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Study of Nitrogen Assimilation with Molybdenum and Rhizobium for Higher Yield of Green Gram (*Vigna radiate* L.)

Utpal Maity*, Bidhan Roy, Bigyananda Mutum, Bijoy Basanta Laya, S. S. Reddy Vennupusa, Sagnik Poddar and Bipul Barman

Dept. of Seed Science and Technology, Uttar Banga Krishi Viswavidyalaya, Pundibai, Coochbehar, West Bengal (736 165), India

Corresponding Author

Utpal Maity
e-mail: utpalmaity.pph@gmail.com

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Abstract

A field experiment was conducted during the rabi season (October–March) in 2018–19 at experimental farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal with four varieties of green gram (*Vigna radiate* L.), namely, B-1, B-27, Sona and Chaitali to assess the effect of differences in treatments of seeds on growth, physiological and economic parameters. For this purpose, the seeds were treated in combination with *Rhizobium* sp. and *Molybdenum* separately prior to sowing to find out the effect of treatment on nitrogen assimilation on yield and quality seed production compared to control (non-treated). This experiment was expected to identify the best performing cultivars (physiological and economic parameters) among other selected alternative cultivar varieties. The results showed a positive effect on the length of root and shoot, accumulation of dry matter, no. of nodule formation, carbohydrate synthesis, etc. Besides, the treatment with *Rhizobium* Sp. and *Molybdenum* had found to promote higher level of the protein content in seed. Among four selected cultivars, Sona cultivar had demonstrated the best results with *inter alia* maximum yield (17.24 q ha^{-1}) which was 48% higher than control. Findings indicate that the combined treated seeds could enhance the growth of different yield contributing parameters which, in turn, helped increase production and productivity of green gram over control. Besides, it would also help the farmer while selecting the best cultivars of green gram in the area of study for economic advantage and welfare of the cultivators.

Keywords: Green gram, nitrogen assimilation, rhizobium, molybdenum, growth

1. Introduction

Green gram (*Vigna radiate* L Wilczek), commonly known as mung bean, is an important grain legume cultivated extensively in tropical and subtropical regions, particularly India (Soren et al., 2012; Singh et al., 2015). In West Bengal, it is typically grown during the pre-kharif and kharif seasons (Ghosh et al., 2006). Traditionally, Indian farmers do not consider green gram a principal crop but rather cultivate it as a subsidiary crop on land with residual soil moisture (Joshi et al., 2002). Despite its significance the yield of green gram remains low (580 kg ha^{-1}) compared to cereals (2237 kg ha^{-1}), as per Anonymous (2024).

Pulse, particularly green gram, serve as a vital source of high-quality protein (approximately 25%), making them an essential dietary component, especially for low-income population due to their high digestibility and nutritional profile (Jukanti et al., 2012; Anonymous, 2022). Green gram is consumed both as whole grains and as split “dal” in a variety of traditional dishes. It is also a rice source of riboflavin, thiamine and ascorbic acid (vitamin C), with levels increasing significant during seed sprouting (Yu et al., 2020; Anonymous, 2023). However, India continues to rely to meet its domestic pulse demand, causing a substantial drain on foreign exchange (Tiwari and Shivhare, 2018; Anonymous, 2023). To address this issue, the government has implemented several initiatives aimed at boosting pulse production, such as the National Food Security mission (NFSM) and pulses Development program (Anonymous, 2023). The declaration of the International Year of Pulse (Anonymous, 2019) by FAO helped promote awareness of pulse’ role in sustainable food system and nutrition security (Anonymous, 2016; Reddy et al., 2023). As a result, on-going efforts have been made to improve pulse productivity through improve crop varieties and integrated nutrient management (Inbasekar, 2014; Anonymous, 2022).

