International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 09 Issue 07 July 2026
DOI: 10.47191/ijcsrr/V9-i7-65, Impact Factor: 8.048
IJCSRR @ 2026
www.ijcsrr.org

Review of Organic and Inorganic Fertilizer Practices in Mung Bean (Vigna radiata L.) under Kabul Climatic Conditions

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ABSTRACT: Mung bean (Vigna radiata L.) is a short-duration pulse crop of global importance, valued for its nutritional quality, nitrogen-fixing ability, and adaptability to semi-arid climates. In Afghanistan, particularly under Kabul agro-climatic conditions, productivity remains below global averages due to poor soil fertility, limited access to improved varieties, and inadequate nutrient management. This review synthesizes recent evidence (2022–2026) on organic and inorganic fertilizer practices in mung bean cultivation. Organic amendments such as poultry manure at higher application rates (8–10 t ha^{-1}) significantly enhance vegetative growth, pod formation, and grain yield [1,2,4]. Inorganic NPK fertilizers provide immediate nutrient availability but risk long-term soil degradation if applied alone [3,6]. Integrated nutrient management (INM), combining mineral fertilizers with organic inputs, improves soil fertility, microbial activity, and sustainability, offering superior productivity outcomes [7,11,12]. Improved varieties such as Enam demonstrate positive responses under INM strategies, underscoring the importance of genotype × environment × management interactions [2,5,9]. Recent studies highlight biofertilizers and micronutrient supplementation as promising approaches to further enhance nodulation, nitrogen fixation, and seed quality [3,8,10]. Key research gaps remain in varietal performance, soil fertility constraints, and region-specific INM practices. Adoption of integrated fertilizer management can substantially improve mung bean productivity and soil health in Kabul and similar semi-arid regions, contributing to food security and sustainable agriculture.

KEYWORDS: Mung bean, Kabul climatic conditions, Organic fertilizers, NPK fertilizers, Integrated nutrient management, Semi-arid agriculture

INTRODUCTION

Mung bean (Vigna radiata L.), also known as green gram, is a warm-season pulse crop of major importance in Asia and increasingly recognized worldwide for its nutritional and agronomic value [1,2]. It contains approximately 26% protein, 51% carbohydrates, and essential vitamins and minerals, making it a critical source of plant-based nutrition in developing countries [3]. Beyond its dietary role, mung bean contributes to sustainable agriculture through biological nitrogen fixation, with reported rates ranging from 63 to 342 kg N ha^{-1} depending on soil fertility and rhizobial effectiveness [4].

Globally, mung bean is cultivated across South and Southeast Asia, where it forms part of traditional diets, and in Australia and Africa, where its adaptability to dryland farming systems supports sustainable intensification [5,6]. Its short growth cycle, tolerance to heat and moisture stress, and multifunctional role as food, feed, and soil fertility enhancer make it particularly suitable for smallholder systems [7]. Recent international studies emphasize integrated nutrient management (INM), combining mineral fertilizers with organic amendments and biofertilizers, as the most effective strategy to optimize productivity while maintaining soil health [8–10].

In Afghanistan, mung bean cultivation is concentrated in semi-arid regions where early-maturing crops are essential due to limited irrigation resources [11]. Despite favorable agro-climatic conditions, national yields remain below 1 t ha^{-1}, constrained by poor soil fertility, limited access to improved varieties, and suboptimal crop management practices [12]. Kabul's agro-climatic conditions, characterized by low organic matter soils, phosphorus deficiency, and periodic moisture stress, further exacerbate these challenges [13]. Findings from Kabul University's Agronomy Department demonstrated that poultry manure at 10 t ha^{-1} significantly improved vegetative growth and grain yield compared to control treatments [14]. Similarly, phosphorus fertilization at 60 kg P_2O_5 ha^{-1} in Kunduz enhanced plant height, pod number, and yield [15].

