International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM January 2026, 17(1): 01-08

Article AR6773

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.6773

Integrated Management of Nutrients on Growth and Yield of Mungbean

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ABSTRACT

A two-year field experiment was conducted in pre-*kharif* season (Feb-April) during 2021 and 2022 in Randomized Block Design with eight treatments replicated 3 times at the instructional farm of UBKV, West Bengal, India to evaluate the efficiency of integrating organic amendments with reduced doses of chemical P fertilizer on the growth, yield attributes of summer mungbean in an acidic soil. Despite of having high protein content, mungbean (*Vigna radiata* L.) productivity was constrained by phosphorus (P) deficiency in widespread acidic soils. Integrated nutrient management (INM) strategies offered a sustainable solution to enhance P availability and crop performance. These treatment included-control (T_1), farmer's practice (T_2), state-recommended dose of P (T_3), NK+150% of the RD of phosphorus through SSP (T_4), and NK+75% of RD of Phosphorus through SSP+25% phosphorus through phosphocompost (T_5), NK+75% of the RD of phosphorus through SSP +25% phosphorus through Farm Yard Manure (FYM) (T_6), NK+75% of RD of phosphorus through SSP+25% phosphorus through vermicompost (T_7), or NK+75% of the RD of phosphorus through SSP+25% phosphorus through rockphosphate +PSB (T_8). Treatment T_7 (75% SSP+25% P as Vermicompost) consistently demonstrated superior performance, recording the maximum values for plant height (55.13 cm), branches plant^{-1} (13.00), pods plant^{-1} (26.87), test weight (35.50 g), seed yield (10.70 q ha^{-1}) and stover yield (20.3 q ha^{-1}). The treatment T_7 was identified as the optimal INM strategy to increas mungbean productivity in acidic soils by improving P use efficiency and soil health, offering a sustainable alternative to sole reliance on inorganic fertilizers.

KEYWORDS: Acidic soil, mungbean, phosphorus, rockphosphate, vermicompost

Citation* (VANCOUVER)*: Balo et al., Integrated Management of Nutrients on Growth and Yield of Mungbean. *International Journal of Bio-resource and Stress Management,* 2026; 17(1), 01-08. HTTPS://DOI.ORG/10.23910/1.2026.6773.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 22nd October 2025 RECEIVED in revised form on 19th December 2025 ACCEPTED in final form on 04th January 2026 PUBLISHED on 12th January 2026

1. INTRODUCTION

India holds a pivotal yet paradoxical position in the global pulse sector, positioning as the world's largest producer, importer, and consumer (Roy et al., 2022). Among the vegetarian diets, pulses serve as the most economical and accessible source of vegetable protein (Teferra et al., 2021). Therefore, increasing their consumption is a critical public health strategy for combating pervasive malnutrition caused by protein deficiency. Despite their importance, domestic production is constrained by chronically low yields, caused by non-availability of quality seed of improved varieties, acidic soil condition, cultivation under high rainfall area with medium to low land and unscientific post harvest management etc (Gowda et al., 2013). A systems-based approach focused on soil health and ecological management can be an alternative strategy for enhancing pulse productivity.Acidic soils, (49 mha of the country's geographical area which represents nearly 15% of the total cultivable land) poses significant challenge to agricultural productivity (Rao et al., 2020). low availability of primary nutreints mainly phosphorous which plays a important role in root growth and protein quality is fixed in low pH soils due to presence of iron and aluminium oxide (Gupta, 2020) resulting less uptake by plants under high rainfall areas (Agegnehu et al., 2021). Mungbean, a significant leguminous pulse, requires balanced phosphatic nutrition for optimal yield despite minimal nitrogen needs, and its seeds are valued for high protein content, digestibility, and absence of flatulence-inducing compounds (Schutyser et al., 2025) because of high cost and inconsistent availability of phosphatic fertilizer. The seeds contain about 24.7% protein, 0.6% fat, 0.9% fiber, 3.7% ash (Potter and Hotchkiss, 1997), and a sufficient amount of phosphorus (0.4%) (Meena et al., 2015). Recently, the integration of organic amendments is recognized as a vital strategy for sustainable agriculture, enhancing crop productivity by improving soil structure and providing a multi-nutrient source. Organic materials hold great promise as a source of multiple nutrients and ability to improve soil characteristics (Moller, 2009). Rock phosphate is not a suitable direct fertilizer due to its low solubility, despite a high phosphorus (P) content of 28–30% (Reddy et al., 2002). Its effectiveness is enhanced by soil organic matter, which releases organic acids after decomposition. These acids lower soil pH and chelate calcium and magnesium ions, thereby solubilizing the fixed phosphorus and increasing its plant availability (Savini et al., 2006). For increased nutrient supply through bio-fertilizers, there is a need for improving the efficiency of biological nitrogen-fixation system. Phosphorus-solubilizing bacteria are also reported to be beneficial in increasing the phosphorus availability in soil and thereby seed yield of mungbean (Bilal et al., 2021). Vermi compost, is a rich source of N, P, K and micronutrients, can be used for sustainable bio-fertilizer regenerated from organic wastes using earthworms enhance improvement of soil's quality (Meena et al., 2015). Farmyard manure (FYM) plays importnt role to increase crop yields sustainably. Research demonstrates that FYM enhances productivity by improving soil health and establishing a concomitant nutrient balance, while also reducing pollution hazards and external fertilizer costs (Nisar et al., 2025). Phosphocompost also results increase in mungbean yield in combination with SSP and seed inoculation with Aspergillus awamori+Psuedomonas striata (Yadav et al., 2017). These findings indicate that using organic amendments can serve as a viable substitute for expensive and hard-to-obtain inorganic fertilizers to enhance mungbean yield in low-input farming systems (Diatta et al., 2023). In light of these facts, the present study was conducted to assess the impact of combined organic nutrient management practices on the growth attributes and yield of summer mungbean, with the objective of identifying the optimal combination of organic and inorganic fertilizers for enhanced yield and quality in acidic Terai soils.

