



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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www.agronomyjournals.com
2024; SP-7(12): 534-544
Received: 02-11-2024
Accepted: 14-12-2024

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Effect of phosphorus, molybdenum and *Rhizobium* on quality and nutrient uptake of greengram (*Vigna radiata* L.) in loamy sand

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DOI: <https://doi.org/10.33545/2618060X.2024.v7.i12Sh.2256>

Abstract

The field experiment titled, “Effect of phosphorus, molybdenum, and *Rhizobium* on quality and nutrient uptake of greengram (*Vigna radiata* L.) in loamy sand” was conducted at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, during the *kharif* seasons of 2019 and 2020, across different but adjacent similar sites. The soil of the experimental field was loamy sand in texture, with a normal pH and electrical conductivity (EC). The field was low in available nitrogen, medium in available phosphorus and potassium, and deficient in available molybdenum. The experiment involved eighteen treatment combinations based on the following factors: Phosphorus: Three levels (P_1 : 20 kg P_2O_5 ha⁻¹, P_2 : 40 kg P_2O_5 ha⁻¹, and P_3 : 60 kg P_2O_5 ha⁻¹), Molybdenum: Three levels (Mo_0 : 0.0 kg Mo ha⁻¹, Mo_1 : 0.5 kg Mo ha⁻¹, and Mo_2 : 1.0 kg Mo ha⁻¹) and *Rhizobium*: Two levels (R_0 : Without *Rhizobium* inoculation and R_1 : With *Rhizobium* inoculation). These treatments were evaluated using the GM 4 cultivar of greengram in a randomized block design (R.B.D.) under a factorial concept, with three replications.

The concentration of P in seed and stover increased significantly with P_2O_5 application, along with a marked uptake of N, P, K, and Mo. Molybdenum application (0.5 kg Mo ha⁻¹) significantly enhanced N and Mo concentrations, protein content, and nutrient uptake in greengram seed and stover compared to the control. Seed inoculation with *Rhizobium* further improved N and Mo content and uptake. Interaction effects of P × Mo and P × *Rhizobium* showed significant increases in N, P, K, and Mo uptake. The combination of 40 kg P_2O_5 ha⁻¹, 0.5 kg Mo ha⁻¹, and *Rhizobium* inoculation was most beneficial for greengram (GM 4) in light-textured soils of north Gujarat.

Keywords: Greengram, nutrient content and nutrient uptake

Introduction

Pulses play a vital role in Indian farming as main, catch, cover, green manure, and intercrops. They are a critical dietary component in India due to their high protein content (23.1%), nearly 2.5 times that of cereals, along with fats (0.5–4.33%), carbohydrates (23.4–66.3%), and vitamins like riboflavin, thiamine, and Vitamin C. Sprouted greengram seeds synthesize significant ascorbic acid (Vitamin C). Recognizing their importance, the UN declared 2016 as the “International Year of Pulses” to promote their nutritional benefits and role in sustainable food security.

Greengram (*Vigna radiata*), a key leguminous pulse crop, is widely grown in India, particularly in states like Odisha, Maharashtra, Andhra Pradesh, and Gujarat, across diverse agro-climatic conditions. India, the largest producer and consumer of pulses, dedicates 40.70 lakh ha to *kharif* greengram, producing 19.01 lakh tonnes annually (2018-19). In Gujarat, greengram thrives in districts like Kachchh, Banaskantha, and Panchmahal under erratic rainfall or irrigated summer conditions.

As a leguminous crop, greengram enriches soil by fixing ~40 kg N ha⁻¹ via atmospheric nitrogen fixation. Phosphorus, a critical nutrient, supports plant energy transfer (ATP synthesis) and metabolic regulation, while molybdenum (Mo) aids nitrate reductase and nitrogenase enzyme activity, essential for nitrogen fixation by *Rhizobium*. Mo deficiency impairs nodulation and leghaemoglobin synthesis, impacting nitrogen fixation.

Effective biological nitrogen fixation in pulses depends on factors like Rhizobium strains, soil conditions, phosphorus, and molybdenum content. Seed inoculation with suitable Rhizobium strains is a cost-effective input, particularly for the light-textured, organic matter-deficient soils of north Gujarat, where studies have shown positive responses in crops like greengram and chickpea.

Materials and Methods

Field experiments were conducted on Plot No. B-11 and B-8 during the *kharif* seasons of 2019 and 2020 using mungbean variety GM 4 at the Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Gujarat. The trials followed a Randomized Block Design (factorial concept) with three replications. Initial soil properties were analyzed using standard methods.

The study included 18 treatment combinations of phosphorus (P), molybdenum (Mo), and Rhizobium inoculation. A common nitrogen dose of 20 kg ha⁻¹ was applied, while P and Mo were supplied through DAP and sodium molybdate, respectively. FYM @ 5 t ha⁻¹ was incorporated, and Rhizobium-treated seeds (@ 25 g kg⁻¹ seed with talc-based inoculants) were prepared using a jaggery solution as a sticker. Seeds were air-dried for 30 minutes before sowing in 45 cm furrows.

In the case of nutrient content and uptake nodule samples were collected at 45 and 60 DAS, while grain and stover samples were collected at harvest during both years. Plant samples for nodulation study were air-dried, followed by oven drying at 70°C until constant weight, then ground and preserved for chemical analysis. Effective nodule samples were stored in polyethylene bags, while seed and stover samples were powdered and stored in polyethylene-lined cloth bags. Fresh leaf samples at 45 DAS were used for chlorophyll estimation.

Chemical Analysis of P and K Estimation: Plant samples were wet-digested using a di-acid mixture (HNO₃:HClO₄ = 3:1) as per Johnson and Ulrich, N Estimation: Samples were digested with

H₂SO₄ and H₂O₂ and diluted to 100 mL for analysis and Mo Estimation: Plant material was ashed in a muffle furnace at 450°C, dissolved in HCl (1+1), evaporated, and redissolved in 2N HCl. The solution was filtered and diluted to 100 mL for analysis.

The filter paper contents were washed with hot double-distilled water until acid-free, and the final volume was made with double-distilled water. This acid extract was used for molybdenum (Mo) estimation.

