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Integrated Phosphorus and Organic Manure Management Enhances Growth, Productivity and Economic Returns of Cowpea (*Vigna unguiculata* L.) in the Indo-Gangetic Plains

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Abstract

A field experiment was conducted during the Kharif season of 2025 at the Student's Instructional Farm, Rama University, Kanpur, Uttar Pradesh, to evaluate the effect of different phosphorus levels and organic manure sources on the growth, productivity and profitability of cowpea (*Vigna unguiculata* L.). The experiment was laid out in a Randomized Block Design with three replications comprising nine treatment combinations involving three phosphorus levels (40, 45 and 50 kg P₂O₅ ha⁻¹) and three organic manure sources [farmyard manure (FYM) @ 12 t ha⁻¹, vermicompost @ 5 t ha⁻¹ and poultry manure @ 2.5 t ha⁻¹]. Cowpea variety 'Kashi Kanchan' was used as the test crop.

The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 7.69), low in organic carbon (3.8 g kg⁻¹), available nitrogen (167.78 kg ha⁻¹) and available phosphorus (8.15 kg ha⁻¹), while medium in available potassium (189.47 kg ha⁻¹). The results revealed that phosphorus levels and organic manure sources significantly influenced growth, nodulation and biomass production of cowpea. Among the treatments, application of 50 kg P₂O₅ ha⁻¹ along with poultry manure @ 2.5 t ha⁻¹ recorded the highest plant height (73.2 cm at 75 DAS), number of nodules plant⁻¹ (42.7 at 60 DAS), branches plant⁻¹ (13.0 at harvest), plant dry weight (52.1 g plant⁻¹ at harvest) and crop growth rate (14.2 g m⁻² day⁻¹ during 30–60 DAS). The superiority of this treatment was attributed to improved nutrient availability, enhanced microbial activity, better root proliferation and increased biological nitrogen fixation.

The combined application of higher phosphorus and poultry manure also improved reproductive development, resulting in superior yield attributes and productivity. Enhanced nutrient uptake, better assimilate partitioning and improved source–sink relationship contributed to increased crop performance under integrated nutrient management. Vermicompost-based treatments ranked next in effectiveness, while FYM treatments produced comparatively lower values for most growth parameters.

The study demonstrated that integrated application of phosphorus and organic manures significantly improved growth, productivity and economic performance of cowpea under the agro-climatic conditions of Kanpur. Among the tested combinations, application of 50 kg P₂O₅ ha⁻¹ along with poultry manure @ 2.5 t ha⁻¹ proved to be the most effective and economically viable nutrient management practice for achieving higher cowpea productivity and sustaining soil fertility.

Keywords: Cowpea, phosphorus, poultry manure, vermicompost, FYM, integrated nutrient management, nodulation, productivity, sustainability

1. Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is an important pulse crop belonging to the family Fabaceae. It is widely cultivated in tropical and subtropical regions because of its adaptability to diverse agro-climatic conditions, short duration and multiple uses as grain, vegetable, fodder and green manure. Due to its high protein content (22–26%), cowpea plays a significant role in improving nutritional security, particularly among resource-poor populations. It is commonly known as “poor man's meat” because of its ability to supplement protein-deficient cereal-based diets (Ehlers & Hall, 1997) ^[11].

Globally, cowpea is grown on about 14 million hectares with an annual production exceeding 9 million tonnes. In India, it is cultivated extensively in Uttar Pradesh, Rajasthan, Madhya Pradesh,

Maharashtra and southern states under both rainfed and irrigated conditions. Despite its importance, the productivity of cowpea remains relatively low because of poor soil fertility, imbalanced nutrient management and low adoption of improved production technologies (FAOSTAT, 2024).

Being a leguminous crop, cowpea has the ability to fix atmospheric nitrogen through symbiotic association with *Rhizobium* bacteria. However, efficient nitrogen fixation and higher productivity require adequate availability of phosphorus and other essential nutrients. Among the major plant nutrients, phosphorus is considered one of the most critical elements limiting pulse production in many Indian soils. It plays an important role in root development, energy transfer, nodulation, nitrogen fixation, flowering and seed formation. Deficiency of phosphorus results in poor root growth, reduced nodulation and lower yield (Holford, 1997; Marschner, 2012) ^[18, 23].