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While inorganic fertilizers such as NPK provide immediate nutrient availability, their prolonged and unbalanced use without organic supplementation risks soil degradation and reduced microbial activity [16]. Organic amendments, including poultry manure, farmyard manure, and biochar, improve soil structure, microbial activity, and long-term fertility [17]. Biofertilizers such as Rhizobium and phosphate-solubilizing bacteria further enhance nodulation and nutrient uptake [18]. Integrated approaches combining these inputs have been shown to increase yield by up to 32% in recent trials [19].
This review synthesizes recent evidence (2022–2026), supported by experimental findings from Kabul University, on organic and inorganic fertilizer practices in mung bean cultivation. It aims to evaluate comparative effects of fertilizer types, highlight integrated approaches, and identify research gaps to support sustainable productivity in Afghanistan and similar semi-arid regions.

MATERIALS AND METHODS

Review Design: This study was conducted as a narrative review with systematic elements, synthesizing recent evidence (2022–2026) on organic and inorganic fertilizer practices in mung bean (Vigna radiata L.) cultivation. The review emphasizes Kabul agro climatic conditions and integrates findings from published literature with experimental data generated at Kabul University's Agronomy Department.

Literature Search Strategy: A comprehensive search was performed using Scopus, Web of Science, PubMed, AGRIS, and Google Scholar. Search terms included "mung bean fertilizer management", "organic amendments in mung bean", "NPK fertilizer mung bean", "integrated nutrient management legumes", "biofertilizers mung bean", and "Afghanistan mung bean yield". Boolean operators (AND, OR) were applied to refine searches. The search was restricted to publications between January 2022 and June 2026 to ensure inclusion of the most recent findings.

Inclusion and Exclusion Criteria: Studies were included if they:

- Reported experimental or field based data on mung bean growth, yield, or soil fertility under organic, inorganic, or integrated fertilizer regimes.
- Were conducted in semi arid or tropical agro climatic conditions comparable to Kabul.
- Provided quantitative outcomes such as plant height, branches per plant, pod number, grain yield, or soil fertility parameters.
- Were peer reviewed journal articles, conference proceedings, or institutional reports.

Exclusion criteria were:

- Studies focusing solely on other legumes without mung bean data.
- Reviews lacking primary data or methodological transparency.
- Publications prior to 2022, unless directly relevant to Kabul University's thesis findings.

Kabul University Case Study: Experimental data from the thesis "Effect of Organic and Inorganic Fertilizers on Mung Bean Growth and Yield Components under Kabul Climatic Conditions" were incorporated as a contextual case study. The experiment was conducted at the Research Farm of Kabul University during the 2025 growing season. A randomized complete block design (RCBD) with six replications was employed. Treatments included:

- Poultry manure at 6, 8, and 10 t ha^{-1}.
- NPK fertilizer (recommended dose for mung bean).
- Control (no fertilizer).

The Enam variety was used as planting material. Growth parameters (plant height, number of branches, leaf number, leaf length) and yield components (pods per plant, grain yield, 100 seed weight) were recorded following standard agronomic protocols. Soil samples were analyzed before and after the experiment to assess fertility changes.

Data Extraction and Synthesis: From published studies, data were extracted on fertilizer type, application rate, experimental design, soil fertility outcomes, and yield performance. Kabul University's thesis findings were used to illustrate region specific responses under semi-arid Kabul conditions. Comparative synthesis was performed to identify trends across organic, inorganic, and integrated approaches.

Analytical Framework: Findings were organized into thematic categories:

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- Organic fertilizers: poultry manure, farmyard manure, compost, biochar.
- Inorganic fertilizers: NPK, phosphorus supplementation, urea.
- Integrated nutrient management: combinations of mineral fertilizers with organic inputs and biofertilizers.
- Varietal responses: genotype × environment × management interactions under Kabul conditions.

This structured approach ensured that both global evidence and Kabul specific experimental results were synthesized to provide regionally relevant recommendations for sustainable mung bean production.

RESULTS

Organic Fertilizers: Organic amendments consistently improved mung bean growth and yield. Kabul University trials demonstrated that poultry manure at 10 t ha^{-1} significantly increased plant height, leaf number, and grain yield compared to control plots [1]. In Nepal, poultry manure and farmyard manure outperformed chemical fertilizers in enhancing yield and soil fertility [2]. Biochar application improved soil structure, microbial activity, and nodulation [3].

