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Research Article

Keywords:

Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10826738/v1>

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Additional Declarations: No competing interests reported.

Growth, Yield, and Economic Performance of Mungbean (*Vigna radiata* L.) Under Different Nutrient Management Practices in Chitwan, Nepal

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ABSTRACT

Mungbean is an emerging legume cash crop in Nepal with numerous agronomic and nutritional benefits. Improper and unbalanced nutrient management practices have resulted in a significant reduction in crop yield. This study was conducted to evaluate the effects of different organic, inorganic, and micronutrient sources on the agronomic and economic performance of mungbean at Chitwan, Nepal, in 2025. The experiment was laid out in Randomized Complete Block Design (RCBD) with six treatments: recommended dose of fertilizer (RDF) + organic manure (OM), RDF+ zinc sulphate, farmers' practice, RDF+ *Rhizobium* inoculation (RI), foliar application of micronutrients (FAM)+OM, and control and replicated four times. Results revealed that most biometric traits were unaffected by treatment intervention, except for the number of leaves at 30 days after sowing (DAS) and the dry weight of stem and leaf at 35 and 60 DAS.

However, yield and yield-attributing traits differed significantly among the treatments. RDF+OM recorded the highest number of seeds per pod (8.95), followed by RDF+RI (8.93). The number of plant populations per hectare was significantly higher under RDF+RI (202777.80). The RDF+OM group also recorded the highest 500-seed weight (20.63 g), while the lowest was observed in the control (15.30). Economic analysis showed the RDF+OM and RDF+RI to be the most profitable nutrient management strategies, with B:C of 1.64 and 1.60, respectively, while the control resulted in financial loss with B:C of 0.98. Thus, this study suggests either RDF+OM or RDF+RI to farmers as the most effective and economically profitable nutrient management strategies for mungbean cultivation in Chitwan, Nepal.

INTRODUCTION

Mungbean (*Vigna radiata* L.) is a globally cultivated, highly nutritious legume crop of family Fabaceae (Khanal, R. P., et al., 2025). Nutritionally, it contains vitamins A (94 mg), iron (7.3 mg), calcium (124 mg), zinc (3 mg), and folate (549 mg) (Chadha, 2010). It is an excellent pulse that is consumed as a *dal* with cereal-based diets and contains a lower amount of sulphur-containing amino acids, which makes it highly and easily digestible as compared to other pulses (Subedi & Yadav, 2012). In Nepal, it is gaining popularity as a promising cash crop among the farmers of the Terai and inner Terai regions (Bam et al., 2022). After the harvest of wheat and before the transplantation of main-season rice, around 400,000 hectares of land remain fallow in the country (Dhakal et al., 2024). Farmers can take an additional benefit by integrating mungbean as a spring-season catch crop during that interval. Mungbean crops have the potential to fix

atmospheric nitrogen through nitrogen-fixing nodules on their root system. The biologically fixed nitrogen stays in the soil after the harvest of the crop, which further lowers the nitrogen requirement for succeeding crops, i.e., rice. Moreover, within cereal-based cropping systems, it functions as a trap crop for pests, thereby minimizing the need for pesticide use (Khanal, N. P., et al., 2025).

Despite huge benefits, mungbean occupies only around 4% (12,000 ha) of Nepal's total pulse crop area (Khanal, R. P., et al., 2025). According to MoALD (2023), mungbean productivity in Nepal is just 0.883 t/ha which is below its production potential of 1.04 t/ha (Khanal, R. P., et al., 2025). The major factors behind this yield gap include inadequate soil moisture during critical growth stages, poor soil and improper nutrient management practices, limited adoption of *Rhizobium* inoculation and improved production technologies, and the prevalence of different diseases and pests (Chaulagain et al., 2024; Khanal, N. P., et al., 2025). More than 75% of mungbean cultivation is concentrated in the eastern and central Terai regions where irrigation is accessible but soils are deficient in nitrogen, phosphorus, potassium and other micronutrient such as zinc and boron (Neupane et al., 2023; Vista et al., 2021). Inadequate and imbalanced fertilizer application by farmers further constrains plant growth, nodulation, and overall yield (Achakzai et al., 2012). Farming on marginal land, acidic soil, and limited use of biofertilizers (*Rhizobium*, *Azotobacter*) are also among the major issues in mungbean cultivation in Nepal (Ghimirey et al., 2025; Singh & Dubey., 2024).

Integrated nutrient management plays a crucial role in achieving better growth and higher yield in mungbean farming. Multiple nutrient sources such as organic fertilizers (Biofertilizer, vermiwash, vermicompost, green manure, crop residue), inorganic fertilizers (nano urea, nano DAP) and micronutrients mixes (zinc, iron, boron etc.) available for crop production (Choudhary et al., 2025), each contributing distinctly to crop growth and development. Organic fertilizers help in improving physiochemical properties of soil along with strengthening the crop's root system (Bam et al., 2022). Plant biofertilizers (*Rhizobium*, *Azotobacter*) are beneficial for biological nitrogen fixation and for enhancing yield-attributing traits (pods, seeds, thousand-grain weight) (Malik et al., 2014). Nitrogen, phosphorus and potassium fertilizers are essential for vegetative growth and help improve key yield components such as number of pods per plant, number of seeds per pod, 1000-seed weight, and total seed yield (Jamro et al., 2018; Tariq et al., 2001). Although mungbean is a leguminous crop that does not require a high dose of nitrogenous fertilizer, a starter dose of 20 kg N ha⁻¹ has shown a significant effect on crop growth and nodule formation (Sankareswari et al., 2025). Furthermore, foliar application of micronutrient mixes has also demonstrated a significant effect in increasing number of branches, fresh and dry weight, chlorophyll content, flowering, pods, and seed formation, ultimately contributing to higher grain yield in mungbean (Selim et al., 2023). Overall, application of integrated nutrient sources rather than relying on a single input promotes growth and maximizes yield in mungbean.

Mungbean is well adapted to the climatic conditions of Chitwan. It is commonly cultivated during the spring season within the rice-wheat cropping system (Khanal, R.

P., et al., 2025). Despite its agronomic and nutritional importance, farmers often perceive it as a minor crop and pay less attention to it after sowing. Minimal fertilizer application and limited intercultural operation retard the growth, development, and productivity of crops. Still, the use of *Rhizobium* inoculation and micronutrient application in legume cultivation is less popular among the Nepalese farmers (Ghimirey et al., 2025). Previous studies on mungbean production in Nepal have largely focused on the use of biofertilizers (Bam et al., 2022; Rasali et al., 2025; Sharma., R., et al., 2024) and *Rhizobium* inoculation, leaving a gap in research on the combined application of organic, inorganic, and micronutrient fertilizers under the specific agro-climatic conditions of the Terai and Inner Terai regions. This study therefore aims to bridge this gap and support farmers in adopting appropriate nutrient management strategies by evaluating the effects of different nutrient sources on the growth, yield attributes, and economic profitability of mungbean in Chitwan, Nepal.

MATERIALS AND METHODS

Experimental Site

The experimental site was located within the premises of the Agriculture and Forestry University (AFU) in Rampur, Chitwan, Nepal (Figure 1). The site lies at an altitude of 208 meters above sea level (masl), with geographical coordinates of 27°40'59.99" N latitude and 84°25'59.99" E longitude. The research was conducted from March to July 2025.

