



## Research Article

## Open Access

## Influence of Inoculant on Nodulation and Vegetative Growth of Summer Mung Bean (*Vigna radiata* L) Cultivars

Mahfujur Rahman<sup>a</sup>, Md. Billal Hossain<sup>b</sup>, Nasira Akter<sup>c</sup>, Md. Ahidul Islam<sup>a</sup>, Md. Mustafizur Rahman<sup>a</sup>, Md. Sagirul Islam Majumder<sup>d\*</sup>

<sup>a</sup>Department of Agricultural Extension, Khamarbari Road, Farmgate, Dhaka 1215, Bangladesh.

<sup>b</sup>Research and Training Centre, Patuakhali Science and Technology University, Patuakhali 8660, Bangladesh.

<sup>c</sup>Regional Horticulture Research Station, Bangladesh Agricultural Research Institute, Bangladesh.

<sup>d</sup>Department of Soil Science, Patuakhali Science and Technology University, Patuakhali-8660, Bangladesh.

## Article info

**Received:** 02 October, 2026

**Accepted:** 25 October, 2026

**Published:** 27 October, 2026

**Available in online:**

27 October, 2026

**\*Corresponding author:**

 [sagirul.ssc@pstu.ac.bd](mailto:sagirul.ssc@pstu.ac.bd)



**Link to this article:**

<https://hnpublication.com/article/21/details>

## ABSTRACT

This field study assessed the effects of *Bradyrhizobium* inoculation on nodulation and vegetative growth of summer mungbean (*Vigna radiata* L.) cultivars at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. The experiment used a split-plot design with three replications, two cultivars [Binamoog-5 ( $V_1$ ) and Binamoog-7 ( $V_2$ )] as main-plot treatments, and six inoculation/nutrient treatments as subplots. The treatment combining inoculant, phosphorus, and potassium (I+PK) at Inoculant + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>) produced the highest overall nodule number at 40 DAS (20.17 mg plant<sup>-1</sup>), while Inoculants+ Phosphorus@25 kg P ha<sup>-1</sup> and Potassium@40 kg P ha<sup>-1</sup>+Cowdung@ 3 ton ha<sup>-1</sup> (I+PK+CD) produced the highest overall nodule dry weight at 40 DAS (51.97 mg plant<sup>-1</sup>) and plant height at harvest (98.74 cm). The I+PK+CD treatment also produced the highest overall shoot dry weight at harvest (17.07 g plant<sup>-1</sup>). Binamoog-7 generally had greater shoot dry weight at 10 and 40 DAS and at harvest, whereas Binamoog-5 had a higher mean at 20 DAS.

**Keywords:** Mungbean; *Bradyrhizobium*; integrated nutrient management; nodulation; plant growth; shoot dry weight.

## INTRODUCTION

Mungbean (*Vigna radiata* L.) is a short-duration grain legume widely cultivated in tropical and subtropical regions, particularly in Asia. It is valued for its dietary protein and its role in crop diversification and biological nitrogen fixation when an effective symbiosis is established (Silva Volpato et al., 2025). In Bangladesh, mungbean is an important pulse crop, especially in southern and coastal areas. The manuscript reports an estimated cultivated area of 0.20–0.25 million hectares, annual production of approximately 0.18–0.20 million tonnes, and average yield of 0.7–1.0 t ha<sup>-1</sup>; these figures should be checked against the original cited data before publication. Reported attainable yields under improved management are higher, indicating scope to improve productivity. However, nutrient-management limitations, input costs, access to quality inputs and suboptimal agronomic practices remain important production constraints (Hosen et al., 2023; Uddin et al., 2023; Nair et al., 2022).

Mungbean production in Bangladesh is constrained by soil-fertility limitations, unbalanced fertilizer use, variable native rhizobial

populations, limited access to quality seed and fertilizer, high input costs, pest and disease pressure, and insufficient extension support (Haque et al., 2014; Uddin et al., 2023; Kundu et al., 2025). The magnitude of these constraints can vary by production environment and management history. General statements about low organic matter, fertilizer imbalance or microbial damage should be supported by site-specific measurements or appropriate sources; this experiment did not report baseline soil properties, so such conditions cannot be assumed for the experimental field. Similar production constraints have been described for mungbean-growing regions elsewhere (Sequeros et al., 2021).

*Bradyrhizobium* inoculants may promote legume nodulation when compatible, viable strains are applied, while phosphorus and potassium support plant growth and organic amendments may affect nutrient availability and soil physical conditions. However, nodule number and nodule dry weight are indirect indicators only; they do not quantify the rate of biological nitrogen fixation. Likewise, plant height and shoot dry weight do not demonstrate grain-yield gains, changes in soil fertility, or economic benefits unless these outcomes are measured.

Previous work has examined rhizobial inoculation, phosphorus nutrition and integrated nutrient management in mungbean. The specific question addressed here is whether two cultivars, Binamoog-5 and Binamoog-7, differ in their nodulation and growth responses to six subplot treatments that include inoculation alone, mineral nutrients, boron, or cow dung under the reported field conditions at BINA, Mymensingh. The objectives were to compare (i) the main effects of cultivar and inoculation/nutrient treatment and (ii) their interaction for nodule number, nodule dry weight, plant height and shoot dry weight.

## MATERIALS AND METHODS

### Experimental Site and Design

The experiment was conducted at the research farm of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the summer season of March to May 2015. The experimental field was located at 24.75° North latitude and 90.50° East longitude at an altitude of 18 meter. The soil belongs to the Old Brahmaputra Alluvial under Agro-ecological Zone (AEZ) 9. The land topography was medium high, sandy loam textured with P<sup>H</sup> 6.7.

