



OPEN ACCESS

EDITED BY

Fabio Gresta,
University of Messina, Italy

REVIEWED BY

Sarita Kudi,
Agriculture University, Jodhpur, India
Om Prakash Aishwath,
National Research Centre on Seed Spices
(ICAR), India

*CORRESPONDENCE

Ram Prasad Khanal

✉ agrilram616@gmail.com

Prakash Ghimire

✉ prakashkoid@gmail.com

RECEIVED 15 July 2025

ACCEPTED 22 September 2025

PUBLISHED 15 October 2025

CITATION

Khanal RP, Dahal KR, Amgain LP, Neupane S,
Adhikari N, Gautam I and Ghimire P (2025)
Effect of nutrient sources on growth
and yield performance of mung bean
(*Vigna radiata* L.) in western Terai, Nepal.
Front. Agron. 7:1666701.
doi: 10.3389/fagro.2025.1666701

COPYRIGHT

© 2025 Khanal, Dahal, Amgain, Neupane,
Adhikari, Gautam and Ghimire. This is an open-
access article distributed under the terms of
the [Creative Commons Attribution License
\(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction
in other forums is permitted, provided the
original author(s) and the copyright owner(s)
are credited and that the original publication
in this journal is cited, in accordance with
accepted academic practice. No use,
distribution or reproduction is permitted
which does not comply with these terms.

Effect of nutrient sources on growth and yield performance of mung bean (*Vigna radiata* L.) in western Terai, Nepal

Ram Prasad Khanal^{1*}, Khem Raj Dahal¹, Lal Prasad Amgain¹,
Samir Neupane¹, Nirjala Adhikari¹, Ishan Gautam²
and Prakash Ghimire^{2*}

¹Post-graduate Program, Institute of Agriculture and Animal Science, Tribhuvan University, Kathmandu, Nepal, ²Institute of Agriculture and Animal Science, Tribhuvan University, Bhairahawa, Nepal

Mung bean (*Vigna radiata* L.) is a multipurpose pulse crop, mostly cultivated as a catch crop in fallow land during the spring season between wheat and rice crops. An experiment entitled “Effect of nutrient sources on growth and yield performance of mung bean at western terai, Nepal” was conducted at the Agronomy Research Farm of Paklihawa Campus during April to July 2023 to improve the production of mung bean with the application of organic and inorganic nutrient sources. The field was laid out in a Randomized Complete Block Design with 8 treatments and 4 replications. Treatment structure consists of Control, Recommended Doses of Nitrogen (RDN) from Prilled Urea (PU), RDN + 25% from PU, RDN-25% from PU, RDN from Farm yard manure, RDN from Poultry manure, Nano urea, and Rhizobium inoculation. Results shows that poultry manure applied plots exhibited better growth and yield performance with higher shoot length (85.54cm), number of leaf plant⁻¹ (13.72), leaf area index (2.26), crop growth rate (0.9910 g day⁻¹), average number of branches plant⁻¹ (2.9), number of pods plant⁻¹ (22.38), pod length (8.08cm), average number of seeds pod⁻¹ (7.22), thousand seeds weight (57.40 g), seed yield (1028 Kg ha⁻¹), stalk yield (1650 Kg ha⁻¹), biological yield (2678 Kg ha⁻¹) and harvest index (38.38%) followed by Farm yard manure (FYM). FYM applied plots had better root length (23.66cm) and number of nodules (13.05). Organic nutrient application is better for short-duration crops like mung beans. Growth and yield increased with an increase in the dose of prilled urea, and hence, the actual yield of mung beans can be increased by increasing the dose of prilled urea above the government recommendation. For precise recommendations in a larger domain, a multi-seasonal and multi-location research is suggested.

KEYWORDS

farmyard manure, mung bean, poultry manure, prilled urea, rhizobium inoculation

1 Introduction

Mung bean (*Vigna radiata* L.), belonging to the family Fabaceae, is cultivated globally for its high nutritional and economic value (Pathak et al., 2023; Chaurasia et al., 2024). It covers over 7.3 million hectares with a total production of 5.3 million tons and an average productivity of 0.72 t ha⁻¹. In a developing nation like Nepal, food self-sufficiency is essential (Chaurasia et al., 2020). The FAO characterized mung beans as a “future smart food” due to their potential to enhance nutrition and food self-sufficiency, aiding Asian countries in combating hunger. In Nepal, mung bean is cultivated during both the spring and rainy seasons. It is gaining popularity as a spring crop in the Terai and inner Terai, serving as an excellent catch crop between winter crops like wheat, potato, and monsoon-season rice (Ghimirey et al., 2024a). Integrating mung bean into a cereal-based cropping system improves soil fertility by adding organic matter and fixing nitrogen biologically, i.e., 30–37 kg ha⁻¹ of nitrogen, equivalent to 43–55 kg of urea fertilizer. This addresses the high nitrogen demand of Nepal’s cereal-based farming system. A 30–40% increase in rice yield has been reported on land planted with spring mung bean (CSISA-NP, 2019). Pulse crops are an important component of the Nepalese cropping system with an area, production, and productivity of 340,692 ha, 404,210 Mt, and 1.1 Mt ha⁻¹ (MOALD, 2021). Mung bean (*Vigna radiata*) is an important and emerging spring season pulse crop; however, its estimated area (12,000 ha, i.e., 4% of total pulse crop area), production (4,500 Mt), and productivity (0.5 Mt ha⁻¹) are still low in Nepal (Joshi et al., 1998).

A sufficient supply of nitrogen is necessary for the normal growth and yield of mung bean. Nitrogen plays a vital role in the synthesis of proteins, enzymes, DNA, and RNA, components necessary for a cell’s initial formation, continued growth, and the maintenance of other plant tissues. Therefore, deficiency of nitrogen in the soil naturally results in a decrease in the biochemical processes responsible for catalyzing plant metabolism and cell division, consequently reducing crop leaf area, photosynthetic assimilation, and seed growth (Sadeghipour et al., 2010). Nutrient management is a critical factor influencing mung bean growth, development, and productivity (Asaduzzaman et al., 2008). Both chemical and organic nutrient sources significantly affected the majority of the growth parameters of mung bean (Uddin et al., 2009). Cost-effective fertilizers can be used to supply the vital nutrients, such as phosphorus and nitrogen, in mung bean production (Barakzai et al., 2020).

Nitrogen is the most important yield-limiting plant nutrient, among all the essential plant nutrients, available in all forms of organic manures and nitrogenous fertilizers. Urea is the main source of nitrogenous fertilizer in South Asian countries, including Nepal. The usual technique for applying urea is a very inefficient practice, with 60–70% of the N applied being lost, and contributes to greenhouse gas (GHG) emissions and water pollution. Despite various measures available for improvement of N management, and a number of organizations have been trying to implement alternative methods, nitrogen use efficiency (NUE) is

still very low in rice-based system (Baral et al., 2020). Among the different physical forms of urea, prilled urea (~ 1.65 mm), a white crystalline solid, is mostly used in Nepal. It is smaller in size and is more readily soluble in water, hence prone to losses to the environment through volatilization, denitrification and leaching. Several alternative formulations of urea have been developed to enhance the performance of prilled urea. Similarly, a new nitrogen fertilizer known as nano urea has emerged, containing nitrogen particles at the nanometer scale, which makes it suitable for foliar application to enhance nitrogen use efficiency (NUE) and minimize environmental losses.

Different from conventional urea, nano urea is absorbed more efficiently because of its ultra-small particle size, which enhances penetration and utilization at leaf surfaces (Raliya et al., 2017). Research indicates that nano urea differs from prilled urea in that it can be used in smaller quantities without affecting crop yields. Moreover, its use decreases nitrogen losses due to leaching, volatilization, and denitrification (Prasad et al., 2021). From an environmental standpoint, using nano urea supports the reduction of greenhouse gas emissions as well as water pollution linked with over-fertilization of nitrogen. This makes it a novel technology for agricultural sustainability (ICAR, 2021). The foliar application of nano urea during critical crop growth stages enhances flower retention, pod setting, and seed formation (Kumar et al., 2021; Saitheja et al., 2022). The improved efficiency is due to nano urea’s high surface area and smart nutrient delivery system, which ensures controlled nutrient release and better absorption. As a result, the yield attributes such as higher flower retention rates, higher flower to pod conversion ratios, and maximum mung bean seed formation rates are positively correlated with the nano urea nutrient supply (Qureshi et al., 2018).

Farmyard manure (FYM) is recognized to play a significant role in increasing the soil’s fertility and yield capacity by enhancing the soil’s physical, chemical, and biological properties, as well as boosting plant nutrition (Ghimirey et al., 2025). FYM provides a favorable soil environment and supplies more nutrients that resulting in better plant growth and improved soil’s physico-chemical and organic properties (Mishra et al., 2016). Poultry manure can be efficiently used for the crops after proper composting to save the nutrients (Amanullah et al., 2022). Compared with other fertilizers, plants cultivated using poultry manure tend to be taller. This may be due to the higher concentration of nutrients and minerals that are more available and accessible in poultry manure, which enhances nutrient uptake, thus faster growth and development of the plants (Enujeke, 2013). Incorporating organic inputs such as farmyard manure (FYM) and poultry manure into soil fertility practices not only boosts crop production but also supports sustainable agriculture by minimizing reliance on chemical fertilizers and promoting long-term soil health. The biological nitrogen fixation (BNF) technique serves as a cost-effective alternative to chemical fertilizers, particularly in boosting the production of grain legumes (Ghimirey et al., 2024b). Khan et al. (2017) reported that rhizobium inoculation increased the nodules count per plant and seed yield. Rhizobium inoculation of mung bean improved dry matter production, photosynthetic

rate, leaf area, and plant height (Mehboob et al., 2012). Providing crops with the right nutrients at the right time is crucial for ensuring optimal growth and high yields.

In Nepal, the yield of mung beans is significantly low (0.5 t ha^{-1}) compared to the potential yield of cultivars, which is 1.04 t ha^{-1} (AITC, 2020). This yield gap is primarily due to poor nutrient management practices employed by farmers. Consequently, 5000 tons of imports are required annually to meet 90% of the current demand (CSISA-NP, 2019). Insufficient research and knowledge regarding proper nutrient management further contribute to the larger yield gap and inadequate production for domestic consumption. Mung bean requires essential nutrients for metabolic processes and to initiate nodulation and nitrogen fixation. Nevertheless, many Nepalese farmers do not practice proper nutrient management. The application of a starter dose of nitrogen fertilizer meets the early nitrogen needs of the plant before biological nitrogen fixation begins, thereby improving crop growth, yield, and quality (Jat et al., 2012). Rhizobium inoculation further promotes mung bean growth and yield (Muthu et al., 2018). To encourage the commercial cultivation of mung beans on fallow land in the Western Terai, it is essential to identify effective strategies that boost crop productivity.

