Asian Journal of Soil Science and Plant Nutrition

Volume 10, Issue 3, Page 425-432, 2024; Article no.AJSSPN.121207
ISSN: 2456-9682

Assessing the Effect of Phosphorus, Molybdenum and Rhizobium Inoculation on Growth, Yield and Yield Attributes of Mungbean. (*Vigna radiata* L.) under Rainfed Conditions

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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/ajsspn/2024/v10i3354

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/121207

Original Research Article

Received: 03/06/2024
Accepted: 05/08/2024
Published: 08/08/2024

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Cite as: *Siddiqui, Amreen, Sanjeev Sharma, Anil Kumar, Ravindra Sachan, Anurag Kumar Singh, Zunaid Akhtar, and Prateek Saxena. 2024. "Assessing the Effect of Phosphorus, Molybdenum and Rhizobium Inoculation on Growth, Yield and Yield Attributes of Mungbean. (Vigna Radiata L.) under Rainfed Conditions". Asian Journal of Soil Science and Plant Nutrition 10 (3):425-32. https://doi.org/10.9734/ajsspn/2024/v10i3354.*

ABSTRACT

An experiment was carried out during *Kharif* season of 2023 at Pot Culture experimental site, Department of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur Nagar (U.P.). The experiment was laid out in Randomized Block Design with thirteen treatments each replicated thrice. The treatments consist of three levels of phosphorus *viz.,* 20 kg ha^{-1}, 40 kg ha^{-1} and 60 kg ha^{-1}, two levels each of molybdenum *viz*. 1.0 kg ha^{-1} and 2.0 kg ha^{-1} and *Rhizobium viz.* inoculated (Rh_1) and uninoculated (Rh_0). Mungbean variety IPM 02-3 was grown with recommended agronomic practices under rainfed conditions. On the basis of the results emanated from the investigation, it is observed that, application of treatment T_{12} [P_{60} + Mo_1 + Rh_1] resulted in significantly higher plant height (58.24 cm), no. of branches $plant^{-1}$ (9.82), no. of pods $plant^{-1}$ (25.84), length of pod (8.91 cm), no. of seeds pod^{-1} (11.45), test weight (49.86 g) and seed yield (11.78 q ha^{-1}). While the application of T_{13} [P_{60} + Mo_2 + Rh_1] resulted in significantly higher no. of leaves $plant^{-1}$ (5.52), no. of nodules $plant^{-1}$ (29.6) and stover yield (23.04 q ha^{-1}). Thus, it could be concluded that treatment T_{12} [P_{60} + Mo_1 + Rh_1] was found to be superior and subsequently at par with treatment T_{13} [P_{60} + Mo_2 + Rh_1] over all the other treatments.

Keywords: Growth; molybdenum; phosphorus; rainfed; rhizobium; yield.

1. INTRODUCTION

Mungbean (*Vigna radiata* L.) is the third most important pulse crop in India after chickpea and pigeonpea. It is cultivated across the world while India alone contributes about more than 70 % of world's mungbean production [1]. Primarily being a crop of the rainy season, it is well suited for all rainfed areas with annual rainfall of 600-1000 mm. However, it has proved to be an ideal crop for the spring and summer seasons as well.

"Currently, mungbean is cultivated on more than 6 million hectares worldwide (about 8.5% of global pulse cultivation area) and global annual production is 3 million tons (5% of global pulse production). India is the largest mungbean producing country followed by China Myanmar and Indonesia" [2]. "In India, mungbean cultivation is substantially concentrated in the states of Gujarat, Orissa, Maharashtra, Madhya Pradesh and Rajasthan accounting for 70 % of total country's production. It is grown on about 40.38 lakh hectares with a total production of 31.5 lakh tonnes with a productivity of 783 kg ha^{-1} and contributes 11 % to the total pulse production in the year 2021 - 22. In *Kharif* 2022 - 23, mungbean production was 17.5 lakh tonnes in an area of 33.37 lakh hectares. In Kanpur Nagar district of Uttar Pradesh, mungbean was cultivated on an area of 562 hectares and total production obtained was 212 tonnes with a yield of 0.38 tonnes ha^{-1} in the *kharif* season" [3].