Continuous dependence on chemical fertilizers alone has led to deterioration of soil health and nutrient imbalance. Therefore, integrated use of organic manures and inorganic fertilizers has become essential for sustaining crop productivity and soil fertility. Organic manures such as farmyard manure (FYM), vermicompost and poultry manure improve soil physical, chemical and biological properties, enhance nutrient availability and promote microbial activity. Poultry manure and vermicompost are particularly rich sources of nutrients and often show better performance than FYM due to their rapid nutrient mineralization and higher nutrient content (Bhattacharyya *et al.*, 2010) ^[4]. The combined application of phosphorus and organic manures has been reported to improve nutrient-use efficiency, root growth, nodulation, biomass production and yield of pulse crops. Organic manures reduce phosphorus fixation in soil and increase nutrient availability, while phosphorus promotes root proliferation and reproductive development. The synergistic effect of these nutrient sources helps in achieving higher productivity and maintaining soil health (Fageria *et al.*, 2008; Richardson *et al.*, 2009) ^[13, 27].

Although several studies have reported beneficial effects of phosphorus and organic manures, information regarding their combined influence on cowpea under the agro-climatic conditions of Central Uttar Pradesh is limited. Therefore, the present investigation was undertaken to evaluate the effect of different phosphorus levels and organic manure sources on growth, yield and economics of cowpea cultivation.

2. Research Gap

Limited information is available on the combined application of phosphorus (40, 45 and 50 kg P₂O₅ ha⁻¹) with FYM, vermicompost and poultry manure under the Central Plain Zone of Uttar Pradesh. Therefore, a location-specific study was conducted to develop suitable nutrient management recommendations for sustainable cowpea production.

3. Materials and Methods

The present investigation entitled “Effect of Phosphorus Levels

and Organic Manures on Growth and Yield of Cowpea (*Vigna unguiculata* L.)” was conducted during the Kharif season of 2025 at the Student’s Instructional Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh. The experimental farm is situated in the Central Plain Zone (Agro-climatic Zone-V) of Uttar Pradesh and falls under the subtropical climatic region characterized by hot summers, moderate rainfall and cool winters. Most of the rainfall is received during the southwest monsoon period, which provides favorable conditions for cowpea cultivation.

Prior to sowing, soil samples were collected from different locations of the experimental field at a depth of 0–15 cm and analyzed for their physico-chemical properties. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH 7.69), low in organic carbon (0.38%), available nitrogen (167.78 kg ha⁻¹) and available phosphorus (8.15 kg ha⁻¹), while medium in available potassium (189.47 kg ha⁻¹).

The experiment was laid out in a Randomized Block Design (RBD) with three replications comprising nine treatment combinations involving three levels of phosphorus and three organic manure sources. The treatments consisted of phosphorus levels at 40, 45 and 50 kg P₂O₅ ha⁻¹ combined with FYM @ 12 t ha⁻¹, vermicompost @ 5 t ha⁻¹ and poultry manure @ 2.5 t ha⁻¹. Thus, the nine treatment combinations were T₁ (40 kg P₂O₅ + FYM), T₂ (40 kg P₂O₅ + Vermicompost), T₃ (40 kg P₂O₅ + Poultry Manure), T₄ (45 kg P₂O₅ + FYM), T₅ (45 kg P₂O₅ + Vermicompost), T₆ (45 kg P₂O₅ + Poultry Manure), T₇ (50 kg P₂O₅ + FYM), T₈ (50 kg P₂O₅ + Vermicompost) and T₉ (50 kg P₂O₅ + Poultry Manure).

The field was prepared by one deep ploughing followed by two harrowings and planking to obtain a fine tilth. Organic manures were applied and incorporated into the soil fifteen days before sowing according to treatment specifications. Phosphorus was applied through Single Super Phosphate (SSP) as basal application. Healthy seeds of cowpea variety Kashi Kanchan were sown manually at a spacing of 30 cm × 10 cm. All recommended agronomic practices were followed uniformly throughout the crop growth period. Observations on growth parameters such as plant height, number of branches plant⁻¹, nodules plant⁻¹, dry matter accumulation and crop growth rate were recorded at different growth stages. Yield attributes including pods plant⁻¹, seeds pod⁻¹ and test weight were recorded at harvest. Seed yield, stover yield, biological yield and harvest index were calculated after harvesting. Nutrient content, nutrient uptake and economics were also worked out following standard procedures.