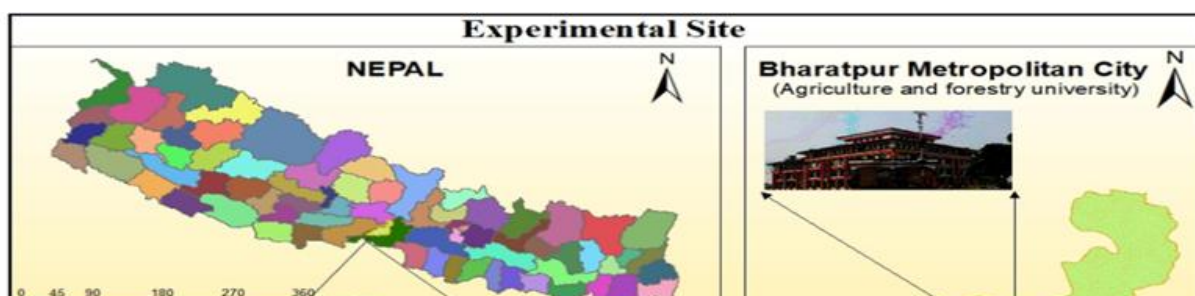


Figure 1: Study map showing research location

Weather

Climatic data were obtained from the meteorological station at the National Maize Research Program (NMRP) in Rampur, Chitwan. The figure 2 shows that temperature, relative humidity,

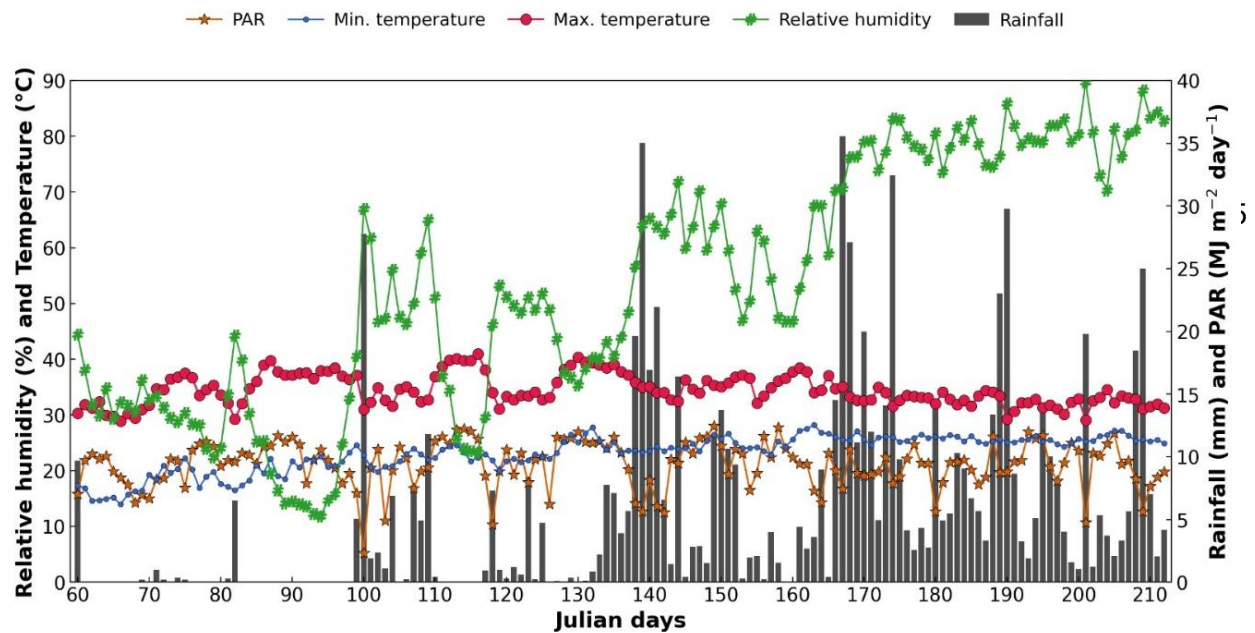


Figure 2. Temporal variation in minimum and maximum temperature, relative humidity, rainfall, and photosynthetically active radiation (PAR) across Julian days 60-212 at Rampur, Chitwan, Nepal in 2025.

Soil

To determine the physico-chemical properties of the soil at the experimental site, soil samples were collected from the top layer (0-15 cm) prior to mungbean planting. Following an 'X' pattern, samples were taken from multiple points and thoroughly mixed. A composite sample of approximately 500 g was prepared and was air-dried, ground, sieved through a 2 mm sieve, and subsequently sent to the Soil and Fertilizer Testing Laboratory for chemical analysis, as presented in Table 1. The soil of experimental plot was sandy loam with 73.44% sand, 15.64% silt and 10.92% clay. The total nitrogen content was medium (0.12%). The available phosphorus was recorded very high (198.1 kg ha⁻¹) and the available potassium was recorded medium (14.22 kg ha⁻¹) while the soil organic matter content was found low (2.40 kg ha⁻¹). The available sulfur was recorded medium (14.22 mg kg⁻¹). The average pH of soil observed acidic (5.5) based on the rating chart of soil given by (Pandey et al., 2018).

Table 1. Physiochemical properties of soil at experimental site

Properties	Content	Rating	Method and References
Physical properties			
Sand (%)	76.68	Sandy	

Silt (%)	15.4	loam	Hydrometer method
Clay (%)	7.92		(Estefan et al., 2013)
Chemical properties			
Soil pH	5.5	Acidic	Beckman Glass electrode pH meter (1:2.5) (Pradhan, 2005)
Soil organic matter (%)	2.40	Low	Walkley and Black (Walkley & Black, 1934)
Available nitrogen (%)	0.12	Medium	Kjeldhal digestion distillation (Jackson, 1967)
Available phosphorus (kg ha ⁻¹)	198.1	Very high	Bray-1 kurtz method (Estefan et al., 2013)
Available potassium (kg ha ⁻¹)	272.4	Medium	Ammonium Acetate method (Schollenberger & Simon, 1945)
Available sulfur (mg kg ⁻¹)	14.22	Medium	Turbidimetric (Chesnin & Yien, 1951)

Experimental Details

The experiment was laid out in a Randomized Complete Block Design (RCBD) taking six treatments, with each treatment replicated four times (Table 2).

Table 2. Specification of Experiment

Description	Details
Research crop	Mungbean

Variety	Kalyan
Design of experiment	Simple RCBD
Number of treatment	6
Number of replication	4
Number of plot	24
Spacing between plot	0.5 m
Spacing between replication	1 m
Size of individual plot	3.2×1.5 m ²
Crop spacing	40 cm×10 cm (RR×PP)
Number of plant per plot	120
Area of field	195.3 m ²

Note: RR: Row to Row, PP: Plant to Plant

Treatment Details

A total of six treatments were evaluated, consisting of various combinations of organic manure, macronutrients (N, P, and K), zinc sulfate, *Rhizobium* inoculation, and foliar fertilizer applications. Treatment details is presented in Table 3.

