Influence of Phosphorus and Boron Application on Yield and Yield Contributing Characters of Mungbean (*Vigna radiata* L.)

.**ABSTRACT**

|  |
| --- |
| This study aimed to assess the effects of phosphorus (P) and boron (B) applications on the yield and yield contributing characters of mungbean, along with determining the optimal nutrient doses for maximizing yields. Field experiments were conducted at the Soil and Water Science field of Yezin Agricultural University during the pre-monsoon and monsoon seasons of 2024. The experimental design followed a 4 x 3 factorial arrangement in a randomized complete block design (RCBD) with three replications. This included four levels of P (P0, P1, P2, P3: 0, 20, 40, and 60 kg P ha-1) and three levels of B (B0, B1, B2: 0, 0.5, and 1.0 kg B ha-1), along with a blanket dose of 20:40 kg N: K ha-1 as basal. The results revealed that both individual and combined applications of P and B significantly enhanced mungbean yield and its attributes. The highest yields were achieved with individual applications of 60 kg P ha-1 and 1.0 kg B ha-1 in both seasons. The combined treatment of P3B2 (60 kg P ha-1 + 1.0 kg B ha-1) yielded the best results for seed yield, plant height, number of pods plant-1, number of seeds pod-1, and total dry matter in both seasons. This treatment was statistically similar to P2B2 (40 kg P ha-1 + 1.0 kg B ha-1) and P3B1 (60 kg P ha-1 + 0.5 kg B ha-1). Thus, P2B2 is recommended as the optimal dose for increasing mungbean yield in similar agroecological zones. This study highlights the importance of balanced fertilization, including P and B, in increasing mungbean production. |

*Keywords: mungbean, phosphorus, boron, yield, yield contributing characters*

1. Introduction

Mungbean (*Vigna radiata* L.) is an important pulse consumed all over the world, especially in Asian countries, and has been used for many years in traditional medicine and food. Mungbean is an important export crop for markets in Europe, Asia, and Japan [1]. It has numerous utilities and is used primarily as a food crop because it is a major source of protein in cereal-based diets because of its high lysine content [2]. Mungbean can fix nitrogen (N) from the atmosphere through their root nodules, improve soil structure by promoting the production and maintenance of soil aggregates, and enhance soil stability, which reduces soil erosion and increases water holding capacity [3]. This crop can enhance planting strategies due to its quick growth and early harvest, making it suitable for use as a catch crop or intercropped alongside other plants. It is primarily utilized in crop rotation with cereal crops [4] [5]. Mungbean serves as a source of food, animal feed, and is also utilized as a green manure crop [6].

Phosphorus (P) is the second most important nutrient for plants, but it is especially important for pulses since it is needed for root formation, which helps fix in the atmosphere. Therefore, in pulse production, P is essential for increasing crop productivity [7]. P is essential for carbohydrate formation and movement, root growth, crop maturation, and disease resistance. As a result, it enhances mungbean yield and improves its quality [8]. Legume needs P for growth, seed formation, and most importantly for the energy-driving process of fixation because legumes are phosphorus-loving plants [9]. Micronutrients, especially B, plays an important role in plant nutrition and is recognized as a significant yield-limiting factor in pulses [10]. Typically, dicot plants, such as cotton and legumes, require 4 to 7 times more B (20-70 mg B kg⁻¹) than monocot plants from the Gramineae family, which need only 5-10 mg B kg⁻¹ [11]. In legumes, adequate B is also necessary for efficient nodulation and fixation [12]. Suitable levels of P (1) can enhance the water uptake in plants, stimulating their growth and transpiration, which in turn can improve B absorption due to these enhanced physiological processes, and (2) P can affect the biochemical properties of the plant rhizosphere, thereby increasing the availability of B in the soil [13].

