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Effect of various levels of phosphorus and molybdenum on growth, yield attributes and yield of summer green gram (*Vigna radiata* L.)

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Abstract

A field experiment was conducted during the Kharif 2025 season at the Research Farm, Faculty of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala, to evaluate the effect of different phosphorus and molybdenum levels on the growth and yield of summer green gram. The experiment was laid out in a split plot design with four phosphorus (Control, 75% RDP, 100% RDP and 125% RDP) and three molybdenum levels (0, 0.5 and 1.0 kg ha⁻¹), replicated three times. Application of 125% RDP recorded the highest values for plant height (61.94 cm), nodules per plant (19.50), seed yield (1032.9 kg ha⁻¹), biological yield (3251.6 kg ha⁻¹), and harvest index (32.10%), while the control produced the lowest values. Similarly, 1.0 kg molybdenum ha⁻¹ resulted in the highest growth and yield. However, 100% RDP was statistically at par with 125% RDP for most parameters. Hence, the application of 100% recommended phosphorus dose along with 1.0 kg molybdenum ha⁻¹ is recommended for improving the productivity of summer green gram under Haryana conditions.

Keywords: Phosphorus, molybdenum, growth, moong bean

1. Introduction

Green gram (*Vigna radiata* L.) is one of the most important pulse crops because of its high nutritional value, short duration, and capacity to improve soil fertility through biological nitrogen fixation. It is an excellent source of plant protein, carbohydrates, vitamins, minerals, and essential amino acids, making it an important component of human nutrition, particularly in developing countries (Hou *et al.*, 2019; Movalia *et al.*, 2018) [4, 5]. Besides its nutritional significance, green gram contributes to sustainable agriculture by enriching soil fertility through its symbiotic association with *Rhizobium*, thereby reducing the dependence on chemical nitrogen fertilizers (Patel *et al.*, 2013; Banerjee and Nath, 2022) [6, 3]. However, despite its economic and nutritional importance, the productivity of green gram in India, including Haryana, remains below its potential due to poor soil fertility, nutrient deficiencies, and inadequate nutrient management practices.

Among the essential plant nutrients, phosphorus and molybdenum play a pivotal role in improving the growth and productivity of pulse crops. Phosphorus is indispensable for root development, energy transfer, photosynthesis, nodulation, flowering, and seed formation, besides enhancing biological nitrogen fixation (Theodorou and Plaxton, 1993; Arsalan *et al.*, 2016) [7, 9]. Molybdenum, although required in trace amounts, is an integral component of the nitrogenase and nitrate reductase enzyme systems and is therefore essential for efficient nitrogen metabolism and symbiotic nitrogen fixation in legumes (Mendel and Hänsch, 2002; Westermann, 2005) [8, 9]. Deficiency of molybdenum adversely affects nodule formation, nitrogen fixation, and plant growth, ultimately resulting in lower productivity (Rao and Singh, 1983; Sun *et al.*, 2009) [10, 11]. Although the beneficial effects of phosphorus and molybdenum have been widely recognized, information regarding their optimum application under the agro-climatic conditions of Haryana remains limited. Crop response to these nutrients varies considerably with soil characteristics, climatic conditions, and crop management practices. Therefore, location-specific nutrient recommendations are essential for improving nutrient use efficiency, sustaining soil fertility, and

maximizing crop productivity (Patel *et al.*, 2024; Reddy *et al.*, 2020) [12, 13].

With the growing demand for pulses and the increasing emphasis on sustainable crop production, balanced nutrient management has become indispensable for enhancing green gram productivity. Optimizing phosphorus and molybdenum nutrition is expected to improve nodulation, nutrient uptake, growth, yield attributes, seed yield, and economic returns while maintaining long-term soil health (Gupta *et al.*, 1991; Hale *et al.*, 2001) [14, 15].