Nutrient concentrations in plants were expressed as percentages for macronutrients and in mg kg⁻¹ for micronutrients (on a dry weight basis). Nutrient uptake was calculated using the following formulas:

$$\text{Macro Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Micro Nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient content (mg kg}^{-1}\text{)} \times \text{Yield (kg ha}^{-1}\text{)}}{1000}$$

Note:- Harvesting was done when pods turned brown, with net plots sun-dried for seven days. Biomass, seed yield, and stover yield were recorded, with stover yield calculated by subtracting seed yield from total biomass. Data on yield parameters were statistically analyzed using the F-test at a 5% significance level, and S.E.m. and C.V. values were calculated.

Results and Discussion

1. Nutrient content

1.1 Nitrogen content

(a) Effect of phosphorus

Data in Table 1 indicate that phosphorus levels did not significantly affect N content in seed or stover across 2019, 2020, or pooled results. However, the highest N content in seed (3.47%, 3.52%, and 3.49%) and stover (0.83%, 0.78%, and 0.80%) was observed with the application of 60 kg P₂O₅ ha⁻¹ in 2019, 2020, and pooled data, respectively.

Table 1: Effect of phosphorus, molybdenum and Rhizobium on nitrogen content of greengram seed and stover

Treatments	Nitrogen content					
	Seed (%)			Stover (%)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	3.35	3.40	3.38	0.80	0.73	0.77
P ₂ : 40	3.45	3.49	3.47	0.82	0.76	0.79
P ₃ : 60	3.47	3.52	3.49	0.83	0.78	0.80
S.E.m.±	0.07	0.08	0.05	0.01	0.02	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	3.23	3.28	3.25	0.77	0.72	0.75
Mo ₁ : 0.5	3.47	3.55	3.51	0.83	0.76	0.79
Mo ₂ : 1.0	3.57	3.58	3.57	0.85	0.79	0.82
S.E.m.±	0.07	0.08	0.05	0.01	0.02	0.01
C.D. (P = 0.05)	0.20	0.23	0.15	0.04	0.05	0.03
Rhizobium						
R ₀ : Without Rhizobium	3.34	3.37	3.36	0.79	0.73	0.76
R ₁ : With Rhizobium	3.51	3.56	3.53	0.84	0.78	0.81
S.E.m.±	0.06	0.07	0.04	0.01	0.01	0.01
C.D. (P = 0.05)	0.16	0.19	0.12	0.04	0.04	0.03
Interaction						
P × Mo	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	8.65	9.85	9.28	7.77	9.57	8.65

(b) Effect of molybdenum

Application of molybdenum (Mo) progressively increased nitrogen content in greengram seed and stover, with significant improvement observed up to 0.5 kg Mo ha⁻¹ compared to the control, though it was statistically at par with 1.0 kg Mo ha⁻¹. On a pooled basis, 1.0 kg Mo ha⁻¹ resulted in 9.84% and 8.0% higher N content in seed, and 9.33% and 5.33% higher in stover, compared to the control and 0.5 kg Mo ha⁻¹, respectively. This increase is attributed to molybdenum's role in nitrogenase enzyme activity, enhancing biological nitrogen fixation (BNF). Similar findings were reported by Dwivedi *et al.* (1996)^[4] and

Bareth (1998)^[1].

(c) Effect of Rhizobium

Data in Table 1 show that seed inoculation with Rhizobium significantly increased N content in mungbean seed (3.51%, 3.56%, and 3.53%) and stover (0.84%, 0.78%, and 0.81%) during 2019, 2020, and pooled data, respectively. This increase is attributed to enhanced biological nitrogen fixation in plant roots facilitated by Rhizobium. Similar results were reported by Chatterjee and Bhattacharjee (2002) and Meena *et al.* (2015)^[6].

Table 2: Effect of phosphorus, molybdenum and Rhizobium on phosphorus content of greengram seed and stover

Treatments	Phosphorus content					
	Seed (%)			Stover (%)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	0.43	0.34	0.39	0.19	0.19	0.19
P ₂ : 40	0.48	0.39	0.43	0.23	0.20	0.21
P ₃ : 60	0.50	0.41	0.45	0.26	0.24	0.25
S.E.m.±	0.007	0.008	0.005	0.004	0.003	0.003
C.D. (P = 0.05)	0.021	0.023	0.015	0.013	0.010	0.008
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	0.46	0.38	0.42	0.22	0.20	0.21
Mo ₁ : 0.5	0.47	0.38	0.43	0.22	0.21	0.22
Mo ₂ : 1.0	0.48	0.39	0.43	0.23	0.22	0.22
S.E.m.±	0.007	0.008	0.005	0.004	0.003	0.003
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Rhizobium						
R ₀ : Without Rhizobium	0.46	0.38	0.42	0.22	0.21	0.22
R ₁ : With Rhizobium	0.47	0.39	0.43	0.23	0.21	0.22
S.E.m.±	0.006	0.007	0.004	0.004	0.003	0.002
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction						
P × Mo	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	6.50	8.90	7.59	8.42	6.98	7.78

1.2 Phosphorus content**(a) Effect of phosphorus**

Data in Table 2 reveal that phosphorus content in greengram seed and stover increased significantly with phosphorus application up to 40 kg P₂O₅ ha⁻¹. The highest P content was observed at 60 kg P₂O₅ ha⁻¹, with 0.50%, 0.41%, and 0.45% in seed, and 0.26%, 0.24%, and 0.25% in stover during 2019, 2020, and pooled data, respectively. This increase is attributed to improved soil P availability and enhanced root growth, facilitating greater P uptake. Similar results were reported by

Roy and Tripathi (1985)^[10], Patel (1989)^[7], Singh and Singh (2017)^[11], and Dharwe *et al.* (2019)^[3].

(b) Effect of molybdenum

Data in Table 2 indicate that P content in greengram seed and stover was not significantly affected by different levels of molybdenum. The highest P content in seed (0.48%, 0.39%, and 0.43%) and stover (0.23%, 0.22%, and 0.22%) was recorded with 1.0 kg Mo ha⁻¹ during 2019, 2020, and pooled data, respectively.