2. Materials and methods

The field experiments were conducted at the Department of Soil and Water Science, Yezin Agricultural University (YAU) in 2024, during both the pre-monsoon (February to May) and monsoon (June to September) seasons. The experimental design utilized a 4 x 3 factorial arrangement in a randomized complete block design (RCBD) with three replications, incorporating four phosphorus ~~(P)~~ levels ~~(P~~~~0~~~~, P~~~~1~~~~, P~~~~2~~~~, and P~~~~3~~ ~~representing 0, 20, 40, and 60 kg P ha~~~~-1~~~~)~~ and three boron (B) levels ~~(B~~~~0~~~~, B~~~~1~~~~, and B~~~~2~~ ~~representing 0, 0.5, and 1.0 kg B ha~~~~-1~~~~).~~ ~~Thus, a total of twelve treatments were included in this experiment.~~

The cultivar under examination was Yezin-15, which has a maturity period of 60 to 73 days. Each unit plot measured 4 m x 3 m, with a spacing of 45 cm x 10 cm. During the final stage of land preparation, all experimental units received 20 kg N ha-1 as the source of urea and 40 kg K ha-1 as the source of muriate of potash (MOP). P and B fertilization treatments were applied at the basal level using triple superphosphate and borax, respectively. The fertilizers were distributed evenly across each plot by hand. Prior to the commencement of the experiment, soil samples were collected to analyze various physiochemical properties, as detailed in Table 1.

Table: The treatment details are as follows

|  |  |
| --- | --- |
| **Factor A (Phosphorus Levels)**  P0 = 0 kg P ha-1  P1 = 20 kg P ha-1  P2 = 40 kg P ha-1  P3 = 60 kg P ha-1 | **Factor B (Boron levels)**  B0 = 0 kg B ha-1  B1 = 0.5 kg B ha-1  B2 = 1.0 kg B ha-1 |

**Table 1. Physicochemical properties of the experimental soils before planting**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Value** | **Rating** | **Method** |
| Texture class  (USDA classification system) | | Sandy Loam | Pipette Method |
| Sand (%) | 76.50 |  |  |
| Silt (%) | 15.76 |  |  |
| Clay (%) | 7.74 |  |  |
| Soil pH | 5.70 | Moderately acid | 1:5 (soil: water) |
| Bulk density (g cm-3) | 1.24 | Low | Core sampler |
| Cation exchange capacity (cmolc kg-1) | 3.27 | Very Low | 1N Ammonium acetate extraction method |
| EC (dS m-1) | 0.04 | Non-saline | 1:5 (soil: water) |
| Organic matter (%) | 0.88 | Low | Wet Digestion |
| Total N (%) | 0.07 | Low | Kjeldahl digestion and distillation |
| Available P (mg kg-1) | 5.00 | Low | Olsen-P Method |
| Available K (mg kg-1) | 23.00 | Low | Ammonium acetate |
| Available boron B (mg kg-1) | 0.74 | Low | Hot water extraction method |

**2.1 Data collection**

Plant height was measured weekly from 14 to 63 days after sowing (DAS), using five plants per treatment. The number of primary branches were counted at harvest from five randomly selected plants in each plot. After harvest, the number of pods per plant were recorded from five randomly selected plants per plot, along with the number of seeds per pod from ten pods. One hundred seeds from each plot were weighed using an electronic balance and reported in grams. Seed yield was calculated from a central harvested area of 3.25 m² per plot and converted to kilograms per hectare (kg ha⁻¹), while total dry matter was assessed from five randomly selected plants per plot.

**2.2 Statistical Analysis**

Statistical analysis of all data was performed using Statistix software version 8.0. Treatment means were compared using the least significant difference (LSD) test at a 5% probability level [14].

**3. RESULTS**

**3.1 Plant Height**

Plant height exhibited significant responses to P and B applications across both pre-monsoon and monsoon seasons (Tables 2, 4). In the pre-monsoon season, the tallest plants (34.29 cm) were observed at 60 kg P ha⁻¹ (P₃), while the control (P₀) recorded the shortest (26.85 cm). Similarly, B at 1.0 kg ha⁻¹ (B₂) increased plant height (31.66 cm) compared to lower doses. A significant P × B interaction was revealed at 56 and 63 days after sowing (DAS) in the pre-monsoon season, with P₃B₂ (60 kg P + 1.0 kg B ha⁻¹) producing the tallest plants (37.18 cm). In the monsoon season, P₃ (60 kg P ha⁻¹) again resulted in the tallest plants (106.49 cm), and B₂ (1.0 kg B ha⁻¹) outperformed higher doses (102.83 cm). No significant interaction was observed during the monsoon (Tables 2- 5).