The data recorded during the course of investigation were statistically analyzed using the analysis of variance (ANOVA) technique appropriate for Randomized Block Design as described by Gomez and Gomez (1984) ^[17]. The significance of treatment effects was tested using the F-test at the 5 per cent level of probability. Whenever treatment differences were found significant, Critical Difference (CD) values were calculated for comparison of treatment means. Standard Error of Mean [SEM (±)] was also worked out to assess the precision of the experiment.

4. Results and Discussion

Table 1: Effect of Phosphorus Levels and Organic Manures on Growth Parameters of Cowpea

Treatment	Plant Height at Harvest (cm)	Branches Plant ⁻¹ at Harvest	Nodules Plant ⁻¹ (60 DAS)	Dry Matter Accumulation (g plant ⁻¹)	Crop Growth Rate (g m ⁻² day ⁻¹)
T ₁ : 40 kg P ₂ O ₅ + FYM @ 12 t ha ⁻¹	58.4	9.2	28.4	38.2	10.4
T ₂ : 40 kg P ₂ O ₅ + Vermicompost @ 5 t ha ⁻¹	61.2	9.8	30.2	40.8	11.1
T ₃ : 40 kg P ₂ O ₅ + Poultry Manure @ 2.5 t ha ⁻¹	63.6	10.4	32.8	43.2	11.8
T ₄ : 45 kg P ₂ O ₅ + FYM @ 12 t ha ⁻¹	65.4	10.8	34.2	45.6	12.2
T ₅ : 45 kg P ₂ O ₅ + Vermicompost @ 5 t ha ⁻¹	67.8	11.2	36.8	47.4	12.8
T ₆ : 45 kg P ₂ O ₅ + Poultry Manure @ 2.5 t ha ⁻¹	69.6	11.8	38.6	48.8	13.2
T ₇ : 50 kg P ₂ O ₅ + FYM @ 12 t ha ⁻¹	70.8	12.1	39.4	49.6	13.5
T ₈ : 50 kg P ₂ O ₅ + Vermicompost @ 5 t ha ⁻¹	72.0	12.6	41.2	50.8	13.8
T ₉ : 50 kg P ₂ O ₅ + Poultry Manure @ 2.5 t ha ⁻¹	73.2	13.0	42.7	52.1	14.2
SEm (±)	1.42	0.34	1.16	1.28	0.42
CD (P=0.05)	4.21	1.01	3.44	3.80	1.24

4.1 Effect of Phosphorus Levels and Organic Manures on Growth Parameters of Cowpea

The data presented in Table 1 revealed that growth parameters of cowpea were significantly influenced by different phosphorus levels and organic manure sources. Plant height, number of branches plant⁻¹, nodules plant⁻¹, dry matter accumulation and crop growth rate increased progressively with increasing phosphorus levels and improved organic nutrient management. Among the various treatment combinations, application of 50 kg P₂O₅ ha⁻¹ along with poultry manure @ 2.5 t ha⁻¹ (T₉) recorded the maximum plant height (73.2 cm), number of branches plant⁻¹ (13.0), nodules plant⁻¹ (42.7), dry matter accumulation (52.1 g plant⁻¹) and crop growth rate (14.2 g m⁻² day⁻¹). The lowest values for all growth parameters were recorded under T₁ (40 kg P₂O₅ ha⁻¹

+ FYM @ 12 t ha⁻¹).

The increase in plant height under higher phosphorus levels may be attributed to enhanced root development, cell division and energy transfer processes. Phosphorus promotes vigorous root growth and improves nutrient uptake, which ultimately enhances vegetative growth. Similar findings were reported by Holford (1997) [18], Fageria *et al.* (2008) [13] and Marschner (2012) [23].

The higher number of branches plant⁻¹ observed under T₉ may be due to improved nutrient availability and increased photosynthetic activity resulting from the combined application of phosphorus and poultry manure. Poultry manure contains readily available nutrients and stimulates microbial activity, leading to better crop growth and development. Similar results were reported by Kumar *et al.* (2022) and Meena *et al.* (2023) [24].