Research shows that applying Rhizobium and micronutrients such as molybdenum, either as seed treatment or soil amendment, significantly improves the physiological and agronomic performance of mung bean (Ahmad et al., 2018; Chaudhary et al., 2018; Banerjee et al., 2022). The integrated use of lime seed coating, Rhizobium, and molybdenum has been shown to increase yield and enhance nodulation (Singh, P. 2017; Dhakal et al., 2019) reported the highest yield and benefit-cost ratio in black gram with boron and molybdenum application. Tejasree (2024) demonstrated that bio-priming pulse seeds with Rhizobium improved nutrient uptake and productivity under nutrient-deficient conditions. Furthermore, Prusty et al. (2020) demonstrated the effectiveness of lime and molybdenum treatment on green gram yield and nutrient uptake in Odisha. Additional studies by Hossain et al. (2004) and Awasthi et al. (2025) also support the use of Rhizobium-molybdenum combinations for enhanced nitrogen fixation and growth in legumes. Recent research highlights that molybdenum plays a critical role in enzyme systems like nitrogenase and nitrate reductase, which are essential for nitrogen metabolism (Taria et al., 2022; Banerjee et al., 2022).

In light of the above considerations, the present study was designed with the primary objective of enhancing crop yield by improving the nitrogen-fixing efficiency of Rhizobium in mung bean (*Vigna radiata*), both in the presence and absence of molybdenum supplementation. To achieve this, four different mung bean cultivars were selected for evaluation under a range of treatment conditions. The experimental treatments aimed to assess their effects on key growth attributes and physiological responses of the plants. By systematically analyzing the interaction between Rhizobium inoculation, molybdenum application, and cultivar performance, the study seeks to identify high-yielding genotypes and economically viable treatment combinations. The insights gained from this research are expected to contribute toward the development of sustainable cultivation practices and improved productivity in mung bean farming systems.

2. Materials and Methods

Four commercial cultivars of mung bean were collected from the stock of Bidhan Chandra Krish Viswavidyalaya, Mohanpur, and Nadia (WB) during the *rabi* season (October –March) in 2018–19 for the study. Prior to sowing, the seeds were thoroughly mixed with *Rhizobium* culture along with Molybdenum. The effects of each treatment- *Rhizobium* and Molybdenum - when applied individually were also recoded. The field experiment was laid out using a split-plot design. Each sub-plot measured 2 sq. meters. The recommended package of practices of mung bean cultivation was followed. All selected growth parameters (including physiological and economic) were recorded during different growth stages through destructive sampling, carried out in a randomized manner at 20 day intervals. From each plot, 10 plants were sampled for each observation.

Observations on the responses of different treatments were recorded on the 45th and and 55th daysafter sowing. Growth parameters such as plant height, root and shoot length, and dry weights of root and shoot were recoded. Additionally, pod number and grain yield plant^{-1} were estimated using standard procedures, including the by Micro-Kjeldahl method (Hedge and Hafreiter, 1962). All findings were presented in tabular form.

3. Results and Discussion

The effects of the treatments on the growth parameters of selected mung bean (green gram) cultivars were recorded on the 45th day after sowing under field condition (Table 1). The responses of the treatments in terms of shoot length,

Table 1: Effect of treatments of growth parameters on different mungbean (Green gram) cv. on 45th day sowing in field condition

Treatment	Shoot length (cm)				Root length (cm)				Root dry wt. plant^{-1} (g)				Shoot dry matter plant^{-1} (g)			
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
Control	20.8	20.6	20.2	20.7	6.7	6.9	6.9	6.5	0.038	0.033	0.030	0.030	0.34	0.37	0.34	0.32
Molybdenum (MO)	21.8	21.6	21.8	21.4	7.5	7.5	7.0	7.9	0.034	0.040	0.040	0.430	0.44	0.44	0.45	0.44
Rhizobium (R)	22.4	22.5	22.3	22.7	8.3	8.2	8.2	8.2	0.043	0.043	0.041	0.040	0.55	0.53	0.50	0.48
Molybdenum (MO)+ Rhizobium (R)	31.0	33.4	33.8	32.4	8.4	8.88	8.9	8.5	0.046	0.046	0.043	0.043	0.62	0.59	0.66	0.63
	LSD-A =NS B=1.119 (1%) S AB=NS SEm±–A=0.3256 B=0.2831 AB=0.5662				LSD-A =NS B=NS AB=NS SEm±– A =2.9262 B=2.8884 AB=5.7767				LSD-A=0.004 (1%)S B=0.004 (1%)S AB=NS SEm±–A=0.0008 B=0.0011 AB=0.0021				LSD-A=NS B=0.026 (1%)S AB=0.039 (5%)S SEm±–A=0.0094 B=0.0068 AB=0.0135			