**3.2 Number of Branches Plant-1**

Phosphorus application significantly influenced branching, with P₃ (60 kg P ha⁻¹) yielding the highest number of branches (2.33 pre-monsoon, 3.89 monsoon) compared to P₀ (1.31 pre-monsoon, 1.91 monsoon). Boron at B₂ (1.0 kg ha⁻¹) also enhanced branching (2.10 pre-monsoon, 3.17 monsoon). However, no significant P × B interaction was observed in either season (Tables 2- 5).

**3.3 Total Dry Matter Accumulation**

Dry matter production increased with higher P and B levels. In the pre-monsoon season, P₃ (60 kg P ha⁻¹) recorded the highest dry matter (2314.50 kg ha⁻¹), while B₂ (1.0 kg B ha⁻¹) yielded 2104.30 kg ha⁻¹. Similar trends were observed in the monsoon, with P₃ (4886.60 kg ha⁻¹) and B₂ (4258.70 kg ha⁻¹) outperforming other treatments. No significant interaction between P and B was found (Tables 2–5).

**3.4 Number of Pods Plant-1**

~~Pod numbers were significantly higher under P₃ (20.24 pre-monsoon, 24.91 monsoon) and B₂ (18.38 pre-monsoon, 22.75 monsoon). A strong P × B interaction was observed in both seasons, with P₃B₂ producing the maximum pods (20.73 pre-monsoon, 26.33 monsoon) (Tables 6–9).~~

**3.4 Number of Seeds Pod-1**

P₃ (60 kg P ha⁻¹) increased seeds per pod (12.07 pre-monsoon, 13.74 monsoon) compared to P₀ (9.50 pre-monsoon, 11.18 monsoon). Boron at B₂ (1.0 kg ha⁻¹) also improved this parameter (11.31 pre-monsoon, 12.81 monsoon). A significant interaction occurred only in the monsoon season, where P₃B₂ recorded 14.43 seeds per pod (Tables 6–9).

**3.5 100-Seed Weight**

Seed weight was maximized under P₃ (6.97 g pre-monsoon, 5.00 g monsoon) and B₂ (6.67 g pre-monsoon, 4.92 g monsoon). No significant P × B interaction was observed in either season (Tables 6–9).

**3.6 Seed Yield**

Seed yield peaked at P₃ (1048.10 kg ha⁻¹ pre-monsoon, 1323.00 kg ha⁻¹ monsoon) and B₂ (944.42 kg ha⁻¹ pre-monsoon, 1177.40 kg ha⁻¹ monsoon). The interaction P₃B₂ yielded the highest seed yield (1091.45 kg ha⁻¹ pre-monsoon, 1401.74 kg ha⁻¹ monsoon), though P₂B₂ (40 kg P + 1.0 kg B ha⁻¹) and P₃B₁ (60 kg P + 0.5 kg B ha⁻¹) were statistically comparable (Tables 6–9)