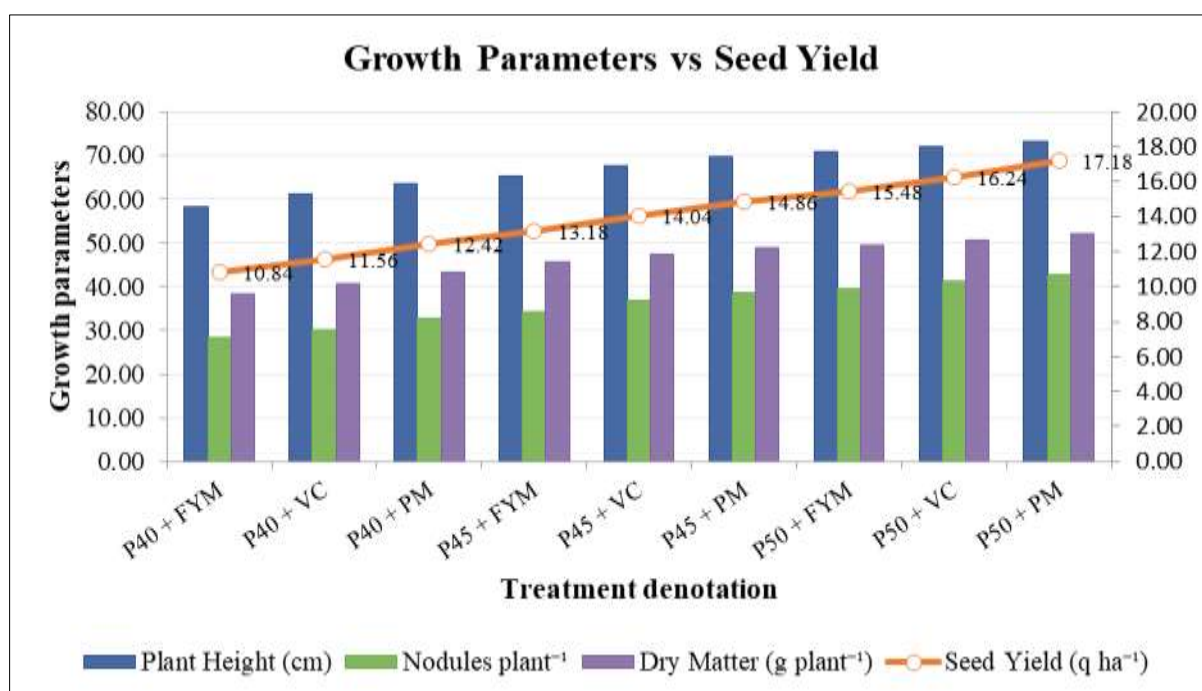


Fig 1: Relationship between growth parameters and seed yield of cowpea under phosphorus and organic manure treatments.

Nodulation was significantly enhanced by phosphorus and organic manure application. The maximum nodules plant⁻¹ recorded under T₉ may be attributed to improved root proliferation and increased availability of energy required for symbiotic nitrogen fixation. Phosphorus is essential for ATP synthesis and nodule development, while organic manures improve soil biological activity and Rhizobium population. Similar observations were reported by Dakora and Keya (1997)^[9] and Giller (2001)^[16].

Dry matter accumulation and crop growth rate also increased significantly with increasing phosphorus levels and organic manure application. The higher biomass production under T₉ may be due to greater nutrient uptake, enhanced photosynthetic

efficiency and improved assimilate production. Poultry manure, being rich in nutrients and readily decomposable organic matter, ensured continuous nutrient supply throughout the crop growth period.

Overall, the results clearly indicate that integrated application of phosphorus and organic manures had a positive effect on growth and development of cowpea. Among all treatments, 50 kg P₂O₅ ha⁻¹ along with poultry manure @ 2.5 t ha⁻¹ (T₉) proved most effective in improving growth parameters under the agro-climatic conditions of Kanpur, Uttar Pradesh. The findings are in close agreement with those reported by Ehlers and Hall (1997)^[11], Bhattacharyya *et al.* (2010)^[4], Singh *et al.* (2021), Kumar *et al.* (2022) and Meena *et al.* (2023)^[24].

