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EFFECT OF DIFFERENT PHOSPHORUS LEVELS AND VARIETIES ON YIELD ATTRIBUTES, YIELD AND ECONOMICS OF MUNGBEAN UNDER CUSTARD APPLE BASED AGRI-HORTI SYSTEM

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ABSTRACT

A field experiment was conducted to assess the impact of various phosphorus levels and varieties on mungbean production characteristics, yield, and economics in an agri-horticultural system based on custard apples. This study used a factorial randomized block design with three different phosphorus levels (34, 46, and 58 kg P_2O_5/ha) and three types of mungbean (HUM-12 Kavita and Samrat). The treatments were repeated three times. The experiment's results showed that variety HUM-12 (729 kg/ha) and 58 kg P_2O_5/ha produced the highest grain yield (919 kg/ha). In an agri-horticultural system based on custard apples, the application of phosphorus 58 kg/ha + HUM-12 resulted in the highest cultivation cost, gross return, net return, and B:C ratio.

***Keywords*:** Agri-horti system; Phosphorus level; Mungbean; Nutrient and Varieties interaction.

Introduction

One of the key components of agroforestry is the agri-horticultural system, which integrates perennial fruit trees with annual agricultural crops on the same land management unit, thereby enhancing resource-use efficiency and system sustainability **(**Das, 2024; Aaron *et al*., 2024**)**. Major fruit crops that are widely recognized for agri-horticultural systems in India include aonla, ber, citrus, custard apple, guava and other fruit species because of their adaptability, productivity, and compatibility with intercrops under diverse agro-climatic conditions (Dhakar *et al*., 2024; Fernandaz *et al*., 2023). Farmers often prefer fruit-based agroforestry systems because fruit trees provide diversified income opportunities, long-term economic returns, enhanced livelihood security, and resilience against climatic and market risks **(**Singh *et al*., 2024; Zheng *et al*., 2024; Liu *et al*., 2024). The agri-horti system is considered an improved form of traditional farming in India, as it enables efficient utilization of land and growing seasons while generating higher productivity and economic returns per unit area through the integration of annual crops and fruit trees (Fernandaz *et al*., 2023; Doddabasawa & Chittapur, 2023; Mvondo *et al*., 2023). Mungbean (*Vigna radiata*) is a nutritionally rich, easily digestible pulse crop that contributes significantly to food and nutritional security, farm profitability, and sustainable agricultural systems in India (Patel *et al*., 2024; Singh *et al*., 2025). Its short duration, adaptability to diverse agro-ecological conditions, and growing market demand make it an important component of pulse-based cropping systems and the national agricultural economy (Siddique *et al*., 2026; Diatta *et al*., 2024). Mungbean can reach its potential output by using agronomic techniques and inputs as efficiently as possible (Siddique *et al*., 2026). Due to its short growing season, mungbean is one of the most important pulse crops in intensive crop production systems (Singh *et al*., 2021; Diatta *et al*., 2024). Because of its early maturity and ability to be grown as a catch crop, mungbean has considerable potential to improve cropping patterns and cropping intensity (Singh *et al*., 2021; Diatta *et al*., 2024). Farmers frequently neglect the application of recommended fertilizers, particularly phosphorus and micronutrients, resulting in suboptimal productivity (Siddique *et al*., 2026; Khangarot *et al*., 2023). As a result, pulse cultivation often remains less profitable and a substantial gap persists between actual production and domestic demand (Siddique *et al*., 2026). The productivity of pulse crops is generally constrained by several soil-related limitations, including nutrient deficiencies and poor phosphorus availability (Khangarot *et al*., 2023; Inyang *et al*., 2023). Chemical fertilizers provide one of the fastest and most effective means of correcting nutrient deficiencies and enhancing crop yields (IFA, 2026). Phosphorus is an essential constituent of all living cells (IFA, 2026; Inyang *et al*., 2023). It plays a central role in structural molecules, nucleic acids, and the storage and transfer of energy during metabolic processes (Mosaic Crop Nutrition, 2025; IFA, 2026). The availability of phosphorus to growing crops is crucial, and it is generally regarded as the second most important macronutrient after nitrogen in crop production (Inyang *et al*., 2023). Phosphorus is an essential component of several biologically important compounds and metabolic enzymes, including ATP, DNA, RNA, and phospholipids (Mosaic Crop Nutrition, 2025; IFA, 2026). Because effective biological nitrogen fixation requires an adequate phosphorus supply, leguminous crops grown under phosphorus-deficient conditions often exhibit symptoms of nitrogen deficiency (Khangarot *et al*., 2023; Singh *et al*., 2021). Therefore, phosphorus nutrition is considered particularly important in legumes because of its direct role in root development, nodulation, nitrogen fixation, and yield formation (Khangarot *et al*., 2023; Singh *et al*., 2021). Phosphorus application has a significant influence on mungbean growth and yield because it plays a vital role in several physiological and biochemical processes, including root development, nodulation, biological nitrogen fixation, energy transfer, dry matter accumulation, and protein synthesis (Kumar *et al*., 2024; Singh *et al*., 2023). Phosphorus also promotes rapid seedling establishment, early flowering and maturity, and improves seed quality and overall crop productivity (Kumar *et al*., 2024; Parashar & Tripathi, 2020). Since phosphorus deficiency is widely recognized as one of the major nutritional constraints limiting pulse productivity in many tropical and subtropical soils, determining the optimum phosphorus dose is essential for maximizing mungbean growth and yield (Khangarot *et al*., 2023; FAO, 2024). Low mungbean productivity in India is attributed to multiple agronomic, genetic, and environmental constraints (Nair *et al*., 2019; Kumari & Malik, 2024). The continued cultivation of old cultivars, inadequate access to quality seed, and imbalanced fertilizer management adversely affect crop growth and yield performance (Kumari & Malik, 2024; Pratap *et al*., 2024). Adoption of improved, high-yielding varieties and the use of quality seed can substantially enhance mungbean productivity and farm profitability (Pratap *et al*., 2024; IIPR, 2023). However, mungbean production remains constrained by a combination of genetic limitations, biotic stresses such as insect pests and diseases, abiotic stresses including drought, heat, salinity, and waterlogging, and suboptimal crop management practices. These factors interfere with critical physiological and biochemical processes during crop growth and development, thereby reducing yield potential and production stability (Nair *et al*., 2019; Kumar *et al*., 2024).