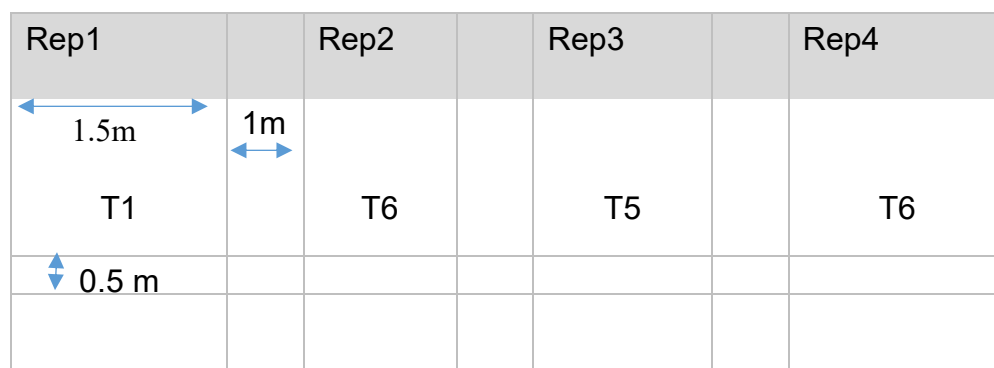
Table 3. Treatment Details

Symbol	Treatments details
T ₁ : RDF+ OM	Recommended dose- N: P ₂ O ₅ : K ₂ O (20:20:20 kg/ha) and Organic manure (FYM-6 tons/ha) and
T ₂ : RDF+ ZnSO ₄	Recommended dose- N: P ₂ O ₅ : K ₂ O (20:20:20 kg/ha) and Zinc sulphate (5kg/ha)

T ₃ : FP	Farmer practices (Organic manure-FYM-2 tons/ha)
T ₄ : RDF+ RI	Recommended dose- N: P ₂ O ₅ : K ₂ O (20:20:20 kg/ha) and <i>Rhizobium</i> inoculation (Strain: L2R19) (40g/kg of seed)
T ₅ : FAM+ OM	Foliar application of Micronutrients (Agromix plus- zinc-6%, copper- 0.5%, iron 1%, manganese- 0.5%, boron-1%, molybdenum- 0.03%, nitrogen-3.55%, phosphorus-1.5%, potassium -1.5%) and organic manure (FYM-6 tons/ha)
T ₆	Control

Experimental Layout

The six treatments were randomly allocated within each of the four replications (Figure 4). The inter-replication distance was maintained at 1.0 m, and the inter-plot distance was 0.5 m, establishing a total field dimension of 21.7 m in length and 9.0 m in width. Each of the 24 individual plots contained 8 rows with 15 plants per row, maintaining the strict 40 cm × 10 cm spacing. Excluding the outer border rows to eliminate edge effects, five representative plants were randomly selected and tagged per plot for sampling.



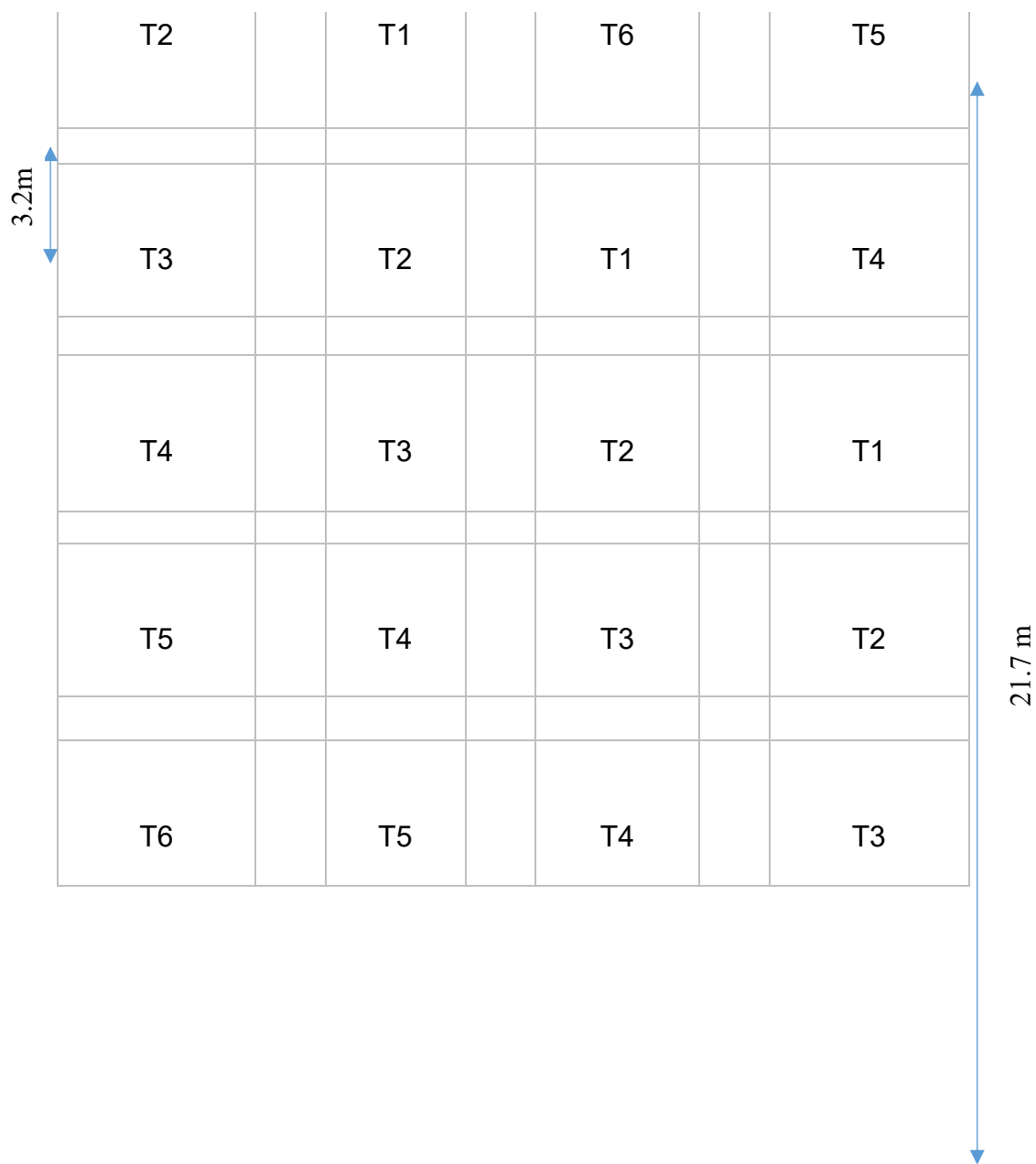


Figure 3. Layout of experimental field

Crop Management and Cultivation Practices

Field Preparation and Layout

Primary tillage was performed using a tractor-drawn cultivator, followed by secondary tillage with a disc harrow and a rotavator for a fine tilth. Following final land preparation, the field layout was marked, and individual plots were prepared manually for seed sowing according to layout.

Seed Rate, Canopy Geometry, Thinning and Gap Filling

Seeds were sown at a recommended rate of 20 kg/ha manually. Two seeds per hill were placed at a depth of 3-4 cm in manual furrows spaced 40 cm apart, with an intra-row hill spacing of 10 cm. To maintain the target plant population, thinning and gap filling operations were carried out at 15 DAS. Excess seedlings were removed, and blank hills were replanted to maintain the target plant population.

