EFFECT OF RHIZOBIUM, PHOSPHORUS AND MOLYBDENUM ON GROWTH, YIELD AND ROOT NODULATION OF MUNGBEAN (*Vigna radiata* l.) AT TIKAPUR, KAILALI.

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ABSTRACT

An experimental trial was conducted at Tikapur, Kailali during spring season of 2023 to study the effect of Rhizobium, phosphorus and molybdenum on growth, root nodulation and yield of mungbean. The trial was laid out in single factorial randomized complete block design with three replications and eight treatments. Ammonium molybdate as a source of molybdenum and single super phosphate for phosphorus supplement was used while Rhizobium leguminosarum was used for seed inoculation. The experimental results revealed that application of Rhizobium in combination with 60 kg ha^{-1} phosphorus and 1.5 kg ha^{-1} molybdenum had significant influence on growth parameters such as plant height, number of leaves, number of branches, number of pods, pod length and number of seeds per pod as well as root parameters: root length, total nodules, effective nodules, dry weight of root, followed by Rhizobium along with 60 kg ha^{-1} phosphorus and 1 kg ha^{-1} molybdenum. Similarly, yield parameters like grain yield (4.43 q ha^{-1}), biomass yield (6.15q ha^{-1}) and 1000 grain weight (54.59 g) were also recorded highest at Rhizobium + 60 kg ha^{-1} phosphorus + 1.5 kg ha^{-1} molybdenum. The effect of Rhizobium inoculation alone as well as increasing level of phosphorus and molybdenum was significant over control for all these parameters. All these parameters were recorded lowest at control concluding Rhizobium + 60 kg ha^{-1} phosphorus + 1.5 kg ha^{-1} molybdenum as best combination for growth, nodulation and yield of mung bean under Tikapur conditions.

Keywords: *Biological nitrogen fixation, Biomass, Inoculation, Ammonium molybdate*

INTRODUCTION

Legumes are vital food crops for nutritional security in Nepal, serving as a major source of plant-based protein. Grain legumes continue to occupy a notable share of cultivated land, with recent estimates indicating production of about 0.38 million metric tons in 2025 and productivity improvements compared to earlier reports of 0.85 t ha^{-1} in 2005, although overall gains remain constrained by climate variability and declining cultivation area (MoALD, 2024). Despite their importance, Nepal's per capita pulse consumption remains around 10 kg per annum (~27 g/day), which is still below recommended dietary levels, highlighting persistent nutritional deficiencies (Ministry of Agriculture and Land Development (MoALD), 2025). Among grain legumes, mungbean (*Vigna radiata* L.), commonly known as green gram, is one of the oldest and widely cultivated crops in South and Central Asia (Singh et al., 2021; Sharma et al., 2011). Due to its high nutritive value, easy digestibility, short growth duration, and ability to improve soil fertility through nitrogen fixation, mungbean is increasingly recognized in Nepal as a promising legume for enhancing food security and sustainable agricultural systems (Joshi et al., 2014; MoALD, 2025).