Materials and Methods

The experiment was conducted at the Agronomy Farm of Rajiv Gandhi South Campus, Barkachha (BHU), Mirzapur, which is located in the Vindhyan region of the district Mirzapur (25º 10' latitude, 82º 37' longitude). It covers an area of more than 1000 hectares and is home to a variety of crops, including horticultural, agricultural, medicinal, and aromatic plants. The soil in Vindhyan is rainfed and usually has low productivity. Agro-climatic zone III A (semi-arid eastern plain zone) applies to this area. Barkachha's climate is generally semi-arid, with high summer and winter temperatures, little precipitation, and moderate humidity. Summer temperatures can reach as high as 39.8 ^{o}C, while winter temperatures can drop as low as 9 ^{o}C. The South West monsoon, which occurs from July to September, produced almost 90% of the locality's 209 mm of annual rainfall. Over the course of the crop, there was a total of 104.2 mm of rainfall, a temperature range of 32.9 ºC to 21.3 ºC, and a relative humidity of 86.5 to 55.9%. The experimental field's soil had a sandy loam texture and poor drainage. It had an acidic response and was low in potash, phosphorus, and nitrogen. Two factors with three levels each were used in the Factorial Randomized Block Design experiment, which was replicated three times. The phosphorus doses used in these treatments were 34, 46, and 58 kg/ha. Fixed amounts of phosphorus (40 kg/ha) and nitrogen (20 kg/ha) were applied as fertilizer. Applying phosphorus was done in accordance with the instructions. The sources of N, P, and K were urea, DAP, and MOP, respectively, and all the nutrients were applied as basal. Samrat, Kavita, and HUM-12 were the varieties being studied. According to treatment, the seeds were manually planted in the kudal-opened furrow at a row distance of 30 cm. The plant population was properly maintained by using a seed rate of 20 kg/ha. About ten days following seeding, thinning was done to maintain a 10 cm plant spacing inside the row. To suppress weeds, Khurpi performed a manual first weeding 20 days after sowing and a second weeding 30 days later. Kranti (Carpet hydrochloride 50% SP) @ 250 ml/ha was sprayed 25 days after sowing to protect the crop, primarily from leaf caterpillars.Pod length, pod weight (g), number of pods per plant, number of grains per pod, test weight (g) and grain, straw, biological yield (kg/ha), and harvest index were among the yield variables that were measured.