Irrigation and Nutrient Management

A light pre-sowing irrigation was applied to ensure optimum soil moisture for uniform seed germination. Surface irrigation was provided following seedling establishment. At 30 days after sowing (DAS), shallow inter-row furrows were formed between rows to facilitate subsequent furrow irrigations. Basal fertilizers were applied at the time of sowing. The recommended dose of 20:20:20 kg/ha of N, P_2O_5 , and K_2O were side-placed 5 cm away from the seed rows using urea, di-ammonium phosphate (DAP), and muriate of potash (MOP), respectively. Well-decomposed farmyard manure (FYM at 6 t/ha) was incorporated into the treatment plots during final land preparation. For specific treatments, seeds were coated with *Rhizobium* biofertilizer, and zinc sulfate was applied

at sowing. Foliar sprays of the micronutrient mixture were applied at the initiation of the flowering stage.

Disease, Pest and Weed Management

Crop protection practices were performed based on field monitoring. Yellow sticky traps were installed to monitor and manage aphid populations. Dimethoate 30% EC was applied twice to control sap-sucking insects and minimize the viral diseases of mungbean. Manual weeding was performed twice-first at 20 DAS and second at 40 DAS along with regular physical cleaning of the plot channels.

Harvesting

Pods from the tagged sample plants were harvested manually when approximately 75% of the pods in the plot had turned brown. The first picking took place at 75 DAS. Harvesting was done manually until 90 DAT at the interval of 5 day.

Agronomic Observations and Data Collection

Five plants were randomly selected and tagged from the inner rows of each plot at 20 DAS. Phonological and yield associated metrics were recorded from these tagged plants.

Growth Parameters

Altogether five growth related parameter were recorded. Plant height was recorded from the five tagged plants at 30, 45, and 60 DAS. Measurement was taken from the base of the stem at the soil surface to the tip of the uppermost growing point. The number of

green leaves per plant (excluding senescent and unexpanded emerging leaves) was recorded at 15 day intervals starting from 30 DAS. The total number of primary branches emerging from the main stem was counted at 30 and 45 DAS. Destructive sampling was performed at 35 and 60 DAS by randomly uprooting five plants from the dedicated sampling rows of each plot. Fresh weights of the leaves and stems were recorded immediately. The plant parts were then oven dried at 70°C until a constant weight was observed, and the final dry biomass was recorded using a digital weighing balance. At 35 and 50 DAS, five plants per plot were randomly selected from the sampling rows for nodulation assessment. The plants were carefully uprooted, and their root were gently washed under slow running tap water to remove adhering soil particles without detaching the nodules. Total visible nodules and effective (pink/red internal color) nodules were counted manually.

Yield and Yield Attributes

Yield parameters were determined from the three central rows of each experimental plot. The total number of mature pods collected from the tagged sample plants across all pickings was recorded and averaged to find the mean number of pods per plant. Pod length was measured using a metric scale from 10 randomly selected mature pods collected from the sample plants during harvest. The same pods were used for counting total number of seeds. A representative sample of 500 clean, seeds was counted from each plot and weighed using an electronic balance. The plant population per hectare was calculated by counting the total number of plants within the net plot area at harvest and converting the value to a per-hectare by using the equation (i).

$$\text{Plant Population ha}^{-1} = \frac{\text{Number of plants counted in the net plot}}{\text{Net plot area (m}^2\text{)}} \times 10,000 \text{ m}^2$$

(i)

For yield calculation, grains harvested from the net plot area were threshed, cleaned, and weighed. The moisture content of the grains was initially 13-14% which was adjusted to a standard level (10%) after shade drying, and the plot yield was converted to kilograms per hectare (kg/ha) using following equation.

$$\text{Adjusted grain yield (kg/ha)} = \text{Raw grain yield (kg)} \times \left(\frac{100 - \text{Harvest moisture \%}}{100 - \text{Target moisture \%}} \right)$$

(ii)

Economic Analysis

The total cost of cultivation for each treatment was calculated by adding the fixed overhead costs to the variable operational costs (including inputs like seeds, fertilizers, labor, and land preparation) using prevailing market rates. Gross returns were calculated by multiplying the total economic grain and byproduct yield by the prevailing local market prices. Net returns and benefit cost ratio (B: C) were calculated using the following formula.

$$\text{Net returns (NPR ha}^{-1}\text{)} = \text{Gross returns} - \text{Total costs of cultivation}$$

(iii)

$$B:C = \frac{\text{Gross financial returns (NRs ha-1)}}{\text{Total cost of cultivation (NRs ha-1)}}$$

(iv)

Statistical Analysis

All experimental data were systematically compiled and organized by treatment in Microsoft Excel (version 2019). The data were subjected to an Analysis of Variance (ANOVA) for a single-factor RCBD using RStudio (version 4.3.3) with the agricolae package. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at a 5% level of significance. For graphical illustration Originpro 2026b (Learning edition) was used.

RESULTS AND DISCUSSION

Effect of Nutrient Management on Plant Height

Plant height increased with increasing the age of the crop across all treatments (Figure 4). Statistical analysis showed that there is no significant difference in the height of mungbean crops among the nutrient management treatments at 30, 45, and 60 DAS. At 30 DAS, plant height ranged from 7.10 cm (FAM + OM) to 8.13 cm (FP), with the RDF + ZnSO₄ (7.65 cm) recording the second tallest plant. At 45 DAS, the highest plant height was observed under FP (16.48 cm), while RDF + RI remained the shortest (14.00 cm). Numerical variation showed that *Rhizobium*-inoculated seedlings treated with the recommended dose of NPK fertilizer (RDF) were the tallest among the treatments.

The non-significant response of plant height to different nutrient management strategies suggests that, under the prevailing field conditions at Rampur, Chitwan, plant height during the vegetative stage was influenced more strongly by the genetic potential of the variety and prevailing agro-climatic conditions than by the applied nutrient sources. Our results on plant height align with Vishnoi et al. (2026), where *Rhizobium*-treated mungbean crops were found to be taller than other treatments. The similar non-significant finding was reported by Arangote et al. (2022) in his pot study of NPK, chicken manure phosphorus, and guano + phosphorus treatment. In contrast to our findings, many studies have reported a significant increment in plant height in response to different nutrient treatments (Pal et al., 2024; Singh et al., 2022).