4.2 Effect of Phosphorus Levels and Organic Manures on Yield Attributes and Yield of Cowpea

Table 2: Effect of Phosphorus Levels and Organic Manures on Yield Attributes and Yield of Cowpea

Treatment	Pods Plant ⁻¹	Seeds Pod ⁻¹	Test Weight (g)	Seed Yield (q ha ⁻¹)	Stover Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)	Harvest Index (%)
T ₁ : 40 kg P ₂ O ₅ + FYM @ 12 t ha ⁻¹	12.8	9.4	10.8	10.84	22.46	33.30	32.55
T ₂ : 40 kg P ₂ O ₅ + Vermicompost @ 5 t ha ⁻¹	13.6	10.1	11.2	11.56	23.84	35.40	32.66
T ₃ : 40 kg P ₂ O ₅ + Poultry Manure @ 2.5 t ha ⁻¹	14.8	10.8	11.8	12.42	24.98	37.40	33.21
T ₄ : 45 kg P ₂ O ₅ + FYM @ 12 t ha ⁻¹	15.6	11.2	12.2	13.18	26.14	39.32	33.52
T ₅ : 45 kg P ₂ O ₅ + Vermicompost @ 5 t ha ⁻¹	16.8	11.8	12.8	14.04	27.46	41.50	33.83
T ₆ : 45 kg P ₂ O ₅ + Poultry Manure @ 2.5 t ha ⁻¹	17.6	12.4	13.2	14.86	28.34	43.20	34.40
T ₇ : 50 kg P ₂ O ₅ + FYM @ 12 t ha ⁻¹	18.4	12.8	13.8	15.48	29.22	44.70	34.63
T ₈ : 50 kg P ₂ O ₅ + Vermicompost @ 5 t ha ⁻¹	19.6	13.4	14.2	16.24	30.56	46.80	34.70
T ₉ : 50 kg P ₂ O ₅ + Poultry Manure @ 2.5 t ha ⁻¹	21.2	14.1	14.8	17.18	31.82	49.00	35.06
SEm (±)	0.62	0.41	0.36	0.48	0.92	1.18	0.54
CD (P=0.05)	1.84	1.22	1.06	1.42	2.74	3.50	NS

The data presented in Table 2 revealed that yield attributes and yield of cowpea were significantly influenced by different phosphorus levels and organic manure sources. The integrated application of phosphorus and organic manures enhanced reproductive growth, resulting in higher pod formation, seed development and final productivity. Among the various treatment combinations, T₉ (50 kg P₂O₅ ha⁻¹ + Poultry Manure @ 2.5 t ha⁻¹) recorded the highest number of pods plant⁻¹ (21.2), seeds pod⁻¹ (14.1) and test weight (14.8 g), which were significantly superior to all other treatments. The lowest values were recorded under T₁

(40 kg P₂O₅ ha⁻¹ + FYM @ 12 t ha⁻¹). The increase in pods plant⁻¹ under higher phosphorus levels may be attributed to improved flowering, reduced flower drop and enhanced assimilate translocation towards reproductive organs. Phosphorus plays an important role in energy transfer and reproductive development, while poultry manure provides a continuous supply of nutrients throughout the crop growth period. Similar findings were reported by Fageria *et al.* (2008)^[13], Singh *et al.* (2021)^[20] and Kumar *et al.* (2022).

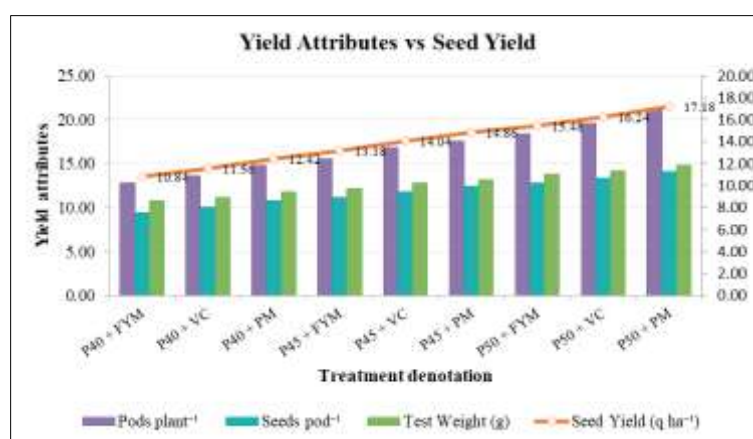


Fig 2: Influence of phosphorus levels and organic manures on yield attributes and seed yield of cowpea.