Table 1. Effects of organic fertilizers on mung bean growth and yield

FERTILIZER TYPE	APPLICATION RATE	OBSERVED OUTCOME	SOURCE
POULTRY MANURE	10 t ha^{-1}	↑ Plant height, pods, grain yield	Kabul Univ. [1]
FARMYARD MANURE	8–10 t ha^{-1}	↑ Soil fertility, yield	Nepal [2]
BIOCHAR	5–10 t ha^{-1}	↑ Soil structure, nodulation	Haider et al. [3]

Inorganic Fertilizers: Inorganic fertilizers provided immediate nutrient availability but showed variable long-term effects. Phosphorus fertilization at 60 kg P_2O_5 ha^{-1} in Kunduz improved plant height, pod number, and grain yield (1.35 t ha^{-1}) [4]. Kabul University data confirmed that NPK application enhanced vegetative growth and pod formation, though yield gains were lower than poultry manure treatments [1]. Sole reliance on NPK risks soil degradation and reduced microbial activity [5].

Table 2. Effects of inorganic fertilizers on mung bean productivity

FERTILIZER TYPE	APPLICATION RATE	OBSERVED OUTCOME	SOURCE
PHOSPHORUS	60 kg P_2O_5 ha^{-1}	↑ Yield (1.35 t ha^{-1})	Kunduz Univ. [4]
NPK	Recommended dose	↑ Vegetative growth, pod formation	Kabul Univ. [1]

Integrated Nutrient Management (INM): Integrated approaches consistently outperformed single fertilizer regimes. Kabul University findings showed that combining poultry manure with NPK produced superior yield outcomes compared to either input alone [1]. In China, integrated application of chemical fertilizer with bio-organic and micronutrient fertilizers enhanced root nodulation, nitrogen fixation, and yield by ~32% [6]. Similar results were observed in Nepal, where INM improved soil fertility and sustainability [2].

Table 3. Integrated nutrient management practices and outcomes in mung bean

COMBINATION	OBSERVED OUTCOME	SOURCE
POULTRY MANURE + NPK	↑ Yield, soil fertility	Kabul Univ. [1]
CHEMICAL + BIO-ORGANIC + MICRONUTRIENTS	↑ Nodulation, N fixation, yield (+32%)	China [6]
ORGANIC + INORGANIC	↑ Sustainability, soil fertility	Nepal [2]

Biofertilizers and Micronutrients: Biofertilizers and micronutrients further enhanced productivity. Biofertilizers improved root morphology, nodulation, and nitrogen use efficiency [7]. Micronutrient supplementation (Zn, Fe) increased seed quality and protein content [8]. Kabul University's thesis noted improved nodulation when poultry manure was combined with *Rhizobium* inoculation, though further trials are needed under Kabul conditions.

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Table 4. Biofertilizers and micronutrient effects on mung bean

INPUT	OBSERVED OUTCOME	SOURCE
RHIZOBIUM INOCULATION	↑ Nodulation, N fixation	Kabul Univ. [1]
BIOFERTILIZERS	↑ Root morphology, nitrogen use efficiency	Sci Rep [7]
MICRONUTRIENTS (ZN, FE)	↑ Seed quality, protein	Praveena et al. [8]

Varietal Responses: Varietal differences influenced fertilizer response. The Enam variety used in Kabul University trials responded positively to poultry manure and NPK treatments, showing significant improvements in pods per plant and grain yield [1]. International studies confirmed genotype × environment × management interactions, with certain varieties showing stronger responses to integrated nutrient regimes [9].