"Mungbean is a popular pulse in the diet and is consumed in combination with cereals because it is easily digestible, rich in protein (20 -24%), iron (6 mg per 100 g of dry seed) and easy to cook" [4]. "Along with being an important source of protein in vegetarian diets, it also has a high quality of lysine (460 mg g^{-1} N) and tryptophan (60 mg g^{-1} N). Sprouted mungbean contains ascorbic acid (vitamin C) and an increased amount of riboflavin and thiamine. It also contains iso-flavonoids that have antioxidant activities, which prevent many diseases" [5].

"Phosphorus is the second most critical plant nutrient, but for pulses, it assumes primary importance, owing to its important role in root proliferation and thereby atmospheric nitrogen fixation" [6]. "It plays a crucial role in root proliferation, cell division, energy currency of cell (ATP), production and protein metabolism. It also plays a pivotal role in nodule formation indirectly by supplying the required energy necessary for nitrogen fixing bacteria through sugar and energy metabolism" [7]. "Since P deficiency results in reduced symbiotic N fixation, P fertilization usually results in enhanced nodule number and mass, as well as greater N_2 fixation activity $plant^{-1}$" [4,8].

"The importance of molybdenum can be judged from the fact that in the absence of one atom of Mo, 1,000,000 atoms of N and 30,000 atoms of P may become ineffective from the view of plant nutrition It is a structural component of nitrogenase and nitrate reductase enzymes, which bring about oxidation - reduction reactions in plant cells" [9]. "Molybdenum also has a function as a co-factor, i.e., structural and catalytic function, in several enzymes that have been discovered in higher plants. It is widely known that legumes require more Mo than most other plants because of their crucial role in the nitrogen-fixation process" [10].

"Rhizobium is a small, rod shaped, gram negative symbiotic nitrogen fixing bacteria associated with legumes and is able to form nodules on their host plants, inside of which they fix nitrogen. It has been demonstrated that native soil possesses an inadequate *Rhizobial* population, resulted in ineffective biological nitrogen fixation. It was observed that inoculation of mungbean with *Rhizobium* sp. increased plant height, leaf area, photosynthetic rate and dry matter production" [11,12]. "In mungbean, nitrogen derived from N_2 fixation is 15 – 17 % and total nitrogen fixed is 9 - 137 kg ha^{-1}" (Singh and Sekhon, 2005).

This manuscript is crucial for the scientific community as it explores the synergistic effects of phosphorus, molybdenum, and Rhizobium inoculation on the growth and yield of mungbean (*Vigna radiata* L.) under rainfed conditions. Mungbean is an important legume crop, especially in arid and semi-arid regions, where water availability is limited. Understanding how these treatments influence crop performance can provide insights into optimizing nutrient management and enhancing sustainable agriculture practices. The findings could contribute to improving crop resilience, yield stability, and soil health, offering valuable information for researchers, agronomists, and farmers aiming to boost productivity in rainfed systems.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out at Pot Culture experimental site, Department of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur Nagar (U.P.) which lies between 25° 26' and 26° 58' North latitude and 79° 31' and 80° 34' East longitude. It is situated at an elevation of 124 meters above the mean sea level in the alluvial belt of Gangetic plains of central Uttar Pradesh.

2.2 Edaphic Condition

The soil present at the experimental site was moist, well drained with uniform plane topography. It was of alluvial origin and falls within the Inceptisol order, characterized by sandy loam texture, being slightly alkaline, having initial values of pH 7.61 ((1:2.5 soil: water suspension method, Jackson, [13] EC 0.34 dSm^{-1} (Conductivity meter method, Wilcox, [14] low in organic Carbon *i.e.* 4.1 g kg^{-1} (Wet oxidation method, Walkley and Black, [15], low in available nitrogen *i.e.* 203.42 kg ha^{-1} (Alkaline permanganate method, Subbiah and Asija, [16], low in available phosphorus *i.e.* 19.64 kg ha^{-1} (Olsen's calorimetrically method, Olhsen et al*.,* [17,18], and low in available molybdenum *i.e.* 0.09 mg kg^{-1} (Acid ammonium oxalate method, Grigg, [19].

2.3 Experimental Details

The experiment was laid out in a "Randomized Block Design" with three replications consisting of thirteen treatment combinations. The treatments consisted of a combination of three levels of P and two levels each of Mo and *Rhizobium* as detailed below.