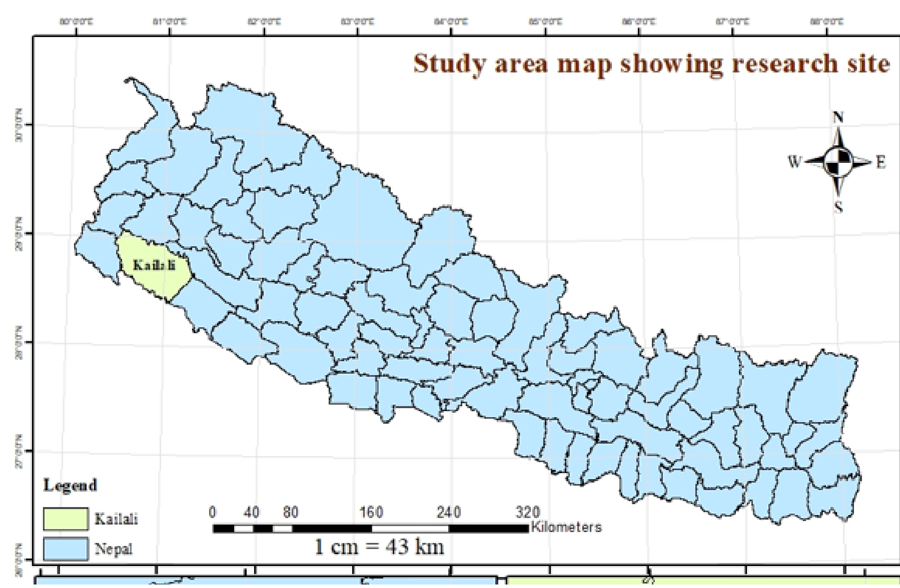
Rhizobium inoculants, a type of biological nitrogen fixation technology, can be applied for grain legumes as an alternative to costly fertilizer, especially to increase the nation's supply of food legumes (Bhuiyan et. al., 2008). Rhizobium and legumes establish symbiotic mutualism to carry out the process of biological nitrogen fixation that depends upon various factors and Phosphorus (P) is one of them. Phosphorus is essential for protein, phospholipids and phytin synthesis in the legumes (Dhakal et. al., 2019). Without the right amount of P, rhizobial activity and nitrogen fixation are reduced. It also encourages the development of healthy, lateral, fibrous roots early on, which is crucial for the production of nodules and the fixation of atmospheric Nitrogen (N) (Hossain et. al., 2018). Additionally, it helps nodule bacteria fix nitrogen for plants during grain development, boosting growth, and is absorbed from the soil as phosphate, though it moves less easily than other major nutrients as it is either absorbed by Fe and Al oxides through ligand exchange or precipitates as orthophosphate in soil (Singh et. al., 2021). Solaiman and Habibullah (1990a) reported that nodulation and N fixation by legumes were influenced with the application of phosphorus along with *Rhizobium* inoculant. Similarly, because Molybdenum (Mo) is directly engaged in the N-fixing enzymes nitrogenase in addition to nitrate reductase, particularly for legumes developing root nodules, it also plays a crucial role in legume yield (Dhakal et al., 2019). According to Williams and Da Silva (2002), molybdenum is primarily found as an essential component of an organic pterin complex known as the Mo cofactor also known as Moco, although it is not physiologically active in and of itself. Mo-requiring enzymes, or molybdoenzymes, which are present in the majority of biological systems (plants, animals, and prokaryotes), can be bound by this cofactor Moco. Similarly, Mo-nitrogenase, one of the three hereditary forms of nitrogenase, is in charge of the majority of biological nitrogen fixation processes that establish the global biogeochemical cycles of carbon and nitrogen. According to Sharma et al. (1985), molybdenum is necessary for the development of nodule tissue consequently boosting nitrogen fixation; in the absence of sufficient molybdenum, microbial activity is reduced and nitrogen fixation could not take place.

Rhizobium, despite having high potential with respect to nutrient management, has not been explored in wide scale in these regions. Moreover, as blanket recommendations of these nutrients, that directly influence the nodule formation and biological nitrogen fixation, may not be suitable due to prevalent spatial variation in soil fertility, this study was conducted with the overall objective of investigating the combined effects and optimal levels of phosphorus, molybdenum, and Rhizobium inoculation to improve nodule formation and mungbean productivity under site-specific conditions in the sandy loam soils of Tikapur, Kailali.

MATERIALS AND METHOD

Experimental site

The experiment was carried out in Tikapur, Kailali district, Nepal, 1.5 km from the School of Agriculture, Far-Western University from April to July of 2023.