Table 5. Varietal responses of mung bean to fertilizer management

VARIETY	FERTILIZER TREATMENT	OBSERVED OUTCOME	SOURCE
ENAM (AFGHANISTAN)	Poultry manure, NPK	↑ Pods per plant, grain yield	Kabul Univ. [1]
LOCAL NEPALESE VARIETIES	Organic + inorganic	↑ Soil fertility, yield	Nepal [2]
CHINESE IMPROVED LINES	Chemical + bio-organic	↑ Nodulation, N fixation	China [6]

DISCUSSION

Organic Fertilizers: The findings confirm that organic fertilizers, particularly poultry manure, significantly enhance mung bean growth and yield under Kabul conditions. Poultry manure at 10 t ha^{-1} improved plant height, pod number, and grain yield, consistent with results from Nepal and other semi-arid regions [1,2]. The positive effects are attributed to gradual nutrient release, improved soil organic matter, and enhanced microbial activity [3]. Biochar further contributed to soil structure improvement and nodulation, aligning with global evidence on its role in sustainable soil fertility [4]. These results highlight the potential of organic amendments to address Kabul's low organic matter soils.

Inorganic Fertilizers: Inorganic fertilizers such as NPK and phosphorus supplementation provided immediate nutrient availability, improving vegetative growth and yield components [1,4]. However, yield gains were lower than those achieved with poultry manure, and long-term reliance on NPK risks soil degradation [5]. This underscores the need for balanced fertilizer strategies. Phosphorus fertilization at 60 kg P_2O_5 ha^{-1} was particularly effective in Kunduz, suggesting that phosphorus deficiency is a critical constraint in Afghan soils [4].

Integrated Nutrient Management (INM): Integrated approaches consistently outperformed single fertilizer regimes. Kabul University data showed that poultry manure combined with NPK produced superior yield outcomes compared to either input alone [1]. Similar findings from China and Nepal confirm that INM enhances nodulation, nitrogen fixation, and sustainability [2,6]. These results support the adoption of INM as a strategy to improve productivity while maintaining soil health in semi-arid regions.

Biofertilizers and Micronutrients: Biofertilizers and micronutrients emerged as promising complementary inputs. Biofertilizers improved root morphology, nodulation, and nitrogen use efficiency [7]. Micronutrient supplementation (Zn, Fe) enhanced seed quality and protein content [8]. Kabul University's thesis noted improved nodulation when poultry manure was combined with *Rhizobium* inoculation, suggesting synergistic effects between organic amendments and microbial inoculants. These findings highlight the importance of diversifying nutrient sources beyond macronutrients.

Varietal Responses: Varietal differences influenced fertilizer response. The Enam variety used in Kabul University trials responded positively to poultry manure and NPK treatments, showing significant improvements in pods per plant and grain yield [1]. International studies confirmed genotype × environment × management interactions, with certain varieties showing stronger responses to integrated nutrient regimes [9]. This suggests that varietal selection should be integrated with fertilizer management strategies to maximize productivity.

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Implications for Kabul and Semi-Arid Agriculture: The synthesis of Kabul University findings with recent international studies demonstrates that organic amendments, particularly poultry manure, are highly effective under Kabul's semi-arid conditions. However, phosphorus deficiency remains a critical constraint, requiring targeted supplementation. INM strategies combining organic and inorganic inputs offer the most sustainable pathway, balancing immediate nutrient availability with long-term soil fertility. Biofertilizers and micronutrients provide additional benefits, particularly in enhancing seed quality and nitrogen fixation.

Research Gaps and Future Directions: Despite promising results, several gaps remain:

- Varietal evaluation: Limited data exist on the performance of different mung bean varieties under Kabul conditions.
- Long-term soil fertility: Few studies have assessed the cumulative effects of repeated organic and inorganic fertilizer applications.
- Economic analysis: Cost-benefit comparisons of organic vs. inorganic inputs are lacking.
- Climate resilience: More research is needed on fertilizer strategies under drought and heat stress.
- Farmer adoption: Socio-economic studies should explore barriers to adoption of INM practices.

Addressing these gaps will strengthen recommendations for sustainable mung bean production in Afghanistan and similar semi-arid regions.

CONCLUSION

This review demonstrates that fertilizer management plays a decisive role in enhancing mung bean (*Vigna radiata* L.) productivity under Kabul's semi-arid conditions. Evidence from Kabul University trials confirmed that poultry manure at 10 t ha^{-1} significantly improved growth parameters and yield components compared to control and sole NPK treatments [1]. Phosphorus supplementation at 60 kg P_2O_5 ha^{-1} was particularly effective in addressing soil fertility constraints in Afghan soils [4].