### Experimental Treatments

The main plots consisted of two mungbean cultivars:

- V<sub>1</sub>: Binamoog-5
- V<sub>2</sub>: Binamoog-7

The six inoculation and nutrient-management treatments were assigned to subplots within each cultivar main plot:

- I<sub>0</sub>: Control (no inoculation, no fertilizer)
- I<sub>1</sub>: *Bradyrhizobium* inoculation
- I<sub>2</sub>: I<sub>1</sub> + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>)
- I<sub>3</sub>: N (30 kg ha<sup>-1</sup>) + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>)
- I<sub>4</sub>: I<sub>1</sub> + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>) + Boron (2 kg ha<sup>-1</sup>)
- I<sub>5</sub>: I<sub>1</sub> + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>) + cow dung (3 t ha<sup>-1</sup>)

### Seed Inoculation and Crop Establishment

A *Bradyrhizobium* strain was obtained from the Soil Microbiology Laboratory at BINA. It was propagated under aseptic conditions in yeast extract mannitol broth. Seeds were individually inoculated by continuous mixing in the liquid culture before being sown. Seeds were sown in rows, with 30 cm between rows, at a depth of about 3 cm. Cropping management was done following standard agronomic practice, including irrigation, weeding, and pest control when warranted.

### Data Collection

Nodulation and growth parameters were recorded at 10, 20, and 40 days after sowing (DAS) and at harvest. Five plants were randomly chosen from each plot and uprooted carefully before being measured.

### Nodulation Parameters

**1) No. of nodules plant<sup>-1</sup>:** Manual counting after washing roots with water to remove soil.

**2) Nodule dry weight (mg plant<sup>-1</sup>):** Nodules were separated, then dried at 70°C in a drying oven until reach weight stability ( $\pm 0.0001$  g) and were weighed on an analytical balance.

### Growth Parameters

**1) Plant height (cm):** Height taken at 10, 20, 40 DAS, and harvest plant height is measured in cm from ground level to the tip of the main stem with the help of a measuring scale.

**2) Shoot dry weight:** Aboveground plant parts were harvested, dried at 70 until reaching constant weight, and recorded in g plant<sup>-1</sup> (10, 20 and 40 DAS and harvest).

### Sampling Procedure

In each plot, a 1 m<sup>2</sup> area was sampled, avoiding edges. The samples were sun-dried for two days after harvesting and processed to obtain the weight of ten dried plants.

### Sampling Procedure

For plant growth and biomass assessment, ten dried plants were selected within the 1 m<sup>2</sup> sampling area of each plot for measurement and destructive sampling, as appropriate for the parameters assessed.

### Statistical Analysis

The data were analyzed using MSTAT software. Analysis of variance (ANOVA) was performed according to the split-plot experimental design, with cultivar as the main-plot factor and nutrient-management treatment as the subplot factor. The appropriate main-plot error term was used to test the cultivar effect, whereas the subplot error term was used to test the nutrient-management treatment effect and the cultivar × treatment interaction. Differences among treatment means were compared using the least significant difference (LSD) test at the 5% level of probability ( $P \leq 0.05$ ). Statistical significance was determined based on the results of the ANOVA

## RESULTS AND DISCUSSIONS

### Total Number of Nodules

#### Effect of Inoculant

Inoculation and nutrient management had a significant effect on the number of nodules per plant at different growth stages (10, 20 and 40 DAS) (Table 1). The highest nodule number at 40 DAS was recorded in the treatment (I<sub>1</sub>+PK), which showed no statistically significant differences with I<sub>1</sub>+PK+B and I<sub>1</sub>+PK+CD treatments, and the lowest values were observed in the control (I<sub>0</sub>) and NPK treatments. The greater number of nodules due to inoculation can be attributed to the effective *Bradyrhizobium* strains introduced, which improved root infection and nodule initiation. Use of inoculation is essential in most soils where native rhizobial populations are low or ineffective to ensure that compatible and effective strains can form symbiosis with the roots of mungbean. I<sub>1</sub> + PK treatment performed better, indicating the vital role of phosphorus (P) and potassium (K) in nodulation. Phosphorus plays an important role in energy transfer (ATP synthesis), which is of course required during the formation of infection threads and nodules.

**Table 1.** Effect of inoculant on nodule number and dry weight of mungbean

| Inoculant         | Nodule number<br>(No. plant <sup>-1</sup> ) |           |           | Nodule dry weight<br>(mg plant <sup>-1</sup> ) |           |           |
|-------------------|---------------------------------------------|-----------|-----------|------------------------------------------------|-----------|-----------|
|                   | 10<br>DAS                                   | 20<br>DAS | 40<br>DAS | 10<br>DAS                                      | 20<br>DAS | 40<br>DAS |
| I <sub>0</sub>    | 3.75e                                       | 4.66c     | 5.76c     | 1.33d                                          | 3.43d     | 9.10d     |
| I <sub>1</sub>    | 9.33 a                                      | 9.50b     | 16.42b    | 4.91b                                          | 6.60c     | 31.50c    |
| I <sub>2</sub>    | 9.08ab                                      | 10.66a    | 20.17a    | 4.51c                                          | 7.18b     | 43.10b    |
| I <sub>3</sub>    | 4.66d                                       | 4.66c     | 6.63c     | 1.25d                                          | 1.48e     | 10.60d    |
| I <sub>4</sub>    | 8.83b                                       | 10.16ab   | 18.83a    | 4.89b                                          | 7.94a     | 45.00b    |
| I <sub>5</sub>    | 8.33c                                       | 9.91ab    | 19.00a    | 6.01a                                          | 8.28a     | 51.97a    |
| Significant level | **                                          | **        | **        | **                                             | **        | **        |
| CV (%)            | 5.36                                        | 8.06      | 7.40      | 4.67                                           | 5.75      | 5.31      |
| LSD0.05           | 0.4699                                      | 0.797     | 1.282     | 0.214                                          | 0.4007    | 2.025     |

I<sub>0</sub>: Control (no inoculation, no fertilizer); I<sub>1</sub>: *Bradyrhizobium* inoculation; I<sub>2</sub>: I<sub>1</sub> + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>); I<sub>3</sub>: N (30 kg ha<sup>-1</sup>) + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>); I<sub>4</sub>: I<sub>1</sub> + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>) + Boron (2 kg ha<sup>-1</sup>); I<sub>5</sub>: I<sub>1</sub> + P (25 kg ha<sup>-1</sup>) + K (40 kg ha<sup>-1</sup>) + cow dung (3 t ha<sup>-1</sup>).