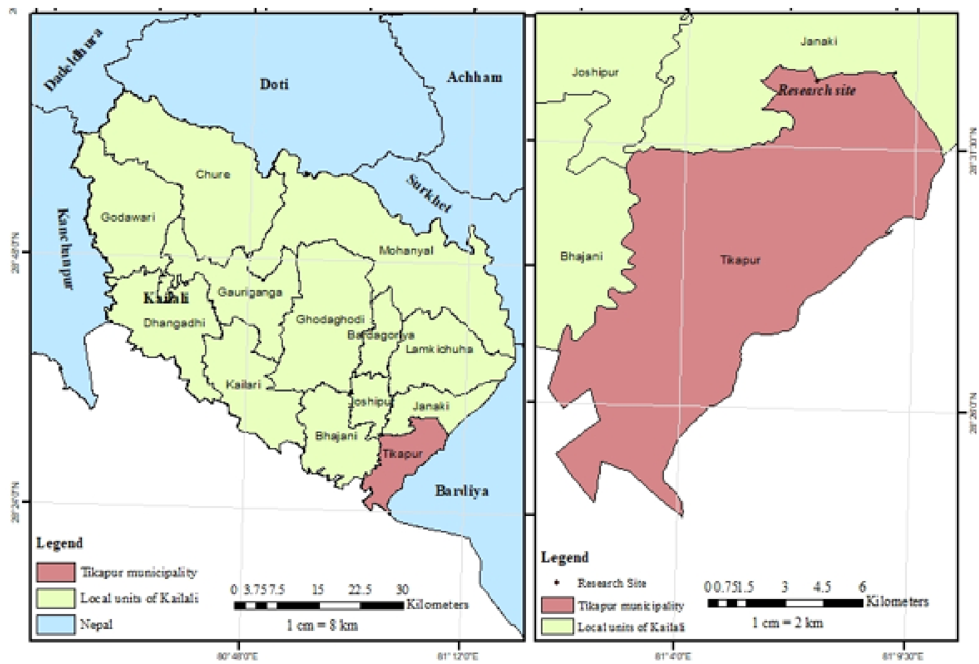


Figure 1: Study area map showing experimental site

Geomorphology and climate of the experimental site

The experimental site is located in southern terai region of Kailali district which has fine sandy loam texture. The experimental site has tropical climate. The mean annual temperature in Tikapur is 23.7 °C while the average annual rainfall is 1385 mm.

Layout of experimental design

Single factor randomized complete block design that consisted of 8 treatments and 3 replications was adopted for the experiment. Each plot size was 3m*2m (i.e. 6m^2) consisting of 10 rows per plot and 20 plant in a row. The distance between each replication was 1 meter and between each plot was 0.5 m within replication.

Treatments

Application of three different doses of phosphorus, two different doses of molybdenum along with *Rhizobium* was done. Including control there were eight treatments. Treatment details are given below.

Table 1. Different treatments and their abbreviations.

Treatment	Treatment combinations	Dose	Abbreviation used
T1	Control	R (0) +P (0 $kgha^{-1}$) +Mo (0 $kgha^{-1}$)	R0P0Mo0
T2	*Rhizobium*	R(RD)	RP0Mo0
T3	*Rhizobium*+ Phosphorus+ Molybdenum	R(RD)+P($kgha^{-1}$) +Mo(1$kgha^{-1}$)	RP20Mo1
T4	*Rhizobium*+ Phosphorus+ Molybdenum	R(RD)+P(20$kgha^{-1}$) +Mo(1.5$kgha^{-1}$)	RP20Mo1.5
T5	*Rhizobium*+ Phosphorus+ Molybdenum	R(RD)+P(40$kgha^{-1}$) +Mo(1$kgha^{-1}$)	RP40Mo1
T6	*Rhizobium*+ Phosphorus+ Molybdenum	R(RD)+P(40$kgha^{-1}$) +Mo(1.5$kgha^{-1}$)	RP40Mo1.5
T7	*Rhizobium*+ Phosphorus+ Molybdenum	R(RD)+P(60$kgha^{-1}$) +Mo(1$kgha^{-1}$)	RP60Mo1
T8	*Rhizobium*+ Phosphorus+ Molybdenum	R(RD)+P(60$kgha^{-1}$) +Mo(1.5$kgha^{-1}$)	RP60Mo1.5