Table 3: Effect of phosphorus, molybdenum and Rhizobium on potassium content of greengram seed and stover

Treatments	Potassium content					
	Seed (%)			Stover (%)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	0.73	0.67	0.70	1.08	1.12	1.10
P ₂ : 40	0.74	0.69	0.71	1.11	1.13	1.12
P ₃ : 60	0.75	0.72	0.73	1.12	1.15	1.13
S.E.m.±	0.01	0.01	0.01	0.02	0.02	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	0.72	0.67	0.71	1.09	1.11	1.12
Mo ₁ : 0.5	0.75	0.70	0.72	1.11	1.14	1.13
Mo ₂ : 1.0	0.76	0.71	0.73	1.13	1.15	1.14

S.E.m.±	0.01	0.01	0.01	0.02	0.02	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Rhizobium						
R ₀ : Without <i>Rhizobium</i>	0.71	0.69	0.71	1.10	1.14	1.12
R ₁ : With <i>Rhizobium</i>	0.73	0.70	0.72	1.11	1.15	1.13
S.E.m.±	0.01	0.01	0.00	0.02	0.01	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction						
P × Mo	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	4.55	5.25	4.89	8.19	6.25	7.26

(c) Effect of *Rhizobium*

Data in Table 2 reveal that P content in greengram seed and stover was not significantly affected by seed inoculation with *Rhizobium*. The highest P content in seed (0.47%, 0.39%, and 0.43%) and stover (0.23%, 0.21%, and 0.22%) was recorded with *Rhizobium* inoculation during 2019, 2020, and pooled data, respectively.

1.3 Potassium content

(a) Effect of phosphorus

Data in Table 3 show that different levels of phosphorus did not significantly affect K content in seed and stover. However, the highest K content in seed (0.75%, 0.72%, and 0.73%) and stover (1.12%, 1.15%, and 1.13%) was recorded with 60 kg P₂O₅ ha⁻¹ during 2019, 2020, and pooled data, respectively.

(b) Effect of Molybdenum

Data in Table 3 show that different levels of molybdenum did not significantly affect K content in seed and stover. However, the highest K content was observed with 1.0 kg Mo ha⁻¹, with 0.76%, 0.71%, and 0.73% in seed and 1.13%, 1.15%, and 1.14% in stover during 2019, 2020, and pooled data, respectively.

(c) Effect of *Rhizobium*

The data in Table 3 indicate that K content in seed and stover was not significantly affected by seed inoculation with *Rhizobium*. The highest K content in seed (0.73%, 0.70%, and 0.72%) and stover (1.11%, 1.15%, and 1.13%) was recorded with *Rhizobium* inoculation during 2019, 2020, and pooled data, respectively.

1.4 Molybdenum Content

(a) Effect of Phosphorus

Table 4 shows that different phosphorus levels did not significantly affect Mo content in seed and stover, but the highest Mo content in seed (1.95%, 1.76%, and 1.84%) and stover (1.36%, 1.22%, and 1.29%) was observed with 60 kg P₂O₅ ha⁻¹ in pooled data, compared to 20 kg P₂O₅ ha⁻¹, but remained at par with 40 kg P₂O₅ ha⁻¹. The increase in Mo content could be attributed to the formation of phosphomolybdate anions, which are more readily absorbed by plants. Similar findings were reported by Reddy (1981) [9].

(b) Effect of Molybdenum

Data from Table 4 show that Mo content in seed and stover increased significantly with increasing levels of molybdenum up to 1.0 kg Mo ha⁻¹ during 2020 and pooled data. In 2019, the significant increase was noted only up to 0.5 kg Mo ha⁻¹. The highest Mo content in seed (1.98%, 1.80%, and 1.91%) and stover (1.39%, 1.26%, and 1.32%) was recorded with 1.0 kg Mo ha⁻¹. The increase is attributed to improved Mo availability in the soil, which was low in available Mo. Similar results were reported by Naphade and Wankhade (1987), Sharma (1998) [5], and Bareth (1998) [1].

(c) Effect of *Rhizobium*

Data in Table 4 show that Mo content in seed and stover did not significantly change due to seed inoculation with *Rhizobium*. The highest Mo content in seed (1.93%, 1.74%, and 1.84%) and stover (1.36%, 1.20%, and 1.28%) was recorded with *Rhizobium* inoculation during 2019, 2020, and pooled data, respectively.

Table 4: Effect of phosphorus, molybdenum and *Rhizobium* on molybdenum content of greengram seed and stover

Treatments	Molybdenum content					
	Seed (mg kg ⁻¹)			Stover (mg kg ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	1.87	1.69	1.78	1.34	1.16	1.25
P ₂ : 40	1.92	1.72	1.81	1.35	1.19	1.27
P ₃ : 60	1.95	1.76	1.84	1.36	1.22	1.29
S.E.m.±	0.03	0.02	0.02	0.02	0.02	0.01
C.D. (P = 0.05)	NS	NS	0.05	NS	NS	NS
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	1.80	1.62	1.71	1.25	1.08	1.16
Mo ₁ : 0.5	1.92	1.71	1.82	1.35	1.17	1.26
Mo ₂ : 1.0	1.98	1.80	1.91	1.39	1.26	1.32
S.E.m.±	0.03	0.02	0.02	0.02	0.02	0.01
C.D. (P = 0.05)	0.09	0.06	0.05	0.05	0.05	0.04
<i>Rhizobium</i>						
R ₀ : Without <i>Rhizobium</i>	1.89	1.70	1.80	1.35	1.18	1.26
R ₁ : With <i>Rhizobium</i>	1.93	1.74	1.84	1.36	1.20	1.28

S.E.m.±	0.03	0.02	0.02	0.01	0.02	0.01
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction						
P × Mo	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	6.95	5.49	6.34	5.56	6.74	6.12

2. Uptake of nutrients (N, P, K and Mo)

2.1 Nitrogen uptake (kg ha⁻¹)

(a) Effect of Phosphorus

Data in Table 5 show that N uptake by greengram seed and stover was significantly higher with the application of 40 kg P₂O₅ ha⁻¹ compared to 20 kg P₂O₅ ha⁻¹, but was at par with 60 kg P₂O₅ ha⁻¹ in both years and pooled data. The highest N uptake was recorded with 60 kg P₂O₅ ha⁻¹. The increased N uptake can be attributed to the improvement in seed and stover yields and nutrient contents due to phosphorus application. On pooled basis, the N uptake increased by 26.02% and 19.20% in seed, and 28.87% and 23.41% in stover with 60 kg and 40 kg P₂O₅ ha⁻¹ over control, respectively. Similar findings were reported by Singh *et al.* (1978), Raju *et al.* (1991)^[8] and Vidhyashree *et al.*

(2018)^[12].