Spring mung bean in rice-based cropping systems is gaining popularity in recent years. It was estimated that about 400 thousand ha of land remain fallow for a period of 90 to 100 days (Nityananda et al., 2006), after harvest of winter wheat and before transplanting of summer rice. Mung beans can be successfully integrated as a catch or filler crop to utilize the short fallow period. It improves soil fertility and rice crop productivity by 25%, and thus provides additional income and food security to the small farmers (Gharti et al., 2014). Being a legume crop, it also improves soil health through atmospheric nitrogen fixation and addition of green biomass, which is ultimately beneficial to the succeeding crops under a rice-based cropping system. The requirement of field crops for major nutrients like nitrogen (N) should be quantified by testing under different levels of nitrogenous fertilizer to attain the target yield at a particular location.

Nitrogen management approaches that include the '4 Rs', i.e., apply the right nutrient source, at the right rate, at the right time, and in the right place, could be a promising agronomic solution that optimizes N-uptake and improves the NUE under rice-based cropping system in Nepal. This study focuses on evaluating the impact of selecting appropriate nutrient sources and optimizing their early-stage application to significantly improve the growth, yield, and profitability of mung bean cultivation. Despite the growing recognition of mung beans as a valuable legume in the Western Terai region of Nepal, nutrient management practices remain suboptimal, often resulting in reduced yield and profitability. The main hypothesis of our study was that different nutrient sources may exert varying levels of influence on mung bean growth and yield. Therefore, the authors' motivation for conducting this study was to determine which nutrient inputs most effectively enhance the growth parameters, yield components, and overall productivity of mung beans to support sustainable legume production in the region.

2 Materials and methods

2.1 Description of the experimental site

The research was carried out at the Paklihawa Campus's Agronomy Research Farm in Rupandehi district from April to July 2023. Geographically, the experimental site is located at an altitude of 87 meters above mean sea level in the Terai belt of the Lumbini province and 265 km west of Kathmandu, the capital city of Nepal. The coordinates of the site are $27^{\circ} 28' 48.24''$ N latitude and $83^{\circ} 26' 50.18''$ E longitude. To examine the chemical properties of the experimental soil, soil samples were randomly obtained using a tube auger from 20 cm deep in a Z-shaped pattern from various sites. To create a composite sample, the soil samples were subsequently air-dried, ground, and sieved using a 2 mm sieve. Finally, the soil sample was taken to the Soil Science Laboratory of the Agricultural Technology Centre, Lalitpur, for examination of chemical properties. The chemical properties of baseline soil of experimental site is shown in Table 1.

The experimental site lies in the sub-tropical humid climate zone of Nepal. Agro-meteorological data were gathered from the National Wheat Research Program, Bhairahawa. The monthly average of maximum and minimum temperatures was 39.81°C and 24.24°C , respectively, and total rainfall recorded was 482.28 mm during the experimental period, as illustrated in Figure 1.

2.2 Experimental details

The experiment was conducted in a Randomized Complete Block Design (RCBD) with eight treatments replicated four times. The experimental area measured 1053 m^2 ($27 \text{ m} \times 39 \text{ m}$), with the experimental unit measuring 24 m^2 ($6 \text{ m} \times 4 \text{ m}$). Yield was obtained from a 1 m^2 area from each plot. The experimental units were separated by one meter. There were eighteen rows of crop spaced 30 by 10 centimeters apart in each of the 32 plots that made up the total, as illustrated in Figure 2.

2.3 Treatment details

Treatments included different sources of nutrients as chemical fertilizers, organic manures, and bio-fertilizers. Farm yard manure and poultry manure were applied during land preparation and incorporated into the soil in T_5 and T_6 , respectively. Only SSP and MOP were applied in T_1 , whereas urea was also applied in T_2 , T_3 , and T_4 along the crop zone before sowing. Foliar application of nano urea was done at 20 and 30 days after sowing in T_7 . Rhizobium was inoculated in the seed a day before sowing for treatment eight. The details of each treatment is shown in Table 2. The percentages of nitrogen, phosphorus, and potassium in FYM were 0.45, 1.63, and 2.25%, respectively, while in poultry manure (PM), they were 1.90, 1.50, and 5.10%, respectively (Soil Science Laboratory, Agriculture Technology Centre, 2023).

TABLE 1 Chemical properties of baseline soil of experimental site at Paklihawa Campus, 2023.

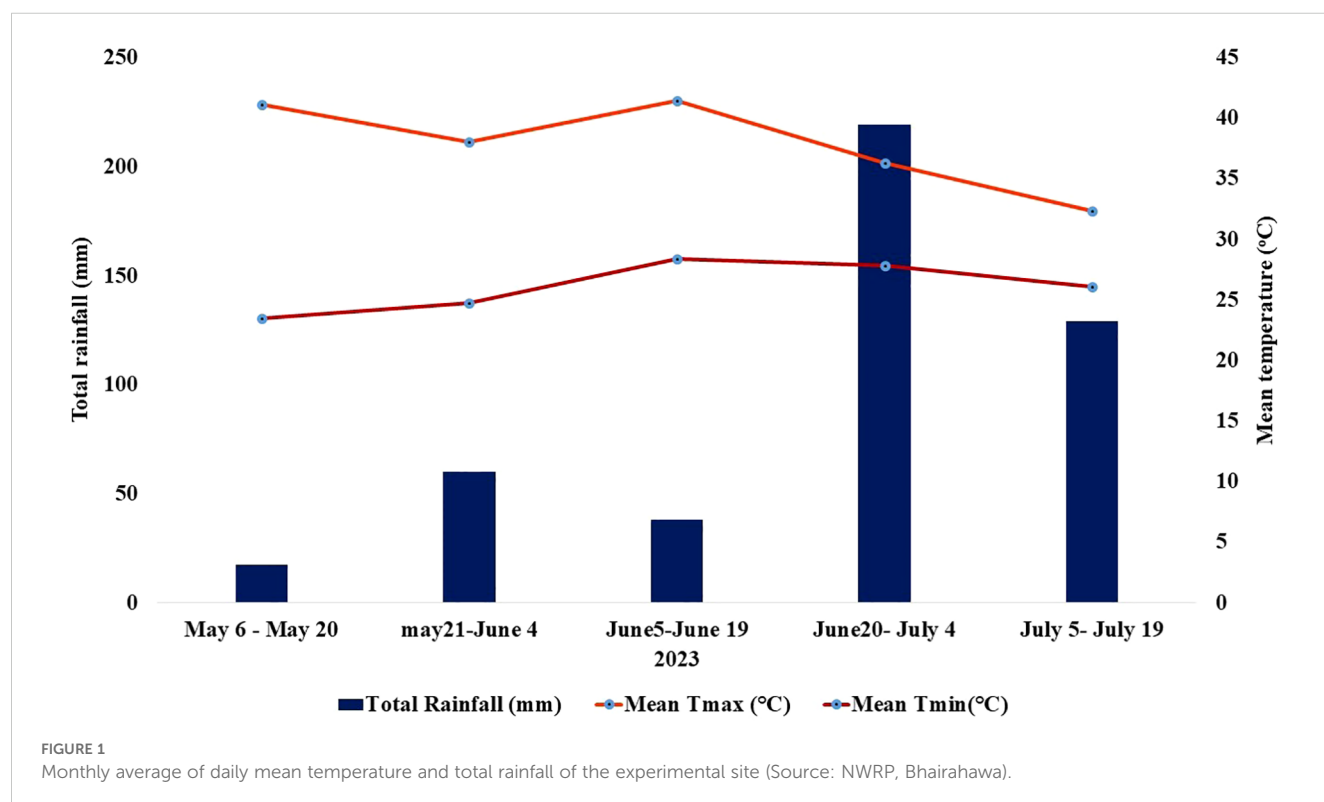
S.N.	Particulars	Method	Value	Status
1	Soil pH	Digital soil pH meter (Thunjai et al., 2001)	7.6	Mildly alkaline
2	Bulk density of soil (gcm ⁻³)	Core ring method (Walter et al., 2016)	1.47	
3	Soil texture	Hydrometer (Faé et al., 2019)		
	Sand (%)		56.3	
	Silt (%)		31.21	
	Clay (%)		11.35	
4	Soil available nitrogen (Kg ha ⁻¹)	Colorimetric analysis of KCl extracts by flow injection analyzer method	36	Low
5	Soil available phosphorus (Kg ha ⁻¹)	The modified Olsen's method (Johnston et al., 2016)	48.3	Medium
6	Soil available potassium (Kg ha ⁻¹)	Ammonium acetate extraction method (Zebec et al., 2017)	134.4	Medium
7	Soil organic matter (%)	Wet digestion method (Benbi, 2018)	2.1	Low
8	Available Zinc (ppm)	DTPA extraction and AAS method (Lindsay and Norvell, 1978)	0.81	Low
9	Available Boron (ppm)	Hot Water Extraction and Azomethine-H Method (Parker and Gardner, 1981)	1.94	High

(Source: Soil Science Laboratory, Agriculture Technology Centre, 2023).

2.4 Crop and nutrient management

Primary tillage was done, followed by secondary tillage with the help of a Mini tiller. Planking and leveling were done to make a good tilt of the soil. Kalyan variety of mung bean was collected from the Grain Legumes Research Program (NARC), Khajura, Banke, and seeds are sown at the rate of 25 Kg ha⁻¹ at a depth of 5cm. Line sowing was done at a spacing of 30cm x 10cm between rows on 2nd

May 2023. Pre-sowing surface irrigation was done 3 days before land preparation for ease of tillage, uniform germination, and to overcome moisture stress during the early period of plant growth. The second irrigation was given at 20 DAS. Manual weeding was done at 15 DAS and 30 DAS. Major weeds recorded in the field were *Cynodon dactylon*, *Cyperus rotundus*, *Solanum nigrum*, and *Chenopodium album*. A few insect pests (aphids and legume pod borer) and yellow mosaic virus disease were recorded in the field.