2. MATERIALS AND METHODS

A two year field experiment was conducted during pre *kharif* season (Feb-April) during 2021 and 2022 at instructional farm of UBKV, West Bengal-India situated at 26 0 19'86"N latitude and 89 0 23'53" E longitude at an elevation of 43 m above mean sea level. The experimental soil was sandy loam, low in available N (85.78 kg ha^{-1}), medium in available P (18.2 kg ha^{-1}) and K (108.68 kg ha^{-1}) with organic carbon 0.39 %, electrical conductivity and pH were 0.041 dS m^{-1} and 5.33, respectively. Soil pH and EC were measured in a 1:2.5 soil-water suspension using a pH meter and conductivity meter respectively. Soil organic carbon was determined by the Walkley and Black (1934) method, available nitrogen by the modified Macro Kjeldahl method (Jackson, 1967), phosphorus by Bray's No. I method (Jackson, 1967), potassium using neutral normal ammonium acetate with flame photometry (Jackson, 1967), and textural class by the Hydrometer method (Bouyoucos, 1962). The experiment was laid out in Randomized Block Design with 8 treatment combinations and three replications; T_1-Control (NK)+P , T_2-Farmer's Practice [Fertilizer dose (kg ha^{-1}) N:P:K^0_-10:40:30], T_3-State recommendation N:P:K-20:60:40 in kg ha^{-1} (RDF),T_4-NK+150% of the RD of Phosphorus through SSP T_5-NK+75% of RD of Phosphorus through SSP+25% Phosphorus through Phosphocompost, T_6-NK+75% of the RD of Phosphorus through SSP+25% Phosphorus through Farm Yard Manure (FYM), T_7-NK+75% of RD of Phosphorus through SSP+25% Phosphorus through Vermicompost T_8-NK+75% of the RD of Phosphorus through SSP+25%

Phosphorus through Rockphosphate+PSB. Vermicompost, Phosphocompost, FYM were applied 10 days before sowing. 20 days prior to sowing Rockphosphate was applied and mixed into topsoil to 10 cm depth. At the time of sowing, 100% doses of inorganic fertilizer were applied while seeds were inoculated with PSB at 20 g seed^{-1} before sowing and kept for 30 min in shade for T_8 treatment. Urea, SSP and MOP were used as sources of N, P and K, respectively, for supplying the levels of RDF. The seeds of mungbean (Samrat variety) were soaked overnight then finally sown at 25 kg ha^{-1} in plot size 5×4 m^2 (20 m^2) under 30×10 cm^2 spacing during 3rd week of Feb for both year. All the recommended agronomic and plant protection practices were carried out in the experimental plots. Five randomly selected plants from each plot were tagged for recording observations on plant height, number of branches, number of pods plant^{-1}, number of seeds pod^{-1}, test weight, seed yield, straw yield and harvest index. Plants were harvested at full maturing stage around 65 days from the experimental plots, then, threshing, pod and seed accounting was carried out. Data were analyzed by using SPSS 27 software. Variations in the average treatment were determined using the least significant difference (LSD) test and the means were compared by Duncan's Multiple Range Test (DMRT) at p=0.05 level of probability following the approach outlined by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Plant height

