International Journal of Plant & Soil Science

Volume 36, Issue 12, Page 496-506, 2024; Article no.IJPSS.128300
ISSN: 2320-7035

Synergistic Effects of Phosphorus, Molybdenum, and Rhizobium on Greengram (*Vigna radiata* L.) Yield in Light Textured Soil

D.A. Patel [a], J.K. Malav [b*] and J.R. Jat [b]

[a] Centre for Research on Integrated Farming System, S.D.A.U, Sardarkrushinagar, India.
[b] C. P. College of Agriculture, S.D.A.U., Sardarkrushinagar, Gujarat, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i125224

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128300

Original Research Article

Received: 19/10/2024
Accepted: 22/12/2024
Published: 27/12/2024

ABSTRACT

A field experiment was carried out during *kharif*, 2019 and 2020 in different adjoining similar sites at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture Sardar krushinagar Dantiwada Agricultural University, Sardar krushinagar. The soil of the experimental field was loamy sand. The experiment comprised of eighteen treatment combinations *i.e.* three levels of phosphorus (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}); three levels of molybdenum (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 two levels of *Rhizobium* (R_0 : without *rhizobium* inoculation and R_1 : with *rhizobium* inoculation) were evaluated with GM 4 cultivar of green gram in randomized block design (R.B.D.) with factorial concept with three replications. Results revealed that application of 40 kg P_2O_5 ha^{-1} and 0.5 kg Mo ha^{-1} significantly enhanced the all-nodulation parameters, growth, yield attributes, seed and stover

**Corresponding author: E-mail: jkmalav@sdau.edu.in;*

Cite as: *Patel, D.A., J.K. Malav, and J.R. Jat. 2024. "Synergistic Effects of Phosphorus, Molybdenum, and Rhizobium on Greengram (Vigna Radiata L.) Yield in Light Textured Soil". International Journal of Plant & Soil Science 36 (12):496-506. https://doi.org/10.9734/ijpss/2024/v36i125224.*

yields of greengram over 20 kg P_2O_5 ha^{-1} and 0.0 kg Mo ha^{-1}. Seed inoculation with *Rhizobium* significantly improved the numbers and weight of effective nodules per plant at 45 and 60 DAS, and others parameters *i.e.,* yield attributes, seed and stover yield. Hence, application of 40 kg P_2O_5 ha^{-1} along with 0.5 kg Mo ha^{-1} and seed inoculation with *Rhizobium* were found to be most beneficial for greengram variety GM 4 grown in the light textured soils.

Keywords: Phosphorus; molybdenum; Green gram; Rhizobium.

1. INTRODUCTION

"Pulses occupy a unique position in every system of Indian farming as a main, catch, cover, green manure and intercrops. In a country like India, here the people are predominantly vegetarian; pulses form an indispensable part of the diet as it contains 23.1 per cent protein which is nearly two and half times more than the cereals, 0.50 to 4.33 per cent fats and 23.4 to 66.3 per cent carbohydrates" (Sinha, 1978). "It is a good source of riboflavin, thiamine and vitamin C. When green gram is sprouted, seed synthesize remarkable quantity of ascorbic acid (Vitamin C). The United Nations, declared 2016 as International Year of Pulses (IYP) to heighten public awareness of the nutritional benefits of pulses as part of sustainable food security and nutrition. Pulses account for around 20% of the area under food grains and contribute around 7 to 10% of the total food grains production in the country" (Mohanty and Satyasai, 2015). "Greengram (*Vigna radiata* L.) is commonly known as moong or golden gram and it belongs to *Leguminosae* family. It is originated from Central Asia. It is one of the most important pulse crop grown in almost all parts of the country over a wide range of agro-climatic conditions. Major greengram producing states in India are Orissa, Maharashtra, Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan and Bihar. The India is the largest producer and consumer of pulses. In India, *kharif* greengram occupies an area of about 40.70 Lha with the production of 19.01 LT" (DE and S, 2018-19). "In Gujarat, greengram is mainly grown in Kachchh, Banaskantha, Mehsana and Panchmahal districts in *kharif* season under inadequate and erratic rainfall conditions. However, it is grown in very large area in summer season in Kheda, Baroda and Panchmahal districts where irrigation facilities are available. Greengram is the most important crop throughout south-east Asia and particularly in the Indian sub-continent" (Jaishree et al., 2024; Chandekar et al., 2023). "Being a leguminous crop, it adds about 40 kg nitrogen ha^{-1} in the soil by the fixing of atmospheric nitrogen, which is subsequently beneficial to the succeeding crop. Phosphorus is a second most important major nutrient for plants because of their high requirement. Phosphorus is an essential both as a part of several key plant structural compounds and as catalyst in the conversion of key biochemical reactions in plant. Phosphorus is a vital component of ATP, the "Energy Unit" of plants. It is also involved in controlling key enzyme reaction and in the regulation of metabolic pathways" (Theodorou and Plaxton, 1993). "Molybdenum is an essential component of two major enzymes in plant *viz.,* nitrate reductase and nitrogenase. Among these, nitrogenase is actively involved in fixation of atmospheric nitrogen by *Rhizobium* bacteria in root nodules of pulse crops. So, Mo requirement of pulse crops is higher. Deficiency of molybdenum resulted in poor nodulation and synthesis of leghaemoglobin" (Rao and Singh, 1983). Thus, "molybdenum has an important role in symbiotic N_2 fixation in pulses. Pulses fix atmospheric nitrogen through root- *Rhizobium* symbiosis which needs to be fully exploited. However, the quantum of biological nitrogen fixed by a crop depends upon the number, size and longevity of active root nodules which is governed by the population and efficiency of rhizobia. The process of biological nitrogen fixation is governed by number of factors like temperature, *Rhizobium* strains, soil reaction, organic matter, phosphorus, molybdenum content in soil *etc.* The seed inoculation with proper strain of *Rhizobium* is one of the cheapest and most important inputs in pulse production. The light textured soils of north Gujarat are very poor in organic matter content" (Anon., 1993) with poor microbial activities. Some studies carried out at Sardarkrushinagar showed good response of *Rhizobium* inoculation by greengram, chickpea *etc.*