Fertilization, seed inoculation and sowing

Nitrogen and Potassium both were applied at the rate of 20 kg per hectare. The required amount of urea and muriate of potash were calculated and broadcasted on each plot according to the recommended dose. Phosphorus was applied through single super phosphate as single row band placement whereas ammonium molybdate was used as a source of molybdenum which was applied by mixing the required amount of ammonium molybdate in the sand for easiness and uniform distribution. Different plots were treated with different treatments. Seed preparation was done by inoculating the seeds with *Rhizobium leguminosarum* inoculants at recommended dose of 10g per kg seeds in 10% sugar solution and shade dried after proper mixing on the date of sowing, i.e. 5th April, 2023. Seeds were sown after 1 hour of inoculation at 2 cm depth with line to line spacing maintained at 30 cm and plant to plant distance of 10 cm.

Data recording and statistical analysis

Quartering for 1m^2 areas on each plot was done for the final yield and 10 plants in each plot outside the quarters were tagged leaving 2 border rows on each side for periodic data recording for growth and yield attributing parameters. For the study of parameters such as root length, and number of effective as well as total root nodules, 3 plants were uprooted randomly from each plot after irrigating the plots, leaving the tagged plants and plants from quarter at 45 DAS. Data for plant height at maturity, number of pods at 90 DAS, grain yield and biomass were also recorded. The data were entered in Ms-Excel and analysed using R studio, version 4.2, "doebioresearch" package. Analysis of variance was done in order to compare the means of different treatments and LSD value was observed at 5% level of significance.

RESULTS AND DISCUSSION

Growth, yield and yield attributes of mungbean

Plant height at maturity (cm)

Mungbean plant height was positively and significantly affected by the combined application of P, Mo, and Rhizobium inoculant. Analysis of the plant's height revealed that phosphorus and molybdenum treatments had a substantial effect on the mungbean's plant height. Average data displays that T8 (RP60Mo1.5) resulted in significantly taller plants (43.9 cm) as compared to control (25.9 cm) Meanwhile, treatment T7 (RP60Mo1) also resulted in taller plants (42.2 cm) which was at par with T8. Similar trends were observed by Muhammad et al. (2004) noted an increase in plant height in mungbean plots that received phosphorus along with rhizobium inoculum. According to Aghatise and Tayo (1994), application of molybdenum considerably raised soybean height in comparison to the control. Additionally, Rhizobium inoculation combined with Mo 2 kg ha^{-1} greatly boosted plant height, according to Ahmad et al. (2013). They contend that Rhizobium and legume symbiosis is essential for improving nodulation, which aids in fixing atmospheric nitrogen, increasing nitrogen's bioavailability and greatly boosting plant development.

Number of leaves (per plant).

The number of leaves at 60 DAS showed similar variations between the treatments and the control. Plants infected with Rhizobium along with P and Mo produced noticeably more leaves (Table 2). The Rhizobium-inoculated treatment had the greatest number of leaves (14), coupled with P and Mo levels of 60 and 1.5 kg ha^{-1}, respectively, which were statistically significant when compared to the control (9). Nevertheless, inoculation alone (T2) was unable to considerably increase the leaf number. Similar observations were made by Dhakal et al. (2019), who observed that in the case of cow pea, there were more leaves when phosphate and molybdenum levels increased together with Rhizobium inoculation. Increased rate of nitrogen fixation helps the plant to synthesize more protein which helps in producing greater number of leaves. These findings were also in line with the results of Bhuiyan et. al. (2008) in case of mungbean.