LSD-A: Variety; B: Treatment; AB: Interaction; SEm-A: Variety; B: Treatment; AB: Interaction; V_1: Sona; V_2: (B1), V_3 (B27); V_4: Chaitali root length, root dry weight and shoot dry matter plant^{-1} are presented in the table and compared with the control (no treatment). It was observed that shoot length, root length and dry matter plant^{-1} increased compared to the control. This improvement shows a positive correlation with micronutrients availability (Mecarty et al., 2022). The root dry weight also showed a significantly increased,with the combined treatment of Molybdenum and *Rhizobium* demonstrating a more pronounced effect than either treatment alone. Among all the cultivars, Sona and B-1 exhibited the highest and most prominent responses. The enhanced effect of the treatment could be attributed to increased photosynthetic activity, likely due to greater nitrogen availability in the soil facilitated by the presence of Molybdenum and *Rhizobium* (Olikar et al., 1978; Khan et al., 1980; Bambara et al., 2010).

Quantitative measurements of the number of branches/plant, number of leaves/plant and average number of nodules/plant on the 45th day revealed a positive and also higher response to the treatments compared to the control, indicating a beneficial effect. Furthermore, the combined application of molybdenum and Rhizobium elicited the maximum response across all four cultivars, with Sona and B-1 again showing the highest response. The results, presented in Table 2, also indicate that the differences in response among the treatments were statistically significant.

Observations were also recorded at the maturity stage of the plant to study pod length, average pod weight and grain weight/ pod, which are important contributors to overall yield. These parameters showed a positive correlation with yield components (Aloweidat et al., 2014). It was found that Molybdenum- treated seeds produced longer pods, whereas the responses from other treatments were more or less similar to the control. The effects were more prominent in the sona and B-1 cultivars. The average pod weight and the grain weight of 100 pods were higher in crops treated with *Rhizobium* compared to the control, and these values were also greater than those recorded for the combined treatment with Molybdenum and *Rhizobium*. However, significant improvements in yield parameters were observed in the B-1 and Chaitali cultivars due to the applied treatments. These results are presented in Table 3.

Table 2: Effect of treatments on growth parameters of different mungbean (Green gram) cv. on 45th day sowing in field condition

Treatment	Branches plant^{-1}				Leaves plant^{-1}				Average nodule no. Plant^{-1}			
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
Control	0.30	0.33	0.33	0.00	4.13	4.46	4.66	4.06	6.00	8.60	6.4	3.90
Molybdenum (MO)	0.33	0.36	0.40	0.00	4.53	4.73	4.86	4.06	6.10	8.60	7.7	7.10
Rhizobium (R)	1.73	1.74	1.80	0.00	4.66	5.20	5.22	4.33	9.40	9.70	9.20	9.10
Molybdenum (MO)+Rhizobium (R)	1.75	1.80	1.83	0.00	4.66	5.86	5.20	4.40	10.20	10.60	10.0	8.90
	LSD-A=0.036 (1%) S B=0.022 (1%) S AB=0.044 (1%) S SEm± -A =0.0.007 B=0.006 AB=0.011				LSD-A=NS B=NS AB=NS SEm± -A =2.9262 B=2.8884 AB=5.7767				LSD-A=0.004(1%)S B=0.004(1%)S AB=NS SEm± -A =0.0008 B=0.0011 AB=0.0021			

LSD–A: Variety; B: Treatment; AB: Interaction; SEm±-A: Variety; B: Treatment; AB: Interaction

Table 4 shows the number of flowers retained in different mung bean (Green gram) cultivars on the 55th day after sowing. The results indicated that cultivar B-27 performed best under both treated and control conditions, followed by B-1. The combined treatment of Molybdenum with *Rhizobium* produced better performance compared to either treatment applied individually, for both flowering and pod development parameters. The differences in responses among treatments and interactions were statistically significant. However, in the case of the Chaitali cultivar, no flowers or pods were observed under either treated or control conditions.