**Table 2. Effects of phosphorus and boron application on growth parameters of mungbean in Pre-monsoon season**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **No. of branches plant-1** | **Total dry matter**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** |  |  |  |
| 0 | 26.85 ± 0.07 d | 1.31 ± 0.08 c | 1644.40 ± 44.05 d |
| 20 | 29.06 ± 0.58 c | 1.93 ± 0.10 b | 1821.00 ± 45.75 c |
| 40 | 31.16 ± 1.21 b | 2.22 ± 0.12 a | 2138.20±146.93 b |
| 60 | 34.29 ± 2.19 a | 2.33 ± 0.07 a | 2314.50 ± 66.94 a |
| Pr>F | \*\* | \*\* | \*\* |
| LSD | 1.54 | 0.15 | 96.76 |
| **Boron (kg ha-1)** | | | |
| 0 | 28.36 ± 0.69 b | 1.80 ± 0.23 c | 1843.10 ± 135.79 c |
| 0.5 | 31.01 ± 1.87 a | 1.95 ± 0.24 b | 1991.20 ± 149.37 b |
| 1.0 | 31.66 ± 2.20 a | 2.10 ± 0.23 a | 2104.30 ± 177.65 a |
| Pr>F | \*\* | \*\* | \*\* |
| LSD | 1.34 | 0.13 | 83.79 |
| CV % | 5.23 | 7.64 | 5.02 |

*In a column, means 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, Mean ± Standard error of mean (n=3)*

**Table 3. Combined effects of phosphorus and boron application on growth parameters of mungbean in pre-monsoon season**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **No. of branches**  **plant-1** | **Total Dry Matter**  **(kg ha-1)** |
| P0B0 | 26.72 ± 0.50 f | 1.20 ± 0.12 | 1561.99 ± 82.06 |
| P0B1 | 26.88 ± 0.86 f | 1.27 ± 0.07 | 1658.60 ± 71.22 |
| P0B2 | 26.95 ± 0.84 ef | 1.47 ± 0.07 | 1712.60 ± 31.87 |
| P1B0 | 27.91 ± 1.42 def | 1.73 ± 0.07 | 1738.11 ± 59.00 |
| P1B1 | 29.57 ± 1.16 def | 2.00 ± 0.12 | 1829.03 ± 52.30 |
| P1B2 | 29.70 ± 1.44 cde | 2.07 ± 0.07 | 1895.98 ± 44.19 |
| P2B0 | 28.79 ± 0.55 cd | 2.00 ± 0.12 | 1867.70 ± 102.78 |
| P2B1 | 31.89 ± 0.87 cd | 2.27 ± 0.07 | 2173.95 ± 17.56 |
| P2B2 | 32.81 ± 0.68 bc | 2.40 ± 0.12 | 2372.89 ± 46.94 |
| P3B0 | 30.00 ± 0.61 b | 2.27 ± 0.07 | 2204.50 ± 28.95 |
| P3B1 | 35.69 ± 0.72 a | 2.27 ± 0.07 | 2303.34 ± 35.61 |
| P3B2 | 37.18 ± 0.73 a | 2.47 ± 0.07 | 2435.59 ± 58.20 |
| Pr>F | \* | ns | Ns |
| LSD | 2.67 | 0.25 | 167.59 |
| CV % | 5.23 | 7.64 | 5.02 |

*In a column, means having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, ns Nonsignificant difference, CV% Coefficient of Variation, Mean ± Standard error of mean (n=3)*

**Table 4. Effects of phosphorus and boron application on growth parameters of mungbean in monsoon season**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **No. of branches**  **plant-1** | **Total Dry Matter**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** | | | |
| 0 | 96.46 ± 0.50 c | 1.91 ± 0.20 d | 2993.70 ± 124.36 d |
| 20 | 100.41 ± 0.81 bc | 2.51 ± 0.14 c | 3621.60 ± 132.99 c |
| 40 | 104.40 ± 0.64 ab | 3.16 ± 0.26 b | 4469.40 ± 219.34 b |
| 60 | 106.49 ± 0.88 a | 3.89 ± 0.09 a | 4886.60 ± 92.77 a |
| Pr>F | \*\* | \*\* | \*\* |
| LSD | 4.64 | 0.27 | 274.81 |
| **Boron (kg ha-1)** |  |  |  |
| 0 | 101.17 ± 2.41 | 2.62 ± 0.48 b | 3773.70 ± 418.73 b |
| 0.5 | 101.83 ± 2.05 | 2.82 ± 0.38 b | 3946.10 ± 429.31 b |
| 1.0 | 102.83 ± 2.32 | 3.17 ± 0.43 a | 4258.70 ± 430.68 a |
| Pr>F | Ns | \*\* | \*\* |
| LSD | 4.02 | 0.24 | 237.99 |
| CV% | 4.63 | 7.64 | 5.02 |