2. MATERIALS AND METHODS

The field experiments were laid out on Plot No. B-11 and B-8 during *kharif*, 2019 and 2020, respectively using mungbean variety GM 4 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of

Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District: Banaskantha (Gujarat). The experiment was carried out in a factorial Randomized Block Design with three replications. Physical and chemical properties of initial soil were estimated by using standard analytical procedure. Eighteen treatment combinations involving three treatments, each of P and Mo and two treatments of *Rhizobium* were under taken in this investigation. Common dose of nitrogen @ 20 kg ha^{-1} was applied. Phosphorus and molybdenum were applied through DAP and sodium molybdate, respectively. Seed treatment with *Rhizobium* @ 25 g kg^{-1} seed. In both the years, after planking, furrows were opened at 45 cm distance. As per the treatment required quantities of DAP to supply P and sodium molybdate to provide Mo along with a common dose of FYM @ 5 t ha^{-1} and 20 kg N ha^{-1} (through urea) in the furrows were applied prior to sowing. The seed inoculation was done just before sowing with a talcum powder based inoculants containing minimum 1×10^8 viable cells of *Rhizobium* g^{-1} and 10 per cent of 300 ml jaggery solution as sticker @ 250 g inoculant per 8-10 kg seed. Thereafter, uniform distribution of inoculant on seed was achieved by through mixing. Then the seeds were dried in shade on gunny bag for 30 minutes. The crop was harvested when leaves turned to reddish brown and start shedding and pods becoming brown to dark brown in colour. The border lines were first harvested and removed from the experimental site. Then after, net plot was harvested and allowed, it to sun-dry in the respective plots for seven days. After sun-drying the weight of total biomass was recorded for each plot separately. The seed yield of each net plot was recorded after threshing and cleaning. The stover yield of each net plot was also recorded by deducting seed yield from total biomass. Standard procedure was followed for recording and analyzed the data on different yield parameters. The significant differences were tested by "F" test and compared with the value of Table F at 5 % level of significance. The value of Table F at 5 % level of significance. The value of S.Em. and co-efficient of variation (C.V. %) were also worked out.

3. RESULTS AND DISCUSSION

3.1 Plant Height

Data presented in Table 1 revealed that different levels of phosphorus did not produce any

Table 1. Effect of phosphorus, molybdenum and *Rhizobium* on plant height of greengram

Treatments	Plant height at 30 DAS (cm)			Plant height at 60 DAS (cm)			Plant height at harvest (cm)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Phosphorus (kg ha^{-1}) :									
P_1 : 20	33.96	32.98	33.47	44.10	45.23	42.89	51.72	51.86	51.79
P_2: 40	35.48	33.66	34.57	46.23	46.08	46.16	53.10	53.41	53.25
P_3: 60	35.58	34.66	35.12	46.56	46.81	46.68	53.25	53.40	53.32
S.Em.±	**0.89**	**0.80**	**0.60**	**1.22**	**1.11**	**0.83**	**1.20**	**1.40**	**0.92**
C.D. (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Molybdenum (kg ha^{-1}) :									
Mo_0: 0.0	34.19	33.30	33.75	44.75	44.81	44.78	52.20	52.58	52.39
Mo_1: 0.5	35.34	33.63	34.49	45.75	45.30	45.52	52.39	52.42	52.40
Mo_2: 1.0	35.48	34.37	34.93	46.39	46.88	46.63	53.47	53.66	53.57
S.Em.±	**0.89**	**0.80**	**0.60**	**1.22**	**1.11**	**0.83**	**1.20**	**1.40**	**0.92**
C.D. (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
***Rhizobium* :**									
R_0 : Without *Rhizobium*	34.82	33.38	34.10	45.43	45.09	45.26	52.14	52.41	52.27
R_1 : With *Rhizobium*	35.19	34.15	34.67	45.83	46.23	46.03	53.24	53.36	53.30
S.Em.±	**0.72**	**0.66**	**0.49**	**1.00**	**0.91**	**0.68**	**0.98**	**1.14**	**0.75**
C.D. (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction :									
P × Mo	NS	NS	NS	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	**10.75**	**10.11**	**10.45**	**11.38**	**10.33**	**10.87**	**9.68**	**11.23**	**10.49**

significant difference in plant height at 30, 60 DAS and at harvest, but numerically the maximum plant height was obtained with the application of 60 kg P_2O_5 ha^{-1} during 2019, 2020 and in pooled, respectively. Application of molybdenum @ 1.0 kg ha^{-1} obtained the maximum plant height during 2019, 2020 and in pooled, respectively at 30, 60 DAS and at harvest. Seed inoculation with *Rhizobium* gave the maximum plant height at 30 60 DAS and at harvest during both the years as well as in pooled.

