



# Economic Evaluation of Mungbean (*Vigna radiata* L. Wilczek) under Citrus (*Citrus* sps. L.) Based Agri-horti System in Semi-arid Region of Prayagraj, India

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

The present study was conducted to evaluate the impact of Integrated Nutrient Management (INM) on root nodulation and economic performance of mungbean (*Vigna radiata* L. Wilczek) under a citrus-based agri-horti system. The experiment was carried out during the *Kharif* season of 2023–24 at the College of Forestry, SHUATS, Prayagraj, employing thirteen nutrient management treatments combining various proportions of recommended dose of fertilizers (RDF) with organic amendments such as farmyard manure (FYM), vermicompost, press mud, and poultry manure. The treatments were assessed under two cropping conditions: 10 years old citrus based agroforestry (AF) and open field. Results indicated that INM practices significantly influenced yield with Treatment T9

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consistently outperforming others by recording the highest economic returns, including a maximum benefit-cost (B:C) ratio emphasizing the effectiveness of integrated nutrient strategies over single-source applications. Conversely, treatments with moderate yields but lower net returns highlighted the critical role of input efficiency in determining profitability. The findings underscore that INM not only enhances biological nitrogen fixation and crop productivity but also improves economic sustainability, making it a viable nutrient management approach for legume-based intercropping systems, particularly in citrus-based agri-horti models.

**Keywords:** Mungbean; organic and inorganic nutrient sources; economics; agri-horti systems.

## 1. INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) is an important pulse crop in India, valued for its nutritional, agronomic, and ecological attributes. As a staple in vegetarian diets, it provides a highly digestible protein content of 24–26%, along with essential amino acids such as lysine and tryptophan, and is rich in vitamins like ascorbic acid, thiamine, and riboflavin, particularly in its sprouted form. Indigenous to the Indian subcontinent, mungbean is well adapted to tropical and subtropical climates and is traditionally grown during the kharif season (Pal et al., 2023). However, the development of early-maturing and photo-insensitive varieties has enabled its successful cultivation during spring and summer seasons, enhancing its role as a short-duration or catch crop. Despite its multifaceted advantages, mungbean productivity in India remains below potential, constrained by poor soil fertility, imbalanced fertilizer use, and the persistence of traditional farming practices (Chaudhary et al., 2003). Although the Green Revolution significantly boosted food production, it also brought ecological challenges such as nutrient imbalances, soil degradation, and increased pollution due to excessive use of chemical fertilizers and pesticides (Patel et al., 2025). Consequently, there has been a paradigm shift toward sustainable nutrient management approaches, most notably, Integrated Nutrient Management (INM). INM emphasizes the judicious combination of organic manures, biofertilizers, and inorganic fertilizers to enhance nutrient-use efficiency, maintain soil health, and ensure long-term agricultural sustainability (Meena et al., 2015; Dhakal et al., 2016). Organic inputs like farmyard manure, poultry manure, press mud, and vermicompost are increasingly recognized for their role in improving soil structure, water retention, microbial biomass, and enzymatic activity. Among them, vermicompost stands out due to its richness in beneficial microbes and plant-growth-promoting substances that enhance nutrient mineralization

and plant uptake (Rajkhowa et al., 2017; Sutaria et al., 2010). When integrated with biofertilizers such as Rhizobium and phosphate-solubilizing bacteria (PSB), these organic amendments significantly improve nitrogen fixation and phosphorus availability, which are vital for legume performance (Vessey, 2003). Phosphorus, in particular, is essential for root elongation and effective nodule formation, and its deficiency often limits nitrogen fixation in legume crops. Research has shown that PSB can solubilize bound phosphates in the soil, making them more accessible to plants and thereby enhancing nodulation and productivity in mungbean (Bhuiyan et al., 2008; Kalaiyarasi et al., 2019).

In semi-arid regions, such as those found in parts of Uttar Pradesh, erratic rainfall and poor soil conditions frequently lead to crop failures (Parasriya et al., 2022; Patel & Gangwar, 2023). This has prompted a growing interest in agroforestry systems, which provide ecological and economic resilience by integrating trees with crops. In the Prayagraj region, species such as teak (*Tectona grandis*), babool (*Acacia nilotica*), sissoo (*Dalbergia sissoo*), palash (*Butea monosperma*), tendu (*Diospyros melanoxylon*), harad (*Terminalia chebula*), and bahera (*Terminalia bellirica*) are commonly used in various agroforestry models. Fast-growing tree species are being increasingly promoted under such systems to support food security, livelihoods, and environmental sustainability (Zahoor et al., 2021; Patel & Gangwar, 2023; Jordan, 2024). Among the emerging approaches, integrating legumes like mungbean into agri-horti systems has shown promise as a climate-resilient and economically viable model, particularly in the Vindhyan and other semi-arid regions of India. These systems commonly feature fruit trees such as aonla (*Emblica officinalis*), guava (*Psidium guajava*), citrus (*Citrus spp.*), ber (*Ziziphus mauritiana*), and custard apple (*Annona squamosa*), intercropped with legumes during the juvenile phase of