Number of branches (per plant)

At 90 DAS, the number of branches of mungbean was shown to be significantly impacted by P, Mo, and Rhizobium inoculant (Table 2). At the crop's harvest stage, plants receiving P, Mo, and Rhizobium had more branches. T8 had the most branches per plant (5.6), while T7 and T8 had statistically identical numbers. Compared to the control, it was much higher. The control group had the fewest branches (2.4). In comparison to the uninoculated control, it was found that the inoculated plants yielded more branches. The treatment with 60 kg ha^{-1} P resulted in the maximum number of branches at later growth stages, which was much greater than the lower phosphorus levels. According to the findings (Table 2), comparable phosphorus levels with varying molybdenum dosages yielded comparable outcomes, suggesting that molybdenum had no noticeable effect on the branch number. Tahir et al. (2011) also discovered that applying 4g/kg seed Mo + Rhizobium to mungbean produced the highest number of pod-bearing branches (11.8). According to Togay et al. (2008), in the case of lentils, both Mo and bacterial inoculation have a favorable impact on the number of branches bearing pod. Similarly, Bhuiyan et al. (2008) discovered that at the mungbean harvest stage, the infected plants supplied with P, Mo, along with seed inoculation by Rhizobium had more branches per plant.

Number of pods (per plant)

The *Rhizobium*, phosphorus, and molybdenum application substantially influenced the pod number. It was observed that the application of phosphorus levels upto 60 kg ha^{-1} significantly increased the pod number when measured at 90 DAS. The maximum number of pods was observed in T8 (38) while the lowest was recorded in control (22) as shown in Table 2. From the study it was observed that T3, T4 and T5 gave the identical results but statistically lower than phosphorus applied at 60 kg ha^{-1}. These outcomes are in agreement with the findings of Solaiman (1999) and Solaiman et al. (2003) in case of chickpea and lentil, respectively. Moreover, Rabbani et al., (2005) also found similar results who claimed that inoculating Rhizobium accompanied with P and Mo application appreciably improved number of pods per plant.

Pod length (cm)

There were comparable differences between control and treatments in case of pod length at 60 DAS. From the experimental data, it was observed that maximum pod length was observed in T7 (8.44 cm), however, the treatments T4, T5, T6 and T8 were at par with T7 (Table 2). There was a significant effect of phosphorus addition as compared to control. The lowest pod length (5.13 cm) was measured from the control plot. Similar results regarding Rhizobium and Mo combined application were observed by Rahmani et al. (2008) that significantly improved pod length.

Number of seeds (per pod)

Analysis regarding seeds per pod as influenced by various doses of molybdenum and phosphorus integrated with *Rhizobium* is presented in Table 2. Different phosphorus levels had a considerable impact on mungbean seed yield. T8 had the maximum seed yield (10.7) per pod, which was far greater than the others. The control group had the fewest seeds per pod (7.14). Treatment inoculated with *Rhizobium* in integration with phosphorus at 60 kg ha^{-1} along with 1 kg ha^{-1} molybdenum produced the 2nd highest seeds number per pod (9.93), however, it remained at par with T6. Also, the treatments T2, T3 and T4 were found to be at par with one another but significantly differed when compared to the control as well as T8. Landge et al. (2002) also found that the seeds number for each pod increased in mung bean after Rhizobium was inoculated with P and Mo application.

Table 2. Effect on growth and yield attributes of mungbean under the field conditions at Tikapur, 2023