*In a column, means 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, Mean ± Standard error of mean (n=3)*

**Table 5. Combined effects of phosphorus and boron application on growth parameters of mungbean in monsoon season**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **No. of branches**  **plant-1** | **Total Dry Matter**  **(kg ha-1)** |
| P0B0 | 95.47 ± 4.96 | 1.53 ± 0.18 | 2809.23 ± 128.05 |
| P0B1 | 96.87 ± 0.84 | 2.00 ± 0.12 | 2941.50 ± 107.34 |
| P0B2 | 97.03 ± 0.55 | 2.20 ± 0.12 | 3230.43 ± 137.88 |
| P1B0 | 98.90 ± 0.87 | 2.27 ± 0.07 | 3414.41 ± 118.26 |
| P1B1 | 100.67 ± 1.49 | 2.53 ± 0.07 | 3580.74 ± 197.39 |
| P1B2 | 101.67 ± 2.13 | 2.73 ± 0.07 | 3869.64 ± 198.84 |
| P2B0 | 105.40 ± 1.65 | 2.87 ± 0.07 | 4145.13 ± 160.43 |
| P2B1 | 103.20 ± 3.13 | 2.93 ± 0.29 | 4375.65 ± 87.26 |
| P2B2 | 104.63 ± 3.23 | 3.67 ± 0.07 | 4887.38 ± 124.03 |
| P3B0 | 104.93 ± 4.19 | 3.80 ± 0.12 | 4725.94 ± 98.90 |
| P3B1 | 106.57 ± 3.46 | 3.80 ± 0.12 | 4886.58 ± 67.85 |
| P3B2 | 107.97 ± 2.53 | 4.07 ± 0.35 | 5047.31 ± 341.45 |
| Pr>F | Ns | ns | ns |
| LSD | 8.04 | 0.47 | 475.98 |
| CV % | 4.63 | 7.64 | 5.02 |

*In a column, means having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, ns Nonsignificant difference, CV% Coefficient of Variation, Mean ± Standard error of mean (n=3)*

**Table 6. Effects of phosphorus and boron application on yield and yield contributing characters of mungbean in pre-monsoon season**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **No. of pods plant-1** | **No. of seeds**  **pod-1** | **100 seed weight (g)** | **Seed yield**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** | | | | |
| 0 | 13.91 ± 0.13 d | 9.50 ± 0.12 d | 6.18 ± 0.07 d | 716.00 ± 12.51 d |
| 20 | 17.16 ± 0.58 c | 10.34 ± 0.25 c | 6.41 ± 0.06 c | 830.50 ± 27.86 c |
| 40 | 18.98 ± 0.91 b | 11.49 ± 0.38 b | 6.64 ± 0.17 b | 946.80 ± 83.26 b |
| 60 | 20.24 ± 0.36 a | 12.07 ± 0.26 a | 6.97 ± 0.09 a | 1048.10 ±29.38 a |
| Pr>F | \*\* | \*\* | \*\* | \*\* |
| LSD0.05 | 0.53 | 0.28 | 0.18 | 37.76 |
| **Boron (kg ha-1)** | | | | |
| 0 | 16.68 ± 1.23 c | 10.46 ± 0.51 c | 6.36 ± 0.16 b | 814.15 ± 63.00 c |
| 0.5 | 17.65 ± 1.40 b | 10.78 ± 0.59 b | 6.61 ± 0.16 a | 897.44 ± 75.28 b |
| 1.0 | 18.38 ± 1.54 a | 11.31 ± 0.64 a | 6.67 ± 0.20 a | 944.42 ± 85.50 a |
| Pr>F | \*\* | \*\* | \*\* | \*\* |
| LSD0.05 | 0.46 | 0.25 | 0.16 | 32.70 |
| CV % | 3.11 | 2.69 | 2.88 | 4.38 |