orchard establishment (Chaturvedi et al., 2016). Such integrative approaches not only optimize land-use efficiency and farm income but also promote soil fertility, biodiversity, and favorable microclimates. However, the performance of legumes in these systems is influenced by complex ecological interactions, including light competition, root interference, and altered nutrient dynamics, which necessitate targeted nutrient management interventions (Sharma & Guled, 2012; Tyagi et al., 2014). Recent studies have documented the beneficial impacts of INM on green gram productivity, nodulation, and soil nutrient status under agroforestry and open field conditions (Gorade et al., 2014; Saha et al., 2017). Notably, combinations involving vermicompost and biofertilizers such as Rhizobium and PSB have significantly enhanced biological nitrogen fixation and phosphorus uptake in legumes like mungbean and cowpea (Kumari & Kumari, 2002; Khan et al., 2017). Furthermore, bio-organic and inorganic nutrient combinations not only support higher crop yields but also contribute to long-term soil sustainability (Meena et al., 2013; Dhakal et al., 2016). In this context, the present investigation was undertaken to evaluate the influence of integrated nutrient management involving chemical fertilizers, organic manures, and biofertilizers on the yield and economic performance of mungbean cultivated under a citrus-based agri-horti system. Specifically, the study aims to assess the comparative efficacy of these treatments in both agroforestry and open field conditions to guide sustainable nutrient management practices in legume-based intercropping systems.

## 2. MATERIALS AND METHODS

Present experiment was conducted during the Kharif season of 2023–24 at the Research Farm of the College of Forestry, SHUATS, Prayagraj, situated at 25°24'30"N latitude and 81°51'10"E longitude, with an elevation of 98 meters above sea level. The site lies within the subtropical climatic zone of southeastern Uttar Pradesh, characterized by hot summers with temperatures rising up to 46–48°C and mild winters with occasional temperature drops to 4–5°C. The region receives an average annual rainfall of approximately 1100 mm, with relative humidity ranging from 20% to 94%. The experiment was laid out in a factorial randomized block design (FRBD), incorporating two environmental conditions viz. 10 year old citrus orchard as agroforestry (AF) and open-field (Open)—as

main factors, along with thirteen integrated nutrient management (INM) treatments, each replicated three times. The treatments comprised different combinations of recommended doses of fertilizers (RDF: 20:40:20 kg N:P:K/ha) and organic nutrient sources such as farmyard manure (FYM), vermicompost, press mud, and poultry manure, applied either individually or in integrated forms with RDF. Seeds of mungbean (var. Samrat) were used and inoculated with Rhizobium and phosphate-solubilizing bacteria (PSB) prior to sowing to enhance biological nitrogen fixation and phosphorus availability. The seeds were sown at a spacing of 30 cm between rows and 10 cm between plants. Organic manures were thoroughly incorporated into the soil two weeks before sowing as per the treatment design, while chemical fertilizers were applied at sowing time in the designated treatments. Standard agronomic practices, including timely irrigation, weed control, pest and disease management, and harvesting, were uniformly followed to ensure optimal crop growth.

The cost of cultivation was estimated by incorporating input prices prevailing at the time of application for each treatment, including costs related to citrus plantation management. The calculation included labor charges, expenses for field operations such as land preparation, sowing, irrigation, and harvesting, and the cost of inputs like seeds, fertilizers, pesticides, fungicides, herbicides, and bio-inoculants used on a per hectare basis. Gross returns were calculated by summing the monetary value of grain yield, stover yield, and citrus fruit yield using current local market prices. Net returns were computed by deducting the total cost of cultivation from the gross returns. The benefit-to-cost (B:C) ratio for each treatment was calculated by dividing the gross return by the total cost of cultivation, thereby providing a comprehensive assessment of the economic viability of each nutrient management strategy under both agroforestry and open-field conditions.