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

It also encourages root growth, which increases the area for rhizobial infection. The role of potassium is in the indirect activation of osmotic regulation and enzyme stimulation, which are mechanisms that support nodule development. Higher or similar

nodulation of the former treatments I1+PK+B and I1+PK+CD may result from more beneficial effects added by boron and organic matter. Boron is involved in cell wall and membrane stabilization, both of which are important for successful infection and nodule differentiation. On the other hand, cow dung enhances soil organic matter, microbial activity, and nutrient availability, thereby making it favourable for rhizobial survival and colonisation. On the other hand, low nodulation in NPK-treated plots indicates that nitrogen supply from the soil is suppressing biological nitrogen fixation, since plants become less reliant on symbiotic nitrogen when extra nitrogen is readily available in the soil. This phenomenon is well known in legumes (Giller, 2001).

Similar results were obtained in previous studies where rhizobial or beneficial bacterial inoculation and phosphorus fertilization boosted nodulation, biological nitrogen fixation, nutrient acquisition, and growth of mungbean (Peoples et al., 2009; Ali et al., 2023; Alori et al., 2022).

#### Response of Cultivar

Cultivars alone had many highly significant differences (Table 2). At 10 and 20 DAS, Binamoog-5 produced more nodules than Binamoog-7, while at 40 DAS, Binamoog-7 showed higher nodulation than the other genotypes. This variation could represent some differences between cultivars in host–rhizobial compatibility and symbiotic efficiency. Quicker establishment of the symbiotic association is reflected in the greater early nodulation of Binamoog-5, while greater nodulation at 40 DAS observed in Binamoog-7 indicates sustained nodule development. Varietal differences in nodule number and  $N_2$ -fixation efficiency have similarly been reported for the mungbean (Rai & Prasad, 1984).

**Table 2.** Response of cultivars to the number and dry weight of nodules of mungbean

| Cultivar          | Nodule number<br>(No. plant <sup>-1</sup> ) |           |           | Nodule dry weight<br>(mg plant <sup>-1</sup> ) |           |           |
|-------------------|---------------------------------------------|-----------|-----------|------------------------------------------------|-----------|-----------|
|                   | 10<br>DAS                                   | 20<br>DAS | 40<br>DAS | 10<br>DAS                                      | 20<br>DAS | 40<br>DAS |
| V1                | 8.55a                                       | 9.58a     | 13.36b    | 3.90a                                          | 5.96a     | 29.95b    |
| V2                | 6.10b                                       | 6.94b     | 15.58a    | 3.73b                                          | 5.67b     | 33.80a    |
| Significant level | **                                          | **        | **        | **                                             | **        | **        |
| CV (%)            | 5.36                                        | 8.06      | 7.40      | 4.67                                           | 5.75      | 5.31      |
| LSD0.05           | 0.2713                                      | 0.4601    | 0.7400    | 0.1237                                         | 0.2314    | 1.169     |

V<sub>1</sub>: Binamoog-5; V<sub>2</sub>: Binamoog-7

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

#### Interaction Effect of Inoculant and Cultivar

The inoculant × cultivar interaction significantly affected the nodule number at each growth stage (Table 3). At 40 DAS, the highest value for nodule number was in the Binamoog-7 × I+PK+CD combination, and the lowest values were detected in the uninoculated treatments. The interaction effect indicates that inoculation and nutrient management response is contingent on rhizobial compatibility with some specific cultivars. The distinct effectiveness of integrated treatments (I1+PK and CD) indicates that the combination of biofertilizers with inorganic and organic nutrients improves the rhizosphere environment, resulting in higher symbiotic effectiveness independent of any genotypes.

#### Nodule Dry Weight Effect of Inoculant

Nodule dry weight was significantly influenced by inoculation and nutrient treatments at all growth stages (Table 1). The maximum nodule dry weight was found in I1+PK+CD, which decreased for I1+PK+B and I1+PK. Greater nodule dry weight reflects improved nodulation and symbiotic activity, while the positive effects of phosphorus are likely related to its involvement in energy

metabolism and biological nitrogen fixation. The increased efficacy in the I1+PK+CD treatment may also indicate better nutrient availability as well as the soil environment from conventional sources when combined with organic manure application. These findings are in agreement with those of Inthasan et al., 2023, who found that rhizobium combined with phosphorus fertilizer improved nodule dry weight and nitrogen fixation of mungbean.

#### Response of Cultivar

Cultivar effects on nodule dry weight varied considerably among cultivars (Table 2). In early stages (10 and 20 DAS), Binamoog-5 exhibited greater nodule dry weight, whereas at 40 DAS, it was the opposite with Binamoog-7. This tendency indicates that genotypes behave differently within the plant regarding nodule initiation and later-stage nodule outgrowth, likely owing to distinct physiological and biochemical properties (e.g., carbon allocation and nitrogen demand) between genotypes.

#### Interaction Effect

The interaction of inoculant & cultivar on nodule dry weight was significant (Table 3). The maximum nodule dry weight was determined in Binamoog-5 × I+PK+CD and the minimums in uninoculated treatments. This suggests that optimum symbiotic performance can only be realized if the efficient cultivar is paired with appropriate inoculation and nutrient management.