Results and Discussion

Effect of Phosphorus

Phosphorus levels have a significant impact on grain weight/plant. Although there were comparable variations between 58 and 46 kg P_2O_5/ha, both yielded considerably more grain weight per plant than 34 kg P_2O_5/ha. Varieties and phosphorus levels had a major impact on the quantity of pods per plant. The pod/plant improved as phosphorus application levels increased, reaching the maximum level of 58 kg P_2O_5/ha.

The lower and medium phosphorus levels, however, continued to be statistically equivalent in terms of the quantity of pods per plant. (Yadav *et al*. 2017) discovered that the highest pod/plant ratio among the various fertilizer application levels was 60 kg/ha, which was nearly identical to the phosphorus application treatment of 40 kg/ha. According to Kumawat *et al*. (2013), the quantity of pods per plant significantly increased. Due to varying phosphorus levels, non-significant variations were found in test weight and the number of grains per pod (Table 1).

Grain yield was considerably increased by applying phosphorus at the greatest possible amount. Grain yield increased by 105.1 and 34.6% when 58 kg P_2O_5/ha was applied compared to 34 and 46 kg P_2O_5/ha, respectively; similarly, grain yield increased by 52.5% when 46 kg P_2O_5/ha was applied at the lowest rate (Table 2). Straw and biological yield/ha showed a similar pattern. According to Yadav *et al*. (2017), the highest grain and straw yields were recorded at 60 kg/ha of fertilizer. Better source to sink absorption may have resulted from the greater phosphorus supply regulating the starch/sucrose ratio in source leaves and reproductive organs.

Table 1: Yield attributes as influenced by phosphorus levels and varieties of mungbean under custard apple based agri-horti system:

Treatments	Grain yield (g/plant)	No. of pods / plant	No. of grains / pod	Test weight (g)
Phosphorus (kg/ha)				
34	2.43	8.88	9.00	3.49
46	2.82	9.90	9.31	3.53
58	3.06	11.82	9.77	3.66
S. Em. $\pm$	0.12	0.71	0.27	0.12
CD at 5%	0.36	2.15	NS	NS
Variety				
Samrat	2.74	11.31	9.77	2.89
Kavita	2.64	8.42	8.64	4.37
HUM-12	2.93	10.87	9.66	3.42
S.Em. $\pm$	0.12	0.71	0.27	0.12
CD at 5%	NS	2.15	0.82	0.36

The beneficial effect of phosphorus on fruiting of plants and better translocation of desired metabolites to the yield contributing parts of the plant might attributed to more grain yield. According to Phogat *et al*. (2018), applying 60 kg of phosphorus per hectare produced the highest yield of black gram. Similarly, the haulm yield was higher at 60 kg/ ha of phosphorus application. According to Dhage *et al*. (2014), phosphorus supplementation increases yield by accelerating cell division and expansion, increasing the metabolism of fat and carbohydrates, and increasing respiratory activity in black gram.

In black gram, Gayatri and Saravanapandian (2019) discovered that phosphorus application at 60 kg/ha produced the highest yield compared to other levels. In a similar vein, applying 60 kg/ha of phosphorus increased the haulm yield. The yield increment of grain and haulm could be due to increased phosphorus supplementation to black gram plants. According to Kumawat *et al*. (2013), biological yield significantly increased. The harvest index was not significantly affected by the phosphorus level. Applying increasing doses of phosphorus up to the maximum amount resulted in a considerable increase in grain yield/ha. These results closely align with those published by Rojh *et al*. (2024) and Fazil *et al*. (2024).

Applying 58 kg P_2O_5/ha resulted in a relatively greater grain yield/ha because of the higher grain yield/plant and its characteristics, such as the number of pods/plant (Table 1). These findings were consistent with those of (Htwe *et al*. 2023) and (Vinay *et al*. 2024). The treatment of 58 kg P_2O_5/ha increased grain, straw, and biological yield, indicating a favorable correlation between vegetative growth and grain yield. Ramamurthy and Ariraman (2023) and Dhiman and Meena (2024) have observed similar findings.