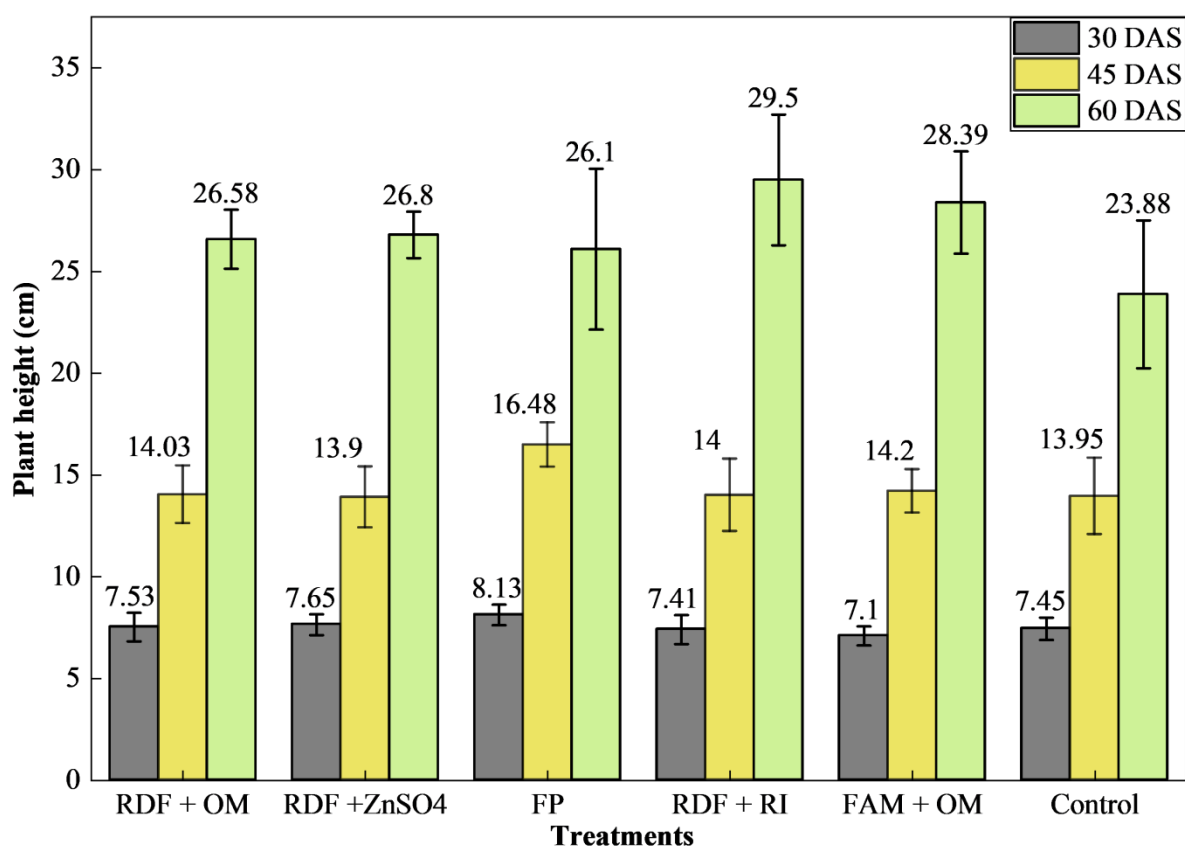


Figure 4. Effects of different nutrient management strategies on plant height of mungbean at different days after sowing in Rampur, Chitwan, 2025

Effect of Nutrient Management on Number of Leaves

The number of leaves increased across all treatments with increasing DAS, which is shown in Table 4. Results revealed a significant effect ($p < 0.01$) of nutrient management treatments on the number of leaves at 30 DAS. The highest number of leaves was recorded in FAM + OM (9.65), which was statistically at par with the control (9.05). The significantly lowest number of leaves was observed under RDF + OM (5.55). In contrast, the number of leaves did not differ significantly among treatments at 45 and 60 DAS. At 45 DAS, leaf number ranged from the lowest 15.90 (RDF + OM) to the highest 20.95 (FP), while at 60 DAS control group maintained the highest number of leaves (30.15) and RDF + OM recorded the lowest values (26.50).

Table 4. Effects of different nutrient management strategies on number of leaves of Mungbean at different DAS in Rampur, Chitwan, 2025

Treatments	Number of Leaves at Different		
	DAS		
	30	45	60
RDF + OM	5.55 ^c	15.90	26.50

RDF +ZnSO ₄	8.75 ^{ab}	20.20	28.40
FP	8.55 ^{ab}	20.95	30.05
RDF + RI	6.65 ^{bc}	17.10	26.65
FAM + OM	9.65 ^a	18.90	27.70
Control	9.05 ^a	20.35	30.15
SEm(±)	0.71	1.50	2.87
F- Test	**	NS	NS
LSD (0.05)	2.16	4.54	8.66
CV%	17.90	17.40	20.35
Grand Mean	8.03	18.90	28.24

Note: SEm (±) = Standard Error of Mean, LSD= Least Significant Difference, CV = Coefficient of

Variance; **: significant at ≤0.01 level of significance, NS= Non-Significant, DAS= Days After Sowing

Despite the nutrient supplementation, the significant reduction in leaf number under RDF + OM at 30 DAS suggests a possible early-stage lag in nutrient availability. Organic nutrient sources such as farmyard manure release nutrients more slowly than mineral nutrients, and only one-third to two-thirds are available in the first season (Niranjan et al., 2023). Several other studies had shown that organic manure often improves crop growth at later vegetative growth stages (50-60 DAS) or at harvest than at the earliest stage (Dhakal et al., 2015; Singh et al., 2022). FAM + OM had significantly increased the number of leaves in this study. The similar findings were also reported by Abdo (2001), Selim et al. (2023), and Jain et al. (2025) in their studies.

Effect of Nutrient Management on Root Nodules

The number of root nodules was found non-significant among the nutrient management treatments at both DAS (Figure 5). At 35 DAS, root nodule ranged from 15.11 (control) to 22.72 (RDF + RI). Again at 50 DAS, the control maintained the lowest nodule number (13.91), and RDF + RI, the highest (19.85). The decline in mean nodule from 35 to 50 DAS across treatments shows the natural senescence of root nodules as the crop shifts toward the reproductive stage (Bhuiyan, Mian, & Islam, 2008). The highest root nodule in the RDF + RI is due to a synergistic crop-microbe interaction. This finding is further supported by Mahmood et al. (2021) and Matkarimov et al. (2019).

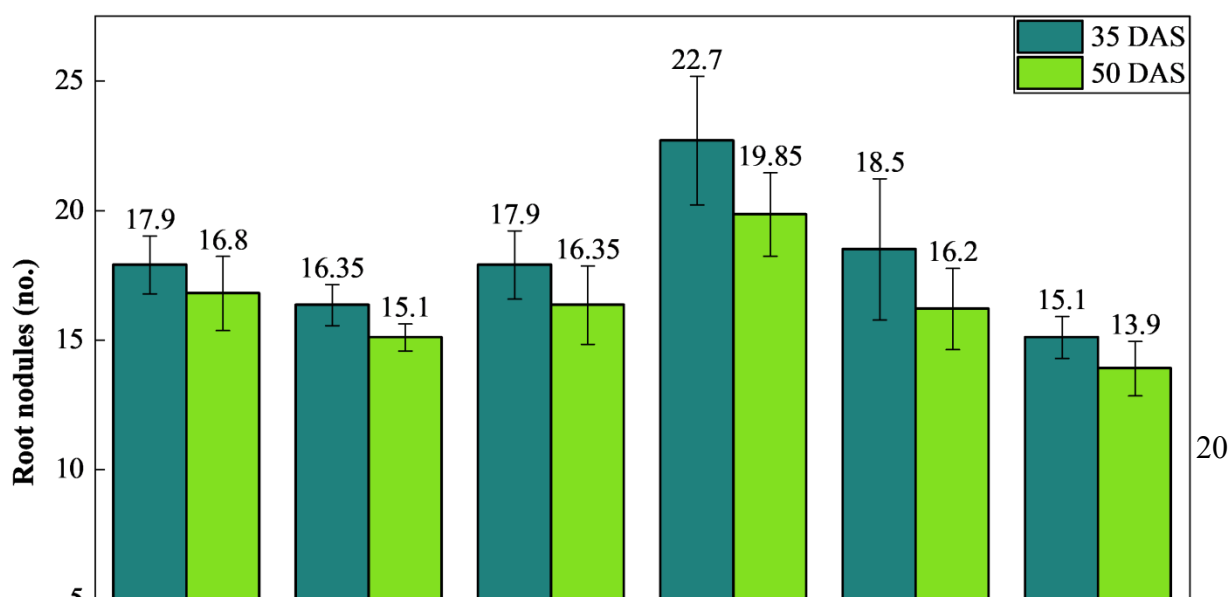


Figure 5. Effects of different nutrient management strategies on root nodules of mungbean at different days after sowing in Rampur, Chitwan, 2025

Effect of Nutrient Management on Number of Branches

The number of branches per plant at 45 and 60 DAS is presented in Figure 6. There were no significant effects of different nutrient management strategies on branch number at either DAS. At 45 DAS, the highest number of branches was recorded on farmer practices (4.90), while the lowest was on organic manure + RDF. Similarly, at the 60 DAS branch, the number ranged from 5.45 (*Rhizobium* inoculation + RDF) to 6.10 (RDF + ZnSO₄), with a grand mean of 5.74.