3.2 Number of Nodules 45 and 60 Days after Sowing

An examination of data presented in Table 2 explicit that application of 40 kg P_2O_5 ha^{-1} significantly increased the number of nodules per plant at 45 DAS over 20 kg P_2O_5 ha^{-1}, but remained at par with 60 kg P_2O_5 ha^{-1} during both the individual years as well as in pooled. Rabbani et al. (2005), Yadav et al. (2007) and Choudhary et al. (2014). The application of 1.0 kg Mo ha^{-1} produced maximum number of nodules per plant at 45 DAS, which was higher by 13.51, 13.49 and 13.50 per cent during 2019, 2020 and in pooled over control, respectively and application of 0.5 kg Mo ha^{-1} gave 9.34, 10.49 and 9.90 per cent higher number of nodules per plant at 45 DAS over control. Agarwal (2000). On an average increase in number of nodules per plant at 45 DAS due to seed inoculation with *Rhizobium* was to the extent of 6.29, 7.32 and 6.83 per cent during 2019, 2020 and in pooled, respectively. Tomar et al. (2001) It is apparent from the data given in Table 2 explicit that number of nodules per plant at 60 DAS increased significantly with increasing level of phosphorus up to 40 kg P_2O_5 ha^{-1} compared to 20 kg P_2O_5 ha^{-1} during both the years as well as in pooled, but it remained at par with 60 kg P_2O_5 ha^{-1} during both the years as well as in pooled. Rabbani et al. (2005). Application of 1.0 kg Mo ha^{-1} produced 20.18, 13.21 and 16.65 per cent more number of nodules per plant at 60 DAS during 2019, 2020 and in pooled over control, respectively. Agarwal (2000). On an average increased the number of nodules per plant at 60 DAS due to seed inoculation with *Rhizobium* was to the extent of 10.55, 7.74 and 9.17 per cent during 2019, 2020 and in pooled, respectively over no seed inoculation. Navgire et al. (2001) and Basu (2011).

Table 2. Effect of phosphorus, molybdenum and *Rhizobium* on no. of nodules and effective nodules of Greengram

Treatments	Number of nodules per plant at 45 DAS			Number of nodules per plant at 60 DAS			Effective nodules per plant at 45 DAS		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
P_1 : 20	29.19	27.20	28.20	13.11	13.57	13.34	20.61	19.79	20.20
P_2: 40	32.67	30.82	31.75	14.45	14.85	14.65	23.83	23.59	23.71
P_3: 60	33.44	31.52	32.48	15.52	15.43	15.48	23.92	23.67	23.79
S.Em.±	**0.69**	**0.62**	**0.46**	**0.41**	**0.30**	**0.25**	**0.61**	**0.47**	**0.38**
C.D. (P = 0.05)	**1.97**	**1.79**	**1.31**	**1.16**	**0.87**	**0.71**	**1.75**	**1.35**	**1.08**
Mo_0: 0.0	29.52	27.64	28.58	12.93	13.62	13.27	21.02	20.59	20.81
Mo_1: 0.5	32.28	30.54	31.41	14.61	14.81	14.71	23.10	23.01	23.06
Mo_2: 1.0	33.51	31.37	32.44	15.54	15.42	15.48	24.23	23.45	23.84
S.Em.±	**0.69**	**0.62**	**0.46**	**0.41**	**0.30**	**0.25**	**0.61**	**0.47**	**0.38**
C.D. (P = 0.05)	**1.97**	**1.79**	**1.31**	**1.16**	**0.87**	**0.71**	**1.75**	**1.35**	**1.08**
R_0 : Without *Rhizobium*	30.80	28.79	29.79	13.64	14.07	13.85	21.93	21.46	21.69
R_1 : With *Rhizobium*	32.74	30.90	31.82	15.08	15.16	15.12	23.65	23.24	23.44
S.Em.	**0.56**	**0.51**	**0.38**	**0.33**	**0.25**	**0.21**	**0.50**	**0.38**	**0.31**
C.D. (P = 0.05)	**1.61**	**1.46**	**1.07**	**0.95**	**0.71**	**0.58**	**1.43**	**1.10**	**0.88**
P × Mo	NS	NS	NS	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mo × R	2.79	2.53	1.85	1.65	1.23	1.01	2.47	1.90	1.53
P × Mo × R	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	**9.17**	**8.83**	**9.02**	**12.51**	**8.76**	**10.83**	**11.33**	**8.89**	**10.21**

Table 3. Effect of phosphorus, molybdenum and Rhizobium on fresh weight and dry weight of nodules of greengram