Table 2: Grain, straw, biological yield, and harvest index as influenced by phosphorus levels and varieties of mungbean under custard apple based agri-horti system:

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Phosphorus (kg/ha)				
34	448	1407	1855	23
46	683	1978	2661	25
58	919	2623	3542	25
S. Em. ±	37	88	118	0.84
CD at 5%	113	266	355	NS
Variety				
Samrat	665	1994	2659	24
Kavita	656	2118	2774	23
HUM-12	729	1897	2626	27
S.Em. ±	37	88	118	0.84
CD at 5%	NS	NS	NS	2.52

Effect of Varieties

There was no discernible difference in the three types' grain yield per plant. Even Nevertheless, Samrat and HUM-12 both have much more pods per plant than Kavita. It was also found to be comparable to HUM-12, however both produced considerably more grains per pod than Kavita, with Kavita producing noticeably bolder grains than the other two kinds. In a similar vein, HUM-12 demonstrated its unique superiority over Samrat in terms of test weight.

The interaction between a variety's genetic composition and the growing environment determines its grain yield. Grain yield data (Table 2) show that the varieties did not offer a meaningful outcome. The biological yield plays a major role in determining a crop's production. One of the characteristics of seed yield is the production of a significant amount of biomass. Table 2's data on biological yield per hectare show that different cultivars had no discernible impact on biological yield.

Test weight is one of the most crucial factors influencing a crop's eventual yield. Varieties had a substantial impact on the test weight, according to the data in Table 1. In contrast to HUM-12, which had a lower test weight but more pods per plant and grains per pod boosted the overall yield compared to Kavita, Kavita had the highest test weight but did not provide a greater yield because of fewer pods per plant and grains per pod.

A crop variety's physiological productive potential is gauged by its harvest index. It is a crop plant's capacity to transform dry materials into a profitable yield. It is the ratio of biological yield to seed yield, and the harvest index value would be higher for varieties with lower biological yield and higher seed production. Production efficiency will increase with a higher harvest index value, or vice versa. Varieties varied considerably due to assimilate conversion efficiency, according to the computed Harvest Index values shown in Table 2.

The harvest index of the study's varieties varied significantly. HUM-12 displayed the highest harvest index (27%), whereas Samrat (24%) was comparable to Kavita (22%). The genetic potential of the variations could be the cause. These results are consistent with those of Taleei *et al*. (1999), who also noted notable variations in the harvest index between several cultivars.

Table 3: Economics of mungbean as influenced by varieties and phosphorus levels under custard apple based agri-horti system.

Treatments	Cost of Cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
(P_1V_1) Phosphorus 34 kg ha^{-1} + Samrat	10349	15654	5305	0.51
(P_1V_2) Phosphorus 34 kg ha^{-1} + Kavita	10269	19338	9069	0.88
(P_1V_3) Phosphorus 34 kg ha^{-1} + HUM-12	10569	16306	5737	0.54
(P_2V_1) Phosphorus 46 kg ha^{-1} + Samrat	10555	25290	14735	1.40
(P_2V_2) Phosphorus 46 kg ha^{-1} + Kavita	10474	24027	13553	1.29
(P_2V_3) Phosphorus 46 kg ha^{-1} + HUM-12	10575	28377	17802	1.68
(P_3V_1) Phosphorus 58 kg ha^{-1} + Samrat	10878	34875	23997	2.21
(P_3V_2) Phosphorus 58 kg ha^{-1} + Kavita	10798	31904	21106	1.95
(P_3V_3) Phosphorus 58 kg ha^{-1} + HUM-12	10858	37610	26752	2.46

The data clearly shows that the application of phosphorus 58 kg/ha + HUM-12 combination (P3V3) resulted in the highest cost of cultivation, gross return, net return, and B:C ratio, whereas phosphorus 34 kg/ha + Samrat (P1V1) produced the lowest.

Conclusion

According to the aforementioned experimental results, using 58 kg P_2O_5/ha is the best way to achieve the highest grain production, net return, and B:C ratio of mungbean in an agri-horticultural system based on custard apples. Any of the three examined varieties can be grown, however HUM-12 was found to be more profitable at the greatest phosphorus dose.

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