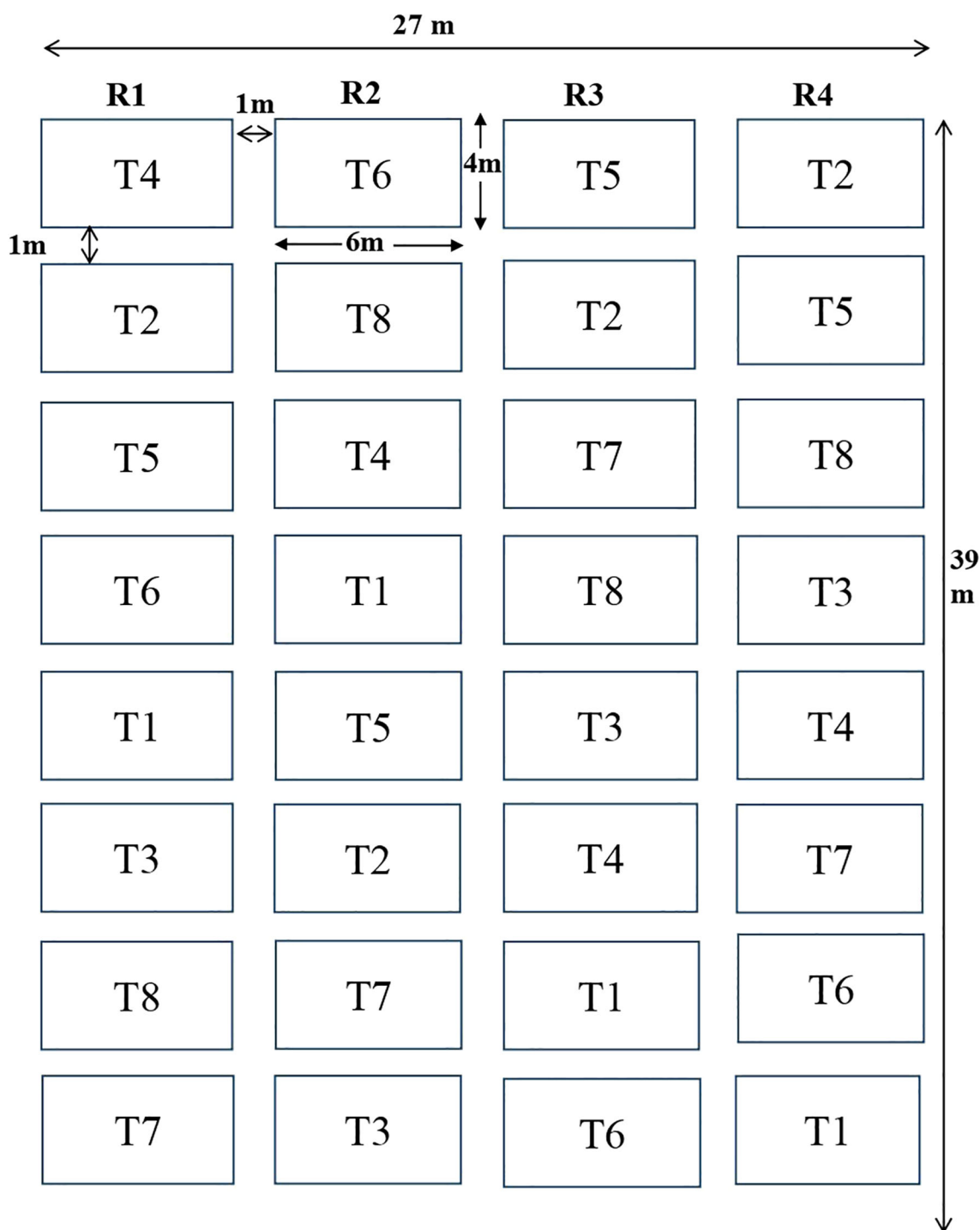


FIGURE 2
Field layout of experimental site in RCBD (R1–4 is replication and T1–8 is treatments).

Disease-infected plants were manually removed from the field. Due to asynchronization in maturity, the mung bean was harvested 2 times at 7-day intervals. Harvesting was done when the leaves were dried, the pods turned from green to grey black, and started to shatter. Pods were plucked manually, and the stalk was collected by cutting plants near to ground surface. Harvested pods were sun-dried for 2 days. Threshing was done to separate seeds and stalks.

The biomass was collected and then weighed. The moisture content of the seed was reduced up to 12% by sun drying and stored in an airtight plastic bag.

Well-decomposed FYM and PM were applied at the rate of 4.444 t ha^{-1} and 1.05 t ha^{-1} in treatments five and six, respectively, as the main source of organic nutrients. Chemical fertilizers applied were prilled urea, Single Super Phosphate (SSP), and Muriate of

TABLE 2 Treatment details of the field experiment at Paklihawa Campus, 2023.

SN	Treatments	Amount of application	Method of application
T ₁	Nitrogen control (N0)	0:40:20 Kg NPK ha ⁻¹	Line application
T ₂	Recommended dose of N (RDN) from Prilled Urea (PU)	20:40:20 Kg NPK ha ⁻¹	Line application
T ₃	RDN +25% from PU	25:40:20 Kg NPK ha ⁻¹	Line application
T ₄	RDN -25% from PU	15:40:20 Kg NPK ha ⁻¹	Line application
T ₅	RDN from Farm Yard Manure (FYM)	44444.4 Kg ha ⁻¹	Incorporated into the soil
T ₆	RDN from Poultry Manure (PM)	1053 Kg ha ⁻¹	Incorporated into the soil
T ₇	Nano urea (NU)	1476 ml ha ⁻¹	Foliar spray 20 and 30 DAS
T ₈	Rhizobium Inoculation (RI)	200 g Kg ⁻¹ seed	Seed inoculation

Potash (MOP). SSP and MOP were applied at the rate of 40:20 Kg PK ha⁻¹ as a basal dose from treatment one to treatment four. Urea fertilizer was applied in treatments two, three, and four.

2.5 Plant sampling and observation

2.5.1 Growth attributes

Five sample plants were randomly selected and tagged, and shoot length was measured at 30, 45, and 60 days after sowing, avoiding the two border rows. Similarly, five sample plants were selected randomly, dug out, and cleaned with water, and the root length was measured at 30, 45, and 60 DAS. At the same time, effective root nodules were counted at 30 and 45 DAS to record an average number of nodules per plant. The total number of trifoliate leaves was counted from sample plants, and the average value was recorded at 30 and 45 DAS. Leaf area was calculated by using the length and breadth of the leaves. A line transect method was used to measure ground cover, in which points where crop leaves touch the line are counted to estimate the percentage of ground covered. The following formula, suggested by Williams (1946), was used to calculate the leaf area index.

Leaf area index = $\frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground cover (cm}^2\text{)}}$ Five sample plants selected randomly for root length were used to calculate crop growth rate (CGR) plant⁻¹ (g) day⁻¹ at 30–45 and 45–60 DAS. Average crop growth rate was determined and expressed as the crop growth rate plant⁻¹ (g) day⁻¹ of individual treatment. CGR was calculated by using this formula.

$$\text{Crop growth rate} = \frac{W_2 - W_1}{T_2 - T_1}$$

Where, W₂ = Plant dry weight at time T₂, and W₁ = Plant dry weight at time T₁.

2.5.2 Yield attributes

Numbers of branches were counted at the maturity stage of the crop. The pods of five randomly selected plants from each plot were recorded, and the average number of pods plant⁻¹ was calculated and expressed as the number of pods plant⁻¹ of each treatment. Ten mature pods from the same plants were selected to

measure pod length, and the average pod length for a single pod in each treatment was computed. Seeds from ten sample pods were manually removed and counted, and an average number of seeds pod⁻¹ was determined. Seed samples were taken randomly out of the seeds harvested from each plot, and 1000 seeds were counted and weighed on a digital weighing balance. Pods were picked when they became yellowish brown to black in color and allowed to sun-dry. Seeds were threshed, cleaned, dried, and the final weight was taken. The moisture percentage of seeds was measured using a Digital Moisture Meter. Yield obtained from the net plot area is converted into yield obtained from one hectare of land. Finally, seed yield was calculated by adjusting moisture content at 12 percent using the formula as suggested by Paudel (1995).

$$\text{Seed yield (Kg ha}^{-1}\text{) at 12\% moisture} = \frac{(100 - \text{MC}) \times \text{plot yield (Kg)} \times 10000 \text{ (m}^2\text{)}}{(100 - 12) \times \text{net plot area (m}^2\text{)}}$$

Where, MC = Moisture content of the seeds in percent.

After the threshing of seeds, the remaining biomasses (total biomass above ground surface excluding seeds and biomass of husk after shelling of seeds) were dried for 2 days and weighted on digital weighing balance to record the stalk yield. Stalk yield was calculated using the formula suggested by Dhakal et al. (2020).

$$\text{Stalk yield (Kg ha}^{-1}\text{)} = \frac{\text{Plot yield (Kg)} \times 10000 \text{ (m}^2\text{)}}{\text{Net plot area (m}^2\text{)}}$$

Harvest index was calculated by using following formula suggested by Nichiporovich (1960).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (Kg ha}^{-1}\text{)}}{\text{Biological yield (Kg ha}^{-1}\text{)}} \times 100$$

Where, Economic yield = Grain yield (Kg ha⁻¹) and Biological yield = Grain yield (Kg ha⁻¹) + Stalk yield (Kg ha⁻¹).

2.6 Economic analysis

To find out a more profitable treatment, the economics of different treatments were worked out in terms of net return (USD/ha) on the basis of the prevailing market rate so that the most

remunerative treatment could be recommended. The net return was worked out by using the following formula.

$$\text{Net return (USD/ha)}$$

$$= \text{Gross return (USD/ha)} - \text{Total Cost (USD/ha)}$$

Treatment-wise benefit-cost (BC) ratio was calculated to ascertain the economic viability of the treatment using the following formula.

$$B : C \text{ ratio} = \frac{\text{Gross return}}{\text{Total cost}}$$

2.7 Statistical analysis

The collected data were tabulated in Microsoft Excel worksheet. The Analysis of Variance (ANOVA) for all data was statistically analyzed using Genstat software (18th edition). Duncan's Multiple Range Test was used to differentiate the means at the 5% significance level (Gomez and Gomez, 1984). The relevant tables and related references were used to interpret the final results. Charts and figures were drawn using MS Excel.

3 Results

3.1 Effect of nutrient sources on growth attributes of mung bean

3.1.1 Shoot length and root length

The data regarding shoot length of mungbean are shown in Figure 3A. There was a significant effect of nutrient sources on the shoot length of mung bean at 30, 45, and 60 DAS. The highest mean value for shoot length was recorded 35.89cm with poultry manure, followed by farm yard manure. The lowest value was recorded at the control, which was 25.72cm at 30 DAS. Similar results were found at 45 DAS and 60 DAS. The average root length of mung bean was observed at 30 DAS for different treatments. It was found maximum

(14.32cm) at farm yard manure applied plots, followed by poultry manure (13.89cm) and minimum at control (11.56cm) as shown in Figure 3B. Similar, results of root length were found at 45 and 60 DAS respectively. However, the root length obtained from farm yard manure and poultry manure was not significantly different. Among, the prilled urea applied plots root length increased with increase in dose of prilled urea up to recommended dose but root length decreased with increase in dose of prilled urea above recommendation dose except 30 DAS. There was no significant difference in root length between nitrogen treatment plots. Rhizobium inoculation give higher root length in comparison to nano urea sprayed plots.