The application of phosphorus significantly influenced mungbean plant height at maturity after sowing during the 2021 and 2022 growing seasons. Based on pooled data, the tallest plants at harvesting stage were recorded with treatment T_7 (55.13 cm), which was statistically at par to T_8 (54.09 cm). The control treatment (T_1) resulted in the shortest plants (45.66 cm) presented in Table 1. These findings indicated that the synergistic application of phosphorus with organic and biofertilizers promotes superior early vegetative growth (Akhtar et al., 2017). This improvement was likely attributable to improved soil physiochemical properties, increased microbial density and enzyme activity, and greater nutrient availability, particularly from amendments like Vermicompost. The results align with previous studies demonstrating that combined organic and inorganic fertilization enhanced plant height than sole application. Treatments with Rhizobium and PSB, especially alongside FYM, resulted in the tallest plants at all growth stages Singh et al. (2023). Similar finding also found by Aslam et al. (2024) that plant height significantly improved with integrated use of vermicompost and chemical fertilizers compared to the control treatment which had the lowest plant height.

3.2. No of branches plant^{-1}

Treatment effects significantly influenced the number of branches plant^{-1} in mungbean across both experimental years. Pooled data revealed that treatment T_7 produced the highest number of branches (11.08), which was statistically superior to all other treatments (Table 1), while the control (T_1) resulted in the lowest (5.77). A positive trend was observed where increasing phosphorus levels, particularly in combination with organic manure, corresponded with enhanced branching by improving capacity to capture sunlight. Khaleeq (2024) observed that phosphorus has critical role in energy metabolism and photosynthesis, which promotes the development of lateral buds. These findings were consistent with previous research indicating that phosphorus application, especially when integrated with bio-inoculants like Rhizobium and PSB, stimulates branching and growth potential in mungbean (Rani et al., 2016 and Siddiqui et al., 2024).

3.3. Pod length

The effect of various treatments on pod length was assessed, but statistical analysis indicated no significant differences among them (Table 1). Despite this, the data showed noticeable variation, with pod lengths ranging from 6.75 cm in treatment T_1 to 9.46 cm in T_7. Treatments T_7 and T_8 (9.42 cm) tended to produce the longest pods, whereas T_1 had the shortest. Although these differences were not statistically significant, the tendency for longer pods in T_7 and T_8 could be attributed to the application of Vermicompost and rock phosphate combined with PSB, which might enhance plant vigor and nutrient availability-especially phosphorus, an important element for reproductive growth under improved soil conditions (Sande et al., 2024). Comparable observations were reported by Khatun et al. (2008), and Rezapoorian et al. (2020), who found that increased

Table 1: Effect of phosphorus and organic treatments on growth parameters of mungbean

Treatment	Plant height (cm)	No of branches plant^{-1}	Pod length (cm)
T_1	45.66^{f}	7.69^{d}	6.75
T_2	49.49^{de}	9.82^{ac}	7.64
T_3	51.16^{cd}	9.99^{bc}	7.86
T_4	48.47^{e}	8.68^{cd}	8.45
T_5	52.76^{bc}	10.63^{b}	7.86
T_6	51.69^{cd}	10.38^{b}	7.02
T_7	55.13^{a}	13.00^{a}	9.46
T_8	54.09^{ab}	11.31^{b}	9.42
Sem±	0.51	0.50	0.67
LSD (p<0.05)	1.55	1.53	NS

phosphorus levels promoted pod length in mungbean. Nevertheless, the absence of statistical significance in the present study suggested that the observed effects were inconsistent or insufficiently strong to draw definitive conclusions. Medhi et al. (2014) suggested that pod length improvement was mainly influenced by growth regulator application rather than phosphorus dose.