Treatments	Fresh weight of nodules per plant at 45 DAS (mg)			Fresh weight of nodules per plant at 60 DAS (mg)			Dry weight of nodules per plant at 45 DAS (mg)			Dry weight of nodules per plant at 60 DAS (mg)		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
Phosphorus (kg ha^{-1}) :												
P_1 : 20	416.11	475.92	446.01	229.57	250.60	240.09	157.07	161.31	159.19	92.85	88.94	90.90
P_2: 40	529.89	614.03	571.96	287.13	304.99	296.06	158.66	165.15	161.90	95.39	90.07	92.73
P_3: 60	570.33	636.92	603.62	294.15	315.66	304.90	162.07	166.67	164.37	97.34	91.17	94.26
S.Em.±	**13.47**	**11.34**	**8.80**	**7.02**	**7.24**	**5.04**	**2.17**	**2.37**	**1.61**	**1.93**	**1.14**	**1.12**
SC.D. (P = 0.05)	**38.71**	**32.60**	**24.85**	**20.17**	**20.82**	**14.23**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Molybdenum (kg ha^{-1}) :												
Mo_0: 0.0	448.06	534.86	491.46	225.79	243.72	234.75	153.00	158.28	155.64	90.24	85.21	87.72
Mo_1: 0.5	528.17	571.47	549.82	290.79	312.94	301.87	160.45	164.62	162.53	94.27	88.25	91.26
Mo_2: 1.0	540.11	620.53	580.32	294.26	314.60	304.43	164.34	170.23	167.28	101.06	96.73	98.89
S.Em.±	**13.47**	**11.34**	**8.80**	**7.02**	**7.24**	**5.04**	**2.17**	**2.37**	**1.61**	**1.93**	**1.14**	**1.12**
C.D. (P = 0.05)	**38.71**	**32.60**	**24.85**	**20.17**	**20.82**	**14.23**	**6.23**	**6.82**	**4.54**	**5.55**	**3.27**	**3.16**
***Rhizobium* :**												
R_0 : Without *Rhizobium*	487.63	542.97	515.30	261.34	279.14	270.24	156.37	161.47	158.92	91.77	87.13	89.45
R_1 : With *Rhizobium*	523.26	608.27	565.76	279.22	301.70	290.46	162.15	167.29	164.72	98.62	92.99	95.81
S.Em.	**11.00**	**9.26**	**7.19**	**5.73**	**5.91**	**4.12**	**1.77**	**1.94**	**1.31**	**1.58**	**0.93**	**0.92**
C.D. (P = 0.05)	**31.61**	**26.62**	**20.29**	**16.47**	**17.00**	**11.62**	**5.09**	**5.57**	**3.70**	**4.53**	**2.67**	**2.58**
Interaction :												
P × Mo	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P × R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P × Mo × R	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
C.V.%	**11.31**	**8.36**	**9.77**	**11.02**	**10.58**	**10.79**	**5.78**	**6.13**	**5.96**	**8.61**	**5.36**	**7.26**

3.3 Number of Effective Nodules at 45 DAS

Data presented in Table 2 explicit that across the years, significantly higher effective nodules per plant at 45 DAS was noted with increasing rates of phosphorus fertilization up to 40 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1}. The highest effective nodules per plant at 45 DAS were recorded with the application of 60 kg P_2O_5 ha^{-1}, but it was remained at par with 40 kg P_2O_5 ha^{-1} during both the years as well as in pooled. Venkatarao et al. (2017). It was observed that application of 1.0 kg Mo ha^{-1} gave numerically the highest effective nodules per plant at 45 DAS of greengram, but it was remained at par with 0.5 kg Mo ha^{-1}. The increased in effective nodules per plant at 45 DAS due to seed inoculation with *Rhizobium* was to the extent of 7.84, 8.29 and 8.06 per cent during 2019, 2020 and in pooled, respectively. Patil and Shinde (1980). Data presented in Table 2 explicit that number of effective nodules per plant at 60 DAS was noted under the treatment of 40 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1}. Maximum number of effective nodules per plant at 60 DAS (7.78, 7.89 and 7.84) was obtained with the application of 60 kg P_2O_5 ha^{-1}, but remained at par with 40 kg P_2O_5 ha^{-1} during both the years as well as in pooled. Venkatarao et al. (2017).

3.4 Fresh Weight of Nodules

Data presented in Table 3 clearly shown that the fresh weight of nodules at 45 DAS increased significantly with increasing rates of phosphorus up to 60 kg P_2O_5 ha^{-1} during 2019 and in pooled results, but it remained at par with 40 kg P_2O_5 ha^{-1} during 2020 only. Singh et al. (1978). It is evident from the data given in Table 3 revealed that different levels of molybdenum significantly affected the fresh weight of nodules at 45 DAS of greengram during both the individual years as well as in pooled. The highest fresh weight of nodules at 45 DAS *i.e.* 540.11, 620.53 and 580.32 mg per plant were noted with the application of 1.0 kg Mo ha^{-1} during 2019, 2020 and in pooled, respectively. However, it remained at par with 0.5 kg Mo ha^{-1} during first year only. Agarwal (2000). The results exhibited in Table 3 explicit that the fresh weight of nodules at 45 DAS of greengram was found to be significant with seed inoculation with *Rhizobium* culture during both the individual years as well as in pooled. Bahadur et al. (2006). The data presented in Table 3 exhibited that the fresh weight of nodules per plant in greengram at 60 DAS was influenced significantly by the application of 40 kg P_2O_5 ha^{-1} *i.e.* 294.15, 315.66 and 304.90 mg plant^{-1} during 2019, 2020 and in pooled, respectively compared to 20 kg P_2O_5 ha^{-1}. Application of P_2O_5 @ 60 kg ha^{-1} gave maximum fresh weight of nodules at 60 DAS, but remained at par with 40 kg P_2O_5 ha^{-1} during both the individual years and in pooled. Singh et al. (1978). It is evident from the data given in Table 3 revealed that significantly the highest fresh weight of nodules per plant in greengram at 60 DAS was noted under the treatment of 0.5 kg Mo ha^{-1} compared to control during both the individual years as well as in pooled. The highest fresh weight of nodules *i.e.* 294.26, 314.60 and 304.43 mg per plant at 60 DAS was obtained with the application of 1.0 kg Mo ha^{-1}. Agarwal (2000). However, it was remained at par with 40 kg P_2O_5 ha^{-1} in both the individual years as well as in pooled. The data exhibited in Table 3 revealed that the fresh weight of nodules at 60 DAS of greengram was found to be significant under seed inoculation with *Rhizobium* culture during both the individual years as well as in pooled. Bahadur et al. (2006).