SN	Treatments	Plant height at maturity (cm)	Number of leaves (per plant)	Number of branches (per plant)	Number of pods (per plant)	Pod length (cm)	Number of seeds (per pod)
1	Control	25.90^{f}	9^{g}	2.4^{f}	22^{f}	5.13^{d}	7.14^{f}
2	*Rhizobium*	33.50^{e}	10^{f}	3.0^{ef}	26^{e}	6.94^{c}	8.06^{e}
3	R+P20+Mo1	37.30^{d}	10^{ef}	3.0^{ef}	30^{d}	7.75^{b}	8.04^{e}
4	R+P20+Mo1.5	39.95^{bc}	11de	3.5d^{e}	31^{d}	8.09^{ab}	8.46^{de}
5	R+P40+Mo1	39.80^{c}	11^{cd}	4.0^{cd}	30^{d}	8.02^{ab}	8.99^{cd}
6	R+P40+Mo1.5	41.30b^{c}	12^{c}	4.5^{bc}	33^{c}	8.23^{ab}	9.56^{bc}
7	R+P60+Mo1	42.20^{ab}	13^{b}	5.0^{ab}	35^{b}	8.44^{a}	9.93^{b}
8	R+P60+Mo1.5	43.90^{a}	14^{a}	5.6^{a}	38^{a}	8.19^{ab}	10.70^{a}
	Mean	**37.99**	**11.30**	**3.87**	**30.63**	**7.60**	**8.86**
	CV%	**3.17**	**4.15**	**11.09**	**2.37**	**3.30**	**4.09**
	LSD $_{(0.05)}$	**2.106**	**0.822**	**0.751**	**1.270**	**0.438**	**0.635**

Note: LSD: Least Significant Difference, CV: Coefficient of Variation, means followed by the same letters within each column are not significantly different at 5% level of significance by DMRT.

Grain yield (kgha^{-1})

The cumulative effect of several yield components, which are impacted by the genetic composition of the variety, different agronomic techniques, and environmental factors, determines the grain yield of the mungbean crop. Table 3 contains information on how phosphorus and molybdenum dosages affect seed development. Research verified that the combination of phosphate and molybdenum with Rhizobium inoculation significantly affected mungbean seed output. Mean data values exposed that treatment RP60Mo1.5 produced higher yield (443 kg ha^{-1}) followed by the treatment RP60Mo1, though lowest yield (308 kg ha^{-1}) was detected in control treatments. Furthermore, treatment containing *Rhizobium* inoculation alone without integration of Phosphorus and Molybdenum also gave significantly lower yield as compared to treatments containing inoculation integrated with different doses of P and Mo. An improvement in grain yield is attributed to cumulative effect of pods per plant, pod length, number of grains per pod and test weight. Similar, results were found by Aslam et al. (2020), Rabbani et al. (2005), Deo and Kothari (2002), who reported an enhanced seed yield with inoculation of *Rhizobium* in the presence of P and Mo. This could be because molybdenum has a synergistic effect that increases nitrogenase activity, which in turn supplies more nitrogen through fixation for improved growth and ultimately higher yield (Biswas *et al* 2009; Biyan *et al*, 2014).

Total biomass (kgha^{-1})

Total biomass yield was affected by the combined application of phosphorus and molybdenum with *Rhizobium* inoculant. Data from the experiment revealed that maximum biomass yield was obtained from the treatment RP60Mo1.5 which was significantly higher than any of the treatments used in the experimental trial. However, lowest biomass yield was attained from control. Our results were assisted by the findings of Junaid et. al. (2022). Similarly, according to Jain et al. (1993) and Singh et al. (2007), rhizobium inoculation, nitrogen, and phosphorus administration increased cowpea grain and straw yield, which was caused by enhanced growth and yield-attributing characteristics. Hussain et. al. (2010), also observed that dry shoot weight increased with the increasing levels of phosphorus, which further enhanced when these treatments were applied along with Rhizobium inoculums.

Test weight (grams)

It was observed that integrating the molybdenum and phosphorus with *Rhizobium* inoculated seeds significantly influenced the weight of a thousand seeds of mungbean as compared to non-inoculated control as well as inoculation alone. The heaviest seeds (54.59) were produced by plants under treatment RP60Mo1.5 whereas lighter seeds (40.59) were recorded in control plots. Treatments T4, T5 and T6 were at par with one another but were significantly lower than T8 which gave highest test weight. The collective effect of Rhizobium inoculant, P, and Mo might have led to improved assimilation of N for the plants resulting in the larger seeds. This finding has the similarity with the result of Solaiman (1999b). Zaman et. al. (1996) also observed that due to application of Mo, 1000 seed weight increased by 34.42% over control. This outcome could be because phosphorus enhances plant growth and increases the amount of assimilates that are transported to the seed for its development (Malik et al., 2015). Our findings also agree with Ahmed et al. (2018) who observed a greater weight of seeds in plots receiving P at 60 kg ha^{-1}. They observed that rising doses of P up to 60 kg ha^{-1} resulted higher seed weight.