*In a column, means 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, Mean ± Standard error of mean (n=3)*

**Table 7. Combined effects of phosphorus and boron application on yield and yield contributing characters of mungbean in pre-monsoon season**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **No. of pods**  **plant-1** | **No. of seedspod-1** | **100 seed**  **weight (g)** | **Seed yield**  **(kg ha-1)** |
| P0B0 | 13.67 ± 0.24 f | 9.33 ± 0.18 | 6.03 ± 0.09 | 695.43 ± 13.64 g |
| P0B1 | 13.92 ± 0.06 f | 9.43 ± 0.12 | 6.24 ± 0.06 | 714.01 ± 7.30 fg |
| P0B2 | 14.13 ± 0.07 f | 9.73 ± 0.12 | 6.27 ± 0.13 | 738.61 ± 10.37 efg |
| P1B0 | 16.07 ± 0.41 e | 9.93 ± 0.12 | 6.30 ± 0.05 | 776.31 ± 8.17 ef |
| P1B1 | 17.33 ± 0.41 d | 10.30 ± 0.10 | 6.51 ± 0.02 | 846.27 ± 7.41de |
| P1B2 | 18.07 ± 0.29 d | 10.80 ± 0.10 | 6.41 ± 0.11 | 868.87 ± 9.29 cd |
| P2B0 | 17.47 ± 0.24 cd | 11.00 ± 0.10 | 6.32 ± 0.06 | 792.84 ± 37.45 c |
| P2B1 | 18.87 ± 0.47 bc | 11.23 ± 0.20 | 6.70 ± 0.10 | 968.74 ± 18.15 b |
| P2B2 | 20.60 ± 0.42 a | 12.23 ± 0.15 | 6.90 ± 0.21 | 1078.75 ±49.83 a |
| P3B0 | 19.53 ± 0.27 b | 11.57 ± 0.23 | 6.80 ± 0.12 | 992.05 ± 10.09 b |
| P3B1 | 20.47 ± 0.33 a | 12.17 ± 0.33 | 7.00 ± 0.12 | 1060.73 ± 33.66 a |
| P3B2 | 20.73 ± 0.29 a | 12.47 ± 0.09 | 7.10 ± 0.13 | 1091.45 ± 4.56 a |
| Pr>F | \* | Ns | ns | \*\* |
| LSD | 0.92 | 0.49 | 0.32 | 65.41 |
| CV % | 3.11 | 2.69 | 2.88 | 4.38 |

*In a column, means having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, ns Nonsignificant difference, CV% Coefficient of Variation, Mean ± Standard error of mean (n=3)*

**Table 8. Effects of phosphorus and boron application on yield and yield contributing characters of mungbean in monsoon season**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **No. of pods plant-1** | **No. of seeds pod-1** | **100 seed weight (g)** | **Seed yield**  **(kg ha-1)** |
| **Phosphorus (kg ha-1)** | | | | |
| 0 | 17.40 ± 0.87 d | 11.18 ± 0.03 c | 4.76 ± 0.01 | 895.60 ± 15.37 d |
| 20 | 19.76 ± 0.10 c | 11.40 ± 0.06 c | 4.82 ± 0.02 | 994.96 ± 11.49 c |
| 40 | 23.18 ± 1.66 b | 12.73 ± 0.72 b | 4.92 ± 0.02 | 1159.00 ± 105.97 b |
| 60 | 24.91 ± 0.97 a | 13.74 ± 0.46 a | 5.00 ± 0.05 | 1323.00 ± 63.84 a |
| Pr>F | \*\* | \*\* | ns | \*\* |
| LSD0.05 | 1.06 | 0.58 | 0.23 | 64.88 |
| **Boron (kg ha-1)** | | | | |
| 0 | 19.77±1.55 c | 11.73±0.39 c | 4.84±0.05 | 1021.30 ± 68.76 c |
| 0.5 | 21.42±1.58 b | 12.26±0.63 b | 4.87±0.05 | 1080.70 ±102.39 b |
| 1.0 | 22.75±2.09 a | 12.81±0.84 a | 4.92±0.07 | 1177.40 ± 122.25 a |
| Pr>F | \*\* | \*\* | ns | \*\* |
| LSD0.05 | 0.92 | 0.50 | 0.20 | 56.19 |
| CV % | 5.15 | 4.82 | 4.91 | 6.10 |