3.5 Dry Weight of Nodules

It is clear from the data presented in Table 3 indicated that the dry weight of nodules per plant at 45 DAS of greengram did not influence significantly by the application of different levels of phosphorus during 2019, 2020 and in pooled. It is evident from the data given in Table 3 explicit that different levels of molybdenum significantly affected the dry weight of nodules per plant at 45 DAS of greengram during both the individual years as well as in pooled. Significantly the highest dry weight of nodules per plant at 45 DAS was noted with the application of 1.0 kg Mo ha^{-1} as compared to control, but it remained at par with 0.5 kg Mo ha^{-1} during both the individual years. Singh (2001). It is explicit from the data presented in Table 3 indicated that the dry weight of nodules at 45 DAS of greengram was found to be significant under seed inoculation with *Rhizobium* culture during both the individual years as well as in pooled. Tomar et al. (2001). The data presented in Table 3 clearly indicated that the dry weight of nodules at 60 DAS of greengram did not differ significantly by the application of different levels of phosphorus. It is evident from the data given in Table 3 explicit that the dry weight of nodules per plant at 60 DAS increased significantly with increasing rates of molybdenum up to 1.0 kg Mo ha^{-1} *i.e.* 101.06, 96.73 and 98.89 mg per plant during 2019, 2020 and in pooled, respectively. Singh (2001). The results given in Table 3 indicated that the dry weight of nodules at 60 DAS of greengram was found to be significant by the seed inoculation with *Rhizobium* culture during both the individual years as well as in pooled. Tomar et al*.* (2001).

3.6 Number of Pods Per Plant

Data presented in Table 4 explicit that across the years, significant increase in number of pods per plant was observed with increasing rates of phosphorus up to 40 kg P_2O_5 ha^{-1}. Numerically, the highest number of pods per plant was recorded with the application of 60 kg P_2O_5 ha^{-1}, but it was remained at par with 40 kg P_2O_5 ha^{-1}. It was observed that 60 kg P_2O_5 ha^{-1} increased in number of pods per plant to the magnitude of 9.05, 10.72 and 9.92 per cent in 2019, 2020 and in pooled, respectively compared to 20 kg P_2O_5 ha^{-1}. Similarly, application of 40 kg P_2O_5 ha^{-1} also recorded 8.85, 10.27 and 9.56 per cent a greater number of pods per plant in 2019, 2020 and pooled compared to 20 kg P_2O_5 ha^{-1}, respectively. Rani et al. (2016) and Parmdeep et al. (2017). Further examination of data, presented in Table 4 revealed that application of Mo significantly increased the number of pods per plant up to 1.0 kg Mo ha^{-1} during 2019 as well as in pooled but in case of 2020 significant improvement was noted only up to 0.5 kg Mo ha^{-1} compared to control. On mean basis, it was observed that 1.0 kg Mo ha^{-1} increased in number of pods per plant to the tune of 5.39, 7.15 and 6.22 per cent in 2019, 2020 and in pooled compared to control. Similarly, application of 0.5 kg Mo ha^{-1} resulted in 3.24, 4.55 and 2.32 per cent a greater number of pods per plant in 2019, 2020 and pooled over control, respectively. Vijayalakshmi and Swarajyalakshmi (2005). It is evident from the data given in Table 4 revealed that number of pods per plant increased significantly by the seed inoculation with *Rhizobium* during both the years as well as on pooled. The increase in number of pods per plant due to seed inoculation with *Rhizobium*was to the extent of 3.83, 4.91 and 4.35 per cent during 2019, 2020 and in pooled, respectively (Togay et al*.,* 2008 and Mohammad et al., 2018).

3.7 Number of Seeds Per Pod

It is evident from the data presented in Table 4 explicit that significantly the higher number of seeds per pod was produced by the crop with the application of 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} application, but remained at par with 40 kg P_2O_5 ha^{-1} during 2020 and in pooled but during 2019 significant increment was noted only up to 40 kg P_2O_5 ha^{-1}. Rani et al. (2016). The results of present investigation presented in Table 4 indicated that number of seeds per pod did not differ significantly under the influence of various levels of molybdenum. Data presented in Table 4 revealed that number of seeds per pod did not influence significantly by seed inoculation with *Rhizobium* during both the years as well in pooled.