(b) Effect of Molybdenum

Data in Table 5 indicate that nitrogen content in seed and stover was significantly higher with the application of 0.5 kg Mo ha⁻¹ compared to control, but was at par with 1.0 kg Mo ha⁻¹. On a pooled basis, the increase was 21.94% and 14.65% in seed, and 27.85% and 19.68% in stover for 1.0 and 0.5 kg Mo ha⁻¹, respectively, over the control. This increase in N uptake can be attributed to Mo's role in biological nitrogen fixation (BNF), along with improvements in greengram yields and nutrient content. Similar findings were reported by Dwivedi *et al.* (1996)^[4], Dadhich (1997), Bareth (1998)^[1], and Laltanmawia *et al.* (2004)^[5]

Table 5: Effect of phosphorus, molybdenum and Rhizobium on nitrogen uptake by greengram seed and stover

Treatments	N uptake					
	Seed (kg ha ⁻¹)			Stover (kg ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	27.44	25.37	26.40	11.82	10.15	10.98
P ₂ : 40	33.38	30.19	31.78	14.34	12.76	13.55
P ₃ : 60	34.41	32.12	33.27	15.10	13.21	14.15
S.E.m.±	1.11	0.90	0.71	0.39	0.37	0.27
C.D. (P = 0.05)	3.19	2.58	2.01	1.12	1.07	0.76
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	28.16	26.16	27.16	11.78	10.49	11.13
Mo ₁ : 0.5	32.34	30.00	31.17	14.34	12.30	13.32
Mo ₂ : 1.0	34.73	31.51	33.12	15.13	13.33	14.23
S.E.m.±	1.11	0.90	0.71	0.39	0.37	0.27
C.D. (P = 0.05)	3.19	2.58	2.01	1.12	1.07	0.76
Rhizobium						
R ₀ : Without Rhizobium	29.95	27.52	28.74	12.75	11.27	12.01
R ₁ : With Rhizobium	33.53	30.92	32.23	14.75	12.81	13.78
S.E.m.±	0.91	0.73	0.58	0.32	0.31	0.22
C.D. (P = 0.05)	2.60	2.11	1.64	0.92	0.88	0.62
Interaction						
P × Mo	NS	NS	3.49	NS	1.86	1.32
P × R	NS	NS	2.85	1.59	NS	1.08
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	14.83	13.02	14.04	12.05	13.17	12.58

(c) Effect of Rhizobium

The data in Table 5 show that seed inoculation with Rhizobium significantly increased N uptake in both seed and stover. On a pooled basis, Rhizobium inoculation led to a 12.14% and 14.74% increase in N uptake by seed and stover, respectively, compared to the uninoculated control. This increase is likely due to the combined effects of higher N content in plant parts and improved greengram yields. Similar results were reported by Singh *et al.* (1978), Vanparia (1991), and Meena *et al.* (2015)^[6].

Interaction Effect of P × Mo in Seed

As per the data in Table 6, the interaction between phosphorus and molybdenum significantly affected N uptake in greengram

seed only in the pooled data. The highest N uptake was observed with the combined application of 40 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹, which was at par with 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ and 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹.

Interaction Effect of P × R in Seed: Data presented in Table 7 reveal that the combination of phosphorus and Rhizobium significantly affected N uptake by greengram seed only in the pooled data. The highest N uptake in seed was recorded with seed inoculation with Rhizobium combined with the application of 40 kg P₂O₅ ha⁻¹. However, this was found to be at par with the combined application of 60 kg P₂O₅ ha⁻¹ and seed inoculation with Rhizobium on a pooled basis.

Table 6: Effect of P × Mo interaction on nitrogen uptake (kg ha⁻¹) by greengram seed on pooled

Phosphorus	Molybdenum		
	Mo ₀	Mo ₁	Mo ₂
P ₁	25.16	26.06	27.99
P ₂	25.41	33.10	36.84
P ₃	30.92	34.34	34.54
S.Em ±	1.24		
C.D. (0.05)	3.49		
C.V. (%)	14.04		

Table 7: Effect of P × R on nitrogen uptake (kg ha⁻¹) by greengram seed on pooled

Rhizobium	Phosphorus		
	P ₁	P ₂	P ₃
R ₀	25.55	28.54	32.12
R ₁	27.25	35.02	34.42
S.Em ±	1.01		
C.D. (0.05)	2.85		
C.V. (%)	14.04		

Interaction Effect of P × Mo in Stover

Data presented in Table 8 reveal that the combination of phosphorus and molybdenum significantly affected N uptake by greengram stover during 2020 and in the pooled data. The highest N uptake in greengram stover was recorded with the combined application of 40 kg P₂O₅ ha⁻¹ and 1.0 kg Mo ha⁻¹. However, this was found to be at par with the following combinations:

- 40 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹
- 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹
- 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹

Table 8: Effect of P × Mo interaction on nitrogen uptake (kg ha⁻¹) by greengram

Phosphorus	Molybdenum					
	Seed			Stover		
	2020			Pooled		
	Mo ₀	Mo ₁	Mo ₂	Mo ₀	Mo ₁	Mo ₂
P ₁	9.49	9.76	11.20	10.22	10.63	12.09
P ₂	9.35	14.06	14.87	10.38	14.57	15.70
P ₃	12.63	13.08	13.91	12.80	14.76	14.90
S.Em ±	0.65			0.47		
C.D. (0.05)	1.86			1.32		
C.V. (%)	13.17			12.58		

Interaction Effect of P × R in Stover

Data presented in Table 9 reveal that the combination of phosphorus and Rhizobium significantly affected N uptake by greengram stover during 2019 and in the pooled data. The highest N uptake in greengram stover was recorded with seed inoculation with Rhizobium along with the application of 40 kg P₂O₅ ha⁻¹. This was found to be at par with the combined application of 60 kg P₂O₅ ha⁻¹ and seed inoculation with Rhizobium.