*In a column, means having the same letter are not significantly different at LSD 5% level. \* Significant difference at 5% level, \*\* Significant difference at 1% level, ns Nonsignificant difference, CV% Coefficient of Variation, Mean ± Standard error of mean (n=3)*

**Table 9. Combined effects of phosphorus and boron application on yield and yield contributing characters of mungbean in monsoon season**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **No. of pods plant-1** | **No. of seeds**  **pod-1** | **100 seed**  **weight (g)** | **Seed yield**  **(kg ha-1)** |
| P0B0 | 15.67 ± 0.35 g | 11.13 ± 0.37 d | 4.75 ± 0.02 | 868.16 ± 25.57 f |
| P0B1 | 18.13 ± 0.93 f | 11.17 ± 0.27 d | 4.77 ± 0.08 | 897.19 ± 27.70 ef |
| P0B2 | 18.40 ± 0.42 f | 11.23 ± 0.22 d | 4.78 ±0.17 | 921.34 ± 15.71 def |
| P1B0 | 19.60 ± 0.76 ef | 11.30 ± 0.49 d | 4.78 ± 0.24 | 976.20 ± 12.24 cdef |
| P1B1 | 19.73 ± 0.58 ef | 11.40 ± 0.25 d | 4.82 ± 0.05 | 992.87 ± 8.28 cde |
| P1B2 | 19.93 ± 0.47 ef | 11.50 ± 0.40 d | 4.84 ± 0.16 | 1015.82 ± 17.62 cd |
| P2B0 | 20.73 ± 0.58 de | 11.60 ± 0.26 cd | 4.89 ± 0.17 | 1044.16 ± 63.56 c |
| P2B1 | 22.47 ± 0.52 cd | 12.53 ± 0.15 bc | 4.94 ± 0.05 | 1062.10 ± 25.37 c |
| P2B2 | 26.33 ± 0.52 a | 14.07 ± 0.23 a | 4.94 ± 0.06 | 1370.66 ± 78.08 a |
| P3B0 | 23.07 ± 1.17 bc | 12.87 ± 0.47 b | 4.95 ± 0.06 | 1196.58 ± 64.03 b |
| P3B1 | 25.33 ± 0.41 ab | 13.93 ± 0.27 ab | 4.95 ± 0.13 | 1370.66 ± 21.57 ab |
| P3B2 | 26.33 ± 0.33 a | 14.43 ± 0.48 a | 5.11 ± 0.22 | 1401.74 ± 15.76 a |
| Pr>F | \* | \* | s | \*\* |
| LSD | 1.85 | 0.98 | 0.40 | 113.42 |
| CV % | 5.17 | 4.75 | 4.91 | 6.19 |

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

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

**No. of pods plant-1**

**Treatments**

**Treatments**

**Figure 1. Mean values of number of pods plant-1 as affected by combined application of phosphorus and boron during pre-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**

**Seed yield (kg ha-1)**

Pr> F = \*\*

LSD0.05 = 65.41

CV(%) = 4.38

**Treatments**

**Figure 2. Mean values of seed yield as affected by combined application of phosphorus and boron during pre-monsoon season, 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**

**Treatments**

**No. of podsplant-1**

Pr> F = \*

LSD0.05 = 1.85

CV(%) = 5.15

**Figure 3. Mean values of number of pods plant-1 as affected by combined application of phosphorus and boron during 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**

**Treatments**

**Figure 4. Mean values of seed yield as affected by combined application of phosphorus and boron during monsoon season, 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**

**4. DISCUSSION**

**4.1 Plant Height**

The significant increase in plant height with P application aligns with its role in promoting cell elongation, root development, and nutrient uptake efficiency [15]. Boron’s enhancement of plant height likely stems from its involvement in cell wall structure and auxin metabolism, which regulate vegetative growth [16]. The synergistic P × B interaction in the pre-monsoon season suggests that combined nutrient availability optimizes metabolic processes under less humid conditions [17].