3.8 Seed Yield

The data presented in Table 5 revealed that seed yield of greengram increased significantly up to 40 kg P_2O_5 ha^{-1} compared to 20 kg P_2O_5 ha^{-1}, but the maximum seed yield was obtained at 60 kg P_2O_5 ha^{-1}, which was found at par with 40 kg P_2O_5 ha^{-1}. Application of 60 kg P_2O_5 ha^{-1} increased the seed yield by 20.67, 23.03 and 21.79 per cent in 2019, 2020 and in pooled compared to 20 kg P_2O_5 ha^{-1}, respectively. Similarly, application of 40 kg P_2O_5 ha^{-1} increased the seed yield by 17.28, 15.75 and 16.55 per cent in 2019, 2020 and in pooled over 20 kg P_2O_5 ha^{-1}, respectively. Lal et al. (2016). The results of present investigation presented in Table 5 illustrated that significantly the highest greengram seed yield was reported under the influenced of 0.5 kg Mo ha^{-1} application during both the individual years as well as in pooled compared to control. The maximum seed yield was recorded with the treatment of 1.0 kg Mo ha^{-1}, which was found at par with 0.5 kg Mo ha^{-1}. Application of 1.0 kg Mo ha^{-1} increased the seed yield by 11.41, 10.56 and 11.00 per cent in 2019, 2020 and in pooled over control. Similarly, application of 0.5 kg Mo ha^{-1} increased the seed yield by 7.0, 5.18 and 6.15 per cent in 2019, 2020 and pooled over control, respectively (Awomi et al*.,* 2012 and Lal et al., 2016). The data presented in Table 5 indicated that the seed inoculation with *Rhizobium* gave significantly higher seed yield of greengram. Greengram seeds inoculated with strain of *Rhizobium* (R_1) produced significantly higher seed yield as compared to uninoculated control (R_0) during both the individual years as well as in pooled. The increase in seed yield due to seed inoculation was to the extent of 6.36, 6.69 and 6.52 per cent during 2019, 2020 and pooled, respectively (Negi et al*.,* 2006 and Rana et al., 2013).

Table 4. Effect of phosphorus, molybdenum and *Rhizobium* on pods per plant and seeds per pod of greegngram

Treatments	Number of pods per plant			Number of seeds per pod		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
Phosphorus (kg ha^{-1}) :						
P_1 : 20	14.80	13.43	14.11	7.10	7.13	7.12
P_2 : 40	16.11	14.81	15.46	7.35	7.59	7.47
P_3 : 60	16.14	14.87	15.51	7.66	7.76	7.71
S.Em.±	**0.24**	**0.28**	**0.19**	**0.16**	**0.22**	**0.14**
C.D. (P = 0.05)	**0.70**	**0.81**	**0.52**	**0.45**	**0.64**	**0.38**
Molybdenum (kg ha^{-1}) :						
Mo_0 : 0.0	15.39	13.83	14.61	7.11	7.22	7.17
Mo_1 : 0.5	15.44	14.46	14.95	7.51	7.56	7.54
Mo_2 : 1.0	16.22	14.82	15.52	7.66	7.71	7.60
S.Em.±	**0.24**	**0.28**	**0.19**	**0.16**	**0.22**	**0.14**
C.D. (P = 0.05)	**0.70**	**0.81**	**0.52**	**NS**	**NS**	**NS**
***Rhizobium* :**						
R_0 : Without *Rhizobium*	15.39	14.03	14.71	7.22	7.35	7.28
R_1 : With *Rhizobium*	15.98	14.72	15.35	7.52	7.65	7.58
S.Em.±	**0.20**	**0.23**	**0.15**	**0.13**	**0.18**	**0.11**
C.D. (P = 0.05)	**0.57**	**0.66**	**0.43**	**NS**	**NS**	**NS**
Interaction :						
P × Mo	1.20	1.41	0.91	NS	NS	NS
P × R	0.98	1.15	0.74	NS	NS	NS
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	**6.54**	**8.33**	**7.42**	**8.97**	**12.68**	**11.01**

Table 5. Effect of phosphorus, molybdenum and *Rhizobium* on seed yield and stover yield of Greengram

Treatments	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
Phosphorus (kg ha^{-1})						
P_1 : 20	819.39	744.24	781.81	1480.89	1381.42	1431.16
P_2 : 40	961.01	861.47	911.24	1736.72	1657.42	1697.07
P_3 : 60	988.77	915.64	952.20	1806.65	1699.75	1753.20
S.Em.±	**22.17**	**19.86**	**14.88**	**35.82**	**31.35**	**23.80**
C.D. (P = 0.05)	**63.73**	**57.07**	**42.00**	**102.96**	**90.09**	**67.17**
Molybdenum (kg ha^{-1})						
Mo_0 : 0.0	869.58	798.52	834.05	1524.74	1443.24	1483.99
Mo_1 : 0.5	930.78	839.96	885.37	1721.45	1616.26	1668.86
Mo_2 : 1.0	968.82	882.87	925.85	1778.06	1679.09	1728.57
S.Em.±	**22.17**	**19.86**	**14.88**	**35.82**	**31.35**	**23.80**
C.D. (P = 0.05)	**63.73**	**57.07**	**42.00**	**102.96**	**90.09**	**67.17**
***Rhizobium* :**						
R_0:Without *Rhizobium*	894.60	813.23	853.91	1608.67	1535.50	1572.08
R_1 : With *Rhizobium*	951.52	867.67	909.59	1740.84	1623.56	1682.20
S.Em.±	**18.10**	**16.21**	**12.15**	**29.25**	**25.59**	**19.43**
C.D. (P = 0.05)	**52.03**	**46.59**	**34.29**	**84.06**	**73.56**	**54.84**
Interaction :						
P × Mo	110.38	98.84	72.74	178.33	156.04	116.33
P × R	90.13	80.70	59.39	145.60	127.40	94.99
Mo × R	NS	NS	NS	NS	NS	NS
P × Mo × R	NS	NS	NS	NS	NS	NS
C.V.%	**10.19**	**10.02**	**10.13**	**9.08**	**8.42**	**8.78**