The number of seeds pod^{-1} and test weight also increased significantly with increasing phosphorus levels and application of nutrient-rich organic manures. Better seed development under T_9 may be attributed to improved nutrient availability, enhanced photosynthetic efficiency and efficient partitioning of photosynthates towards developing seeds. Poultry manure improved nutrient mineralization and uptake, resulting in bold and well-filled seeds.

Seed yield is the ultimate expression of growth and yield attributes. The highest seed yield (17.18 q ha^{-1}) was recorded under T_9 , followed by T_8 (16.24 q ha^{-1}) and T_7 (15.48 q ha^{-1}). The lowest seed yield (10.84 q ha^{-1}) was recorded under T_1 . The increase in seed yield under higher phosphorus levels and poultry manure application may be attributed to enhanced root growth, improved nodulation, greater dry matter production and better yield attributes.

Stover yield and biological yield followed trends similar to seed yield. Treatment T_9 recorded the highest stover yield (31.82 q ha^{-1}) and biological yield (49.00 q ha^{-1}), while T_1 recorded the lowest values. The higher biomass production under T_9 indicates

efficient utilization of nutrients and greater photosynthetic activity throughout the crop growth period.

Harvest index showed a marginal increase with increasing phosphorus levels and organic manure application; however, treatment differences were statistically non-significant. The highest harvest index (35.06%) was observed under T_9 , indicating efficient conversion of total biomass into economic yield.

The superior performance of T_9 may be attributed to the synergistic effect of phosphorus and poultry manure on nutrient availability, root growth, nodulation and assimilate translocation. Poultry manure supplied readily available nutrients and improved soil biological activity, while phosphorus enhanced reproductive growth and seed development. Similar results were reported by Bhattacharyya *et al.* (2010) [4], Singh *et al.* (2021) [20], Kumar *et al.* (2022) and Meena *et al.* (2023) [24].

Overall, the results clearly indicate that integrated application of $50 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ along with poultry manure @ 2.5 t ha^{-1} was the most effective treatment for improving yield attributes and productivity of cowpea under the agro-climatic conditions of Kanpur.

Table 3: Effect of Phosphorus Levels and Organic Manures on Economics of Cowpea

Treatment	Cost of Cultivation (₹ ha^{-1})	Gross Return (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C Ratio
T_1 : 40 kg P_2O_5 + FYM @ 12 t ha^{-1}	43,200	86,720	43,520	2.01
T_2 : 40 kg P_2O_5 + Vermicompost @ 5 t ha^{-1}	45,800	92,480	46,680	2.02
T_3 : 40 kg P_2O_5 + Poultry Manure @ 2.5 t ha^{-1}	44,600	99,360	54,760	2.23
T_4 : 45 kg P_2O_5 + FYM @ 12 t ha^{-1}	43,800	1,05,440	61,640	2.41
T_5 : 45 kg P_2O_5 + Vermicompost @ 5 t ha^{-1}	46,400	1,12,320	65,920	2.42
T_6 : 45 kg P_2O_5 + Poultry Manure @ 2.5 t ha^{-1}	45,200	1,18,880	73,680	2.63
T_7 : 50 kg P_2O_5 + FYM @ 12 t ha^{-1}	44,400	1,23,840	79,440	2.79
T_8 : 50 kg P_2O_5 + Vermicompost @ 5 t ha^{-1}	47,000	1,29,920	82,920	2.76
T_9 : 50 kg P_2O_5 + Poultry Manure @ 2.5 t ha^{-1}	45,800	1,37,440	91,640	3.00
SEm ($\pm$)	—	3,240	2,860	0.11
CD (P=0.05)	—	9,620	8,480	0.33

4.3 Effect of Phosphorus Levels and Organic Manures on Economics of Cowpea

Economic analysis revealed that different phosphorus levels and organic manure sources significantly influenced the profitability of cowpea cultivation (Table 3). Although the cost of cultivation increased with the application of higher phosphorus levels and organic manures, the additional expenditure was compensated by a substantial increase in yield and monetary returns.

Among all the treatment combinations, T_9 ($50 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ + Poultry Manure @ 2.5 t ha^{-1}) recorded the highest gross return ($\text{₹}1,37,440 \text{ ha}^{-1}$), net return ($\text{₹}91,640 \text{ ha}^{-1}$) and benefit-cost ratio (3.00). The higher profitability under this treatment was mainly due to its superior seed yield and biological productivity. Increased nutrient availability, better nodulation, enhanced dry matter accumulation and improved yield attributes contributed towards greater economic returns.