**4.2 Number of Branches**

Higher branching under P and B applications reflects improved carbohydrate partitioning and meristematic activity [18] [19]. The absence of interaction implies independent mechanisms: P’s role in energy metabolism and B’s function in tissue differentiation.

**4.3 Total Dry Matter**

Increased dry matter with higher P levels is due to improved nutrient availability and enhanced photosynthetic activity from better light exposure [20]. Boron affects cell division, and plants may develop more quickly if they absorb nitrogen from the soil, which results in their dry weight [21].

**4.4 Number of Pods plant-1**

Pod numbers increased with P due to its role in flower initiation and pollen viability [22], while B’s effect relates to pollen tube growth and stigma receptivity [23]. The strong P × B interaction highlights their combined influence on reproductive success, particularly under favorable monsoon conditions.

**4.4 Number of Seeds Pod-1**

The increase in seeds per pod at higher P levels is attributed to improved nutrient availability, enhanced carbohydrate accumulation, and better remobilization to reproductive parts [24]. The boron treatment increases the number of flowers, which makes the stigma sticky and responsive, making pollen seeds viable. Better pollination results in more seeds per pod [25]. The monsoon-specific interaction may reflect enhanced B mobility under higher rainfall, improving nutrient utilization.

**4.5 100-Seed Weight**

Increased seed weight with higher P levels is linked to enhanced photosynthate transfer to grains, promoting seed size and number [26] while B’s effect on sugar metabolism and cell division supports seed filling [27]. The ‘lack of interaction in the monsoon may indicate B leaching under heavy rainfall.

**4.6 Seed Yield**

Phosphorus increases yield by supporting root development, enhancing nitrogen fixation, improving nutrient availability, and optimizing rhizosphere conditions.[26]. Boron is essential for cell membrane function, potassium transport, and water balance regulation, supporting xylem vessels and root hair tips to boost plant growth and yield [23]. The yield-maximizing effects of P₃B₂ reflect integrated improvements in vegetative growth, reproductive efficiency, and resource allocation. The non-significant difference between P₃B₂, P₂B₂, and P₃B₁ suggests that 40 kg P ha⁻¹ with 1.0 kg B ha⁻¹ (P₂B₂) could optimize yield while reducing input costs. This aligns with findings by Jakhar et al. [28], emphasizing balanced P-B fertilization for sustainable mungbean production.

**5. CONCLUSION**

~~This study investigated the effects of phosphorus (P) and boron (B) fertilization on mungbean (~~*~~Vigna radiata~~* ~~L.) growth, yield, and yield-contributing traits during pre-monsoon and monsoon seasons. Field experiments tested four P levels (0, 20, 40, 60 kg P ha⁻¹) and three B levels (0, 0.5, 1.0 kg B ha⁻¹) in a factorial RCBD design. Results showed that increasing P and B doses significantly enhanced plant height, branching, total dry matter, pods per plant, seeds per pod, 100-seed weight, and seed yield, with optimal performance at 60 kg P ha⁻¹ and 1.0 kg B ha⁻¹.~~ The combined treatment P₃B₂ (60 kg P + 1.0 kg B ha⁻¹) maximized seed yield (1,401.74 kg ha-1 in monsoon) by improving pod formation and seed retention. However, P₂B₂ (40 kg P + 1.0 kg B ha⁻¹) yielded comparable results at lower P input. Significant P × B interactions were observed for pods per plant, seeds per pod, and seed yield, highlighting synergistic effects. The study concludes that balanced P-B fertilization, particularly P₂B₂, optimizes mungbean productivity while reducing input costs, highlighting the importance of integrating these nutrients for sustainable cultivation.

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