3.9 Stover Yield

The data presented in Table 5 explicit that during both the years of experimentation application of phosphorus significantly increased the stover yield of greengram up to 40 kg P_2O_5 ha^{-1} compared to 20 kg P_2O_5 ha^{-1}. But the maximum stover yield was obtained at 60 kg P_2O_5 ha^{-1} and found at par with 40 kg P_2O_5 ha^{-1}. It was observed that 60 kg P_2O_5 ha^{-1} increased in stover yield of greengram to the tune of 21.99, 23.04 and 22.50 per cent in 2019, 2020 and in pooled compared to 20 kg P_2O_5 ha^{-1}, respectively. Similarly, application of 40 kg P_2O_5 ha^{-1} increased the stover yield by 17.27, 19.97 and 18.58 per cent in 2019, 2020 and on pooled. A perusal of data given in Table 5 revealed that across the year of experimentation, significant increase in stover yield of greengram was noted up to 0.5 kg Mo ha^{-1} application, which was found at par with 1.0 kg Mo ha^{-1} application. Application of 1.0 kg Mo ha^{-1} recorded maximum stover yield of greengram 1778.06 and 1679.09 kg ha^{-1} in first and second year of study, respectively. It was found that application of 1.0 kg Mo ha^{-1} increased the stover yield by 16.61, 16.34 and 16.48 per cent over control. Similarly, application of 0.5 kg Mo ha^{-1} increased the stover yield by 12.90, 11.98 and 12.45 per cent in 2019, 2020 and pooled over control, respectively. Lal et al*.,* 2016. A perusal of data presented in Table 5 revealed that stover yield of greengram influenced significantly by the *Rhizobium* seed inoculation treatments during both the years s well as in pooled analysis. On an average increase in seed yield due to seed inoculation was to the extent of 8.21, 5.73 and 7.0 per cent during 2019, 2020 and pooled, respectively (Rana et al., 2013).

4. CONCLUSIONS

The study can be concluded that application of 40 kg P_2O_5 ha^{-1} along with 0.5 kg Mo ha^{-1} and seed inoculation with *Rhizobium* were found to be most beneficial for greengram variety GM 4 grown in the light textured soils. The application of 40 kg P2O5 ha-1 along with 0.5 kg Mo ha-1 and seed inoculation with Rhizobium were found to be most beneficial for greengram variety GM 4 grown in the light textured soils.

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 writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Agarwal, S. (2000). Response of chickpea (*Cicer arietinum L.*) to iron and molybdenum fertilization in light-textured soil. *M.Sc. (Agri.) Thesis, R.A.U., Bikaner (Rajasthan)*.

Anonymous. (1993). Thirty-first AGRESCO Report, Micronutrient Research Scheme, Regional Research Station, Gujarat Agricultural University, Sardarkrushinagar, 15–29.

Awomi, T. A., Singh, A. K., Kumar, M., & Bordoloi, L. J. (2012). Effect of phosphorus, molybdenum, and cobalt nutrients on yield and quality of mungbean (*Vigna radiata L.*) in acidic soil of Northeast India. *Indian Journal of Hill Farming, 25*(2), 22–26.

Bahadur, A., Singh, J., Singh, K. P., & Rai, M. (2006). Plant growth, yield, and quality attributes of garden pea as influenced by organic amendments and biofertilizers. *Indian Journal of Horticulture, 63*(4), 464–466.

Basu, T. K. (2011). Effect of cobalt, *Rhizobium,* and *Phosphobacterium* inoculations on growth, yield, quality, and nutrient uptake of summer groundnut (*Arachis hypogaea*). *American Journal of Experimental Agriculture, 1*(1), 21–26.

Chandekar, S. M., & Umesha, C. (2023). Effect of spacing and biofertilizer on the growth and yield of green gram (*Vigna radiata*). *International Journal of Environment and Climate Change, 13*(10), 3732–3738. https://doi.org/10.9734/ijecc/2023/v13i103045

Choudhary, A., Yadav, B. L., Choudhary, S., & Puniya, M. M. (2014). Response of integrated phosphorus management on nodulation and productivity of mungbean on *Typic Ustipsamment. Green Farming, 5,* 222–225.

Dharwe, D. S., Dixit, H. C., Dotaniya, C. K., Khandagle, A., Mohbe, S., & Doutaniya, R. K. (2019). Effect of phosphorus and sulfur on the yield and nutrient content of green gram. *International Journal of Chemical Studies, 7*(2), 1–5.