Keeping these facts in view, the present investigation was undertaken to evaluate the effect of different levels of phosphorus and molybdenum on the growth, yield attributes, yield, nutrient uptake, and economics of summer green gram under the agro-climatic conditions of Ambala, Haryana. The findings of the study are expected to generate scientific information for developing location-specific nutrient management strategies to enhance the productivity, profitability, and sustainability of summer green gram cultivation in the region.

2. Materials and Methods

2.1 Experimental Site

The field experiment was conducted during the *kharif* season of 2025 at the Research Farm (Agronomy Section), Faculty of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, Haryana.

2.2 Experimental details:

The field experiment was conducted at Research Farm, MMDU, Ambala, in a Split block design comprising twelve treatments (table 1) with three replications with moong variety MH 1142. All the agronomic practices were performed as per mentioned in package and practice of CCSHAU, Hisar.

Main plot (phosphorus)	Sub plot (molybdenum)
P ₁ : Control	M ₁ : Ammonium molybdate (0gm)
P ₂ : 75% RDP	M ₂ : Ammonium molybdate (500gm)
P ₃ : 100% RDP	M ₃ : Ammonium molybdate (1000gm)
P ₄ : 125% RDP	

2.3 Observations recorded

Observations on growth, nodulation, yield attributes, and yield were recorded at different crop growth stages using standard procedures. Plant height (cm) and the number of primary branches were measured from five randomly tagged plants at 25 DAS, 45 DAS, and at harvest. Dry matter accumulation (g) was determined by destructive sampling after oven drying the plant samples to constant weight. At 45 DAS, root nodules from the tagged plants were counted and their dry weight was recorded after oven drying. Yield attributes, including the number of pods per plant, seeds per pod, and 1000-seed weight, were assessed at maturity. Seed yield, stover yield, and biological yield were recorded on a plot basis and converted to kg ha⁻¹. Harvest index (%) was calculated as the ratio of seed yield to biological yield and expressed as a percentage.

Data Analysis

The data collected from experiment undergo Statistical analysis by applying the split plot design for analysis of variance (ANOVA) as suggested by O.P Sheoran (2004).

3. Results

3.1 Plant height (cm)

The data presented in Table 1 indicate that plant height of summer green gram increased progressively with crop age and was

significantly influenced by phosphorus and molybdenum application, whereas their interaction remained non-significant at all growth stages. Among the phosphorus treatments, the application of 125% RDP recorded the maximum plant height of 24.30 cm, 44.90 cm, and 61.94 cm at 30 DAS, 45 DAS, and harvest, respectively, which was statistically at par with 100% RDP (24.00, 44.80, and 61.70 cm). The lowest plant height was observed under the control treatment (20.30, 41.30, and 58.23 cm). Similarly, molybdenum application significantly enhanced plant height, with 1.0 kg ha⁻¹ producing the tallest plants (23.90, 44.60, and 61.70 cm), followed closely by 0.5 kg ha⁻¹ (23.30, 44.40, and 60.88 cm), while the untreated control recorded the minimum values (21.00, 42.00, and 58.90 cm). The interaction effect between phosphorus and molybdenum was found to be non-significant throughout the crop growth period.

Table 1: Effect of phosphorus and molybdenum levels on plant height (cm) at different growth stages of summer green gram

Treatments	Plant Height (cm)		
	25 DAS	45 DAS	At Harvest
Phosphorus levels			
Control	20.30	41.30	58.23
75% RDP	22.40	43.60	60.10
100% RDP	24.00	44.80	61.70
125% RDP	24.30	44.90	61.94
SEm±	0.19	0.27	0.60
CD (P = 0.05)	0.56	0.79	1.75
Molybdenum levels			
0 kg ha ⁻¹	21.00	42.00	58.90
0.5 kg ha ⁻¹	23.30	44.40	60.88
1.0 kg ha ⁻¹	23.90	44.60	61.70
SEm±	0.19	0.34	0.36
CD (P = 0.05)	0.55	0.99	1.04
Phosphorus × Molybdenum			
CD (P = 0.05)	N.S.	N.S.	N.S.