The effects of treatments on the growth parameters of different mung bean (Green gram) cultivars, recorded on the 45th day after sowing, are presented in Table 5. The growth parameters considered for analysis included the number of pods plant^{-1}, seed pod^{-1} and yield ha^{-1} (q ha^{-1}). The combined treatment of Molybdenum+*Rhizobium* resulted in the highest number of pods plant^{-1} in the Sona cultivar, followed by B-1, B-27 and Chaitali respectively. In terms of seeds/pod, B-1 exhibited the best performance across all treatments, including the control, followed by the Sona variety. In both parameters, significant variations in responses and interaction between treatments and cultivars was observed, indicating a close interrelationship between yield and its component traits (Damodaram et al., 1989). The most important aspect of the study-yield/ha-showed that the maximum yield (17.24 q ha^{-1}) was obtained from the Sona variety under the combined treatment of Molybdenum and Rhizobium, which represented a 48% increase over the control. The same variety also produced high yields when treated individually with Molybdenum (14.28 q ha^{-1}) and *Rhizobium* (15.06 q ha^{-1}),

Table 3: Effect of seed treatment with rhizobium and molybdenum on yield parameters of mungbean (Green gram)

Treatment	Pod length (cm)				Average pod weight (g)				100 grain weight (g)			
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
Control	6.65	6.91	6.72	6.66	0.39	0.39	0.38	0.39	2.20	2.20	2.19	2.19
Molybdenum (MO)	6.79	7.03	6.80	6.74	0.41	0.40	0.41	0.40	2.21	2.21	2.24	2.21
Rhizobium(R)	6.37	6.62	6.65	6.82	0.45	0.49	0.47	0.46	2.45	2.38	2.37	2.32
Molybdenum (MO)+Rhizobium (R)	6.65	6.95	6.66	6.87	0.35	0.52	0.35	0.52	2.49	2.48	2.47	2.49
	LSD-A=0.030 (1%) S B=0.042 (1%) S AB=0.085 (1%) S SEm± -A=0.0.006 B=0.011 AB=0.085				LSD-A=0.013 (1%) S B=0.016 (1%) S AB=0.032 (1%) S SEm± -A=0.004 B=0.004 AB=0.008				LSD-A=NS B=0.056 (1%) S AB=NS SEm± -A=0.017 B=0.014 AB=0.029			

LSD–A: Variety; B: Treatment; AB: Interaction; SEm±-A: Variety; B: Treatment; AB: Interaction

Table 4: Number of flowers and pod number plant^{-1} retained in different mungbean (Green gram) CV. on 55th day after sowing in field conditions

Treatment	Flower no. plant^{-1}				Pod no. plant^{-1}			
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
Control	3.73	3.26	3.80	0.00	6.26	6.00	6.86	0.00
Molybdenum (MO)	3.86	3.60	3.90	0.00	6.70	6.55	6.85	0.00
Rhizobium (R)	3.80	3.43	3.85	0.00	6.53	6.13	6.65	0.00
Molybdenum (MO)+Rhizobium (R)	3.90	3.75	3.98	0.00	6.80	6.70	6.95	0.00
	LSD-A=0.169 (1%) S B=0.100 (1%) S AB=0.0850.148 (1%) S SEm± -A =0.0.032 B=0.026 AB=0.051				LSD-A =0.182 (1%) S B=0.147 (1%) S AB=0.0294 (1%) S SEm± -A=0.035 B=0.037 AB=0.074			