2.2 Phosphorus uptake (kg ha⁻¹)**(a) Effect of Phosphorus**

The data presented in Table 10 show that phosphorus uptake by

greengram seed and stover increased significantly with increasing levels of phosphorus up to the application of 60 kg P₂O₅ ha⁻¹, except during 2019 for seed, where significant improvement was noted only up to 40 kg P₂O₅ ha⁻¹. The significant increases in phosphorus uptake under the application of 60 kg P₂O₅ ha⁻¹ were 38.41% and 6.52% in 2019, and 46.90% and 12.80% in 2020 for seed, and 59.28% and 19.79% in 2019, and 59.61% and 25.0% in 2020 for stover, compared to the 20 and 40 kg P₂O₅ ha⁻¹ treatments, respectively. The increased phosphorus uptake by greengram seed and stover can be attributed to improved dry matter yield in the P-treated plots, which contributed to the enhanced phosphorus uptake by different plant components. Similar findings were also reported by Singh *et al.* (1978), Raju *et al.* (1991)^[8], and Vidhyashree *et al.* (2018)^[12].

Table 9: Effect of P × R on nitrogen uptake (kg ha⁻¹) by greengram stover

Rhizobium	Phosphorus					
	2019			Pooled		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
R ₀	11.60	12.42	14.23	10.59	11.97	13.47
R ₁	12.03	16.26	15.96	11.37	15.13	14.84
S.Em ±	0.55			0.38		
C.D. (0.05)	1.59			1.08		
C.V. (%)	12.05			12.58		

(b) Effect of Molybdenum

The data in Table 10 indicate that significantly higher phosphorus uptake by greengram seed and stover was noted with the application of molybdenum in both individual years and pooled results. The treatment of 0.5 kg Mo ha⁻¹ resulted in significantly higher phosphorus uptake compared to the control, though it remained at par with the 1.0 kg Mo ha⁻¹ treatment. In pooled results, the increase in phosphorus uptake was 15.71% and 9.14% in seed, and 21.56% and 14.68% in stover with the application of 1.0 and 0.5 kg Mo ha⁻¹ over control, respectively. The considerable increase in phosphorus uptake by seed and stover could be due to the involvement of molybdenum in biological nitrogen fixation (BNF) and the improvement in greengram yields. Similar findings were also reported by Dwivedi *et al.* (1996)^[4], Dadhich (1997), Bareth (1998)^[11], and Laltanmawia *et al.* (2004)^[5].

(c) Effect of Rhizobium

The data presented in Table 10 reveal that phosphorus uptake by greengram seed and stover increased significantly under the influence of seed inoculation with Rhizobium during both individual years and in pooled results. The corresponding values of phosphorus uptake by greengram seed were 4.53, 3.39, and 3.96 kg ha⁻¹, and 4.02, 3.49, and 3.75 kg ha⁻¹ in stover during 2019, 2020, and in pooled, respectively. The considerable increase in phosphorus uptake by seed and stover with Rhizobium inoculation over uninoculated control may be attributed to the combined effect of increased phosphorus content in various plant parts and the increased greengram yields. Similar findings were reported by Singh *et al.* (1978), Vanparia (1991), and Meena *et al.* (2015)^[6].

Table 10: Effect of phosphorus, molybdenum and Rhizobium on phosphorus uptake by greengram seed and stover

Treatments	P uptake					
	Seed (kg ha ⁻¹)			Stover (kg ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	3.54	2.58	3.06	2.80	2.60	2.70
P ₂ : 40	4.60	3.36	3.98	3.94	3.32	3.63
P ₃ : 60	4.90	3.79	4.34	4.72	4.15	4.44
S.Em.±	0.12	0.12	0.08	0.12	0.09	0.07
C.D. (P = 0.05)	0.35	0.33	0.24	0.34	0.25	0.21
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	3.98	3.03	3.50	3.44	2.97	3.20
Mo ₁ : 0.5	4.39	3.26	3.82	3.91	3.43	3.67
Mo ₂ : 1.0	4.67	3.44	4.05	4.12	3.67	3.89
S.Em.±	0.12	0.12	0.08	0.12	0.09	0.07
C.D. (P = 0.05)	0.35	NS	0.24	0.34	0.25	0.21
Rhizobium						
R ₀ : Without Rhizobium	4.17	3.09	3.63	3.63	3.22	3.42
R ₁ : With Rhizobium	4.53	3.39	3.96	4.02	3.49	3.75
S.Em.±	0.10	0.09	0.07	0.10	0.07	0.06
C.D. (P = 0.05)	0.28	0.27	0.19	0.28	NS	0.17
Interaction						
P × Mo	0.60	NS	0.41	NS	NS	0.36
P × R	0.49	NS	0.33	NS	NS	0.29
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	11.72	15.16	13.19	13.25	10.85	12.29

Interaction Effect of P × Mo in Seed

The data presented in Table 11 reveal that the combination of phosphorus and molybdenum significantly affected phosphorus uptake by greengram seed in 2019 and in pooled results. Significantly the highest phosphorus uptake by greengram seed was recorded with the combined application of 40 kg P₂O₅ ha⁻¹ along with 1.0 kg Mo ha⁻¹. However, it was found at par with the combined application of 60 kg P₂O₅ ha⁻¹ + 0.0 kg Mo ha⁻¹, 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹, and 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹.

Interaction Effect of P × R in Seed

The data presented in Table 12 reveal that the combination of phosphorus and Rhizobium significantly affected phosphorus uptake by greengram seed in 2019 and in pooled results. Significantly the highest phosphorus uptake by greengram seed was recorded under seed inoculation with Rhizobium along with

the application of 60 kg P₂O₅ ha⁻¹. However, it was found at par with the combined application of 60 kg P₂O₅ ha⁻¹ without seed inoculation with Rhizobium and 40 kg P₂O₅ ha⁻¹ with seed inoculation with Rhizobium in 2019 and in pooled results.