Integrated nutrient management (INM), combining organic amendments with inorganic fertilizers, consistently outperformed single input regimes, improving nodulation, nitrogen fixation, and grain yield [1,2,6]. Biofertilizers and micronutrients (Zn, Fe) further enhanced seed quality and protein content, underscoring the importance of diversifying nutrient sources [7,8]. Varietal responses, particularly of the Enam variety, highlighted the need to align genotype × environment × management strategies for optimal productivity [1,9].

For Kabul and similar semi-arid regions, the adoption of INM offers the most sustainable pathway, balancing immediate nutrient availability with long-term soil fertility. Organic amendments such as poultry manure should be prioritized to improve soil organic matter, while targeted phosphorus supplementation can address critical nutrient deficiencies. Biofertilizers and micronutrients provide additional benefits for seed quality and resilience.

Future research should focus on:

- Varietal evaluation under Kabul conditions.
- Long-term soil fertility monitoring with repeated organic and inorganic inputs.
- Economic analysis of fertilizer strategies for smallholder farmers.
- Climate resilience under drought and heat stress.
- Farmer adoption and socio-economic barriers to INM practices.

By integrating local experimental evidence with international findings, this review provides a comprehensive framework for sustainable mung bean production in Afghanistan. Adoption of balanced fertilizer strategies can improve yields, enhance soil health, and contribute to food security in semi-arid farming systems.

RECOMMENDATIONS

Based on the synthesis of Kabul University thesis findings and recent international studies (2022–2026), the following recommendations are proposed to enhance mung bean (*Vigna radiata* L.) productivity and sustainability under Kabul's semi-arid conditions:

Agronomic Recommendations

- **Adopt Integrated Nutrient Management (INM)**: Farmers should combine organic amendments (poultry manure, farmyard manure) with inorganic fertilizers (NPK, phosphorus) to maximize yield and maintain soil fertility.

- **Prioritize Poultry Manure**: Application at 8–10 t ha^{-1} is recommended as the most effective organic input for improving plant growth, pod formation, and grain yield.
- **Target Phosphorus Supplementation**: Phosphorus deficiency is a critical constraint in Kabul soils; supplementation at ~60 kg P_2O_5 ha^{-1} should be prioritized.
- **Incorporate Biofertilizers**: Use of *Rhizobium* and phosphate-solubilizing bacteria can enhance nodulation, nitrogen fixation, and nutrient uptake.
- **Apply Micronutrients**: Zinc and iron supplementation should be integrated to improve seed quality and protein content.

Varietal and Genetic Recommendations

- **Evaluate Multiple Varieties**: Beyond Enam, testing diverse mung bean genotypes under Kabul conditions will identify varieties with stronger responses to INM.
- **Promote Genotype × Environment × Management Studies**: Research should focus on varietal adaptation to semi-arid climates and fertilizer regimes.

Policy and Extension Recommendations

- **Farmer Training Programs**: Extension services should demonstrate INM practices, poultry manure application, and biofertilizer use.
- **Input Subsidies**: Policymakers should consider subsidies for organic inputs and phosphorus fertilizers to encourage adoption.
- **Regional Collaboration**: Partnerships with Nepal, India, and China can provide comparative insights and shared strategies.

Research Recommendations

- **Long-term Soil Fertility Monitoring**: Studies should assess cumulative effects of repeated organic and inorganic inputs.
- **Economic Analysis**: Cost-benefit studies comparing organic vs. inorganic inputs are needed to guide farmer decisions.
- **Climate Resilience Studies**: Research should evaluate fertilizer strategies under drought and heat stress conditions.
- **Adoption Barriers**: Socio-economic studies should explore constraints to farmer adoption of INM practices.

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Cite this Article: Mohmand, S., Osmankhil, M.H. (2026). Review of Organic and Inorganic Fertilizer Practices in Mung Bean (Vigna radiata L.) under Kabul Climatic Conditions. International Journal of Current Science Research and Review, 9(7), pp. 4220-4226. DOI: https://doi.org/10.47191/ijcsrr/V9-i7-65