Table 2: Effect of phosphorus and molybdenum levels on total number of branches per plant at different growth stages of summer green gram

Treatments	Total number of branches per plant		
	25 DAS	45 DAS	At Harvest
Phosphorus levels			
Control	2.10	4.20	5.10
75% RDP	2.70	4.70	5.60
100% RDP	3.20	5.20	5.80
125% RDP	3.20	5.20	5.80
SEm±	0.03	0.04	0.06
CD (P = 0.05)	0.08	0.12	0.17
Molybdenum levels			
0 kg ha ⁻¹	2.30	4.40	5.30
0.5 kg ha ⁻¹	3.00	4.90	5.70
1.0 kg ha ⁻¹	3.20	5.10	5.80
SEm±	0.02	0.04	0.04
CD (P = 0.05)	0.07	0.12	0.11
Phosphorus × Molybdenum			
CD (P = 0.05)	N.S.	N.S.	N.S.

3.2 Total number of branches plant⁻¹

The results presented in Table 2 revealed that the total number of branches per plant increased steadily from 25 DAS to harvest and was significantly affected by phosphorus and molybdenum application, while their interaction was found to be non-significant. Among the phosphorus treatments, 100% RDP and 125% RDP recorded the highest number of branches (3.20, 5.20, and 5.80 at 25 DAS, 45 DAS, and harvest, respectively), and both treatments were statistically at par. The lowest number of

branches was observed under the control treatment (2.10, 4.20, and 5.10). Application of molybdenum also significantly increased branching, with 1.0 kg ha⁻¹ producing the maximum number of branches (3.20, 5.10, and 5.80), followed by 0.5 kg ha⁻¹ (3.00, 4.90, and 5.70), whereas the untreated control recorded the minimum values (2.30, 4.40, and 5.30). The interaction effect of phosphorus and molybdenum on branch production remained non-significant throughout the crop growth period.

Table 3: Effect of phosphorus and molybdenum levels on nodulation parameters at 45 DAS of summer green gram

Treatments	Number of nodules per plant	Dry weight of nodules per plant (mg)
Phosphorus levels		
Control	14.80	23.90
75% RDP	16.80	25.90
100% RDP	19.30	27.50
125% RDP	19.50	28.00
SEm±	0.16	0.20
CD (P = 0.05)	0.47	0.58
Molybdenum levels		
0 kg ha ⁻¹	15.50	24.50
0.5 kg ha ⁻¹	18.20	26.90
1.0 kg ha ⁻¹	19.20	27.70
SEm±	0.10	0.17
CD (P = 0.05)	0.29	0.50
Phosphorus × Molybdenum		
CD (P = 0.05)	N.S.	N.S.

3.3 Nodulation parameters

The data presented in Table 4.3 showed that both phosphorus and molybdenum significantly influenced the number and dry weight of root nodules in summer green gram, whereas their interaction effect was non-significant. Among the phosphorus treatments, the application of 125% RDP produced the highest number of nodules (19.50 plant⁻¹) and maximum nodule dry weight (28.00 mg plant⁻¹), which was statistically at par with 100% RDP (19.30 nodules plant⁻¹ and 27.50 mg plant⁻¹). The lowest values were recorded under the control treatment (14.80 nodules plant⁻¹ and 23.90 mg plant⁻¹). Likewise, molybdenum application significantly improved nodulation, with 1.0 kg ha⁻¹ recording the highest number of nodules (19.20 plant⁻¹) and greatest nodule dry weight (27.70 mg plant⁻¹), followed by 0.5 kg ha⁻¹ (18.20 nodules plant⁻¹ and 26.90 mg plant⁻¹). The control (0 kg ha⁻¹) treatment

exhibited the lowest nodulation (15.50 nodules plant⁻¹) and nodule dry weight (24.50 mg plant⁻¹). The interaction between phosphorus and molybdenum was not significant for either parameter.