**Table 3.** Interaction effect of inoculant and cultivars on number and dry weight of nodules of mungbean.

| Inoculant<br>× Cultivar         | Number of nodules<br>(No. plant <sup>-1</sup> ) |           |           | Dry weight of nodule<br>(mg plant <sup>-1</sup> ) |           |           |
|---------------------------------|-------------------------------------------------|-----------|-----------|---------------------------------------------------|-----------|-----------|
|                                 | 10<br>DAS                                       | 20<br>DAS | 40<br>DAS | 10<br>DAS                                         | 20<br>DAS | 40<br>DAS |
| V <sub>1</sub> × I <sub>0</sub> | 4.50f                                           | 4.66g     | 5.33g     | 1.50e                                             | 3.43f     | 8.600g    |
| V <sub>1</sub> × I <sub>1</sub> | 10.00b                                          | 10.00c    | 14.50e    | 4.00d                                             | 6.96d     | 26.00e    |
| V <sub>1</sub> × I <sub>2</sub> | 11.50a                                          | 12.0ab    | 20.00bc   | 4.50c                                             | 7.08d     | 41.20c    |
| V <sub>1</sub> × I <sub>3</sub> | 6.00e                                           | 6.33f     | 5.66g     | 1.33ef                                            | 1.52g     | 9.00g     |
| V <sub>1</sub> × I <sub>4</sub> | 10.00b                                          | 13.00a    | 19.6bcd   | 5.73b                                             | 7.80bc    | 44.00bc   |
| V <sub>1</sub> × I <sub>5</sub> | 9.33b                                           | 11.50b    | 15.00e    | 6.35a                                             | 9.00a     | 50.93a    |
| V <sub>2</sub> × I <sub>0</sub> | 3.00g                                           | 4.66g     | 6.20fg    | 1.17f                                             | 3.44f     | 9.60fg    |
| V <sub>2</sub> × I <sub>1</sub> | 8.66c                                           | 9.00cd    | 18.30cd   | 5.83b                                             | 6.24e     | 37.00d    |
| V <sub>2</sub> × I <sub>2</sub> | 6.66e                                           | 9.33cd    | 20.33b    | 4.530c                                            | 7.28cd    | 45.00 b   |
| V <sub>2</sub> × I <sub>3</sub> | 3.33g                                           | 3.00h     | 7.60f     | 1.17f                                             | 1.44g     | 12.20f    |
| V <sub>2</sub> × I <sub>4</sub> | 7.66d                                           | 7.33ef    | 18.00d    | 4.06d                                             | 8.08 b    | 46.00b    |
| V <sub>2</sub> × I <sub>5</sub> | 7.330d                                          | 8.330de   | 23.00 a   | 5.67 b                                            | 7.560bcd  | 53.00a    |
| Significant level               | **                                              | **        | **        | **                                                | **        | **        |
| CV (%)                          | 5.36                                            | 8.06      | 7.40      | 4.67                                              | 5.75      | 5.31      |
| LSD0.05                         | 0.6645                                          | 1.127     | 1.813     | 0.3029                                            | 0.5667    | 2.864     |

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

#### Plant Height

The results at 10, 20, 40 DAS and at harvest, effect of inoculant, cultivars and their interaction have been presented in Table 4-6.

#### Effect of Inoculant

Overall, inoculation and nutrient management had a significant effect on plant height across all growth stages, including 10 (DAS), 20 (DAS), 40 (DAS), as well as at harvest. Among differentials (the 4 treatments of each genotype), all treated plots produced visibly taller plants than the uninoculated control (I<sub>0</sub>), which is consistent with our previous findings. The tallest plant height at harvest (98.74 cm) was also recorded in the I+PK+CD and the shortest in the control. The improvement in plant height that resulted from inoculation can be explained by the increased biological nitrogen fixation (BNF) triggered by *Bradyrhizobium*, which provides direct nitrogen to the plant. In plants, nitrogen is most notably found in chlorophyll and amino acids; therefore, nitrogen availability

stimulates cell division, elongation, and vegetative growth, making the plant taller.

**Table 4.** Effect of inoculant on height of mungbean plant

| Inoculant         | Plant height (cm) at different DAS |         |        |         |
|-------------------|------------------------------------|---------|--------|---------|
|                   | 10 DAS                             | 20 DAS  | 40 DAS | Harvest |
| I <sub>0</sub>    | 11.82b                             | 16.67 c | 56.51b | 83.80c  |
| I <sub>1</sub>    | 13.13a                             | 18.75a  | 65.61a | 91.76b  |
| I <sub>2</sub>    | 12.97a                             | 17.6 b  | 65.28a | 92.20b  |
| I <sub>3</sub>    | 13.78a                             | 19.24a  | 66.33a | 92.86b  |
| I <sub>4</sub>    | 13.57a                             | 18.89a  | 68.00a | 94.03b  |
| I <sub>5</sub>    | 13.18a                             | 19.01a  | 68.07a | 98.74a  |
| Significant level | **                                 | **      | **     | **      |
| CV (%)            | 4.81                               | 4.04    | 3.67   | 2.37    |
| LSD0.05           | 0.754                              | 0.889   | 2.857  | 2.615   |

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

The inferior performance of inoculation alone is further supported by the fact that all integrated treatments (I<sub>1</sub>+PK, I<sub>1</sub>+PK+B, and I<sub>1</sub>+PK+CD) exceeded this treatment in terms of plant growth. It is important for energy transfer (ATP production) and for root development, which enhances the efficiency of nutrient uptake. Sources of Potassium: Potassium contributes to the activation of numerous enzymes, stomatal regulation, and maintenance of water balance (utilized in osmosis to maintain turgor pressure), as well as assisting in stem elongation. However, the combination of organic manure with NPK fertilizer at I<sub>1</sub>+PK+CD yielded the highest plant height. It enhances soil structure, improves aeration of the soil, moisture retention, and microbial activity, which can enhance better rooting and availability of nutrients through barnyard manure. Nutrients are released slowly and continuously, thereby supplementing the plant during its entire growth cycle.