Table 11: Effect of P × Mo on phosphorus uptake (kg ha⁻¹) by greengram seed

Phosphorus	Molybdenum					
	2019			Pooled		
	Mo ₀	Mo ₁	Mo ₂	Mo ₀	Mo ₁	Mo ₂
P ₁	3.41	3.46	3.75	2.99	2.97	3.22
P ₂	3.76	4.68	5.35	3.27	4.09	4.58
P ₃	4.76	5.02	4.91	4.26	4.41	4.36
S.Em ±	0.21			0.14		
C.D. (0.05)	0.60			0.41		
C.V. (%)	11.72			13.19		

Table 12: Effect of P × R on phosphorus uptake (kg ha⁻¹) by greengram seed

Rhizobium	Phosphorus					
	2019			Pooled		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
R ₀	3.61	4.18	4.70	3.04	3.63	4.22
R ₁	3.46	5.02	5.10	3.08	4.33	4.47
S.Em ±	0.17			0.12		
C.D. (0.05)	0.49			0.33		
C.V. (%)	11.72			13.19		

Interaction Effect of P × Mo in Stover

The data presented in Table 13 reveal that the combination of phosphorus and molybdenum significantly affected phosphorus uptake by greengram stover in pooled results only. Significantly the highest phosphorus uptake by greengram stover was recorded under the combined application of 60 kg P₂O₅ ha⁻¹ along with 1.0 kg Mo ha⁻¹. However, it was found at par with the combined application of 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ in pooled results.

Table 13 : Effect of P × Mo on phosphorus uptake (kg ha⁻¹) by greengram stover on pooled

Phosphorus	Molybdenum		
	Mo ₀	Mo ₁	Mo ₂
P ₁	2.58	2.66	2.85
P ₂	3.01	3.84	4.03
P ₃	4.01	4.50	4.80
S.Em ±	0.13		
C.D. (0.05)	0.36		
C.V. (%)	12.29		

Interaction Effect of P × R in Stover

The data presented in Table 14 reveal that the combination of phosphorus and Rhizobium significantly affected phosphorus uptake by greengram stover in pooled results only. Significantly the highest phosphorus uptake by greengram stover was recorded under seed inoculation with Rhizobium along with the application of 60 kg P₂O₅ ha⁻¹. However, it was found at par with the combined application of 60 kg P₂O₅ ha⁻¹ + without Rhizobium seed inoculation in the pooled results.

2.3 Potassium uptake (kg ha⁻¹)

(a) Effect of phosphorus

It is evident from the data presented in Table 15 that significantly higher potassium (K) uptake by greengram seed and stover was noted under the treatment of 40 kg P₂O₅ ha⁻¹ application over the control during 2020, and in pooled results, K uptake by seed increased significantly with increasing rates of phosphorus up to 60 kg P₂O₅ ha⁻¹ compared to the lower levels. The considerably higher potassium uptake by greengram seed and stover can be attributed to the improvement in dry matter yield of various plant parts under phosphorus-treated plots, which likely contributed to the remarkable increase in the uptake of K by different components of the greengram plant, coupled with higher yields. Similar findings were also reported by Singh *et al.* (1978), Raju *et al.* (1991)^[8], and Vidhyashree *et al.* (2018)^[12].

(b) Effect of molybdenum

It is explicit from the data presented in Table 15 that significantly higher potassium (K) uptake by greengram seed and stover was noted under the application of 0.5 kg Mo ha⁻¹, both in seed and stover, during both individual years as well as in pooled results. This was compared to the control, and it remained at par with the application of 1.0 kg Mo ha⁻¹, except in pooled results for seed, where K uptake increased significantly with increasing rates of molybdenum up to 1.0 kg Mo ha⁻¹. The magnitude of the increase in pooled results was 15.69% and 8.53% in seed, and 19.31% and 14.39% in stover, with 1.0 and 0.5 kg Mo ha⁻¹ application over the control, respectively. The considerable increase in K uptake by seed and stover can be attributed to the involvement of molybdenum in biological nitrogen fixation (BNF), which improved the yields and K content in greengram. Similar findings were reported by Dwivedi *et al.* (1996)^[4], Dadhich (1997), Bareth (1998)^[1], and Laltanmawia *et al.* (2004)^[5].

Table 14 : Effect of P × R interaction on phosphorus uptake (kg ha⁻¹) by greengram stover on pooled

Rhizobium	Phosphorus		
	P ₁	P ₂	P ₃
R ₀	2.67	3.29	4.31
R ₁	2.72	3.97	4.56
S.E.m ±	0.10		
C.D. (0.05)	0.29		
C.V. (%)	12.29		

Table 15: Effect of phosphorus, molybdenum and Rhizobium on potassium uptake by greengram seed and stover

Treatments	K uptake					
	Seed (kg ha ⁻¹)			Stover (kg ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	5.99	5.12	5.56	16.21	15.46	15.83
P ₂ : 40	7.09	5.96	6.52	19.38	19.08	19.23
P ₃ : 60	7.40	6.44	6.92	20.18	19.55	19.86
S.E.m.±	0.17	0.14	0.11	0.57	0.43	0.36
C.D. (P = 0.05)	0.48	0.41	0.31	1.64	1.23	1.01
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	6.24	5.49	5.86	16.64	16.29	16.46
Mo ₁ : 0.5	6.90	5.83	6.36	19.14	18.51	18.83
Mo ₂ : 1.0	7.35	6.20	6.78	19.99	19.29	19.64
S.E.m.±	0.17	0.14	0.11	0.57	0.43	0.36
C.D. (P = 0.05)	0.48	0.41	0.31	1.64	1.23	1.01
Rhizobium						
R ₀ : Without Rhizobium	6.59	5.64	6.12	17.78	17.45	17.61
R ₁ : With Rhizobium	7.06	6.04	6.55	19.40	18.61	19.01
S.E.m.±	0.14	0.12	0.09	0.47	0.35	0.29
C.D. (P = 0.05)	0.40	NS	0.25	1.34	NS	0.82
Interaction						
P × Mo	NS	0.71	0.54	NS	NS	1.75
P × R	0.69	NS	0.44	NS	NS	1.42
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	10.48	10.33	10.45	13.04	10.08	11.70

(c) Effect of Rhizobium

The data presented in Table 15 revealed that K uptake by greengram seed and stover increased significantly under the influence of seed inoculation with Rhizobium during both individual years as well as in pooled results. The corresponding values of K uptake under seed inoculation with Rhizobium were 7.06, 6.04, and 6.51 kg ha⁻¹ for seed, and 19.40, 18.61, and 19.01 kg ha⁻¹ for stover during 2019, 2020, and in pooled,

respectively. The considerable increase in K uptake by seed and stover with Rhizobium inoculation over uninoculated control might be due to the combined effect of increased K content in various plant parts coupled with increased greengram yields. Similar findings were also reported by Singh *et al.* (1978), Vanparia (1991), and Meena *et al.* (2015)^[6].