According to Mondal and Gera (2024), nutrient management effects appear significant only when the treatment matches the genotype and the site constraints. The overall lack of significant treatment response for both root nodulation and branching in this study suggests that these growth parameters were more probably governed more by crop genetic factors, soil properties, and environmental conditions at the experimental site than by the specific nutrient management practices applied.

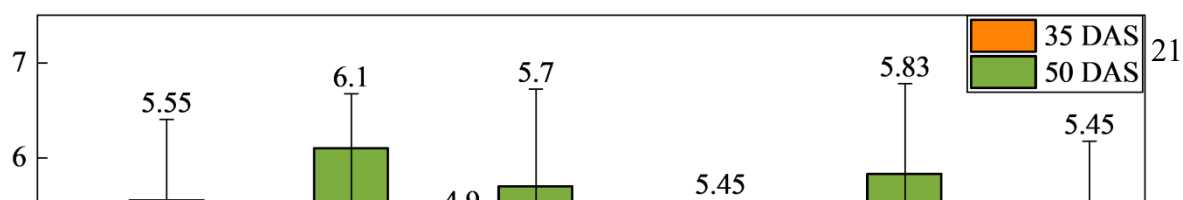


Figure 6. Effects of different nutrient management strategies on branch number of mungbean at different days after sowing in Rampur, Chitwan, 2025

Effect of Nutrient Management on Dry Weight of Stem and Leaf

The effect of different nutrient management practices on the dry weight of stem and leaf of mungbean at 35 and 60 DAS is presented in Table 5. Unlike the earlier growth parameters, dry matter accumulation in both stem and leaf showed significant treatment responses at both DAS.

At 35 DAS, the highest stem dry weight was recorded in the control (11.50 g), which was statistically at par with FAM + OM (9.12 g) and were followed by RDF + OM (7.43 g). By 60 DAS, the trend shifted. FAM + organic manure recorded the highest stem dry weight (21.58 g), statistically at par with RDF + OM (16.40 g) and FP (17.23 g). At both DAS RDF + RI recorded the lowest weight (4.40 and 5.45, respectively). In the case of leaf dry weight, at 35 DAS, FP recorded the significantly highest leaf dry weight (10.12 g). This was followed by control (6.52 g), which was statistically similar to FAM + OM (5.95 g). The lowest leaf dry weights were recorded in RDF + RI (4.00 g). At 60 DAS, FAM + OM produced the highest leaf dry weight (27.90 g), which is statistically similar to FP (22.76 g) and control (22.50 g). RDF+ RI again recorded the significantly lowest leaf dry weight (17.22 g).

In this study, despite the high root nodulation, RDF + RI recorded the lower aboveground biomass accumulation. This finding is supported by Bhuiyan, and Rahman, et al. (2008), where the author also found the highest root nodulation and highest root and shoot dry weight in different treatments. According to Figueiredo et al. (2016), a high number of nodulation in RDF + RI is due to active symbiosis. For higher above-ground biomass accumulation, there must be efficient conversion of fixed nitrogen into shoots. Nodulation and shoot growth often increase together, but not proportionally; therefore, maximal nodulation and maximal dry matter occurred at different nutrient treatments (Paul Tandra et al., 2026).

Table 5. Effect of different nutrient management practices on dry weight of stem and leaf of mungbean at DAS in Rampur, Chitwan 2025

Treatments	Dry Weight of Stem (g)		Dry Weight of Leaf (g) at	
	at Different DAS		Different DAS	
	35	60	35	60
RDF + OM	7.43 ^{bc}	16.40 ^{ab}	4.61 ^c	20.92 ^b
RDF +ZnSO ₄	5.87 ^c	14.97 ^b	4.06 ^c	19.70 ^b
FP	6.06 ^c	17.23 ^{ab}	10.12 ^a	22.76 ^{ab}
RDF + RI	5.90 ^c	12.21 ^b	4.00 ^c	17.22 ^b
FAM + OM	9.12 ^{ab}	21.58 ^a	5.95 ^{bc}	27.90 ^a
Control	11.50 ^a	15.88 ^b	6.52 ^b	22.50 ^{ab}
SEm(±)	0.85	1.70	0.60	1.89
F- Test	**	*	***	*
LSD (0.05)	2.58	5.13	1.81	5.70
CV%	22.37	20.81	20.51	17.33
Grand Mean	7.65	16.38	5.87	21.83

Note: SEm (±) = Standard Error of Mean, LSD= Least Significant Difference, CV = Coefficient of Variance; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; ***: significant at ≤0.001 level of significance, NS= Non-Significant, DAS= Days After Sowing.

Effect of Nutrient Management on Yield Attributing Characters

The effect of different nutrient management practices on number of pods per plant (NPP), pod length (PL), number of seeds per pod (NSP), plant population per hectare (PP/ha), and 500-seed weight is presented in the Table 6. NPP did not differ significantly among treatments, although numerical values ranged from 13.71 (FP) to

16.35 (RDF + OM). PL also showed non-significant results among treatments, ranging from 7.52 cm (RDF + OM) to 8.11 cm (FAM + OM), with a grand mean of 7.79 cm. NSP differed significantly among treatments ($p < 0.05$). The highest NSP was recorded in RDF + OM (8.95), statistically at par with RDF + RI (8.93) and RDF + ZnSO_4 (8.78). RDF + OM produced the significantly highest number of plant per hectare (PP/ ha) (194,444.40), while RDF + RI (202,777.80) and RDF + ZnSO_4 (186,111.10) were statistically at par with each other. The control group recorded the significantly lowest PP/ ha (165,277.80). 500-seed weight (SW) were also found significantly higher (20.63 g) in RDF + OM treatments.