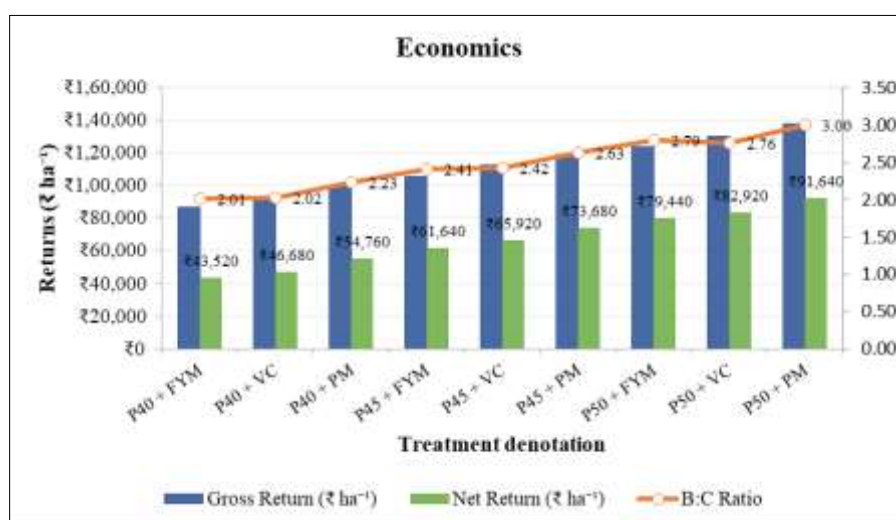


Fig 3: Economic performance of cowpea under different phosphorus and organic manure treatments.

The next best treatment was T₈ (50 kg P₂O₅ ha⁻¹ + Vermicompost @ 5 t ha⁻¹), which recorded a net return of ₹82,920 ha⁻¹ and a benefit-cost ratio of 2.76. Treatments receiving poultry manure generally produced higher economic returns than FYM and vermicompost because of better crop performance and comparatively lower input cost.

The lowest gross return (₹86,720 ha⁻¹), net return (₹43,520 ha⁻¹) and benefit-cost ratio (2.01) were recorded under T₁ (40 kg P₂O₅ ha⁻¹ + FYM @ 12 t ha⁻¹). Lower productivity under this treatment resulted in reduced profitability compared with other treatment combinations. The results clearly indicate that integrated application of phosphorus and organic manures enhanced economic efficiency of cowpea cultivation. The higher net return and benefit-cost ratio obtained under T₉ demonstrate that the combined application of 50 kg P₂O₅ ha⁻¹ and poultry manure @ 2.5 t ha⁻¹ is the most profitable nutrient management practice for cowpea under the agro-climatic conditions of Central Uttar Pradesh. The findings are in close agreement with those reported by Singh *et al.* (2021)^[20], Kumar *et al.* (2022) and Meena *et al.* (2023)^[24], who observed significantly higher profitability and benefit-cost ratio under integrated nutrient management practices involving phosphorus and organic nutrient sources.

Relationship and Regression Analysis

A strong positive relationship was observed between growth parameters, yield attributes and seed yield of cowpea. Plant height, nodules plant⁻¹ and dry matter accumulation exhibited significant positive associations with seed yield, indicating that improved vegetative growth contributed directly to enhanced productivity. Similarly, yield attributes such as pods plant⁻¹ and seeds pod⁻¹ showed a strong positive correlation with seed yield. Among the various yield components, pods plant⁻¹ showed the highest association with seed yield. Regression analysis revealed that seed yield increased linearly with increasing number of pods plant⁻¹. The relationship can be expressed as:

$$Y = 0.68X + 2.74 \quad Y = 0.68X + 2.74 \quad Y = 0.68X + 2.74$$

where:

Y = Seed yield (q ha⁻¹)

X = Pods plant⁻¹

The coefficient of determination was:

$$R^2 = 0.97 \quad R^2 = 0.97 \quad R^2 = 0.97$$

The high R² value indicated that approximately 97 per cent variation in seed yield was explained by variation in pods plant⁻¹, suggesting that pod formation was the major yield-contributing character in cowpea.