3.1.2 Number of effective nodules

The nodulation of mung bean was found significantly different among various treatments. Maximum average number of nodules plant⁻¹ were found in farm yard manure which were statistically par with poultry manure. Minimum value of average number of nodules plant⁻¹ were found under control. Values of average number of nodules plant⁻¹ obtained from rhizobium inoculated plot was statistically similar to farm yard manure, poultry manure and recommended dose of nitrogen at 45 DAS. The results show average number of nodules plant⁻¹ increased at 45 DAS than at 30 DAS because, in mung bean nodulation start only after 14 to 25 DAS and increases rapidly up to pod formation stage and after that nodule growth stops and their senescence starts gradually.

3.1.3 Number of leaves and leaf area index

Table 3 revealed that there was a significant effect of nutrient sources on number of leaves plant⁻¹ and leaf area index in mung bean. The average leaf number plant⁻¹ and leaf area index of mung bean was found highest in poultry manure at 30 and 45 DAS respectively which was at par with farm yard manure. Lowest value of average number of leaf plant⁻¹ and leaf area index was found in control.

3.1.4 Crop growth rate

A significant effect of nutrient sources on crop growth rate plant⁻¹ day⁻¹ was found in mung bean (Figure 4). The average crop

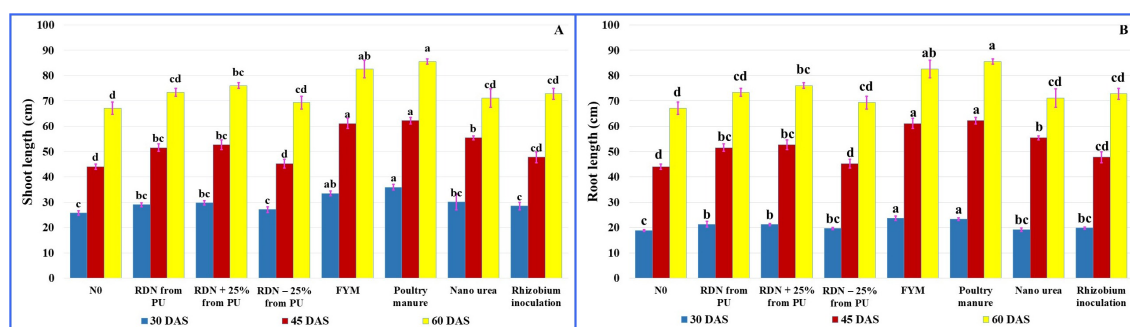


FIGURE 3

Shoot length of plant (A) and root length of plant (B) of mung bean as influenced by the different nutrient sources (Same letters showed non-significant difference between treatments and error bars represent the standard error of mean).

TABLE 3 Effect of nutrient sources on number of effective nodules, number of leaves and leaf area index of mung bean.

Treatments	Number of effective nodules plant ⁻¹		Number of leaves plant ⁻¹		Leaf area index	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
N0	4.12 ^c ± 0.14	9.60 ^b ± 1.01	4.55 ^c ± 0.54	11.22 ± 1.24	0.42 ^d ± 0.02	1.28 ^c ± 0.18
RDN from PU	6.03 ^{bc} ± 0.40	12.98 ^a ± 0.65	6.62 ^{ab} ± 0.17	13.45 ± 0.63	0.53 ^{bc} ± 0.01	1.79 ^{abc} ± 0.14
RDN + 25% from PU	4.27 ^c ± 0.40	11.35 ^{ab} ± 0.82	6.20 ^b ± 0.21	13.03 ± 0.55	0.57 ^b ± 0.01	1.48 ^c ± 0.11
RDN – 25% from PU	5.02 ^{de} ± 0.37	11.60 ^{ab} ± 0.53	6.05 ^b ± 0.12	12.70 ± 0.97	0.44 ^d ± 0.00	1.37 ^c ± 0.14
Farm yard manure	7.27 ^a ± 0.53	13.05 ^a ± 1.04	7.20 ^a ± 0.28	13.68 ± 0.30	0.68 ^a ± 0.03	2.15 ^{ab} ± 0.20
Poultry manure	6.82 ^{ab} ± 0.52	12.40 ^a ± 0.55	7.30 ^a ± 0.24	13.72 ± 0.43	0.69 ^a ± 0.01	2.26 ^a ± 0.22
Nano urea	5.32 ^{cd} ± 0.50	11.06 ^{ab} ± 0.17	5.90 ^b ± 0.50	12.63 ± 0.40	0.48 ^{cd} ± 0.04	1.64 ^{bc} ± 0.20
Rhizobium inoculation	6.45 ^{ab} ± 0.38	12.18 ^a ± 0.41	6.05 ^b ± 0.18	11.95 ± 0.45	0.54 ^{bc} ± 0.03	1.67 ^{bc} ± 0.14
LSD	0.96	1.92	0.86	1.92	0.07	0.53
SEM (±)	0.32	0.65	0.29	0.65	0.02	0.18
F-Probability	<.001***	0.023*	<.001***	Ns	<.001***	0.009**
CV (%)	11.6	11.1	9.50	10.2	9.7	21.2
Grand mean	5.67	11.78	6.23	12.80	0.54	1.71

Means followed by the same letter(s) are not significantly different at 5% ($p=0.05$) level of significance. * Significant at ($p<0.05$), *** Significant at ($p<0.001$), LSD, Least significance difference; CV, Coefficient of variance; SEM, Standard error of mean; DAS, Days after sowing; data after $\pm$ showed how much variation or uncertainty there is around the mean measurement across replicates.

growth rate plant⁻¹ day⁻¹ of mung bean was found highest (0.6210 and 0.9910) in poultry manure at 30–45 and 45–60 days after sowing respectively which was followed by farm yard manure (0.5883 and 0.8927) at 30–45 and 45–60 days after sowing. Lowest value of average crop growth rate plant⁻¹ day⁻¹ was found (0.3520 and 0.4568) in control.

3.2 Effect of nutrient sources on yield attributes of mung bean

3.2.1 Number of branches plant⁻¹ and pods plant⁻¹

Application of nutrient sources found to have significant effect on number of branches plant⁻¹ and number of pods plant⁻¹ of mung

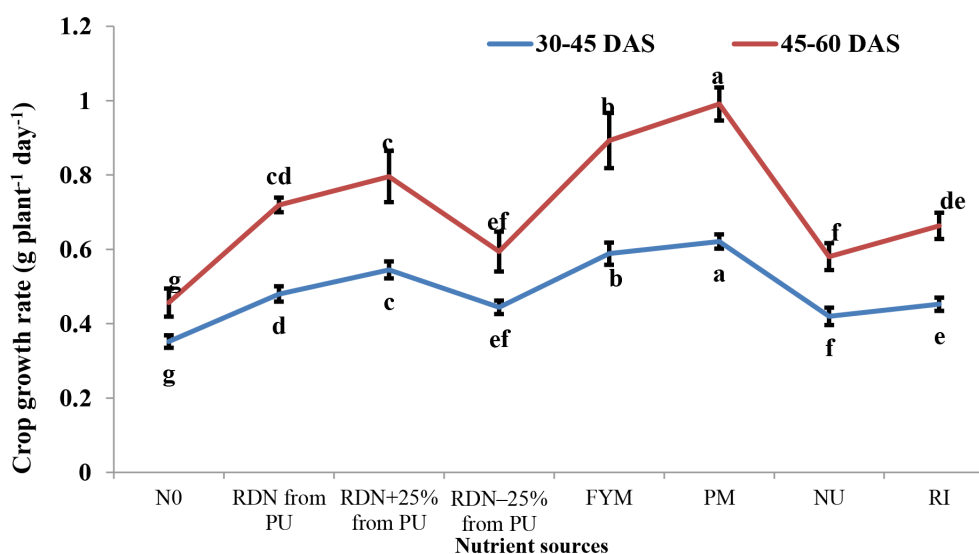


FIGURE 4

Effect of nutrient sources on crop growth rate (CGR) plant⁻¹ day⁻¹ of mung bean (Same letters represent non-significant difference between treatments and error bars represent the standard error of mean).

bean as shown in Figure 5. Highest average number of branches plant⁻¹ (2.9) and number of pods plant⁻¹ (22.38) was observed in poultry manure, followed by farm yard manure whereas lowest average number of branches plant⁻¹ (1.87) and number of pods plant⁻¹ (15.18) was observed in the control. The results also showed that average number of pods plant⁻¹ increased with increase in dose of prilled urea.

3.2.2 Pod length and number of seeds pod⁻¹

Figure 5 showed a significant effect of nutrient sources on the pod length and number of seeds pod⁻¹ of mung bean over the control. The plot with poultry manure recorded maximum value of average pod length (8.08cm) and number of seeds pod⁻¹ (7.22) followed by farm yard manure, whereas minimum value of average pod length (6.96cm) and number of seeds pod⁻¹ (5.65) was recorded in the control. The maximum value of average number of seeds pod⁻¹ found in poultry manure was statistically par with farm yard manure. The results showed that an average number of pods plant⁻¹ increased with increase in dose of prilled urea. The reason behind this may be due to an increase in the dose of prilled urea increases chlorophyll content in the leaf which enhances photosynthetic efficiency.

3.2.3 Seed yield, stalk yield, and biological yield

Application of nutrient sources found to have a significant effect on seed yield, stalk yield, and biological yield of mung bean, as mentioned in Table 4. The highest average value of seed yield (1028.04 Kg ha⁻¹), stalk yield (1650.30 Kg ha⁻¹), and biological yield (2678.34 Kg ha⁻¹) was recorded from poultry manure which was

followed by farm yard manure with respective values of (920.67 Kg ha⁻¹, 1559.16 Kg ha⁻¹ and 2479.83 Kg ha⁻¹). The lowest average value of seed yield (560.70 Kg ha⁻¹), stalk yield (1352.21 Kg ha⁻¹), and biological yield (1912.91 Kg ha⁻¹) was recorded from the control.

3.2.4 Thousand seed weight and harvest index

The results showed a significant effect of nutrient sources on thousand-seed weight of mung beans (Table 4). The average value of thousand seed weight was found to be maximum (57.40 g) in poultry manure, which was statistically par with farm yard manure and RDN + 25% from PU, having values (54.28 g and 54.26 g) respectively. The minimum value of thousand seed weight (44.20 g) was recorded in the control. The value of thousand seed weight increased with an increase in the dose of prilled urea. Harvest index estimates the amount of seed yield over the total biological yield. The maximum value of harvest index (38.38%) was found in poultry manure, which was statistically at par (37.12%) with farm yard manure. Similarly, the lowest value of harvest index (29.31%) was found in the control.

