha-1)** | | | |
| 0 | 13.48 ± 0.18 c | 9.79 ± 0.59 c | 6.68 ± 0.02 b | 747.82 ± 51.71 c |
| 20 | 16.73 ± 2.47 b | 10.97 ± 0.44 b | 6.82 ± 0.05 ab | 845.45 ± 79.15 b |
| 40 | 17.90 ± 2.56 a | 11.58 ± 0.30 a | 6.88 ± 0.05 a | 918.01 ± 89.91 a |
| 60 | 18.31 ± 2.36 a | 11.64 ± 0.21 a | 6.90 ± 0.04 a | 928.26 ± 87.90 a |
| LSD0.05 | 0.66 | 0.23 | 0.15 | 14.41 |
| Pr>F |  |  |  |  |
| P | \*\* | \*\* | \*\* | \*\* |
| K | \*\* | \*\* | \* | \*\* |
| P x K | \*\* | \*\* | ns | \*\* |
| CV% | 4.80 | 2.56 | 2.72 | 2.01 |

In a column, means having the same letters are not significantly different at LSD 5% level.

\* Significant difference at 5% level, \*\* Significant difference at 1% level, ns non-significant difference, CV% Coefficient of Variation, Mean ± standard error of mean (n=3)

**Table 7. Mean effects of different rates of P and K application on number of pods plant-1, number of seeds pod-1, 100 seeds weight, seed yield and total dry matter of mungbean during monsoon season, 2024**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **No. of pods plant-1** | **No. of seeds pod-1** | **100 seeds weight (g)** | **Seed yield**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** | | | |
| 0 | 12.63 ± 1.68 d | 11.52 ± 0.33 d | 4.91 ± 0.14 b | 935.47 ± 6.99 c |
| 20 | 15.52 ± 1.89 c | 12.44 ± 0.14 c | 5.11 ± 0.10 b | 977.21 ± 13.12 c |
| 40 | 20.70 ± 0.32 b | 13.26 ± 0.19 b | 5.55 ± 0.09 a | 1293.94 ± 53.14 b |
| 60 | 23.37 ± 0.84 a | 13.68 ± 0.05 a | 5.70 ± 0.03 a | 1395.84 ± 18.25 a |
| LSD0.05 | 0.88 | 0.14 | 0.21 | 28.88 |
| **Potassium (kg ha-1)** | | | |
| 0 | 14.75 ± 2.41 c | 11.38 ± 0.22 d | 5.09 ± 0.05 c | 972.99 ± 17.51 c |
| 20 | 17.53 ± 3.51 b | 12.83 ± 0.46 c | 5.30 ± 0.28 b | 1181.28 ± 161.87 b |
| 40 | 19.67 ± 2.23 a | 13.31 ± 0.42 a | 5.32 ± 0.20 b | 1209.81 ± 164.67ab |
| 60 | 20.27 ± 1.23 a | 13.38 ± 0.36 a | 5.56 ± 0.20 a | 1238.39 ± 167.24 a |
| LSD0.05 | 0.88 | 0.14 | 0.21 | 28.88 |
| Pr>F |  |  |  |  |
| P | \*\* | \*\* | \*\* | \*\* |
| K | \*\* | \*\* | \*\* | \*\* |
| P x K | \*\* | \*\* | ns | \*\* |
| CV% | 5.87 | 1.29 | 4.68 | 3.02 |

In a column, means having the same letters are not significantly different at LSD 5% level.

\* Significant difference at 5% level, \*\* Significant difference at 1% level, ns non-significant difference, CV% Coefficient of Variation, Mean ± standard error of mean (n=3)

1. **(B)**

Pr>F = \*\*

LSD0.05 = 1.78

CV (%) = 4.80

**Figure 1. Mean values of the number of pod plant-1 as affected by combined application of P and K during (A) pre-monsoon and (B) monsoon seasons, 2024. Error bar represents standard error of the mean (n=3). Column bars having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, CV% Coefficient of Variation**

Pr>F = \*\*

LSD0.05 = 0.47

CV (%) = 2.56

1. **(B)**

**Figure 2. Mean values of the number of seeds pod-1 as affected by combined application of P and K during (A) pre-monsoon and (B) monsoon seasons, 2024. Error bar represents standard error of the mean (n=3). Column bars having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, CV% Coefficient of Variation**

1. **(B)**

**Figure 3. Mean values of seed yield as affected by combined application of P and K during (A) pre-monsoon and (B) monsoon seasons, 2024. Column bars having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, CV% Coefficient of Variation**

**4. DISCUSSION**

**4.1 Plant height**

The marked increase in plant height associated with P corroborates the findings of Kubure et al. [13], which reported that P enhances root development and nutrient uptake in faba bean. The increase in plant height resulting from K can be attributed to its role in promoting cell expansion, as proposed by Abbas et al. [14]. The lack of a significant effect between P and K suggests that their effects may function independently in an additive manner; however, the superior performance of P₆₀K₄₀ indicates potential synergistic physiological benefits that warrant further investigation.