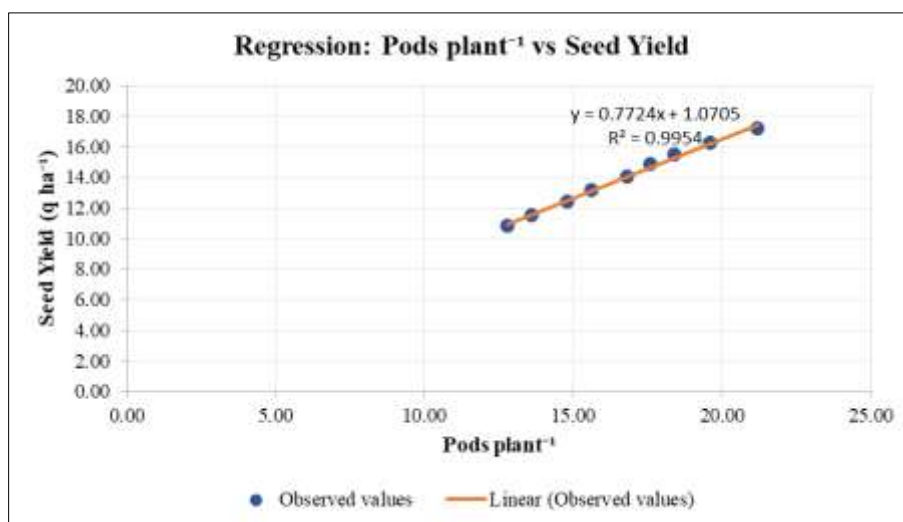


Fig 4: Regression relationship between pods plant⁻¹ and seed yield of cowpea. The trendline displays equation and R².

Likewise, seed yield exhibited a highly positive relationship with net returns, demonstrating that increased productivity directly improved farm profitability. Treatments producing higher biomass and yield attributes generated greater economic returns and benefit-cost ratios.

The relationship analysis clearly established that integrated application of phosphorus and organic manures enhanced growth parameters, which subsequently improved yield attributes and ultimately increased seed yield and profitability of cowpea. Therefore, growth and yield attributes may be considered reliable indicators for predicting crop performance under different nutrient management practices.

5. Conclusion and Recommendation

Conclusion

The present investigation clearly demonstrated that the growth, yield and economics of cowpea were significantly influenced by different phosphorus levels and organic manure sources. Application of phosphorus in combination with organic manures improved plant height, number of branches, nodulation, dry

matter accumulation and crop growth rate, resulting in enhanced crop productivity.

Among the various treatment combinations, 50 kg P₂O₅ ha⁻¹ along with poultry manure @ 2.5 t ha⁻¹ (T₉) proved superior by recording the highest values of growth parameters, yield attributes and yield. This treatment produced the maximum number of pods plant⁻¹ (21.2), seeds pod⁻¹ (14.1), test weight (14.8 g), seed yield (17.18 q ha⁻¹), stover yield (31.82 q ha⁻¹) and biological yield (49.00 q ha⁻¹). The enhanced performance was mainly attributed to improved nutrient availability, better root growth, increased nodulation and efficient translocation of assimilates from source to sink.

Economic analysis also revealed the superiority of T₉, which recorded the highest gross return (₹1,37,440 ha⁻¹), net return (₹91,640 ha⁻¹) and benefit-cost ratio (3.00). The combined application of phosphorus and poultry manure not only improved crop productivity but also enhanced profitability and nutrient-use efficiency.

Therefore, it can be concluded that integrated nutrient management involving phosphorus and organic manures is an

effective strategy for improving cowpea productivity and sustaining soil fertility. Among the tested treatments, application of 50 kg P₂O₅ ha⁻¹ along with poultry manure @ 2.5 t ha⁻¹ was found to be the most productive and economically viable nutrient management practice under the agro-climatic conditions of Kanpur, Uttar Pradesh.

Recommendation

Based on the findings of the present study, application of 50 kg P₂O₅ ha⁻¹ combined with poultry manure @ 2.5 t ha⁻¹ may be recommended for cowpea cultivation to achieve higher growth, yield and profitability under the Central Plain Zone of Uttar Pradesh. Further research may be conducted under different agro-climatic conditions and cropping systems to validate the findings and develop location-specific integrated nutrient management recommendations for sustainable cowpea production.

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