3.3 Linear regression between yield and yield attributes

There was a positive linear relationship between seed yield and the number of branches per plant, explaining 54.25% of the yield variation. Similarly, pods per plant showed a positive relationship

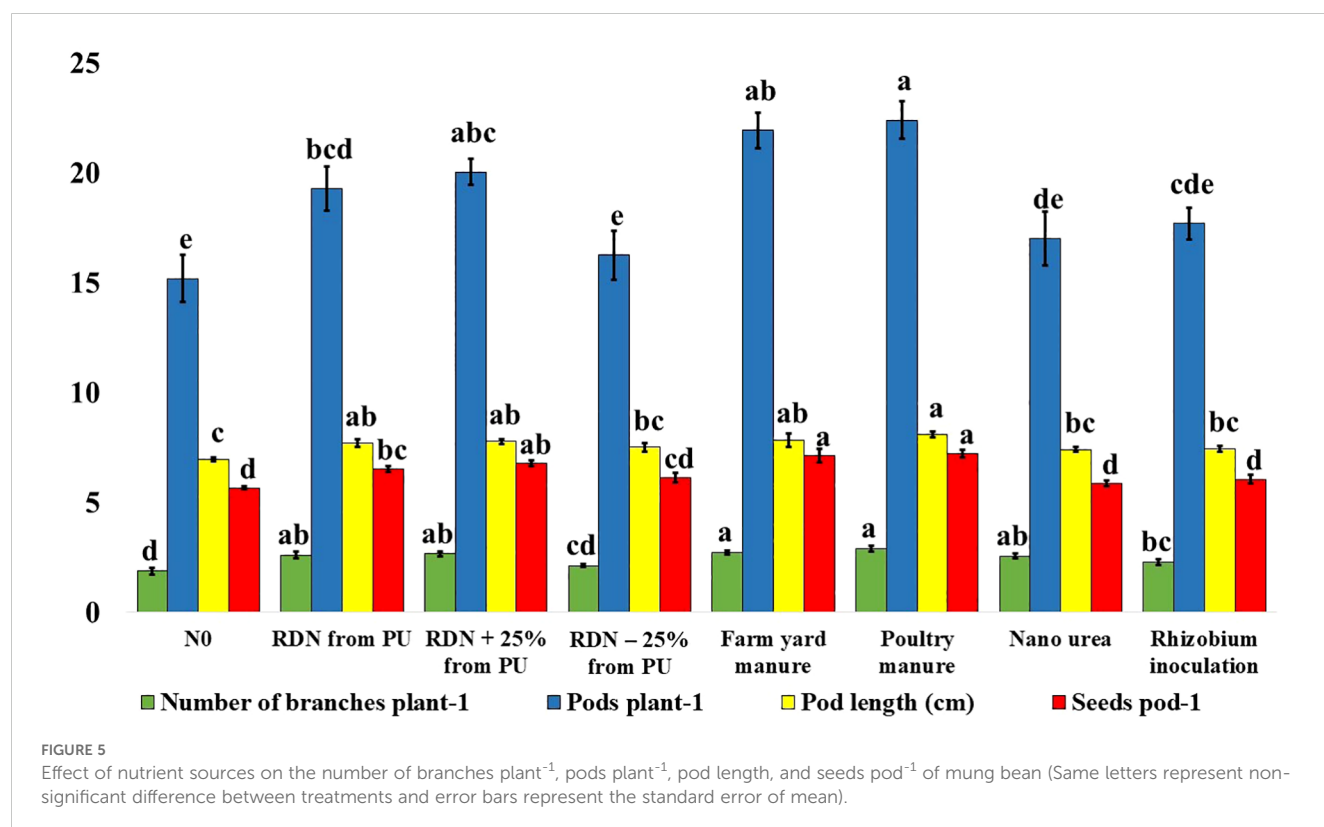


TABLE 4 Effect of nutrient sources on 1000 seed weight, seed yield, stalk yield, biological yield and harvest index of mung bean.

Treatments	1000 seed weight (g)	Seeds yield (Kg ha ⁻¹)	Stalk yield (Kg ha ⁻¹)	Biological yield (Kg ha ⁻¹)	Harvest index (%)
N0	44.20 ^c ± 1.22	560.70 ^f ± 22.41	1352.21 ^c ± 46.42	1912.91 ^c ± 66.41	29.31 ^c
RDN from PU	50.05 ^b ± 1.10	717.12 ^d ± 17.05	1463.43 ^{abc} ± 58.05	2180.55 ^{cd} ± 61.80	32.88 ^{bc}
RDN + 25% from PU	54.26 ^a ± 2.20	827.18 ^c ± 22.67	1490.61 ^{abc} ± 61.28	2317.79 ^{bc} ± 43.97	35.68 ^{ab}
RDN – 25% from PU	46.92 ^{bc} ± 0.83	622.45 ^e ± 16.55	1413.32 ^{bc} ± 50.88	2035.77 ^{de} ± 46.31	30.57 ^c
Farm yard manure	54.28 ^a ± 1.25	920.67 ^b ± 21.56	1559.16 ^{ab} ± 68.28	2479.83 ^b ± 78.92	37.12 ^a
Poultry manure	57.40 ^a ± 0.86	1028.04 ^a ± 30.72	1650.30 ^a ± 72.80	2678.34 ^a ± 45.37	38.38 ^a
Nano Urea	46.00 ^c ± 0.97	637.56 ^e ± 15.00	1420.47 ^{bc} ± 47.79	2058.03 ^{de} ± 47.36	30.97 ^c
Rhizobium inoculation	46.92 ^{bc} ± 0.97	661.50 ^{de} ± 11.86	1437.64 ^{bc} ± 59.21	2099.14 ^{de} ± 59.59	31.51 ^c
LSD	3.86	55.77	180.80	180.00	0.0331
SEM (±)	1.31	18.96	61.50	61.20	0.0112
F-value	<.001***	<.001***	0.064*	<.001***	<.001***
CV (%)	5.3	5.1	8.3	5.5	6.8
Grand mean	50.01	746.90	1473.39	2220.29	33.30

Means followed by the same letter(s) are not significantly different at a 5% (p=0.05) level of significance by DMRT. * Significant at (p<0.05), *** Significant at (p<0.001), LSD, Least significance difference; CV, Coefficient of variance; SEM, Standard error of mean.

with seed yield, accounting for 62.30% of the variation. Pod length also had a positive linear relationship with seed yield, contributing 51.23% to the variation. The strongest relationship was observed between seed yield and the number of seeds per pod, explaining 68.33% of the variation, with the rest influenced by other factors. The strongest relationship was observed between seed yield and the number of seeds per pod, explaining 68.33% of the variation, with the rest influenced by other factors as shown in Figure 6.

3.4 Economics analysis

Gross return, net return, and benefit-cost (B:C) ratio were significantly affected by the application of organic and inorganic nutrient sources in mung beans. Results showed that the highest gross return (1,412.84 USD/ha) was obtained from the poultry manure applied plot, surpassing the returns from the other treatments. The lowest gross return (686.83 USD/ha) was recorded from the control. Net return varied significantly among different treatments. The highest net return was observed in poultry manure with 930.68 USD/ha, while the lowest was in control with 315.90 USD/ha. The maximum benefit-cost ratio was found in poultry manure with a value of 2.93, whereas the lowest was in control, with a value of 1.85. Both net return and benefit-cost ratio increased significantly with the application of poultry manure. The increase in net return can be attributed to the higher yield resulting from organic manure sources. Additionally, the B:C ratio increased with the rising dose of prilled urea as shown in Table 5.

4 Discussion

4.1 Effect of nutrient sources on growth attributes of mung bean

The maximum shoot length of the mung bean was obtained from poultry manure applied plots. This may be due to the availability of most of the macro and micro nutrients in poultry manure and farm yard manure, and their role in improving soil properties and creating a favorable growing environment for the plants. Similar results were reported by Gurjar et al. (2022) and Mahabub et al. (2016). Among the prilled urea applied plots, shoot length increased with an increase in dose of prilled urea, which might be due to the low government recommendation dose of prilled urea and its key role in the physiological processes in plants. These results are in line with the findings of Omran et al. (2018) and Achakzai et al. (2012), which indicate that adding nitrogen fertilizer to mung bean plants resulted in a slight to extremely significant increase in shoot length.

The root growth in mung bean was accelerated by the application of farm yard manure, leading to increased branching and increased uptake of nutrients and water. Plots treated with farm yard manure (FYM) have the longest roots, which could be because FYM creates a more favorable soil environment. As a result, moisture and nutrients supply increase and promote better plant growth. It also forms the physico-chemical and organic properties of the soil. Mishra et al. (2016) also found similar results that farm yard manure-treated plots give higher root length in mung beans.

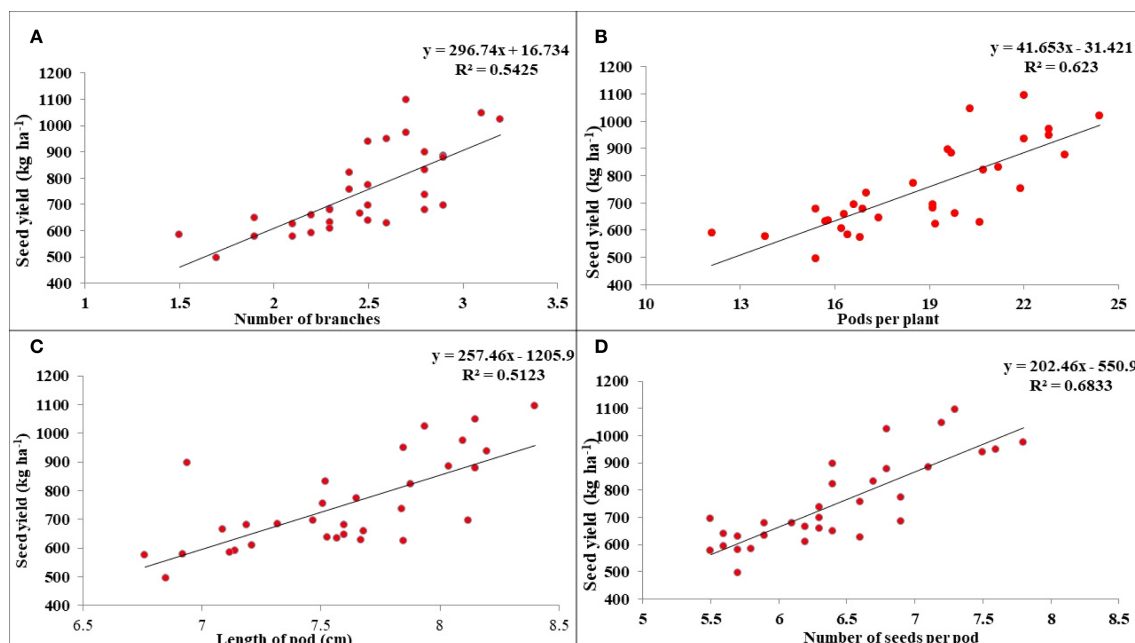


FIGURE 6

Relationship between (A) seed yield and number of branches plant⁻¹ (B) seed yield and pods plant⁻¹ (C) seed yield and pod length (D) seed yield and number of seeds pod⁻¹ influenced by nutrient sources.