**Table 5.** Response of cultivar on the height of mungbean plant

| Cultivar          | Plant height (cm) at different DAS |         |         |         |
|-------------------|------------------------------------|---------|---------|---------|
|                   | 10 DAS                             | 20 DAS  | 40 DAS  | Harvest |
| V <sub>1</sub>    | 12.83 b                            | 17.90 b | 66.24a  | 91.22b  |
| V <sub>2</sub>    | 13.31a                             | 18.79a  | 63.69 b | 93.24a  |
| Significant level | *                                  | **      | **      | **      |
| CV (%)            | 4.81                               | 4.04    | 3.67    | 2.37    |
| LSD0.05           | 0.4350                             | 0.5131  | 1.650   | 1.510   |

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

NPK (inorganic chemical fertilizer) treatment resulting in a lower plant height than the integrated treatments may indicate that chemical fertilizer did not optimize biological activity, and nitrogen supply through effective symbiosis from biological fixation is limited. Additionally, input of external nitrogen can inhibit nodulation and thus limit the long-term availability of nitrogen (Giller, 2001). These findings are in agreement with the reports by Ali et al., 2023, Yasmi et al., 2016, and Inthasan et al., 2023. For example, Shankar et al., 2023 found that the combined application of rhizobial inoculants with inorganic fertilizers and organic amendments not only promotes plant height in legumes but also increases nutrient availability by 28% and active microbial population activity.

#### Response of Cultivar

At each stage of growth, significant differences ( $P \leq 0.05$ ) in plant height were observed between cultivars (Table 5). Binamoog-7 produced taller plants at 10, 20 DAS, and harvest than Binamoog-5; however, Binamoog-5 showed slightly higher plant height at 40 DAS. These differences can be due to genetic variation in growth

potential and nutrient use efficiency. Binamoog-7 likely has higher photosynthetic and nutrient capture capacity, both of which may contribute to its improved biomass accumulation efficiency. On the other hand, the relatively higher height of Binamoog-5 at 40 DAS suggests stage-specific growth advantages, possibly related to early vegetative development.

Genotypic variation in plant height and growth performance in mungbean has also been reported by Rane et al., 2021 and Trustinah, 2021, who noted that varietal differences significantly influence growth traits under different management practices.

#### Interaction Effect of Inoculant and Cultivar

The interaction between inoculant and cultivar had a significant effect on plant height at 10 and 20 DAS and at harvest, but was not significant at 40 DAS (Table 6). The tallest plants at harvest (101.6 cm) were recorded in the combination of Binamoog-7 × I<sub>1</sub>+PK+CD, while the lowest values were found in the uninoculated treatments. This interaction effect indicates that the response of plant height to inoculation and nutrient management is dependent on cultivar-specific characteristics. The superior performance of Binamoog-7 under integrated treatments suggests that this cultivar has a higher capacity to utilize nutrients and benefit from enhanced rhizobial activity. The absence of significant interaction at 40 DAS may indicate that environmental or physiological factors temporarily reduced treatment differences, but the effect became pronounced again at harvest due to cumulative nutrient uptake and growth.

On the whole, integrated nutrient management involving biofertilizer along with inorganic nutrients and organic amendments enhances the resultant effects of synergy to improve nutritional availability, enhance root development and physiological processes, leading to improved plant height.

**Table 6.** Interaction effect of inoculant and cultivar on height of mungbean plant

| Inoculant × Cultivar            | Plant height (cm) at different DAS |          |       |         |
|---------------------------------|------------------------------------|----------|-------|---------|
|                                 | 10 DAS                             | 20 DAS   | 40DAS | Harvest |
| V <sub>1</sub> × I <sub>0</sub> | 10.95d                             | 15.50d   | 59.06 | 84.60d  |
| V <sub>1</sub> × I <sub>1</sub> | 13.60abc                           | 18.56ab  | 68.36 | 92.47b  |
| V <sub>1</sub> × I <sub>2</sub> | 12.55c                             | 16.98c   | 67.10 | 90.40c  |
| V <sub>1</sub> × I <sub>3</sub> | 13.81ab                            | 19.29ab  | 66.99 | 92.33b  |
| V <sub>1</sub> × I <sub>4</sub> | 13.24abc                           | 18.11bc  | 67.22 | 91.67c  |
| V <sub>1</sub> × I <sub>5</sub> | 12.85abc                           | 19.24ab  | 68.72 | 95.87b  |
| V <sub>2</sub> × I <sub>0</sub> | 12.70abc                           | 17.85bc  | 53.96 | 83.00d  |
| V <sub>2</sub> × I <sub>1</sub> | 12.65bc                            | 18.94ab  | 62.86 | 91.06c  |
| V <sub>2</sub> × I <sub>2</sub> | 13.38abc                           | 18.29abc | 63.45 | 94.00b  |
| V <sub>2</sub> × I <sub>3</sub> | 13.75abc                           | 19.19ab  | 65.68 | 93.40b  |
| V <sub>2</sub> × I <sub>4</sub> | 13.90a                             | 19.67a   | 68.78 | 96.40b  |
| V <sub>2</sub> × I <sub>5</sub> | 13.50abc                           | 18.78ab  | 67.42 | 101.6a  |
| Significant                     | **                                 | **       | NS    | **      |
| CV (%)                          | 4.81                               | 4.04     | 3.67  | 2.37    |
| LSD0.05                         | 1.066                              | 1.257    | 4.041 | 3.699   |

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

#### Shoot dry weight

The data on the effect of inoculant, cultivar and their interaction on shoot dry weight of mungbean at 10, 20 and 40 DAS have been presented in Table 4- 6.