Table 3. Effect of integration of phosphorus, molybdenum and rhizobium on mungbean yield under the field conditions at Tikapur, 2023

Sn	Treatments	Grain yield (kg ha^{-1})	Total biomass (kg ha^{-1})	Test weight (grams)
1	Control	308^{h}	405^{g}	41^{f}
2	*Rhizobium*	348^{g}	451^{f}	43^{e}
3	R+P20+Mo1	365^{f}	483^{e}	44de
4	R+P20+Mo1.5	374^{e}	502de	45^{cd}
5	R+P40+Mo1	384^{d}	511^{d}	47^{c}
6	R+P40+Mo1.5	401^{c}	542^{c}	48^{c}
7	R+P60+Mo1	422^{b}	579^{b}	50^{b}
8	R+P60+Mo1.5	443^{a}	615^{a}	55^{a}
	Mean	**380.71**	**510.99**	**46.57**
	CV%	**0.98**	**2.21**	**2.67**
	LSD $_{(0.05)}$	**6.558**	**19.798**	**2.179**

Note: LSD: Least Significant Difference, CV: Coefficient of Variation, means followed by the same letters within each column are not significantly different at 5% level of significance by DMRT.

Root parameters

Root length (cm)

The effect of various treatments on root length of mungbean was found significant both at 45 DAS and 90 DAS (Table 4). The root length at 45 DAS ranged from 7.78 to 13.48 cm whereas at 90 DAS it ranged from 11.2 to 17.7 cm. Plants receiving P, Mo with *Rhizobium* inoculant had higher root length. At 45 DAS the root length increased by 73.2% in case of T8 over control, however, this increment declined to 58% at 90 DAS. The highest root length (17.7 cm) was found in treatment inoculated with *Rhizobium* integrated with P 60 kg ha^{-1} and Mo 1.5 kg ha^{-1} measured at 90 DAS, which was at par with T7. *Rhizobium* inoculant alone gave 9.8 % more root length over control at 90 DAS. These findings were in line with results of Bhuiyan et. al. (2008), who stated that plants that received *Rhizobium* inoculant together with P and Mo had longer roots. P 60 kg ha^{-1} and Mo 1.0 kg ha^{-1} had the longest roots (11.90 cm), which was 82% longer than the uninoculated control.

Total root nodules (per plant)

There were comparable differences between treatments and control in case of total number of root nodules at 45 DAS which is presented in Table 4. The total nodule number was significantly higher in RP60Mo1.5 over other treatments which was 51.78. The total nodules ranged from 20.99 to 51.78 per plant with overall mean value of 34.8. The findings of Dhakal et al. (2019) showed that the treatments that received phosphate, molybdenum, and *rhizobium* inoculation had the most nodules. In a similar vein, yield parameters such as stem diameter, plant height, canopy, and number of leaves increased as nodules increased. Singh et al. (2007) also reported similar findings, demonstrating that *rhizobium* inoculation with phosphate application improved cowpea growth characteristics.

Number of effective root nodules (per plant)

Applying varying amounts of P and Mo with *Rhizobium* inoculation had a substantial impact on the number of effective root nodules per plant at 45 DAS that ranged from 12.89 to 39.4 (Table 4). The control group had the fewest effective nodules (12.89). The effective nodule number per plant increased by the greatest amount (202.87%) in treatment T8 compared to control. Compared to the uninoculated control, plants that received *Rhizobium* inoculation alone or with varying amounts of P and Mo generated more nodules. Satter and Ahmed (1992) reported similar findings. According to Othman W. M. W. (1994), *rhizobium* inoculation also led to an improvement in growth parameters by improving the number of nodules, and nitrogen fixation. The fact that molybdenum is a vital nutrient for nitrate reductase, an enzyme that aids in the reduction of inorganic nitrate and ultimately produces more nodules, may be the cause of an increase in nodules (Ryan et al., 2012).