TABLE 5 Effect of nutrient sources on gross return, net return, and benefit-cost ratio (B:C ratio) of mung bean.

Treatments	Total cost (USD/ha)	Gross return (USD/ha)	Net return (USD/ha)	B:C ratio
N0	370.95 ^g	686.83 ^f	315.90 ^f	1.85 ^e
RDN from PU	450.79 ^c	1056.06 ^d	604.70 ^d	2.36 ^b
RDN + 25% from PU	482.00 ^b	1159.73 ^c	677.00 ^c	2.40 ^{bc}
RDN – 25% from PU	409.67 ^d	848.76 ^e	339.10 ^e	2.07 ^e
Farm yard manure	542.20 ^a	1349.08 ^b	806.70 ^b	2.48 ^b
Poultry manure	481.79 ^b	1412.84 ^a	930.68 ^a	2.93 ^a
Nano Urea	399.22 ^e	848.46 ^e	449.23 ^e	2.12 ^{de}
Rhizobium inoculation	382.41 ^f	849.05 ^e	466.64 ^e	2.22 ^d
LSD	439.88	1026.10	586.31	2.30
SEM (±)	<.001***	<.001***	<.001***	<.001***
F-value	3.94	46.59	46.49	0.10
CV (%)	1.35	15.96	15.93	0.03
Grand mean	0.6	3.1	5.4	3.1

Means followed by the same letter(s) are not significantly different at a 5% ($p=0.05$) level of significance by DMRT. *** Significant at ($p<0.001$), LSD, Least significance difference; CV, Coefficient of variance; SEM, Standard error of mean.

Increased nitrogen dose increased the availability of nutrients and increased root length up to the recommended dose of nitrogen. An additional increase in nitrogen levels caused nutritional toxicity and decreased root length (Razzaque et al., 2015). Similar results were discovered by previous researchers. Higher root length results from Rhizobium inoculation at 45 DAS after poultry manure and FYM. It is commonly recognized that Rhizobia influence plant growth and development through a variety of pathways such as enhanced mineral absorption, N_2 fixation, the synthesis of plant growth regulators (PGRs) and the inhibition of plant diseases, which is in line with the statement of Kennedy et al. (2004) and Patten and Glick (1996).

Application of farm yard manure led to considerably higher values for the number of effective root nodules plant⁻¹. It might be due to higher microbial activity in the soil by the FYM. This finding is consistent with previous research findings of Giri et al. (2024) and Das et al. (2014). Similarly, Yasmin et al. (2016) recorded the highest number of effective nodules plant⁻¹ from the farm yard manure applied plots, which agreed with the observation of Nagarajan and Balachandar (2001). Farm yard manure produced a higher number of nodules due to slow nitrogen release at an earlier stage, which agreed with the observations of Ganeshamurthy and Sammi Reddy (2000). There is an inhibitory effect of higher doses of N fertilizer on nodulation; this finding is in line with the result of Pons et al. (2007).

Mung beans produced a maximum number of leaves under the application of poultry manure. Poultry manure improved soil aeration, root development, and increased microbial and biological activities in the rhizosphere. This, in turn, would have improved assimilation of nutrients, and thus, dry weight might be increased. These results are in agreement with Sachan et al. (2020) and Islam et al. (2023). Maximum

leaf area index was obtained from poultry manure applied plots, which is consistent with previous research findings of Anwar et al. (2018) and Zaman (2010). Higher CGR was found in organic manure applied plots (PM followed by FYM), which is in line with the result statement of Kumar et al. (2023). This is because organic manures are concentrated sources of macro and micronutrients that improve plant growth by enhancing growth attributes through quick cell division and elongation. CGR increased with an increase in dose of prilled urea, which is in line with the findings of Razzaque et al. (2017). Higher N levels increased N in chlorophyll, which increased photosynthesis and enhanced the meristematic activity of the plant.

4.2 Effect of nutrient sources on yield attributes of mung bean

Applying poultry manure greatly increased the number of branches plant⁻¹ of the mung bean which was significantly superior to other treatments. The increased number of branches seen in poultry manure applied plots may be due to the result of a sufficient supply of macro and micronutrients, which aided in the plant's vegetative growth. These outcomes are consistent with findings of Chandekar and Umesha (2023); Gurjar et al. (2022), and Verma et al. (2022). Rao et al. (2013) also observed similar results regarding the number of branches. The number of branches plant⁻¹ was affected by nitrogen level, and the number of branches plant⁻¹ increased with increasing nitrogen level, which aligns with findings of Khan et al. (2017).

Poultry manure exhibited a greater number of pods plants⁻¹ of mung beans. Poultry manure can improve soil physical properties, which provide favorable soil health and conditions and thereby

increase the growth and yield contributing parameters. It is consistent with previous research findings of Santhosh Kumar et al. (2021) and Tarafder et al. (2020). Increasing nitrogen level led to an increase in pod plant⁻¹, this finding aligns with the result of Anjum et al. (2006). This indicates that mung beans require additional N for better pod development, although it is capable of fixing atmospheric N through rhizobium species living in root nodules. Higher number of pods per plant might have been possible due to more vigor and strength attained by the plants as a result of better photosynthetic activities with sufficient availability of light, and supply of nutrients in balanced quantity of the plants at growing stages. This ultimately resulted in a higher number of seeds pod⁻¹ and a higher length of the pod of the mung bean which is similar to the statement of Anwar et al. (2018) and Gadi et al. (2017). Length of pod increased with an increase in the number of seeds pod⁻¹ on the mung bean.

Mung beans produced the maximum number of seeds pod⁻¹ from poultry manure applied plots. The application of poultry manure may have contributed to a larger root system and increased nodulation, which has increased metabolite production and its translocation to different sinks, particularly the productive structures (seeds and pods), that may have increased the number of pods plant⁻¹ in addition to overall growth. These findings are similar to the statements of different researchers. Mainul et al. (2014) and Verma et al. (2022) found the maximum number of seed pod⁻¹ of mung bean by application of poultry manure. Application of nitrogen enhances the plant growth that increases fruit-bearing branches, seed setting, and seed development, which is consistent with findings from previous research of Basu and Bandyopadhyay (1990), indicating that the number of seeds pod⁻¹ of mung bean increased with an increase in prilled urea.

Poultry manure applied plots give the highest thousand-seed weight of mung bean. Poultry manures contain plant nutrients, growth-promoting substances, and beneficial microbes, which provide favorable soil conditions to enhance nutrient use efficiency, ultimately producing healthy and bold seeds. Baghlani et al. (2024) and Gadi et al. (2017) also reported the maximum thousand-seed weight from poultry manure applied plots. Mainul et al. (2014) also found similar results. Basu and Bandyopadhyay (1990) found a significant effect of increased nitrogen level on the thousand-seed weight of mung bean.

Maximum seed yield, stalk yield, and biological yield were recorded from plants treated with poultry manure followed by farmyard manure. The higher seed yield might be attributed to the increased supply of almost all plants' essential nutrients by translocation of photosynthates accumulated under the influence of the source of organic nutrients. The increased stalk yield might be because of better vegetative growth and higher dry matter production due to the availability of all plant nutrients and better physical properties of soil. These results are in agreement with the findings of Chandekar and Umesh (2023). As in this experiment, Singh et al. (2015) and Yadav et al. (2007) observed that the poultry manure gives maximum seed yield, stalk yield and biological yield

in their trial. The enhanced seed and stalk yield was due to the supply of different nutrients attributed to the activation of metabolic processes, which role in faster cell division and cell elongation with enhanced assimilation rates is well known.

Plots treated with poultry manure had the highest harvest index. Addition of organic sources of nutrients (poultry manure, FYM) improves soil structure, porosity, water holding capacity and decreases bulk density and chemical properties such as soil organic carbon and available nutrients will also be improved. All these promote soil health, crop growth, yield and harvest index on a sustained basis. Similar findings are given by Santhosh Kumar et al. (2021); Karangwa et al. (2015) and Zaman (2010). Harvest index of mung bean increased with increasing nitrogen dose, which is in line with findings of Malik et al. (2003). All the growth and yield attributing parameters increased as the nitrogen level increased which increases yield and harvest index.

The economic analysis showed that the profitability of mung bean production was greatly influenced by the management of nutrient sources. Poultry manure was found to perform better economically, and therefore, it had the best gross return, net return, and B: C ratio. This might be due to its capacity to increase the soil fertility and enhance the crop yield, thus creating greater returns in the market than the other treatments. The findings of the study align with the results from Agbede (2025). The least economic gains achieved in control further demonstrate the significance of nutrient supplementation in the mung bean production. It is worth noting that the highest B: C ratio is 2.93 under the poultry manure, which shows that the investment in this organic input proved to be very profitable which yielding almost three times the cost. Also, the finding that the B: C ratio increases with increased doses of prilled urea implies that inorganic fertilizers, too, have a positive effect on profitability, although not to the same degree as poultry manure (Yeasmin et al., 2024). Altogether, the results highlight the promise of poultry manure as a low-cost and sustainable alternative enhancing the yield and economic profits of growing mung beans.

5 Conclusion

The potential for organic mung bean production is supported by the fact that the crop exhibited the best growth, yield performance and profitability when exposed to poultry manure and farmyard manure. Increases in growth, yield and profit were observed with higher doses of prilled urea, suggesting that there is room to boost mung bean yields beyond what is recommended by the government. However, an increasing dose of prilled urea will be costly to smallholder farmers. Application of poultry manure serves as a more economical nutrient option, positioning it as a preferable alternative when both organic and inorganic nutrient sources are limited. Efforts can be directed toward promoting the use of organic manure and bio-fertilizer. This approach will provide a sustainable nutrient management solution to costly and hard-to-obtain synthetic fertilizers, while aiding farmers in adapting to a

progressively challenging and unpredictable environment. A multi-seasonal and multi-location study is recommended for accurate recommendations in broader domains.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding authors.