Table 4: Effect of phosphorus and molybdenum levels on yield attributes of summer green gram

Treatments	Number of pods per plant	Number of seeds per pod	Test weight (g)
Phosphorus levels			
Control	14.20	8.70	40.90
75% RDP	15.10	9.60	42.70
100% RDP	15.90	10.20	44.00
125% RDP	16.00	10.30	44.10
SEm±	0.21	0.04	0.35
CD (P = 0.05)	0.61	0.12	1.01
Molybdenum levels			
0 kg ha ⁻¹	14.50	9.00	41.70
0.5 kg ha ⁻¹	15.60	9.90	43.30
1.0 kg ha ⁻¹	15.80	10.20	43.80
SEm±	0.13	0.07	0.36
CD (P = 0.05)	0.37	0.19	1.06
Phosphorus × Molybdenum			
CD (P = 0.05)	N.S.	N.S.	N.S.

3.4 Yield attributes

The data presented in Table 4 indicated that phosphorus and molybdenum application significantly improved the yield attributes of summer green gram, whereas their interaction effect remained non-significant. Among the phosphorus treatments, 125% RDP recorded the highest number of pods per plant (16.00), seeds per pod (10.30), and test weight (44.10 g), which was statistically at par with 100% RDP (15.90 pods plant⁻¹, 10.20 seeds pod⁻¹, and 44.00 g). The control treatment produced the lowest values (14.20 pods plant⁻¹, 8.70 seeds pod⁻¹, and 40.90 g). Similarly, application of 1.0 kg Mo ha⁻¹ resulted in the maximum number of pods per plant (15.80), seeds per pod (10.20), and test weight (43.80 g), followed by 0.5 kg Mo ha⁻¹ (15.60, 9.90, and 43.30 g, respectively). The untreated control (0 kg Mo ha⁻¹) recorded the minimum values (14.50 pods plant⁻¹, 9.00 seeds pod⁻¹, and 41.70 g). Thus, adequate phosphorus and molybdenum nutrition markedly enhanced the yield-contributing characters of summer green gram.

Table 5: Effect of phosphorus and molybdenum levels on yield parameters of summer green gram

Treatments	Seed yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
Phosphorus levels				
Control	759.6	1806.5	2566.1	29.61
75% RDP	892.7	2028.5	2921.2	29.89
100% RDP	1022.1	2199.3	3221.5	30.71
125% RDP	1032.9	2218.7	3251.6	32.10
SEm±	7.58	16.72	37.29	0.19
CD (P = 0.05)	21.07	46.46	103.59	0.54
Molybdenum levels				
0 kg ha ⁻¹	805.7	1886.6	2692.3	30.18
0.5 kg ha ⁻¹	953.5	2119.8	3073.2	30.70
1.0 kg ha ⁻¹	1021.3	2183.4	3204.7	30.85
SEm±	4.78	16.85	18.62	0.19
CD (P = 0.05)	13.27	46.82	51.73	NS
Phosphorus × Molybdenum				
CD (P = 0.05)	NS	NS	NS	NS

3.5. Yield

The data presented in Table 5 showed that phosphorus application significantly enhanced seed yield, stover yield, biological yield, and harvest index of summer green gram. The highest values were recorded with 125% RDP, which produced 1032.9 kg ha⁻¹ seed yield, 2218.7 kg ha⁻¹ stover yield, 3251.6 kg ha⁻¹ biological yield, and a 32.10% harvest index. However, seed, stover, and biological yields under 125% RDP were statistically comparable with 100% RDP (1022.1, 2199.3, and 3221.5 kg ha⁻¹, respectively). The control treatment recorded the lowest seed yield (759.6 kg ha⁻¹), stover yield (1806.5 kg ha⁻¹), biological yield (2566.1 kg ha⁻¹), and harvest index (29.61%). Molybdenum application also significantly increased seed, stover, and biological yields, with 1.0 kg ha⁻¹ recording the maximum values (1021.3, 2183.4, and 3204.7 kg ha⁻¹, respectively), followed by 0.5 kg ha⁻¹. The 0 kg ha⁻¹ treatment produced the lowest yields (805.7, 1886.6, and 2692.3 kg ha⁻¹, respectively). However, the harvest index was not significantly affected by molybdenum application, and the interaction between phosphorus and molybdenum was non-significant for all the yield parameters.