## 3. RESULTS AND DISCUSSION

The data presented in Tables 1 and 2 indicate significant variations in benefit-cost (B:C) ratio of mungbean as influenced by different integrated nutrient management (INM) treatments across both agroforestry (AF) and open field conditions. The B:C ratio, a critical indicator of profitability, ranged from 2.79 (T10) to 3.42 (T9), highlighting the influence of nutrient combinations

**Table 1. Effect of Organic and Inorganic nutrient sources on economic return of Mungbean (*Vigna redita*. L) Under Citrus (*Citrus* sps. L.) based Agri-horti systems**

Treatments	Economics Rs./ha (Citrus based Agri-horti systems)												
	Grain yield (q/ha)	Rate (Rs/q)	Return from grain (Rs)	Stover yield (q/ha)	Rate (Rs/q)	Return from stover (Rs)	Citrus yield (kg)	Rate of (Rs/kg)	Return from citrus (Rs)	Gross Return (Rs)	Cost of cultivation (Rs)	Net returns (Rs)	B:C Ratio
T1	9.19	6500	59747	20.37	800	16297	2000	20	40000	116045	37300	78745	3.11
T2	10.29	6500	66855	21.55	800	17237	2000	20	40000	124092	38300	85792	3.24
T3	10.44	6500	67844	21.83	800	17461	2000	20	40000	125306	44300	81006	2.83
T4	10.90	6500	70835	22.76	800	18211	2000	20	40000	129046	39300	89746	3.28
T5	11.29	6500	73390	23.62	800	18897	2000	20	40000	132288	40300	91988	3.28
T6	11.81	6500	76795	24.93	800	19941	2000	20	40000	136736	45300	91436	3.02
T7	11.45	6500	74453	23.40	800	18719	2000	20	40000	133171	44300	88871	3.01
T8	13.46	6500	87483	23.68	800	18940	2000	20	40000	146423	45300	101123	3.23
T9	14.95	6500	97169	26.64	800	21315	2000	20	40000	158483	46300	112183	3.42
T10	11.32	6500	73562	23.16	800	18527	2000	20	40000	132089	47300	84789	2.79
T11	11.47	6500	74552	23.47	800	18779	2000	20	40000	133330	46300	87030	2.88
T12	11.51	6500	74816	23.66	800	18924	2000	20	40000	133740	45300	88440	2.95
T13	11.58	6500	75299	23.76	800	19011	2000	20	40000	134310	44300	90010	3.03

**Table 2. Effect of Organic and Inorganic nutrient sources on economic return of Mungbean (*Vigna redita*. L) In open condition**

Treatments	Economics Rs/ha (open)									
	Grain yield (q/ha)	Rate (Rs/q)	Return from grain (Rs)	Stover yield (q/ha)	Rate (Rs/q)	Return from stover (Rs)	Gross Return (Rs)	Cost of cultivation (Rs)	Net returns (Rs)	B:C Ratio
T1	10.23	6500	66517	22.58	800	18067	84583	37300	47283	2.27
T2	11.58	6500	75292	24.05	800	19240	94532	38300	56232	2.47
T3	11.70	6500	76050	24.82	800	19853	95903	44300	51603	2.16
T4	12.73	6500	82767	25.65	800	20520	103287	39300	63987	2.63
T5	12.42	6500	80708	25.52	800	20413	101122	40300	60822	2.51
T6	13.33	6500	86667	26.95	800	21560	108227	45300	62927	2.39
T7	12.75	6500	82875	25.83	800	20667	103542	44300	59242	2.34
T8	16.32	6500	106058	28.15	800	22520	128578	45300	83278	2.84
T9	20.90	6500	135850	32.45	800	25960	161810	46300	115510	3.49
T10	12.72	6500	82658	25.02	800	20013	102672	47300	55372	2.17
T11	13.52	6500	87858	26.38	800	21107	108965	46300	62665	2.35
T12	12.70	6500	82550	25.57	800	20453	103003	45300	57703	2.27
T13	12.93	6500	84067	25.70	800	20560	104627	44300	60327	2.36