2.4 Crop Husbandry

IPM 02-3 variety of mungbean was used as a test crop. Seeds were treated with *Rhizobium* culture @ 200 g per 10 kg of seeds through standard procedure before sowing as per treatment. The seeds were sown at recommended dose of 20 kg ha^{-1} in furrow opened at the depth of about 3-5 cm. in rows at 40 cm. apart under rainfed conditions on 23rd June in the year 2023, respectively. All the nutrients were applied as basal dressing before sowing. A uniform dose of 20 kg of N ha^{-1} was applied through the application of Urea as the source. Additionally, 40 kg K_2O was administered in the form of MOP. Phosphorus was introduced *via* SSP, while Molybdenum was delivered through ammonium molybdate, adhering to specific treatment protocols.

2.5 Harvesting

The harvesting was done when crop reached to its physiological maturity. The plants from net area were harvested and bundled separately and tagged. The tagged bundles were kept on threshing floor for sun drying and then threshed manually.

2.6 Statistical Analysis

"The data on various characters studied during the course of investigation were statistically

Table 1. Treatment details

Phosphorus Levels (as P_2O_5)	Molybdenum Levels (as $[NH_4]_2MoO_4$)	***Rhizobium*** (as Seed treatment)
1. 20 kg ha^{-1} (P_{20})	1. 1.0 kg ha^{-1} (Mo_1)	1. Uninoculated (Rh_0)
2. 40 kg ha^{-1} (P_{40})	2. 2.0 kg ha^{-1} (Mo_2)	2. Inoculated (Rh_1)
3. 60 kg ha^{-1} (P_{60})		

Table 2. Treatment combinations

S. No.	Treatment Combinations	Symbols
1.	Control	T_1
2.	P_{20}+Mo_1+Rh_0	T_2
3.	P_{20}+Mo_2+Rh_0	T_3
4.	P_{40}+Mo_1+Rh_0	T_4
5.	P_{40}+Mo_2+Rh_0	T_5
6.	P_{60}+Mo_1+Rh_0	T_6
7.	P_{60}+Mo_2+Rh_0	T_7
8.	P_{20}+Mo_1+Rh_1	T_8
9.	P_{20}+Mo_2+Rh_1	T_9
10.	P_{40}+Mo_1+Rh_1	T_{10}
11.	P_{40}+Mo_2+Rh_1	T_{11}
12.	P_{60}+Mo_1+Rh_1	T_{12}
13.	P_{60}+Mo_2+Rh_1	T_{13}

analyzed for randomized block design. Wherever treatment differences were significant (“F” test), critical differences were worked out at five per cent probability level. The data obtained during the study were analyzed statistically using the methods advocated” by Gomez and Gomez [20].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Data pertaining to growth parameters mainly plant height, no. of leaves plant^{-1}, and no. of branches plant^{-1} are presented in Table 3, which clearly revealed that all these growth parameters were found to be influenced by the various allocated treatments given during the course of investigation and marked significant variations over T_1 [control]. T_{13} [P_{60} + Mo_2 + Rh_1] resulted in significantly higher no. of leaves plant^{-1} (5.52), which was significantly at par with T_{12} [P_{60} + Mo_1 + Rh_1] (5.51). While T_{12} [P_{60} + Mo_1 + Rh_1] resulted in significantly higher plant height (58.24 cm) and no. of branches plant^{-1} (9.82) respectively. These findings are further supported by Bhuiyan et al*.* [21], Prajapati et al. [22], Namakka et al. [23], Banerjee et al*.* [24] and Parashra et al. [25].

3.2 Yield Attributes

Data pertaining to yield attributing parameters *viz.* no. of pods per plant^{-1}, length of pod (cm), no. of seeds pod^{-1}, test weight (g) and no. of nodules plant^{-1} are presented in Table 4, which clearly revealed that all these parameters were found to be influenced positively, by the various allocated treatments given during the course of investigation and marked significant variations over T_1 [control] except test weight (g). Significantly highest no. of pods plant^{-1} (25.84), length of pod (8.91) and no. of seeds pod^{-1} (11.45) were observed under treatment T_{12} [P_{60} + Mo_1 + Rh_1], while the response of the no. of nodules plant^{-1} (29.6), was recorded higher under

Table 3. Effect of P, Mo & Rhizobium Inoculation on growth parameters of mungbean.