4. Discussion

4.1 Plant height (cm)

The improvement in plant height and number of branches with increasing phosphorus and molybdenum application may be attributed to their complementary roles in promoting plant growth and nutrient utilization. Adequate phosphorus enhanced root development, nodulation, biological nitrogen fixation, and energy transfer through ATP and ADP, thereby improving nutrient uptake and photosynthetic efficiency, which ultimately stimulated vegetative growth (Kumar and Yadav, 2018 and Sahu *et al.*, 2021)^[16, 17]. Likewise, molybdenum application at 1.0 kg ha⁻¹ enhanced plant growth by improving nitrogen metabolism, assimilate production, and their efficient translocation within the plant, resulting in greater plant height and branching. Similar findings were also reported by Alam *et al.* (2020)^[1].

4.2 Yield attributes

The improvement in yield attributes, including the number of nodules, nodule dry weight, pods per plant, seeds per pod, and test weight, was primarily associated with the balanced application of phosphorus and molybdenum. Higher phosphorus levels enhanced root growth, nodulation, photosynthetic efficiency, energy transfer, and biological nitrogen fixation, resulting in improved assimilate production and better partitioning towards reproductive organs (Hangsing *et al.*, 2019; Maish *et al.*, 2020; Sahu *et al.*, 2021)^[18, 19, 17]. Similar improvements in seed formation under adequate phosphorus nutrition were also reported by Kumar and Debbarma (2023)^[20]. Application of molybdenum at 1.0 kg ha⁻¹ further promoted nodulation, nitrogen metabolism, and nutrient utilization, leading to superior yield-contributing characters. These findings are in agreement with those of Jena *et al.* (2022)^[21], while the increase in test weight may be attributed to improved photosynthate translocation as reported by Singh *et al.* (2018)^[22] and Vaishnavi *et al.* (2023)^[23].

4.3 Yield

The significant improvement in seed yield, stover yield, biological yield, and harvest index with phosphorus and molybdenum application can be attributed to enhanced nutrient availability, efficient photosynthesis, and improved assimilate production and translocation. Adequate phosphorus promoted root development, nitrogen fixation, energy transfer, and reproductive growth, thereby increasing biomass accumulation

and seed production (Hangsing *et al.*, 2019; Maish *et al.*, 2020)^[18, 19]. Improved source-to-sink translocation under optimum phosphorus nutrition also contributed to higher yields, as reported by Kumar and Debbarma (2023)^[20] and Rathod *et al.* (2023)^[24]. Similarly, application of molybdenum at 1.0 kg ha⁻¹ enhanced nitrogen metabolism and nutrient utilization, resulting in greater biomass production and yield. These findings are consistent with the observations of Jena *et al.* (2022)^[21], who reported improved pulse productivity under adequate molybdenum nutrition.

5. Conclusion

In conclusion, it can be demonstrated that the application of phosphorus and molybdenum significantly improved the growth, nodulation, yield attributes, and yield of summer green gram. Although 125% RDP produced the higher values for most parameters, it remained statistically at par with 100% RDP. Application of molybdenum at 1.0 kg ha⁻¹ consistently enhanced crop performance. Therefore, 100% recommended phosphorus dose combined with 1.0 kg molybdenum ha⁻¹ may be considered an efficient and economically viable nutrient management practice for maximizing summer green gram productivity.

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