Author contributions

RK: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. KD: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. LA: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. SN: Data curation, Formal Analysis, Investigation, Software, Writing – original draft, Writing – review & editing. NA: Data curation, Formal Analysis, Investigation, Software, Writing – original draft, Writing – review & editing. IG: Data curation, Formal Analysis, Investigation, Software, Writing – original draft, Writing – review & editing. PG: Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

References

- Achakzai, A. K. K., Habibullah, B. H. S., and Wahid, M. A. (2012). Effect of nitrogen fertilizer on the growth of mung bean [*Vigna radiata* (L.) Wilczek] grown in Quetta. *Pak. J. Bot.* 44, 981–987.
- Agbede, T. M. (2025). Poultry manure improves soil properties and grain mineral composition, maize productivity and economic profitability. *Sci. Rep.* 15, 16501. doi: 10.1038/s41598-025-00394-8
- Amanullah Yar, M., Khalid, S., Elshikh, M. S., and Akram, H. M. (2022). Phenology, growth, productivity, and profitability of mungbean as affected by potassium and organic matter under water stress vs. no water stress conditions. *J. Plant Nutr.* 45 (5), 629–650.
- AITC (2020). *Agriculture and livestock dairy 2020* (Hariharbawan, Lalitpur, Nepal: Agriculture Information and Training Centre).
- Anjum, M. S., Ahmed, Z. I., and Rauf, C. A. (2006). Effect of Rhizobium inoculation and nitrogen fertilizer on yield and yield components of mung bean. *Int. J. Agric. Biol.* 8, 238–240.
- Anwar, S., Saeed, B., Islam, M., Khan, M. O., and Ahmad, J. (2018). 33. Response of mung bean to organic sources and nitrogen levels. *Pure Appl. Biol.* 7, 692–699.
- Asaduzzaman, M. D., Karim, M. F., Ullah, M. J., and Hasanuzzaman, M. (2008). Response of mung bean (*Vigna radiata* L.) to nitrogen and irrigation management. *American-Eurasian J. Sci. Res.* 3, 40–43.
- Baghlani, A. W., Alefzai, M., Hussainee, H., and Haidari, M. D. (2024). Influence of poultry manure level compared to nutrient-rich organic fertilizer on growth and yield of mung bean (*Vigna radiata* L.). *Int. J. Res. Agron.* 7, 348–358. doi: 10.33545/2618060X.2024.v7.i4e.588
- Barakzai, K. R., Dhar, S., Khalili, A., Rasooli, M., and Tanha, J. (2020). Effect of sources of nutrient and biofertilizers on growth and yield of mung bean (*Vigna radiata* L.). *Int. J. Chem. Stud.* 8, 555–559. doi: 10.22271/chemi.2020.v8.i1h.8319
- Baral, B. R., Pande, K. R., Gaihre, Y. K., Baral, K. R., Sah, S. K., Thapa, Y. B., et al. (2020). Increasing nitrogen use efficiency in rice through fertilizer application method under rainfed drought conditions in Nepal. *Nutrient Cycling Agroecosystems* 118, 103–114. doi: 10.1007/s10705-020-10086-6
- Basu, T. K., and Bandyopadhyay, S. (1990). Effects of Rhizobium inoculation and nitrogen application on some yield attributes of moong. *Environ. Ecol.* 8, 650–654.
- Benbi, D. K. (2018). Evaluation of a rapid microwave digestion method for determination of total organic carbon in soil. *Commun. Soil Sci. Plant Anal.* 49, 2103–2112. doi: 10.1080/00103624.2018.1495732
- Chandekar, S. M., and Umesh, C. (2023). Effect of spacing and biofertilizer on growth and yield of greengram (*Vigna radiata*). *Int. J. Environ. Climate Change* 13, 3732–3738. doi: 10.9734/ijec/2023/v13i103045
- Chaurasia, J., Parajuli, M., and Khadka, G. B. (2020). Changing approach to food self-sufficiency on the scenario of the pandemic “Covid 19”. *Environ. Ecosystem Sci.* 4, 43–46. doi: 10.26480/ees.01.2020.43.46

Acknowledgments

The authors extend their appreciation to the Institute of Agriculture and Animal Science, Kirtipur, Nepal, for their generous support of research facilities.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