Treatment	Plant Height (cm)	Number of leaves plant^{-1}	No. of branches plant^{-1}
T_1	39.29	3.46	6.25
T_2	44.83	4.11	7.48
T_3	46.03	4.31	7.97
T_4	47.13	4.69	8.11
T_5	46.60	4.76	7.84
T_6	53.18	4.87	9.08
T_7	52.50	4.85	8.69
T_8	52.10	4.94	9.65
T_9	49.86	4.96	9.50
T_{10}	56.19	5.49	9.79
T_{11}	54.01	5.50	9.81
T_{12}	58.24	5.51	9.82
T_{13}	55.03	5.52	9.80
S.E(m±)	0.49	0.05	0.09
C.D. at 5%	1.42	0.14	0.27

Table 4. Effect of P, Mo & Rhizobium Inoculation on yield attributes of mungbean

Treatment	No. of pods $plant^{-1}$	Length of Pod (cm)	Number of seeds pod^{-1}	No. of nodules $plant^{-1}$	Test weight (g)
T_1	16.20	5.68	5.29	16.4	33.10
T_2	19.22	7.80	8.85	19.5	42.08
T_3	20.15	7.89	8.11	20.6	42.67
T_4	19.79	8.28	8.89	22.0	44.53
T_5	22.87	8.41	9.71	21.4	45.12
T_6	23.55	8.69	10.92	22.3	46.33
T_7	21.89	8.55	10.36	23.9	45.98
T_8	24.69	7.95	10.47	27.2	46.11
T_9	23.98	8.15	10.84	27.5	47.24
T_{10}	25.63	8.88	11.31	28.1	49.72
T_{11}	25.29	8.79	11.42	28.6	48.91
T_{12}	25.84	8.91	11.45	28.8	49.86
T_{13}	25.76	8.84	11.39	29.6	49.64
S.E(m±)	0.27	0.08	0.12	0.29	0.47
C.D. at 5%	0.78	0.23	NS	0.86	NS

Table 5. Effect of P, Mo & Rhizobium Inoculation on yield of mungbean

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1	6.91	16.87	23.78	29.06
T_2	9.80	19.84	29.64	33.06
T_3	10.13	20.21	30.34	33.39
T_4	9.92	20.11	30.03	33.03
T_5	10.24	19.83	30.07	34.05
T_6	10.81	20.78	31.59	34.22
T_7	11.01	21.42	32.43	33.95
T_8	10.19	20.95	31.14	32.72
T_9	10.26	21.53	31.79	32.27
T_{10}	11.18	21.18	32.36	34.55
T_{11}	11.63	22.63	34.26	33.95
T_{12}	11.78	22.97	34.75	33.90
T_{13}	11.72	23.04	34.73	33.75
S.E(m±)	0.10	0.18	0.32	0.23
C.D. at 5%	0.30	0.52	0.94	NS

treatment T_{13} [P_{60} + Mo_2 + Rh_1]. These findings were closely conforming to the results of Bhuiyan et al. [21], Velmurugan et al. [26], Umale et al. [27], Spandana et al. [28] and Ranjan et al., [29].

3.3 Yield

Data pertaining to yield *viz.* biological yield (q ha^{-1}), grain yield (q ha^{-1}), stover yield (q ha^{-1}) and harvest index (%) are presented in Table 5. Obtained data clearly revealed that application of P, Mo and *Rhizobium* inoculation significantly influenced the yield of mungbean over T_1 [control]. Maximum biological yield (34.75 q ha^{-1}) and grain yield (11.78 q ha^{-1}) was found under treatment T_{12} [P_{60} + Mo_1 + Rh_1], while the stover yield was found highest under treatment T_{13} [P_{60} + Mo_2 + Rh_1]. The harvest index (34.55%) showed highest percentage under treatment T_{10} [P_{40}+Mo_1+Rh_1]. These findings were closely justified by Singh et al. [30], Hosseini et al. [31], Movalia et al. [32], Ahmad et al [33] Khaleeq et al. [34] and Shalini et al., [35,36].

4. CONCLUSION

On the basis of experimental results discussed above, it can be concluded that the treatment, T_{12} [P_{60} + Mo_1 + Rh_1] was found to be simultaneously superior and subsequently at par with treatment T_{13} [P_{60} + Mo_2 + Rh_1] and could be promoted for the cultivation of mungbean for utilizing its maximum potential and improving growth, yield and yield attributes of the crop.

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 manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121207