3.4. Pod number plant^{-1}

Integrated phosphorus management significantly increased the number of pods plant^{-1} in mungbean (Table 2). The highest pod count was recorded in treatment T_7 (26.87), followed by T_8 (25.97) both significantly greater than the control T_1 (22.01). This improvement was attributed to the synergistic effect of phosphorus applied with phosphate-solubilizing bacteria (PSB) and organic amendments. PSB enhanced phosphorus solubility and uptake, thereby supporting reproductive development. These findings aligned with previous research demonstrating that combining organic sources with PSB inoculation significantly boosts pod production in legumes through improved nutrient availability. The collaborative effect of rock phosphate with phosphate-solubilizing bacteria (PSB) and organic amendments (e.g., Vermicompost, FYM) secrets organic acids and growth-promoting substances which solubilized fixed forms of P under acidic soils. Thus increased reproductive growth and pod development. Additionally, Vermicompost used in the treatments served as a rich source of nutrients, including carbohydrates, amino acids, and proteins which contributed to improved seed quality and pod formation (Olle, 2019). The positive effect of PSB and phosphorus on pod development was well-supported in the literature, with similar results reported by Bilal et al. (2021) in their study on integrated nutrient management for legumes.

Table 2: Effect of phosphorus and organic treatments on yield attributing parameters of mungbean (pooled mean from consecutive two years)

Treatment	Pods plant^{-1}	Seeds pod^{-1}	Test weight (g)
T_1	22.01^{e}	6.29^{b}	31.13^{cd}
T_2	24.15^{cd}	6.62^{b}	30.55^{d}
T_3	25.04^{bcd}	7.26^{a}	32.74^{bc}
T_4	24.07^{d}	7.20^{a}	33.58^{ab}
T_5	25.59^{abc}	7.69^{a}	32.26^{bcd}
T_6	26.02^{ab}	7.30^{a}	31.36^{cd}
T_7	26.87^{a}	7.45^{a}	35.50^{a}
T_8	25.97^{ab}	7.55^{a}	35.25^{a}
Sem±	0.364	0.19	0.55
LSD (p<0.05)	1.114	0.61	1.70

3.5. Seeds pod^{-1}

The number of seeds pod^{-1} was significantly evaluated by treatment combinations (Table 2). Values ranged from 6.29 in the control (T_1) to 7.55 in T_8, with treatments T_5, T_7, and T_6 consistently producing more seeds pod^{-1} than the control. Maximum seeds pod^{-1} was recorded in T_7 (7.45). This results clearly suggested that the improved phosphorus availability and overall plant health was facilitated by amendments such as Phosphocompost, Vermicompost, and rock phosphate combined with Phosphate Solubilizing Bacteria (PSB). Similar kind of results also observed by Shamsurahman et al. (2020). These results aligned with previous studies confirming that phosphorus fertilization, particularly when integrated with organic inputs, promoted better seed formation in leguminous crops by improving nutrient uptake and photosynthetic efficiency (Ghosh et al., 2007; Khan et al., 2017)

3.6. Test weight

Statistically significant differences in test weight were recorded across treatments, ranging from 31.13 g (T_1) to 35.50 g (T_7) (Table 2). The superior test weight in T_7 indicates that Vermicompost application positively influenced pod development by contributing plant vigour and nutrient uptake, thus improving resource mobilization and assimilate partitioning to the grains. This result aligned with findings with Singh et al. (2011) and Hussen et al. (2020). On the other hand, lowest test weights suggest a higher proportion of less dense seeds, which could adversely affect yield and nutritional quality, observed by Singh et al. (2007) and Khanal et al. (2025). Additionally, test weight increased proportionally with rising phosphorus levels, supporting enhanced nutrient use efficiency at optimal P supply, which facilitated assimilate translocation during critical grain-filling stages (Dejene et al., 2016; Tairo and Ndakidemi, 2013).

3.7. Seed yield

Seed yield was significantly influenced by phosphorus treatments, with the maximum yield (1070 kg ha^{-1}) observed in T_7 which was statistically on par with T_8 (963 kg ha^{-1}) (Table 3). The lowest yield was recorded in the control T_1 (4.95 q ha^{-1}). The increased yield in T_7 was attributed to improved nutrient uptake, enhanced nodulation, and increased photosynthetic activity facilitated by Vermicompost and chemical phosphatic fertilizer application. Vermicompost promotes nutrient mineralization through enzymatic activity (e.g., protease, cellulase), improving soil health and nutrient availability (Jat and Ahlawat, 2006). Similarly, rock phosphate application and phosphorus-solubilizing bacteria (PSB) increased yield by improving root growth, nutrient mobilization, higher foliage growth, increased photosynthetic activity and assimilate