LSD-A: Variety; B: Treatment; AB: Interaction; SEm±-A: Variety; B: Treatment; AB: Interaction

Table 5: Effect of treatments on growth parameters of different mungbean (Green gram) cv. on 45th day sowing in field condition

Treatment	Pods plant^{-1}				Seed pod^{-1} (g)				Yield ha^{-1} (q)				% yield increase over control			
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
Control	17.93	15.80	16.06	10.13	0.28	0.29	0.26	0.25	12.04	10.99	10.02	6.07	---	---	---	---
Molybdenum (MO)	20.53	17.00	18.26	11.60	0.29	0.32	0.28	0.27	14.28	13.05	12.27	7.51	18.60	18.74	22.45	23.72
Rhizobium (R)	20.93	18.26	18.50	12.45	0.30	0.32	0.29	0.28	15.06	14.02	12.87	8.36	25.08	27.57	28.44	37.72
Molybdenum (MO) + Rhizobium (R)	22.45	19.06	18.60	13.15	0.32	0.34	0.31	0.29	17.24	15.55	13.83	9.15	43.18	41.49	38.02	50.74
	LSD-A =1.720 (1%) S B=0.855 (1%) S AB=NS SEm± -A=0.3281 B=0.2163 AB=0.4325				LSD-A =0.018 (1%) S B=0.015 (1%) S AB=NS SEm± -A=0.0035 B=0.0040 AB=0.0081				LSD-A=0.0679 (1%)S B=0.533 (1%)S AB=0.786 (5%) S SEm± -A=0.1297 B=0.1348 AB=0.2695				Variable can not be analysis by			

representing yield increases of 41.49% and 38.02% over the control, respectively. The second-highest yield was recorded in the B-1 cultivar, followed by B-27 and Chaitali. These, finding suggest that the combined application of Molybdenum and Rhizobium, as well as their individual use, significantly enhanced yield compared to the over control across all the selected mung bean cultivars.

An analysis of carbohydrate content in seed was also conducted for the different treatments and cultivars. The findings, presented in Table 6**,** indicate that carbohydrate content increased significantly under the combined treatment of Molybdenum with *Rhizobium* sp*.,* followed by the individusl treatments of *Rhizobium* sp. and Molybdenum, respectively. The highest response was observed in the Sona cultivar, followed by B-1, B-27 and Chaitali. These results suggest that the increased in carbohydrate content may be attributed to enhanced nitrogen-fixing efficiency by *Rhizobium sp*., which was further supported by molybdenum application. This improvement is positive correlated with increase photosynthetic efficiency in the crop (Olikar et al., 1978).

Table 6: Effect of treatments on total varbohydrate content of mature seed of mungbean (Data expressed as per cent per 100 mg of dry material)

Treatment	Flower no. plant^{-1}			
	V_1	V_2	V_3	V_4
Control	59.62	57.34	56.87	52.80
Molybdenum (MO)	63.14	59.06	58.78	53.46
Rhizobium (R)	63.75	60.43	59.16	54.52
Molybdenum (MO)+Rhizobium (R)	64.32	62.25	61.34	56.78
	LSD-A=0.24 (1%)S B=0.017 (1%)S AB=0.034 (5%)S SEm± -A =0.005 B =0.004 AB=0.009			

LSD–A: Variety; B:Treatment; AB: Interaction; SEm± -A: Variety; B: Treatment; AB: Interaction

4. Conclusion

The study demonstrated that Molybdenum enhanced nitrogen- fixing efficiency of *Rhizobium* sp.in mung bean by promoting nitrate reductage activity. It also contributed to increased photosynthetic activity, resulting in higher carbohydrate content in seeds. *Rhizobium* inoculation improved growth parameters compared to control. However, when the *Rhizobium* treatment was supplemented with molybdenum, productivity increased significantly. The experiment identified the Sona cultivar as the highest- yielding variety, producing a maximum yield of17.24 q ha^{-1} an increase of 48% over control.

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