- Chaurasia, J., Poudel, B., Mandal, T., Acharya, N., and Ghimirey, V. (2024). Effect of micronutrients, rhizobium, salicylic acid, and effective microorganisms in plant growth and yield characteristics of green gram [*Vigna radiata* (L.) Wilczek] in Rupandehi, Nepal. *Heliyon* 10. doi: 10.1016/j.heliyon.2024.e26821
- CSISA-NP (2019). *Agronomy and seed systems sealing annual report* (Cereal Systems Initiative for South Asia), 64. Dhaka (Bangladesh).
- Das, I., Pradhan, A. K., and Singh, A. P. (2014). Yield and yield attributing parameters of organically cultivated mung bean as influenced by PGPR and organic manures. *J. Crop Weed* 10, 172–174.
- Dhakal, K., Baral, B. R., Pokhrel, K. R., Pandit, N. R., Thapa, S. B., Gaihre, Y. K., et al. (2020). Deep placement of briquette urea increases agronomic and economic efficiency of maize in sandy loam soil. *AGRIVITA J. Agric. Sci.* 42, 499–508. doi: 10.17503/agrivita.v42i3.2766
- Enujeke, E. C. (2013). Response of watermelon to five different rates of poultry manure in asaba area of delta state, Nigeria. *IOSR J. Agric. Veterinary Sci.* 5, 45–50. doi: 10.9790/2380-0524550
- Faé, G. S., Montes, F., Bazilevskaya, E., Añó, R. M., and Kemanian, A. R. (2019). Making soil particle size analysis by laser diffraction compatible with standard soil texture determination methods. *Soil Sci. Soc. America J.* 83, 1244–1252. doi: 10.2136/sssaj2018.10.0385
- Gadi, P., Dawson, J., and Shankar, M. (2017). Effect of different organic manures, inorganic fertilizers and growth regulator on yield attributes and yield of greengram (*Vigna radiata* L.). *Int. J. Curr. Res.* 12, 1567–1572.
- Ganeshamurthy, A. N., and Sammi Reddy, K. (2000). Effect of integrated use of farmyard manure and sulphur in a soybean and wheat cropping system on nodulation, dry matter production and chlorophyll content of soybean on swell-shrink soils in Central India. *J. Agron. Crop Sci.* 185, 91–97. doi: 10.1046/j.1439-037x.2000.00403.x
- Gharti, D. B., Darai, R., Subedi, S., Sarker, A., and Kumar, S. (2014). Grain legumes in Nepal: Present scenario and future prospects. *World J. Agric. Res.* 2, 216–222.
- Ghimirey, V., Chaurasia, J., Acharya, N., Dhungana, R., and Chaurasiya, S. (2024b). Biofertilizers: A sustainable strategy for enhancing physical, chemical, and biological properties of soil. *Innov. Agric.* 7, 1–11. doi: 10.3897/ia.2024.128697
- Ghimirey, V., Chaurasia, J., Dhungana, R., and Poudel, B. (2025). Soil properties and yield of mung bean [*VIGNA RADIATA* (L.) WILCZEK] as influenced by tillage and phosphorous fertilizer management on sandy loam soil in Chitwan, Nepal. *J. Saudi Soc. Agric. Sci.* doi: 10.1016/j.jssas.2024.10.001
- Ghimirey, V., Chaurasia, J., Acharya, N., and Poudel, B. (2025). Organic fertilizers and their efficacy on soil characteristics, growth and yield of cauliflower (*Brassica oleracea* var. botrytis) in sandy loam soil of Nepal. *Front. Soil Sci.* 5. doi: 10.3389/fsoil.2025.1556283
- Gomez, K. A., and Gomez, A. A. (1984). *Statistical procedures for agricultural research* (Philippines: John Wiley & sons).
- Gurjar, S. S., Hasan, A., David, A. A., Thomas, T., Reddy, I. S., and Yadav, P. (2022). Influence of different combinations of neem cake and poultry manure on growth, yield and economics of green gram (*Vigna radiata* L.). *Pharma Innovation J.* 11, 2899–2910.
- ICAR (2021). *ICAR annual report 2020–21* (New Delhi: Indian Council of Agricultural Research).
- Islam, M. Z. A., Alim, S. M. A., Hoque, M. M., Islam, M. M., and Adhikary, S. (2023). Effect of nano urea foliar spray on yield and yield attributes of Black Gram (*Vigna mungo* L.). *J. Agroforestry Environ.* 16, 64–66. doi: 10.55706/jae
- Jat, R. A., Wani, S. P., Sahrawat, K. L., Singh, P., Dhaka, S. R., and Dhaka, B. L. (2012). Recent approaches in nitrogen management for sustainable agricultural production and eco-safety. *Arch. Agron. Soil Sci.* 58, 1033–1060. doi: 10.1080/03650340.2011.557368
- Johnston, A. E., Poulton, P. R., White, R. P., and Macdonald, A. J. (2016). Determining the longer term decline in plant-available soil phosphorus from short-term measured values. *Soil Use Manage.* 32, 151–161. doi: 10.1111/sum.12253
- Joshi, M., Neupane, R. K., and Bhujel, R. B. (1998). “Mung bean research status in Nepal,” in *International consultation workshop on mung bean; Proceedings of the* (Taiwan: AVRDC).
- Karangwa, A., Niyitanga, F., Bucagu, C., Musabanganji, E., and Habimana, S. (2015). Effect test of Industrial Organic Manure on the Physical Growth and Yield Performance of Bean in Bugesera District Environment. Case of Earth Boost fertilizer on Colta variety. *East Afr. J. Sci. Technol.* 5, 32–49.
- Kennedy, I. R., Choudhury, A. T. M. A., and Kecskés, M. L. (2004). Non-symbiotic bacterial diazotrophs in crop-farming systems: can their potential for plant growth promotion be better exploited? *Soil Biol. Biochem.* 36, 1229–1244. doi: 10.1016/j.soilbio.2004.04.006
- Khan, F. U., Asad, A. K., Asif, I., Akhtar, A., Mazhar, I., Madeeha, A., et al. (2017). Effect of phosphorus and rhizobium inoculation on yield and yield components of mungbean. *J. Pharmacog Phytochem. SPI*, 252–258.
- Kumar, A., Ram, H., Kumar, S., Kumar, R., Yadav, A., Gairola, A., et al. (2023). A comprehensive review of nano-urea vs. conventional urea. *Int. J. Plant Soil Sci.* 35, 32–40. doi: 10.9734/ijps/2023/v35i234212
- Kumar, Y., Tiwari, K. N., Singh, T., and Raliya, R. (2021). Nanofertilizers and their role in sustainable agriculture. *Ann. Plant Soil Res.* 23, 238–255. doi: 10.47815/aprs.2021.10067
- Lindsay, W. L., and Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci. Soc. America J.* 42, 421–428. doi: 10.2136/sssaj1978.03615995004200030009x
- Mahabub, S. T., Khan, M. S. H., Mazed, H. E. M. K., Sarker, S., and Tareque, H. (2016). Effect of cow manure on growth, yield and nutrient content of mung bean. *Asian Res. J. Agric.* 2, 1–6. doi: 10.9734/ARJA/2016/29297
- Mainul, M. I., Rupa, W. S., Nasir, A., Mehraj, H., and Jamal Uddin, A. F. M. (2014). Performance of mung bean (BARI mung 6) to different nitrogen levels. *Int. J. business Soc. Sci. Res.* 1, 172–175.
- Malik, M. A., Saleem, M. F., Ali, A., and Mahmood, I. (2003). Effect of nitrogen and phosphorus application on growth yield and quality of mung bean (*Vigna radiata* L.). *Pakistan J. Agric. Sci.* 40, 133–136.
- Mehboob, I., Zahir, Z. A., Arshad, M., Tanveer, A., and Khalid, M. (2012). Comparative effectiveness of different Rhizobium sp. for improving growth and yield of maize (*Zea mays* L.). *Soil Environ.* 31, 37–46.
- Mishra, R., Patel, A., Singh, R. K., Kumar, A., and Sharma, A. (2016). Effect of nutrient management practices on growth and yield of green gram (*Vigna radiata* L.). *Adv. Life Sci.* 5, 11139–11143.
- MOALD (2021). *Statistical Information on Nepalese Agriculture*. SinghaDurbar, Kathmandu, Nepal: Ministry of Agricultural and Livestock Development, Monitoring, Evaluation and Statistics Division, Agri Statistics Section.
- Muthu, M. C., Sushree, A., and Srivastava, R. (2018). Influence of production factors on seed quality parameters of green gram (*Vignaradiata*) CV. KKM-3. *Legume Research-An Int. J.* 41, 891–894. doi: 10.18805/LR-3810
- Nagarajan, P., and Balachandrar, D. (2001). Influence of Rhizobium and organic amendments on nodulation and grain yield of blackgram and greengram in acid soil. *Madras Agric. J.* 88, 703–705.
- Nichiporovich, A. A. (1960). Photosynthesis and theory of obtaining high crops yields. *Abstract Field Crop J.* 13, 169–175.
- Nityananda, K., Harris, D., Sherpa, L. T., Giri, R. K., and Joshi, K. D. (2006). Testing and promotion of mungbean in cereal fallows in the low hills and terai agroecosystems of Nepal. In *Improving income and nutrition by incorporating mungbean in cereal fallows in the Indo-Gangetic Plains of South Asia DFID Mungbean Project for 2002–2004*. Proceedings of the final workshop and planning meeting, Punjab Agricultural University, Ludhiana, Punjab, India, 27–31 May 2004 (pp. 255–267). Asian Vegetable Research and Development Center (AVRDC).
- Omran, A. H., Dass, A., Jahish, F., Dhar, S., Choudhary, A. K., and Rajanna, G. A. (2018). Response of mung bean (*Vigna radiata* L.) to phosphorus and nitrogen application in Kandahar region of Afghanistan. *Ann. Agric. Res.* 39, 57–62.
- Parker, D. R., and Gardner, E. H. (1981). The determination of hot-water-soluble boron in some acid Oregon soils using a modified azomethine-H procedure. *Commun. Soil Sci. Plant Anal.* 12, 1311–1322. doi: 10.1080/00103628109367237
- Pathak, R., Panchariya, P., Choudhary, M., Solanki, K., Rani, R., Kakani, R. K., et al. (2023). Morphophysiological and molecular diversity in mung bean (*Vigna radiata* L.). *Legumes: Physiol. Mol. Biol. Abiotic Stress Tolerance*, 115–147. doi: 10.1007/978-981-19-5817-5
- Patten, C. L., and Glick, B. R. (1996). Bacterial biosynthesis of indole-3-acetic acid. *Can. J. Microbiol.* 42, 207–220. doi: 10.1139/m96-032
- Paudel, M. N. (1995). *Nutrient management for Sulphan buri-90 rice variety in acid sulfate soil with green leaf manure* (Bankok, Thailand: Asian Institute of Technology), 23–51.
- Pons, T. L., Perreijn, K., Van Kessel, C., and Werger, M. J. (2007). Symbiotic nitrogen fixation in a tropical rainforest: 15N natural abundance measurements supported by experimental isotopic enrichment. *New Phytol.* 173, 154–167. doi: 10.1111/j.1469-8137.2006.01895.x
- Prasad, R., Shivay, Y. S., and Kumar, D. (2021). Nano fertilizers: A recent approach for nutrient management. *J. Plant Nutr.* 44, 1694–1704. doi: 10.1080/01904167.2021.1876722
- Qureshi, A., Singh, D. K., and Dwivedi, S. (2018). Nano-fertilizers: a novel way for enhancing nutrient use efficiency and crop productivity. *Int. J. Curr. Microbiol. Appl. Sci.* 7, 3325–3335. doi: 10.20546/ijcmas.2018.702.398
- Raliya, R., Saharan, V., Dimkpa, C., and Biswas, P. (2017). Nanofertilizer for precision and sustainable agriculture: current state and future perspectives. *J. Agric. Food Chem.* 66, 6487–6503. doi: 10.1021/acs.jafc.6b02168
- Rao, K. T., Rao, A. U., and Reddy, D. S. (2013). Residual effect of organic manures on growth, yield and economics of greengram in maize-sunflower-greengram system. *Int. J. Agric. Sci.* 9, 275–279.
- Razzaque, M. A., Haque, M. M., and Karim, M. A. (2017). Effect of nitrogen on growth and yield on mung bean in low nutrient soil. *Bangladesh J. Agric. Res.* 42, 77–85. doi: 10.3329/bjar.v42i1.31981
- Razzaque, M. A., Haque, M. M., Karim, M. A., Solaiman, A. R. M., and Rahman, M. M. (2015). Effect of nitrogen on different genotypes of mung bean as affected by nitrogen level in low fertile soil. *Bangladesh J. Agric. Res.* 40, 619–628. doi: 10.3329/bjar.v40i4.26937
- Sachan, H. K., Krishna, D., and Prasad, A. (2020). Combined effect of organic and inorganic fertilization on the growth and yield of mung bean (*Vigna radiata*). *Res. Crops* 21, 676–680. doi: 10.31830/2348-7542.2020.105
- Sadeghipour, O., Monem, R., and Tajali, A. A. (2010). Production of mung bean (*Vigna radiata* L.) as affected by nitrogen and phosphorus fertilizer application. *J. Appl. Sci.* 10, 843–847.

- Saitheja, V., Senthivelu, M., Prabukumar, G., and Prasad, V. (2022). Maximizing the productivity and profitability of summer irrigated greengram (*Vigna radiata* L.) by combining basal nitrogen dose and foliar nutrition of nano and normal urea. *Int. J. Plant Soil Sci.* 34, 109–116. doi: 10.9734/ijps/2022/v34i2231362
- Singh, R. V., Prakash, C., Tripath, S. K., Sharma, B., and Singh, R. P. (2015). Effect of integrated nutrient management on productivity, nutrient uptake and economics of green gram (*Vigna radiata* L.) in custard apple under rainfed condition. *J. Progressive Agric.* 6, 23–26.
- Soil Science Laboratory, Agriculture Technology Centre (2023). Lalitpur, Nepal.
- Tarafder, S., Rahman, M. A., Hossain, M. A., and Chowdhury, M. A. H. (2020). Integrated Approach of Organic and Inorganic Fertilizer Management on Nutrient Composition and Uptake of Mung bean (*Vigna radiata* L.) in Udic Rhodustalf Soil. *Asian J. Adv. Agric. Res.* 14, 1–16. doi: 10.9734/ajaar/2020/v14i130119
- Thunjai, T., Boyd, C. E., and Dube, K. (2001). Point soil pH measurement. *J. World Aquaculture Soc.* 32, 141–152. doi: 10.1111/j.1749-7345.2001.tb00365.x
- Uddin, M. S., Amin, A. K. M. R., Ullah, M. J., and Asaduzzman, M. (2009). Interaction effect of variety and different fertilizers on the growth and yield of summer mung bean. *American-Eurasian J. Agron.* 2, 180–184.
- Verma, R., Singh, M., Dawson, J., Muddassir, P., and Khan, I. (2022). Effect of bio-fertilizers and organic manures on growth and yield of green gram (*Vigna radiata* L.). *Pharma Innovation J.* 11, 1599–1602.
- Walter, K., Don, A., Tiemeyer, B., and Freibauer, A. (2016). Determining soil bulk density for carbon stock calculations: a systematic method comparison. *Soil Sci. Soc. America J.* 80, 579–591. doi: 10.2136/sssaj2015.11.0407
- Williams, S. R. F. (1946). Methods of growth analysis. *Plant photosynthetic production manual Methods*, 348–391.
- Yadav, A. K., Varghese, K., and Abraham, T. (2007). Response of biofertilizers, poultry manure and different levels of phosphorus on nodulation and yield of greengram (*Vigna radiata* L.) cv. k-851. *Agric. Sci. Digest* 27, 213–215.
- Yasmin, K., Aziz, M. A., and Kashem, M. A. (2016). Effect of Cowdung, NPK AND Rhizobium Inocula on Nodules Number, Yield Contributing Attributes and Yield of Summer Mung bean (*Vigna radiata*) in Acid Soil. *Am. J. Experi. Agric.* 11, 1–7.
- Yeasmin, S., Uddin, M. K., Chowdhury, M. A. H., Mohiuddin, K. M., and Saha, B. K. (2024). Poultry manure-urea fertilizer potentially influences nitrogen use efficiency, nutritional quality, and yield of baby corn (*Zea mays* L.). *J. Agric. Food Res.* 18, 101409. doi: 10.1016/j.jafr.2024.101409
- Zaman, R. (2010). Effect of poultry manure with and without biofertilizers on growth and yield of summer mung bean. M.S Thesis. Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, 59.
- Zebec, V., Rastija, D., Lončarić, Z., Bensa, A., Popović, B., and Ivezić, V. (2017). Comparison of chemical extraction methods for determination of soil potassium in different soil types. *Eurasian Soil Sci.* 50, 1420–1427. doi: 10.1134/S1064229317130051