Dry weight of roots (grams per plant)

The effect of P, Mo and *Rhizobium* inoculant increased dry weight of root of mungbean compared to control significantly. The comparison of overall means for different treatments revealed that maximum oven dry root weight was noted in T8 (*Rhizobium* inoculated along with 60 kg ha^{-1} phosphorus and 1.5 kg ha^{-1} molybdenum) which was

153.77% higher over control treatment. The dry weight of roots ranged from 1.99 to 5.05 grams plant^{-1} (Table 4). Our findings were supported by Bhuiyan et. al. (2008), who observed that *Rhizobium* inoculant alone as well as fertilizers along with inoculum produced significantly higher root dry weight compared to control. They also reported a positively correlation between dry weight of root and total number of nodules.

Table 4. Effect of integration of phosphorus, molybdenum and rhizobium on root parameters of mungbean under the field conditions at Tikapur, 2023.

Sn	Treatments	Root length @45 DAS (cm)	Root length @90 DAS (cm)	Total root nodules @45 DAS (per plant)	No. of effective root nodules @45 DAS (per plant)	Dry weight of roots (grams)
1	Control	7.78^{e}	11.20^{f}	20.99^{f}	12.89^{e}	1.99^{g}
2	*Rhizobium*	8.43^{e}	12.30^{e}	25.40^{e}	14.10^{e}	2.25^{fg}
3	R+P20+Mo1	9.72^{d}	14.10^{d}	26.71^{e}	20.20^{d}	2.52^{ef}
4	R+P20+Mo1.5	11.20^{c}	14.90^{c}	29.78^{e}	21.30^{cd}	2.83^{e}
5	R+P40+Mo1	12.06^{bc}	16.10^{b}	35.67^{d}	24.40^{c}	3.31^{d}
6	R+P40+Mo1.5	12.02^{bc}	16.20^{b}	41.56^{c}	32.44^{b}	3.88^{c}
7	R+P60+Mo1	13.27^{ab}	17.60^{a}	46.46^{b}	33.89^{b}	4.41^{b}
8	R+P60+Mo1.5	13.48^{a}	17.70^{a}	51.78^{a}	39.40^{a}	5.05^{a}
	Mean	**10.99**	**15.04**	**34.80**	**24.85**	**3.28**
	CV%	**6.6**	**2.5**	**7.0**	**7.7**	**6.4**
	LSD $_{(0.05)}$	**1.272**	**0.656**	**4.266**	**3.351**	**0.367**

Note: LSD: Least Significant Difference, CV: Coefficient of Variation, means followed by the same letters within each column are not significantly different at 5% level of significance by DMRT.

CONCLUSION

The major objective of this study was to assess how applying *Rhizobium* inoculum in combination with varying phosphorus and molybdenum levels affected mungbean growth, yield, and root properties. In accord with our hypothesis, the highest seed yield was obtained from the treatment containing *Rhizobium* inoculum in integration with 60 kg ha^{-1} phosphorus and 1.5 kg ha^{-1} molybdenum. Combined phosphorus and molybdenum with Rhizobium inoculation significantly improved plant growth, yield traits, and root parameters. Likewise, the integrated application of P, Mo with *Rhizobium* inoculant had considerable effect on aboveground as well as total biomass. So, this paper supports the combined use of *Rhizobium*, molybdenum and phosphorus in adequate proportion preferably at 60 kg ha^{-1} phosphorus and 1.5 kg ha^{-1} molybdenum under agro-ecological conditions of Tikapur for better performance of mungbean, nonetheless, further testing across seasons, sites, and economic conditions is needed before broad use is recommended.

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