Table 6. Effect of different nutrient management on different yield attributing characters of Mungbean in Rampur, Chitwan 2025

Treatments	NPP	PL	NSP	PP/ha	500-SW
RDF + OM	16.35	7.52	8.95 ^a	194444.40 ^a	20.63 ^a
RDF + ZnSO_4	15.99	7.70	8.78 ^a	186111.10 ^{ab}	20.55 ^a
FP	13.71	7.76	8.48 ^{ab}	180555.60 ^{ab}	18.62 ^{bc}
RDF + RI	16.32	7.94	8.93 ^a	202777.80 ^a	20.24 ^{ab}
FAM + OM	14.24	8.11	7.86 ^b	202777.80 ^a	18.22 ^c
Control	13.94	7.70	8.41 ^{ab}	165277.80 ^b	15.30 ^d
SEm(±)	0.55	0.08	0.05	8017.41	0.33
F- Test	NS	NS	*	*	***
LSD (0.05)	2.25	0.88	0.68	24167.10	1.74
CV%	9.89	7.53	5.27	8.49	6.12
Grand Mean	15.09	7.79	5.27	188657.40	18.92

Note: SEm ($\pm$) = Standard Error of Mean, LSD= Least Significant Difference, CV = Coefficient of Variance; *: significant at ≤ 0.05 level of significance; ***: significant at ≤ 0.001 level of significance, NS= Non-Significant. NPP: Number of Pods/Plant; PL: Pod Length (cm); NSP: Number of Seeds/Pod; PP/ha: Plant Population per hectare; 500-SW: 500 Seed Weight (g)

Overall, RDF + OM performed better among the treatments for improving yield attributes especially NSP, PP/ ha, and 500-seed weight. Choudhary et al. (2025) had also reported a higher yield attributing characters in RDF + OM. Since, organic manure release the nutrient slowly, incorporating recommended dose of inorganic fertilizer with them helps in boosting the productivity of crops (Panday et al., 2024). Furthermore, use of RDF + ZnSO₄ and RDF + RI had also showed a positive correlation in yield attributing characters. Application of ZnSO₄ alongside inorganic fertilizers improved root capacity to absorb nutrients from soil, helped in primordial initiation, and translocation of photosynthates from green leaves to reproductive organs (Singh & Dubey, 2024). Foliar spray of zinc accelerated the rate of photosynthesis which further enhanced the mobilization of food from leaves to developing grains and ultimately increased the overall crop yields (Kaur & Sharma, 2025). The significantly higher NSP showed that RDF + RI have positive effects on seed formation. The results are in agreement with the findings of Khan et al. (2017) and Paul Tandra et al. (2026) who also found the similar results with *Rhizobium* inoculation.

Effect of Nutrient Management on Grain Yield

The different nutrient management strategies had significantly increased the grain yield of mungbean (Figure 7). The highest grain yield was recorded under RDF + RI (1066.90

kg/ha), which was statistically at par with RDF + OM (1060.40 kg/ha). Compared to the control group, the yield of the RDF + RI group is approximately 132% more. The control group recorded the significantly lowest grain yield (459.57 kg/ha). Overall, the results demonstrates that combining recommended NPK with either OM or RI produced the highest grain yield in mungbean. The highest yield in RDF + RI and RDF + OM might be due to higher yield-attributing character (NPP, PL, NSP, PP/ha, and 500-SW) observed in Table 3. This result is supported by Bam et al. (2022); Bhuiyan, Mian, and Islam, (2008).

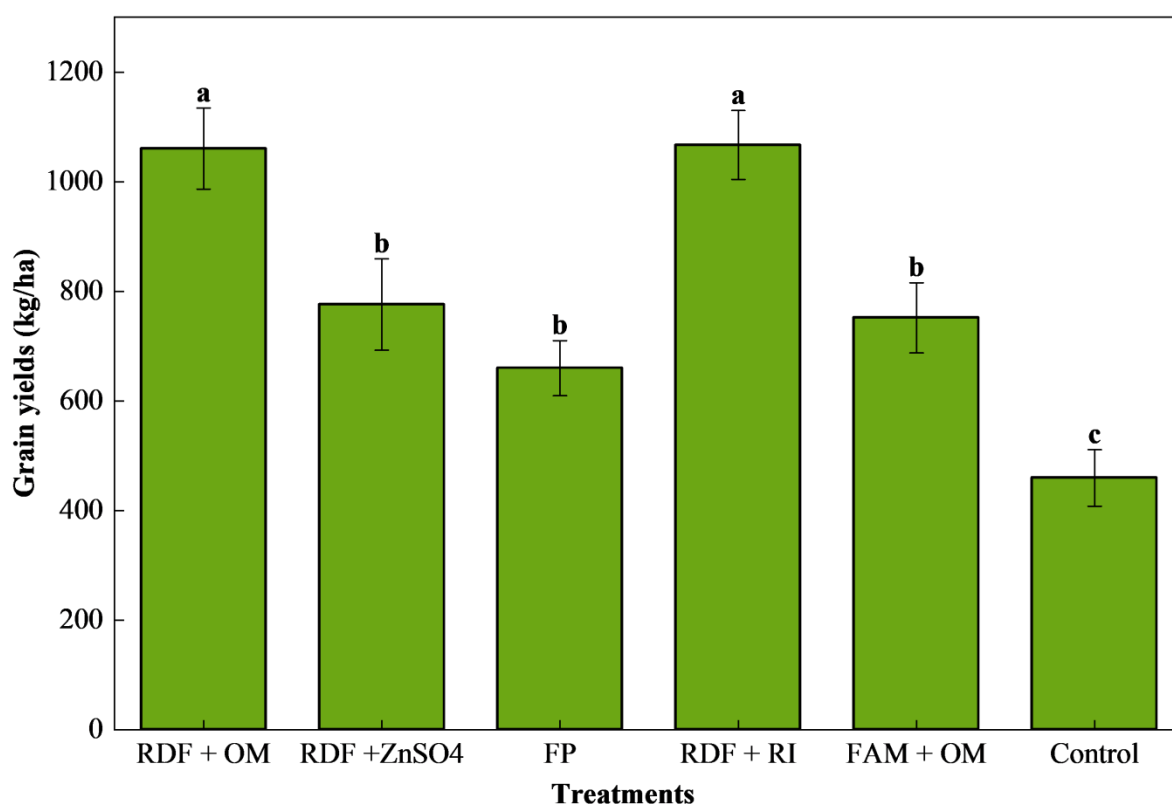


Figure 7. Effects of different nutrient management strategies on grain yield of mungbean in Rampur, Chitwan, 2025

Correlation among Yield and Yield Attributing Traits of Mungbean

Triangular Pearson correlation analysis performed to assess the relationships among number of pods per plant (NPP), pod length (PL), number of seeds per pod (NSP), pod yield per hectare (PP/ha), grain yield, and 500-seed weight (500-SW) of mungbean is presented in Figure 8. The results shows a strong positive correlations of grain yield with most of the yield attributing traits, particularly NPP ($r = 0.85$), 500-SW ($r = 0.86$), and PP/ha ($r = 0.81$). These three traits contributed directly to final grain yield in this study. Yield also showed a moderate positive relationship with NSP ($r = 0.60$), whereas its association with pod length ($r = -0.04$) was negative.

Among the yield components themselves, NPP was strongly positively correlated with NSP ($r = 0.78$) and 500-SW ($r = 0.81$). The findings suggest that plants bearing more pods also tended to produce more seeds per pod along with heavier seeds. PP/ha showed a positive correlation with NPP ($r = 0.53$), PL ($r = 0.51$), and 500-SW ($r = 0.68$) whereas, PL showed negative correlations with NPP ($r = -0.28$) and NSP ($r = -0.65$). This value clearly indicates that plants with longer pods tended to produce fewer pods and fewer seeds per pod. This inverse relationship, together with the weak negative correlation between pod length and grain yield, suggests that pod length was not a major determinant of yield performance under these field conditions, and increased pod length may have come at the expense of pod or seed number.