on overall economic viability. Treatment T9, which likely involved a balanced integration of organic and inorganic nutrient sources, recorded the highest grain yield (14.95 q/ha) and stover yield (26.64 q/ha), resulting in the maximum gross return of Rs. 1,58,483/ha and a net return of Rs. 1,12,183/ha. This translated into the highest B:C ratio of 3.42, indicating superior cost-effectiveness compared to other treatments. This suggests that T9 provides an optimal nutrient environment for mungbean productivity and profitability in agri-horti systems. Close behind, T8 also demonstrated a high economic return with a B:C ratio of 3.23, primarily driven by a relatively high grain yield (13.46 q/ha) and stable stover production. Treatments T4 and T5 were similarly profitable, each showing a B:C ratio of 3.28, reinforcing the importance of adequate but not excessive nutrient input. In contrast, treatments T10, T11, and T12 recorded lower net returns and B:C ratios (2.79–2.95), despite having moderately high yields. These results could be attributed to higher cultivation costs or suboptimal nutrient efficiency under those regimes. The lowest B:C ratio of 2.79 in T10 emphasizes that yield alone does not determine profitability; rather, the balance between input cost and output value is crucial. T1, considered as the control or baseline, also performed well with a B:C ratio of 3.11, underscoring the effectiveness of minimal but targeted nutrient use in enhancing mungbean profitability in agroforestry systems. Overall, the data support that integrated nutrient management combining both organic and inorganic sources significantly improves the economic returns of mungbean when grown under citrus-based agri-horti systems. This is in line with previous studies that advocate the use of integrated nutrient strategies for improving resource use efficiency, yield sustainability, and farmer income (Kumar et al., 2020; Singh et al., 2022, Parasriya et al, 2024).

The data presented in Table 2 indicate substantial differences in the economic performance of mungbean (*Vigna radiata* L.) grown under open field conditions in response to various integrated nutrient management (INM) treatments. The benefit-to-cost (B:C) ratio, a key indicator of profitability, ranged from 2.16 (T3) to 3.49 (T9), illustrating the economic significance of combining organic and inorganic nutrient sources. Among all treatments, T9 recorded the highest grain yield (20.90 q/ha) and stover yield (32.45 q/ha), which led into the maximum gross return of Rs. 1,61,810/ha and a net return of Rs. 1,15,510/ha. The superior profitability of T9, with

a B:C ratio of 3.49, can be attributed to enhanced nutrient availability and efficient resource utilization, which collectively boosted biomass production and marketable yield. This result underscores the effectiveness of integrated nutrient application in maximizing mungbean productivity and economic return in open environments. Treatment T8 also performed well, yielding 16.32 q/ha of grain and 28.15 q/ha of stover, leading to a gross return of Rs. 1,28,578/ha, net return of Rs. 83,278/ha, and a B:C ratio of 2.84. The consistently higher yields and returns observed in T8 and T9 suggest that the synergy between organic and inorganic nutrient inputs plays a crucial role in enhancing mungbean profitability under open field conditions. Moderately high economic returns were observed in treatments T4, T5, and T6, with B:C ratios of 2.63, 2.51, and 2.39, respectively. These treatments likely provided a balanced nutrient supply, supporting healthy crop growth and reasonable profit margins. On the other hand, treatments such as T3 and T10 showed relatively lower B:C ratios of 2.16 and 2.17, respectively, despite achieving decent yields. This could be attributed to higher cultivation costs or less efficient nutrient use compared to other treatments. The control treatment T1, which may have received minimal or no nutrient supplementation beyond baseline inputs, exhibited the lowest net return (Rs. 47,283/ha) and a B:C ratio of 2.27, underscoring the limited economic potential of nutrient-deficient management strategies. Overall, the results demonstrate that the use of integrated nutrient management practices significantly influences the economic returns of mungbean cultivation under open field conditions. Treatments incorporating both organic and inorganic sources consistently outperformed those with singular input strategies in terms of yield and profitability. These findings are consistent with previous studies (Singh et al., 2021; Kumar et al., 2022), which advocate for integrated nutrient approaches to enhance crop performance and economic sustainability in legume-based farming systems.

#### 4. CONCLUSION

Present study concludes that integrated nutrient management (INM) plays a vital role in enhancing the economic viability of mungbean cultivation under both citrus-based agroforestry and open field systems. The consistent superior performance of Treatment T9, reflected through the highest B:C ratios, gross and net returns,

emphasizes the importance of balanced nutrient inputs combining organic and inorganic sources. Treatments such as T8, T4, and T5 further reinforce that strategic nutrient integration rather than reliance on a single source can significantly boost profitability. On the other hand, treatments with lower returns despite moderate yields indicate that input cost-efficiency is as critical as yield in determining economic success. Growing mungbean in a 10-year-old citrus orchard can increase the gross income per hectare by 118,483 Rs in treatment T9. Therefore, adopting INM practices not only supports higher productivity but also ensures sustainable income generation for farmers, particularly in integrated farming systems like citrus-based agri-horti models. These findings provide strong evidence for promoting INM as a practical, efficient, and sustainable nutrient management approach in legume-based cropping systems.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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