Directorate of Economics and Statistics (D.E. and S.). (2018–19). *Department of Agriculture and Cooperation, New Delhi.*

Jaishree, S., Silambarasan, M., Issac Manuel, R., Sugitha Kumari, & Indira Petchiammal. (2024). Studies on the effect of liquid bio-inoculant Rhizophos on the agronomic traits of green gram (*Vigna radiata*). *Journal of Experimental Agriculture International, 46*(6), 24–29. https://doi.org/10.9734/jeai/2024/v46i62453

Lal, M., Pal, A. K., Agrawal, M. C., Usha Rani, K., Suma Chandrika, D., & Singh, A. P. (2016). Effect of phosphorus and molybdenum on yield and nutrient uptake of faba bean in alluvial soil. *Annals of Plant and Soil Research, 18*(3), 262–265.

Mohammad, S., Mohammad, A., Parihar, C. M., Jat, S. L., Mandal, B. N., Kumar, L., & Meena, B. R. (2018). Effect of tillage practices and phosphorus doses on the performance of mungbean (*Vigna radiata*) in the semi-arid Kandahar region of Afghanistan. *Indian Journal of Agronomy, 63*(4), 532–534.

Mohanty, S., & Satyasai, K. J. (2015). Feeling the pulse: Indian pulses sector. *NABARD Rural Pulses, Issue X,* July–August 2015.

Navgire, K. D., Datar, V. V., Asewar, B. V., & Dahiwal, A. L. (2001). Response of mungbean cultivars to different *Rhizobium* strains under rainfed conditions. *Annals of Plant Physiology, 15*(2), 134–137.

Negi, S., Singh, R. V., & Dwivedi, D. K. (2006). Effect of biofertilizers, nutrient sources, and lime on growth and yield of garden pea. *Legume Research, 29*(4), 282–285.

Parmdeep, S., Yadav, K. K., Singh, F. M., Singh, B., & Singh, R. (2017). Effect of phosphorus and sulfur on yield attributes, yield, and nutrient uptake of mungbean (*Vigna radiata*) in the central plain zone of Punjab, India. *Plant Archives, 17*(2), 1756–1760.

Patil, R. N., & Shinde, P. A. (1980). Studies on nodulation patterns in gram (*Cicer arietinum*). *Journal of Maharashtra Agricultural University, 5,* 211–213.

Rabbani, M. G., Solaiman, A. R. M., Hossain, K. M., & Hossain, T. (2005). Effects of *Rhizobium* inoculants, nitrogen, phosphorus, and molybdenum on nodulation, yield, and seed protein in pea. *Korean Journal of Crop Science, 50*(2), 112–119.

Rana, M., Pathania, P., & Khaswan, S. L. (2013). Effect of biofertilizers and phosphorus on the productivity and nutrient uptake of soybean (*Glycine max*). *Annual Agricultural Research New Series, 34*(3), 245–247.

Rani, M., Prakash, V., & Khan, K. (2016). Response of mungbean (*Vigna radiata*) to phosphorus, sulfur, and PSB during the summer season. *Agriculture Science Digest, 36*(2), 146–148.

Rao, L. K., & Singh, K. (1983). Effect of phosphorus and biofertilizers on leghaemoglobin and nitrogen fixation of chickpea. *Madras Agricultural Journal, 70,* 572–577.

Singh, A. (2001). Response of clusterbean (*Cyamopsis tetragonoloba*) to FYM, molybdenum, and *Rhizobium* inoculation. *M.Sc. (Agri.) Thesis, R.A.U., Bikaner (Rajasthan).*

Singh, D. V., Chauhan, R. P. S., Singh, K., & Pal, B. (1978). Nitrogen and phosphorus needs of gram (*Cicer arietinum*) along with bacterial fertilization. *Madras Agricultural Journal, 65,* 363–366.

Sinha, S. K. (1978). *Food legumes: Distribution, adaptation, and biology of yield.* FAO, Rome, p. 96.

Theodorou, M. E., & Plaxton, W. C. (1993). Metabolic adaptations of plant respiration to nutritional phosphate deprivation. *Plant Physiology, 101,* 339–344.

Togay, N., Togay, Y., Cimrin, K. M., & Turan, M. (2008). Effects of *Rhizobium* inoculation, sulfur, and phosphorus applications on yield, yield components, and nutrient uptakes in chickpea (*Cicer arietinum*). *African Journal of Biotechnology, 7*(6), 776–782.

Tomar, A., Kumar, N., Pareek, R. P., & Chaube, A. K. (2001). Synergism among VAM, phosphate-solubilizing bacteria, and *Rhizobium* for symbiosis with black gram (*Vigna mungo*) under field conditions. *Pedosphere, 11*(4), 327–332.

Venkatarao, V., Naga, S. R., Yadav, B. L., Koli, D. K., & Rao, I. J. (2017). Effect of phosphorus and biofertilizer on the growth and yield of mungbean (*Vigna radiata*). *International Journal of Current Microbiology and Applied Sciences, 6*(7), 3992–3997.

Vijayalakshmi, B., & Swarajyalakshmi, G. (2005). Growth and yield of *Rhizobium*-inoculated black gram and green gram as influenced by phosphorus and molybdenum fertilization. *Madras Agricultural Journal, 92*(10–12), 684–687.

Yadav, A. K., Kins, V., & Abraham, T. (2007). Response of greengram (*Vigna radiata*) to phosphorus and biofertilizer. *Indian Journal of Agricultural Science, 20*(2), 75–77.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/128300