Table 3: Effect of phosphorus and organic treatments on yield and harvest index of mungbean (pooled mean from consecutive two years)

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1	495^{f}	629^{b}	31.13^{cd}
T_2	587^{ef}	662^{b}	30.55^{d}
T_3	693^{d}	726^{a}	32.74^{bc}
T_4	656de	720^{a}	33.58^{ab}
T_5	881^{bc}	769^{a}	32.26^{bcd}
T_6	810^{c}	730^{a}	31.36^{cd}
T_7	1070^{a}	745^{a}	35.50^{a}
T_8	963^{b}	755^{a}	35.25^{a}
Sem±	0.31	0.19	0.55
LSD (p<0.05)	1.73	0.61	1.70

partitioning (Suryantini, 2016) under acid soils. Integrated nutrient management, including organic amendments like FYM, Phosphocompost and Vermicompost with optimal P levels and bio-inoculants, consistently improved mungbean growth and yield associated traits of Samrat cultivars (Raiger et al., 2023; Amanullah et al., 2017), offering a sustainable strategy to enhance productivity.

3.8. *Stover yield*

Organic manure and chemical phosphatic fertilizer showed significant variation among the treatments for stover yield (Table 3). The highest yields were recorded in T_7, T_8, and T_5, demonstrating the efficacy of integrated phosphorus sources. Treatments T_3 (726 kg ha^{-1}) to T_8 (755 kg ha^{-1}) recorded moderate yields and were statistically at par. The lowest stover yield was observed in the control T_1 (629 kg ha^{-1}), followed by T_2 (662 kg ha^{-1}). Biomass accumulation in superior treatment was explained due to improved nutrient availability and uptake, facilitated by the synergetic effects of organic amendments, optimized phosphorus levels, and microbial inoculants. This combination promoted robust plant growth and development, produced greater dry matter production. These findings was supported by Rekha et al. (2018), Singh et al. (2022) and Yousaf et al. (2024) confirming that integrated nutrient management was a viable strategy for enhancing stover yield in summer mungbean in pre-*kharif* season.

3.9. *Harvest index*

The highest harvest index was recorded in T_7 (34.55), followed by T_8 (32.75), while T_1 showed lowest value (31.35). There was no significant difference among the treatment har harvest index as it was a inherent property of the variety which could not be changed due to varied nutrient application (Table 3). Though increased value under T_7 and T_8 was likely due to enhanced phosphorus availability, which facilitated assimilate translocation and metabolic processes critical for seed filling. This effect was mainly increased due to the combined application of phosphorus-solubilizing bacteria (PSB) organic amendments and chemical fertilizer, which enhanced nutrient uptake photosynthetic efficiency and heavier seeds (Jha et al., 2012). Similarly, Tahir et al. (2020) reported a maximum harvest index in mungbean with combined Rhizobium and PSB inoculation, attributing this to enhanced nodulation, nitrogen fixation, and phosphorus solubilization.

4. CONCLUSION

Integrated nutrient management (75% of the recommended phosphorus from SSP combined with 25% from vermicompost ~T7) was found as an optimal strategy for summer mungbean (Samrat variety) in acidic soils of terai regions, as it increased seed yield by 127% (10.70 q ha^{-1}) over the control. T_8 also suggested that integrating organic amendments and bio-inoculants with reduced chemical fertilizers was a viable and sustainable approach to overcome phosphorus constraints and achieve higher yields.

5. FURTHER RESEARCH

Future research should prioritize the integration of multi-disciplinary approaches to explain the genetic and molecular mechanisms on primary phosphorus acquisition of mung bean and utilization efficiency under combined organic and inorganic fertilization regimes. Furthermore, in long-term, multi-location field trials are essential to systematically assess the synergistic effects of integrated nutrient management, specifically the combination of biofertilizers, vermicompost, and reduced synthetic phosphorus on soil microbial community structure, carbon sequestration dynamics, and crop resilience to abiotic stresses.

6. ACKNOWLEDGEMENT

We thank the government of West Bengal for providing financial support to1st author University Research Fellow scholarship during the study. We also sincerely acknowledge the Department of Soil Science and Agricultural Chemistry, Uttar Banga Krishi Viswavidyalaya, Coochbehar for providing all logistic support during the experiment.

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