#### Effect of Inoculant

Shoot dry weight of mungbean was significantly influenced by inoculation and nutrient management at all growth stages (10, 20, 40 DAS and at harvest) (Table 7). All treated plots produced higher shoot biomass than the uninoculated control (I<sub>0</sub>), with the

highest shoot dry weight at harvest (17.07 g plant<sup>-1</sup>) recorded in the I1+PK+CD treatment. The lowest values were consistently observed in the control. The increase in shoot dry weight due to inoculation can be explained by enhanced biological nitrogen fixation (BNF) through *Bradyrhizobium*, which improves nitrogen availability to the plant. Nitrogen is an important nutrient and has been implicated in protein synthesis, chlorophyll formation, enzymatic activity, photosynthesis, and biomass accumulation.

**Table 7.** Effect of inoculant on dry weight of mungbean shoots

| Inoculant         | Dry weight of Shoot at different DAS (g plant <sup>-1</sup> ) |         |        |         |
|-------------------|---------------------------------------------------------------|---------|--------|---------|
|                   | 10 DAS                                                        | 20 DAS  | 40 DAS | Harvest |
| I <sub>0</sub>    | 60.50d                                                        | 118.6 c | 6.15d  | 12.77c  |
| I <sub>1</sub>    | 61.80c                                                        | 151.4b  | 8.24c  | 15.70b  |
| I <sub>2</sub>    | 64.50b                                                        | 154.7b  | 9.36a  | 16.40ab |
| I <sub>3</sub>    | 65.00b                                                        | 156.3b  | 8.39c  | 15.94b  |
| I <sub>4</sub>    | 65.00ab                                                       | 158.1b  | 9.46a  | 15.86b  |
| I <sub>5</sub>    | 66.00a                                                        | 173.0a  | 8.94b  | 17.07a  |
| Significant level | **                                                            | **      | **     | **      |
| CV (%)            | 4.25                                                          | 3.49    | 3.73   | 5.04    |
| LSD0.05           | 0.9579                                                        | 6.361   | 0.3767 | 0.9436  |

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

The significantly better performance of combined treatments (I1+PK, I1+PK+B, and I1+PK+CD) vs inoculation per se suggested that balanced nutrient supply also increased plant growth. Introduction: Phosphorus is an essential nutrient element for plant growth and development, contributing to energy transfer (ATP synthesis), which is required in biosynthesis and biomass assimilation. Potassium plays vital roles in enzyme activation, modulation of stomatal aperture, and translocation of assimilates, resulting in effective biomass production as one of the three principal macronutrients.

**Table 8.** Response of cultivars to dry weight of mungbean shoots

| Cultivar          | Dry weight of Shoot at different DAS (g plant <sup>-1</sup> ) |         |        |         |
|-------------------|---------------------------------------------------------------|---------|--------|---------|
|                   | 10 DAS                                                        | 20 DAS  | 40 DAS | Harvest |
| V1                | 62.27 b                                                       | 154.0a  | 8.287b | 15.05b  |
| V2                | 65.33a                                                        | 150.00b | 8.558a | 16.19a  |
| Significant level | **                                                            | *       | **     | **      |
| CV (%)            | 4.25                                                          | 3.49    | 3.73   | 5.04    |
| LSD0.05           | 0.5530                                                        | 3.675   | 0.2175 | 0.5448  |

\*\* = Significance at 1% and \* = Significance at 5% level of probability.

The maximum shoot dry weight in the I1+PK+CD treatment indicates an advantage of extra cow dung. Organic manure increases soil organic matter content, microbial biomass, and nutrient mineralization, thus relatively improving the availability of nutrients and their uptake. Soil physical properties, including water-holding capacity and aeration, which favor the growth of roots as well as overall plant health, are also improved. The less effective NPK treatment compared to the integrated treatments indicates that chemical fertilizers alone cannot maintain optimal microbial performance and soil health for sustainable productivity (Almendros et al. Additionally, the dependence on artificial nitrogen could reduce the host plant's reliance on symbiotic nitrogen fixation and restrict biomass production.

These results are consistent with those of Rane et al., (2021) and Yasmi et al., (2016), indicating that the use of beneficial microbial inoculation and integrated nutrient management increased

biomass production, attributes, and growth of mungbean due to higher uptake of nutrients and soil improvement.

#### Response of Cultivar

At all growth stages, mean shoot dry weight differed substantially ( $p < 0.01$ ) among cultivars (Table 8). At 10 DAS, 40 DAS, and at harvest, Binamoog-7 recorded significantly higher shoot dry weight than Binamoog-5, but values for Binamoog-5 were superior to those of Binamoog-7, except at 20 DAS. Genotypic differences in growth rate, photosynthetic efficiency, and nutrient use efficiency may explain some of the variation. It was concluded that the higher biomass production in Binamoog-7 indicates a better capacity for accumulation of assimilates as well as a better utilization of available nutrients. Binamoog-5 performance was comparatively higher at 20 DAS, suggesting an advantage for faster initial establishment regardless of less development efficiency (higher RHP and CE) than other genotypes.

Differential Biomass Accumulation among Genotypes Singh et al. (2021) and Rane et al. This is in agreement with the previously reported observations by Rane et al., (2021), who emphasized the role of varietal selection in maximizing growth and productivity of mungbean.