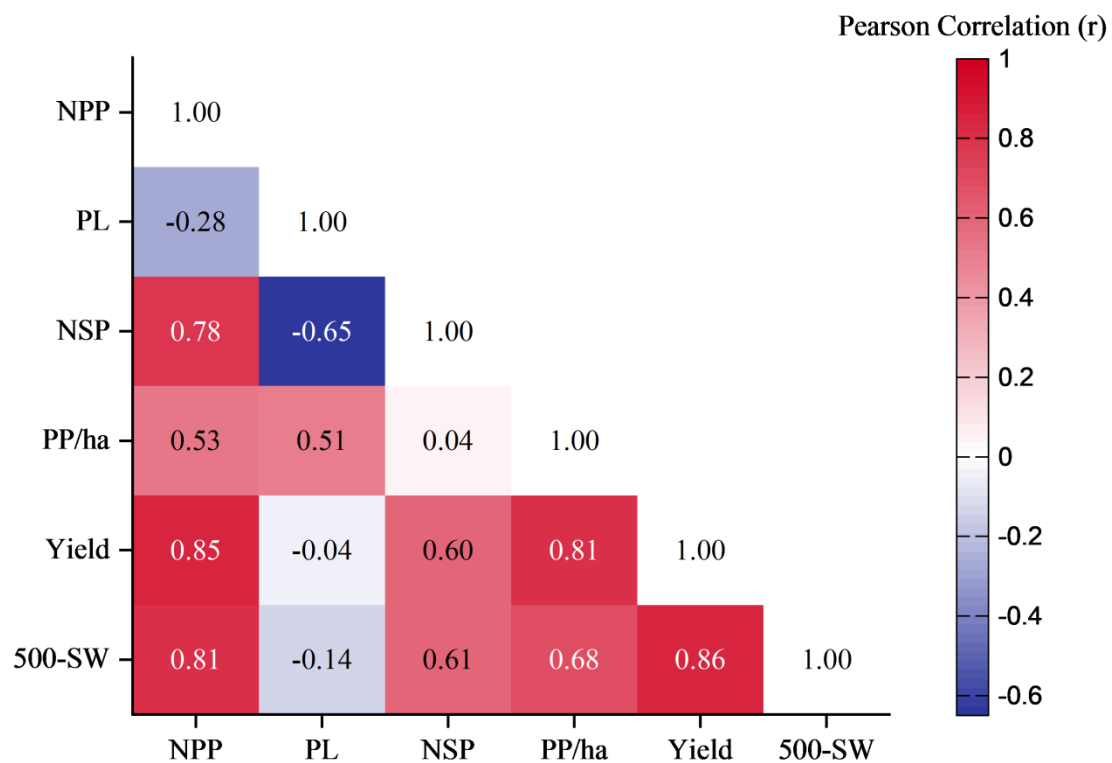


Figure 8. Triangular Pearson correlation heatmap of key crop yield attributes. The color scale represents the correlation coefficient (r), where red indicates a strong positive correlation and blue indicates a strong negative correlation. *NPP*: Number of pods/plant; *PL*: Pod length (cm); *NSP*: Number of seeds/pod; *PP/ha*: Plant population per hectare; *500-SW*: 500 seed weight (g)

Economic Analysis

The economic analysis of mungbean production under different nutrient management practices is presented in Table 7. Total cost of cultivation was calculated from treatment input costs and gross returns was from mean yield $\times$ fixed price. Total cost of cultivation ranged from NRs 70,400/ha (Control) to NRs 99,675/ha (RDF + RI). The variation was due to added input costs of fertilizers, biofertilizers, and organic manure across treatments. The control maintained the lowest cultivation cost since no external nutrient inputs were applied, while RDF + RI incurred the highest cost, mainly due to combined costs of recommended fertilizer and *Rhizobium* inoculant.

B: C was found significantly the highest for RDF + OM (1.64) and RDF + RI (1.60), meaning farmers earned NRs 1.63 and NRs 1.60 respectively for every NRs 1 invested under these treatments. To be an economically viable, any agricultural enterprises must cross the threshold value of 1.5 (Bam et al., 2022). In our study, RDF + OM and RDF + RI showed the most economically efficient nutrient management practices. RDF + ZnSO₄ (1.17), FAM + OM (1.20), and FP (1.12) showed a B: C below threshold value, while the control results in financial loss with B: C of 0.98.

Table 7. Analysis of benefit cost ratio (B: C ratio) of mungbean production under different nutrient management sources

Treatments	Total Cost of Cultivation (NRs/ ha)	Gross return (NRs/ha)	Net return (NRs/ha)	B:C ratio
RDF + OM	97175.00 ^c	159061.05 ^a	61886.05 ^a	1.64 ^a
RDF +ZnSO ₄	98875.00 ^b	116393.34 ^b	17518.34 ^b	1.18 ^b

FP	87900.00 ^e	98941.74 ^b	11041.74 ^b	1.13 ^b
RDF + RI	99675.00 ^a	160036.07 ^a	60361.07 ^a	1.60 ^a
FAM + OM	91400.00 ^d	112738.88 ^b	21338.88 ^b	1.23 ^b
Control	70400.00 ^f	68935.60 ^c	-1464.39 ^b	0.98 ^b
SEm(±)	0	8001.50	8001.50	0.08
F- Test	***	***	***	***
LSD (0.05)	0	24119.11	24119.11	0.27
CV%	0	13.40	56.25	13.89
Grand Mean	90904.17	119351.10	28446.95	1.29

Note: SEm (±) = Standard Error of Mean, LSD= Least Significant Difference, CV = Coefficient of Variance; ***: significant at ≤0.001 level of significance; B:C=Benefit Cost Ratio

CONCLUSION

The results indicate that integrated application of recommended dose of fertilizer (RDF) with either *Rhizobium* inoculation or organic manure was the most effective and economically profitable nutrient management strategy for mungbean cultivation at Chitwan, Nepal. Although treatment interventions had minor effects on biometric traits, yield and yield-attributing traits were significantly higher under RDF + RI and RDF + OM. Thus, this study concludes that either of these two nutrient management options can effectively address the nutrient management challenges faced by mungbean growers in Chitwan, Nepal. Farmers adopting these treatments can obtain higher grain yield and greater economic returns compared to other nutrient management practices. Further multilocation trials across diverse edaphic conditions are recommended to validate these findings and support their wider recommendation for mungbean production in Nepal.

Ethics

This study did not involve human participants, animals, or personal data. Therefore, ethical approval was not required. The plant material used in the experiment was the registered mungbean variety 'Kalyan', obtained from the National Grain Legumes Research Program (NGLRP), Khajura, Nepalgunj, Nepal.

Data Availability Statement

The datasets are available from the corresponding author on reasonable request from corresponding author.

Consent to Participate

Not applicable. This study did not involve human participants.

Consent to Publish

Not applicable. This study did not involve any individual person's identifiable information or images.

Funding Statement

The authors received no financial support or funding for the research, authorship, or publication of this article.

Conflict of Interest

The authors declare that they have no conflict of interest related to the publication of this article.

Author contribution

Rabindra Kumar Bhandari conducted the research and prepared the manuscript.

Deepika Timsina conceptualized the research and contributed to the preparation, review, and finalization of the manuscript. Khumananda Kandel performed the data analysis and contributed to manuscript preparation.

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