**4.2 Number of branches plant-1**

The observed increase in branching associated with P₆₀ and K₆₀ treatments is likely a reflection of enhanced metabolic activity and increased production of cytokinin, as reported by Tariq et al. [15] and Biswash et al. [16]. The lack of a significant effect implies that P and K may stimulate branching independently, potentially through mechanisms that enhance sink strength and optimize resource allocation.

**4.3 Total dry matter**

The superior dry matter accumulation observed with P₆₀ aligns with findings by Reddy et al. [17], which illustrated that P enhances photosynthetic efficiency. Additionally, the role of K₆₀ in facilitating carbohydrate translocation, as indicated by Hussain et al. [18], further explains its positive influence on dry matter accumulation. The enhanced performance of the P₆₀K₄₀ combination likely resulted from optimized source-sink relationships, maximizing biomass partitioning towards reproductive structures and overall plant productivity.

**4.4 Number of pods plant-1**

The strong correlation observed between pod numbers and the P₆₀K₄₀ treatment validates the conclusions drawn by Mota et al. [19], which posited that P promotes flower initiation while K minimizes pod abscission. The consistency of pod production from P₆₀K₄₀ treatment across varying moisture conditions underscores its potential adaptability in diverse environmental conditions.

4.5 Number of seeds pod-1

The increase in number of seeds pod-1 observed with the P₆₀K₄₀ combination aligns well with findings by Baite et al. [20], demonstrating that P enhances sink capacity while K improves nutrient remobilization. Interestingly, the non-significant effect of K (K60 and K40) in the monsoon season may indicate seasonal dynamics affecting nutrient availability or potential dilution effects associated with increased rainfall.

4.6 100-seed weight

The weights of 100 seeds were not significantly affected by the combined P and K applications in both seasons. Numerically, the seed weight associated with the P₆₀K₄₀ treatment was the heaviest among the treatments, consistent with the observations of Khan et al. [21], where P was found to boost the supply of assimilates, and K contributed to the regulation of osmotic balance.

4.7 Seed yield

The maximization of seed yield under the P₆₀K₄₀ treatment supports the findings of Hassan et al. [22], who proposed that balanced fertilization with P and K optimizes source-sink relationships. The observed shift in the optimal treatment towards P₆₀K₂₀ during the monsoon may reflect adaptive K management practices under rainfed conditions. This shift may be attributed to the altered soil nutrient dynamics during the monsoon, where high rainfall increases K solubility and mobility, potentially reducing the requirement for additional K inputs. Moreover, excessive moisture can lead to nutrient leaching, but moderate K application (P₆₀K₂₀) might be sufficient to support crop growth without excessive loss. The highest K rate (60 kg K ha-1) in our study may cause nutrient imbalance in soil, particularly affecting the availability of calcium (Ca) and magnesium (Mg). This imbalance may reduce photosynthesis efficiency and subsequently decrease crop yields. Overall, these findings underscore the importance of tailored nutrient management to enhance productivity in varying climatic conditions.

5. Conclusion

Based on the experimental findings, it may be concluded that the performance of mungbean was significantly influenced by different fertilizer treatments. The combined application of phosphorus at 60 kg P ha-1 and potassium at 40 kg K ha-1 had a notable impact on growth parameters, as well as yield and yield-attributing characteristics, including the number of pods per plant and the number of seeds per pod. However, the weight of 100-seed was not significantly affected by the combined p and k applications. The maximum seed yields were resulted in pre-monsoon season (1126.87 kg ha-1) and in monsoon season (1561.17 kg ha-1) at P60K40 treatment (60 kg P ha-1 + 40 kg K ha-1). The seed yield from P60K40 was not statistically different from P60K60 in pre-monsoon and was not statistically different from P60K20 and P60K60 in monsoon seasons but different from all other treatment combinations. P₆₀K₄₀ is recommended for pre-monsoon cultivation, while a lower potassium application (P₆₀K₂₀) is adequate during the monsoon season, likely due to variations in nutrient availability under wetter conditions. The combined application of P and K fertilizers significantly enhanced mungbean growth and yield compared to single applications. This synergistic interaction between P and K positively influenced the yield and yield components of mungbean. Therefore, to optimize the yield of mungbean, the combined application of P and K fertilizers should be used rather than single applications for farmers. However, to reach a specific conclusion and recommendation, more research work on mungbean should be done in different agro ecological zones.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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