**Table 9.** Interaction effect of inoculant and cultivars on shoot dry weight of mungbean

| Inoculant × Cultivar | Dry weight of Shoot at different DAS (g plant <sup>-1</sup> ) |          |         |          |
|----------------------|---------------------------------------------------------------|----------|---------|----------|
|                      | 10 DAS                                                        | 20 DAS   | 40DAS   | Harvest  |
| V1 × I <sub>0</sub>  | 59.00g                                                        | 119.8e   | 5.560l  | 12.47e   |
| V1 × I <sub>1</sub>  | 60.60f                                                        | 156.8bc  | 8.28efg | 15.87bcd |
| V1 × I <sub>2</sub>  | 62.00ef                                                       | 161.2 b  | 9.41ab  | 14.90d   |
| V1 × I <sub>3</sub>  | 64.00cd                                                       | 158.5 b  | 8.00g   | 14.67d   |
| V1×I <sub>4</sub>    | 63.00 de                                                      | 155.0bcd | 9.78a   | 15.60cd  |
| V1×I <sub>5</sub>    | 65.00 bc                                                      | 172.7 a  | 8.69def | 16.80abc |
| V2 × I <sub>0</sub>  | 62.00ef                                                       | 117.4 e  | 6.73h   | 13.06e   |
| V2 × I <sub>1</sub>  | 63.00 de                                                      | 146.0 d  | 8.20fg  | 15.53cd  |
| V2 × I <sub>2</sub>  | 67.00a                                                        | 148.2 cd | 9.31abc | 17.90a   |
| V2 × I <sub>3</sub>  | 66.00 ab                                                      | 154.1bcd | 8.78cde | 17.20ab  |
| V2 × I <sub>4</sub>  | 67.00a                                                        | 161.2 b  | 9.15bcd | 16.13bcd |
| V2× I <sub>5</sub>   | 67.00a                                                        | 173.3a   | 9.18bcd | 17.34ab  |
| Significant          | **                                                            | *        | **      | **       |
| CV (%)               | 4.25                                                          | 3.49     | 3.73    | 5.04     |
| LSD0.05              | 1.355                                                         | 8.995    | 0.5328  | 1.334    |

\*\* = Significance at 1% and \* = Significance at 5% level of probability

#### Interaction Effect of Inoculant and Cultivar

There was a significant interaction between inoculant and cultivar for shoot dry weight at all growth stages (Table 9). The combination of Binamoog-7 × I1 + PK produced the highest shoot dry weight at harvest (17.90 g plant<sup>-1</sup>), followed by Binamoog-7 × I1 + PK + CD, whereas the lowest values were obtained for unimproved control combinations. This interaction effect indicates that the response to nutrient management depends on the genetic potential of the cultivar and its compatibility with rhizobial inoculation. The superior performance of Binamoog-7 under integrated treatments suggests that this cultivar has a higher capacity to utilize the benefits of improved nutrient availability and enhanced symbiotic activity. The increased biomass under combined treatments can be explained by synergistic effects of biofertilizer, inorganic nutrients, and organic manure, which together improve:

- nitrogen fixation
- nutrient uptake

- photosynthetic efficiency
- assimilate partitioning

These factors ultimately result in greater accumulation of shoot dry matter.

The majority of the measured parameters showed significance at the 1% level ( $P \leq 0.01$ ). This may be attributed to the relatively low experimental error as indicated by low coefficients of variation (CV values ranged from approximately 3–8%), suggesting good precision of the experiment. In addition, the treatments imposed in this study involved strong contrasts, particularly between uninoculated control and integrated nutrient management treatments (inoculant combined with PK and cow dung), which resulted in pronounced differences in nodulation and growth parameters. Legume crops such as mungbean are highly responsive to rhizobial inoculation and nutrient management, especially under conditions where native rhizobial populations are limited. Therefore, the observed high level of statistical significance is biologically reasonable and consistent with the magnitude of treatment effects (Inthasan et al., 2023; Khan et al., 2021; Rane et al., 2021).

## CONCLUSIONS

This field experiment compared two summer mungbean cultivars and six inoculation/nutrient-management treatments for nodulation, plant height and shoot dry weight. In the reported means, I1+PK had the highest overall nodule number at 40 DAS (20.17 nodules plant<sup>-1</sup>), whereas I1+PK+CD had the highest overall nodule dry weight at 40 DAS (51.97 mg plant<sup>-1</sup>), plant height at harvest (98.74 cm), and shoot dry weight at harvest (17.07 g plant<sup>-1</sup>). Binamoog-7 had greater shoot dry weight at 10 and 40 DAS and at harvest; Binamoog-5 had the higher mean at 20 DAS. These conclusions are limited to the variables measured. The study did not measure nitrogen-fixation rate, grain yield, changes in soil fertility or economic return, so no direct claims about those outcomes can be made. Further trials should include direct nitrogen-fixation measurements, grain yield and yield components, soil properties before and after the experiment, and an economic assessment.

Under the conditions of this experiment, I1+PK+CD was associated with the highest reported overall nodule dry weight, plant height at harvest and shoot dry weight at harvest. These results support further evaluation of the treatment, but do not establish increased grain yield, improved soil fertility, reduced dependence on chemical nitrogen, or economic sustainability. Recommendations for wider use should await replicated trials across seasons and sites with complete soil, yield and economic measurements.