Interaction effect of P × Mo in seed

Data presented in Table 16 revealed that the combination of phosphorus and molybdenum on K uptake by greengram seed was found to be significant during 2020 and in pooled results.

Table 16: Effect of P × Mo interaction on potassium uptake (kg ha⁻¹) by greengram seed

Phosphorus	Molybdenum					
	2020			Pooled		
	Mo ₀	Mo ₁	Mo ₂	Mo ₀	Mo ₁	Mo ₂
P ₁	5.07	4.84	5.46	5.44	5.37	5.86
P ₂	4.96	6.19	6.73	5.43	6.78	7.35
P ₃	6.45	6.47	6.40	6.72	6.94	7.11
S.Em ±	0.25			0.19		
C.D. (0.05)	0.71			0.54		
C.V. (%)	10.33			10.45		

The data presented in Table 16 indicated that significantly the highest K uptake by greengram seed was recorded with the combined application of 40 kg P₂O₅ ha⁻¹ along with 1.0 kg Mo ha⁻¹. However, it was found to be at par with the combined application of 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ and 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹ in both 2020 and pooled results. Additionally, the treatment combination of 40 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ and 60 kg P₂O₅ ha⁻¹ + 0.0 kg Mo ha⁻¹ were also found at par in 2020 only.

Interaction effect of P × R in seed

The data presented in Table 17 revealed that the combination of phosphorus and Rhizobium on K uptake by greengram seed was found to be significant in 2019 and in pooled results. Significantly, the highest K uptake by greengram seed was recorded under seed inoculation with Rhizobium along with the application of 60 kg P₂O₅ ha⁻¹. However, it was found to be at par with the combined application of 60 kg P₂O₅ ha⁻¹ + without seed inoculation with Rhizobium, as well as with the combination of 40 kg P₂O₅ ha⁻¹ + seed inoculation with Rhizobium in both 2019 and pooled results.

Table 17: Effect of P × R interaction on potassium uptake (kg ha⁻¹) by greengram seed

Rhizobium	Phosphorus					
	2019			Pooled		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
R ₀	6.12	6.58	7.08	5.51	6.07	6.77
R ₁	5.87	7.59	7.73	5.60	6.98	7.07
S.Em ±	0.24			0.16		
C.D. (0.05)	0.69			0.44		
C.V. (%)	10.48			10.45		

Interaction effect of P × Mo in stover

Data presented in table 18 revealed that combination of phosphorus and molybdenum on K uptake by greengram stover was found to be significant in pooled only. Significantly the highest K uptakes by greengram stover were recorded with combined application of 40 kg P₂O₅ ha⁻¹ along with 1.0 kg Mo ha⁻¹. However, it was found at par with combined application of 40 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹, 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ and 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹.

Interaction effect of P × R in stover

The data presented in Table 19 revealed that the combination of

phosphorus and Rhizobium on K uptake by greengram stover was found to be significant only in the pooled results. Significantly, the highest K uptake by greengram stover was recorded under seed inoculation with Rhizobium along with the application of 40 kg P₂O₅ ha⁻¹. However, it was found to be at par with the combined application of 60 kg P₂O₅ ha⁻¹ + without seed inoculation with Rhizobium, as well as with the combination of 60 kg P₂O₅ ha⁻¹ + seed inoculation with Rhizobium in the pooled results.

Table 18: Effect of P × Mo interaction on potassium uptake (kg ha⁻¹) by greengram stover on pooled

Phosphorus	Molybdenum		
	Mo ₀	Mo ₁	Mo ₂
P ₁	15.07	15.48	16.95
P ₂	16.00	20.52	21.17
P ₃	18.32	20.47	20.79
S.Em ±	0.62		
C.D. (0.05)	1.75		
C.V. (%)	11.70		

Table 19: Effect of P × R on potassium uptake (kg ha⁻¹) by greengram stover on pooled

Rhizobium	Phosphorus		
	P ₁	P ₂	P ₃
R ₀	15.68	17.52	19.64
R ₁	15.99	20.94	20.09
S.Em ±	0.50		
C.D. (0.05)	1.42		
C.V. (%)	11.7		

2.4 Molybdenum uptake (g ha⁻¹)

(a) Effect of Phosphorus

It is evident from the data presented in Table 20 that significantly higher molybdenum (Mo) uptake by greengram seed during 2019 and by stover during both 2019 and 2020 were noted under the treatment of 40 kg P₂O₅ ha⁻¹ compared to 20 kg P₂O₅ ha⁻¹. However, in 2020 and in the pooled results, the Mo uptake in both seed and stover increased significantly with the increasing rate of phosphorus up to 60 kg P₂O₅ ha⁻¹. The considerable Mo uptake by greengram seed and stover might be due to the improvement in dry matter yield of various plant parts under phosphorus-treated plots, which likely contributed to the remarkable increase in the uptake of Mo by different components of the greengram plant. Similar findings were also reported by Singh *et al.* (1978), Raju *et al.* (1991) [8], and Vidhyashree *et al.* (2018) [12].

(b) Effect of Molybdenum

It is explicit from the data presented in Table 20 that Mo uptake by greengram seed and stover during both individual years as well as in the pooled results increased significantly with increasing rates of Mo up to 1.0 kg Mo ha⁻¹ compared to the other levels. The considerable increase in the uptake of Mo by seed and stover could be attributed to the higher uptake of molybdenum by the crop under the application of various levels of molybdenum, which improved the yields and Mo content in greengram. Similar findings were also reported by Dwivedi *et al.* (1996) [4], Dadhich (1997), Bareth (1998) [1], and Laltanmawia *et al.* (2004) [5].