## REFERENCES

- Ali, Q., Shabaan, M., Ashraf, S., Kamran, M., Zulfiqar, U., Ahmad, M., Zahir, Z. A., Sarwar, M. J., Iqbal, R., Ali, B., Ali, M. A., Elshikh, M. S., & Arslan, M. (2023). Comparative efficacy of different salt-tolerant rhizobial inoculants in improving growth and productivity of *Vigna radiata* L. under salt stress. *Scientific Reports*, 13, 17442. <https://doi.org/10.1038/s41598-023-44433-8>
- Alori, E. T., et al. (2022). Coupling phosphate-solubilizing bacteria (PSB) with inorganic phosphorus fertilizer improves mungbean (*Vigna radiata*) phosphorus acquisition, nitrogen fixation, and yield in alkaline-calcareous soil. *Heliyon*, 8(3), e09081. <https://doi.org/10.1016/j.heliyon.2022.e09081>
- Giller, K. E. (2001). *Nitrogen fixation in tropical cropping systems* (2nd ed.). CABI.
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons.
- Haque, M., Miah, M. M., Ali, A., & Luna, A. (2014). Adoption of mungbean technologies and technical efficiency of mungbean (*Vigna radiata*) farmers in selected areas of Bangladesh. *Bangladesh Journal of Agricultural Research*, 39(1), 113–125. <https://doi.org/10.3329/bjar.v39i1.20149>
- Hosen, M., Sarker, S., Hossain, H., Roy, M., Hasanuzzaman, M., & Rahman, A. (2023). Yield of mungbean as influenced by planting geometry and integrated fertilizer management. *Bangladesh Agronomy Journal*, 25(2), 97–107. <https://doi.org/10.3329/baj.v25i2.65953>
- Inthasan, J., Santasup, C., & Dechjirathanasiri, C. (2023). Co-rhizobium inoculation and phosphate fertilizer management on nitrogen fixation and yield of mungbean. *International Journal of Agricultural Technology*, 19(2), 447–458. <https://li04.tcithaijo.org/index.php/IJAT/article/view/9484>
- Khan, M. S., et al. (2021). Comparative effect of inoculation of phosphorus-solubilizing bacteria and phosphorus as sustainable fertilizer on yield and quality of mung bean (*Vigna radiata* L.). *Sustainability*, 13, 11004. <https://doi.org/10.3390/su131911004>
- Kundu, N. D., Uddin, M. T., Sarkar, M. M. A., Toma, N. I., Rashid, M. M., & Ahmed, S. (2025). Profitability and value addition of mungbean production in Barishal and Patuakhali districts of Bangladesh. *Bangladesh Journal of Nuclear Agriculture*, 38(2), 137–149. <https://doi.org/10.3329/bjnag.v38i2.79584>
- Nair, R., Win, M. M., Myint, T., Alam, A. K. M. M., Malik, S. R., Schreinemachers, P., & Chaudhari, S. (2022). *Improved mungbean harvesting and seed production systems for Bangladesh, Myanmar and Pakistan: Final report*. Australian Centre for international Agricultural Research.
- Peoples, M. B., Brockwell, J., Herridge, D. F., Rochester, I. J., Alves, B. J. R., Urquiaga, S., Boddey, R. M., Dakora, F. D., Bhattarai, S., Maskey, S. L., Sampet, C., Rerkasem, B., Khan, D. F., Hauggaard-Nielsen, H., & Jensen, E. S. (2009). The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. *Symbiosis*, 48, 1–17. <https://doi.org/10.1007/BF03179980>
- Rai, R., & Prasad, V. (1984). Studies on growth and symbiotic nitrogen fixation of *Rhizobium* of *Vigna radiata* under stress conditions. *The Journal of Agricultural Science*, 102(2), 399–404. <https://doi.org/10.1017/S0021859600042738>
- Rane, J., Raina, S. K., Govindasamy, V., Bindumadhava, H., Hanjagi, P., Giri, R., Jangid, K. K., Kumar, M., & Nair, R. M. (2021). Use of phenomics for differentiation of mungbean (*Vigna radiata* L. Wilczek) genotypes varying in growth rates per unit of water. *Frontiers in Plant Science*, 12, 692564. <https://doi.org/10.3389/fpls.2021.692564>
- Sequeros, T., Ochieng, J., Schreinemachers, P., et al. (2021). Mungbean in Southeast Asia and East Africa: Varieties, practices and constraints. *Agriculture & Food Security*, 10, 2. <https://doi.org/10.1186/s40066-020-00273-7>
- Silva Volpato, N. D., Gómez, F. M., Giménez, V. D., et al. (2025). A global dataset on mungbean for managing seed yield and quality. *Scientific Data*, 12, 658. <https://doi.org/10.1038/s41597-025-05016-6>
- Singh, V. S., Bell, M. B., & Rane, J. (2021). Genotypic variability in architectural development of mungbean (*Vigna radiata* L.) root systems and physiological relationships with shoot growth dynamics. *Frontiers in Plant Science*,

- 12,725915. <https://doi.org/10.3389/fpls.2021.725915>
- Trustinah. (2021). Genetic parameters for determining useful parents in mungbean (*Vigna radiata* (L.) Wilczek) breeding for early maturity, small seed size, and high seed yield. *Scientifica*, 2021, 3910073. <https://doi.org/10.1155/2021/3910073>
- Uddin, M., Roy, S., & Hoq, M. (2023). Farmers' perception and factors affecting adoption of mungbean in Patuakhali district of Bangladesh. *Bangladesh Journal of Agricultural Research*, 46(4), 385–396. <https://doi.org/10.3329/bjar.v46i4.64693>
- Yasmi, K., Aziz, M. A., & Kashem, M. A. (2016). Effect of cowdung, NPK and *Rhizobium* inocula on growth and soil status of summer mungbean (*Vigna radiata*) in acid soil. *International Journal of Plant & Soil Science*, 12(5), 1–7. <https://doi.org/10.9734/IJPSS/2016/27499>

**How to cite:** Rahman, M., Hossain, M.B., Akter, N., Islam, M.A., Rahman, M.M. and Majumder, M.S.I. 2026. Influence of Inoculant on Nodulation and Vegetative Growth of Summer Mung Bean (*Vigna radiata* L) Cultivars, Journal of Contemporary Agriculture and Bioscience 3(2), 31-37.