Table 20: Effect of phosphorus, molybdenum and Rhizobium in molybdenum uptake by greengram seed and stover

Treatments	Mo uptake					
	Seed (g ha ⁻¹)			Stover (g ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha⁻¹)						
P ₁ : 20	1.54	1.26	1.40	1.99	1.59	1.79
P ₂ : 40	1.86	1.49	1.67	2.36	1.99	2.17
P ₃ : 60	1.92	1.61	1.76	2.47	2.08	2.28
S.Em.±	0.05	0.04	0.03	0.05	0.04	0.03
C.D. (P = 0.05)	0.15	0.11	0.09	0.15	0.13	0.10
Molybdenum (kg ha⁻¹)						
Mo ₀ : 0.0	1.56	1.29	1.43	1.91	1.55	1.73
Mo ₁ : 0.5	1.80	1.44	1.62	2.32	1.89	2.10
Mo ₂ : 1.0	1.95	1.62	1.78	2.60	2.22	2.41
S.Em.±	0.05	0.04	0.03	0.05	0.04	0.03
C.D. (P = 0.05)	0.15	0.11	0.09	0.15	0.13	0.10
Rhizobium						
R ₀ : Without <i>Rhizobium</i>	1.70	1.39	1.54	2.18	1.82	2.00
R ₁ : With <i>Rhizobium</i>	1.85	1.51	1.68	2.37	1.96	2.16
S.Em.±	0.04	0.03	0.03	0.04	0.04	0.03
C.D. (P = 0.05)	0.12	0.09	0.07	0.12	0.11	0.08
Interaction						
P × Mo	NS	NS	0.16	0.26	0.22	0.17
P × R	NS	NS	0.13	NS	NS	0.14
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	12.12	11.36	11.88	9.73	10.09	9.92

(c) Effect of Rhizobium

The data presented in Table 20 revealed that molybdenum (Mo) uptake by greengram seed and stover increased significantly under the influence of seed inoculation with *Rhizobium* during both individual years as well as in pooled results. The increase in Mo uptake by greengram was 8.82%, 8.63%, and 9.09% in seed and 8.77%, 7.69%, and 8.0% in stover during 2019, 2020, and in pooled results, respectively, over no seed inoculation. The significant improvement in Mo uptake with *Rhizobium* inoculation can be attributed to the fact that *Rhizobium* seed treatment improves seed and stover yield as well as Mo content in both seed and stover of greengram. Similar findings were also reported by Singh *et al.* (1978), Vanparia (1991), and Meena *et al.* (2015)^[6].

Interaction Effect of P × Mo in Seed

Data presented in Table 21 revealed that the combination of phosphorus and molybdenum on Mo uptake by greengram seed was found to be significant in the pooled results only. Significantly the highest Mo uptake by greengram seed was recorded with the combined application of 40 kg P₂O₅ ha⁻¹ along with 1.0 kg Mo ha⁻¹. However, it was found at par with the combined application of 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ and 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹.

Table 21: Effect of P × Mo on molybdenum uptake (g ha⁻¹) by greengram seed on pooled

Phosphorus	Molybdenum		
	Mo ₀	Mo ₁	Mo ₂
P ₁	1.30	1.33	1.57
P ₂	1.33	1.73	1.95
P ₃	1.66	1.81	1.83
S.Em ±	0.06		
C.D. (0.05)	0.16		
C.V. (%)	11.88		

Interaction Effect of P × Mo in Stover

Data presented in Table 22 revealed that the combination of phosphorus and molybdenum on Mo uptake by greengram stover was found to be significant during 2019, 2020, and in pooled results. Significantly, the highest Mo uptake by greengram stover was recorded with the combined application of 40 kg P₂O₅ ha⁻¹ along with 1.0 kg Mo ha⁻¹ during 2019 and in pooled results. This combination was found to be at par with the application of 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹ during both 2019 and in pooled results. However, the application of 60 kg P₂O₅ ha⁻¹ + 0.5 kg Mo ha⁻¹ was also found at par during 2019 only. In 2020, significantly higher Mo uptake was obtained with the application of 60 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹, and this result remained at par with the application of 40 kg P₂O₅ ha⁻¹ + 1.0 kg Mo ha⁻¹.

Table 22: Effect of P × Mo on molybdenum uptake (g ha⁻¹) by greengram stover

Phosphorus	Molybdenum								
	2019			2020			Pooled		
	Mo ₀	Mo ₁	Mo ₂	Mo ₀	Mo ₁	Mo ₂	Mo ₀	Mo ₁	Mo ₂
P ₁	1.81	1.95	2.22	1.46	1.54	1.78	1.63	1.74	2.00
P ₂	1.86	2.38	2.83	1.44	2.10	2.42	1.65	2.24	2.63
P ₃	2.05	2.62	2.74	1.77	2.02	2.46	1.91	2.32	2.60
S.Em ±	0.09			0.08			0.06		
C.D. (0.05)	0.26			0.22			0.17		
C.V. (%)	9.73			10.09			9.92		

Interaction Effect of P × R in Seed and Stover

Data presented in Table 23 revealed that the combination of phosphorus and *Rhizobium* on K uptake by greengram seed and stover was found to be significant in the pooled results only. Significantly, the highest K uptake by greengram seed was recorded with seed inoculation with *Rhizobium* along with the application of 40 kg P₂O₅ ha⁻¹. However, this result was found to be at par with the combined application of 60 kg P₂O₅ ha⁻¹, whether with or without seed inoculation with *Rhizobium*.

For Mo uptake by greengram stover, significantly higher Mo uptake was noted under the combined application of 60 kg P₂O₅ ha⁻¹ with seed inoculation with Rhizobium. This result remained at par with the application of 40 kg P₂O₅ ha⁻¹ with seed inoculation with Rhizobium.

Table 23: Effect of P × R on molybdenum uptake (g ha⁻¹) by greengram on pooled

Rhizobium	Phosphorus					
	Seed			Stover		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
R ₀	1.37	1.52	1.73	1.79	2.00	2.19
R ₁	1.43	1.82	1.79	1.79	2.34	2.36
S.Em ±	0.05			0.05		
C.D. (0.05)	0.13			0.14		
C.V. (%)	11.88			9.92		

Conclusion

The results indicate that Rhizobium inoculation significantly enhanced molybdenum (Mo) uptake by greengram seeds and stover. The highest Mo uptake was observed with Rhizobium inoculation across both individual years and pooled results. Additionally, the combination of phosphorus and molybdenum had a significant impact on Mo uptake, with the best results achieved using 40 kg P₂O₅ ha⁻¹ and 1.0 kg Mo ha⁻¹ for both seeds and stover. Furthermore, the interaction between phosphorus and Rhizobium also improved Mo uptake, with the highest values seen in treatments with Rhizobium inoculation and phosphorus application. These findings highlight the beneficial role of Rhizobium and nutrient interactions in optimizing Mo uptake in greengram.

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