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RESEARCH ARTICLE
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Optimizing Pigeon Pea Productivity: A Study on Growth, Nutrient use Efficiency and Economics under Integrated Nutrient Management Practices

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ABSTRACT

Background: The indiscriminate use of chemical fertilizers has led to soil degradation and declining soil health. To address this issue, integrating organic sources with chemical fertilizers could be a sustainable approach which helps to restore soil fertility while enhancing crop productivity.

Methods: The research trial was conducted at Instructional Farm of Karunya Institute of Technology and Sciences, Coimbatore, during the late *Rabi* season of 2024-25 with eleven different treatments. The treatment included various integrated nutrient management practices by combining vermicompost and farmyard manure with synthetic fertilizers.

Result: The results revealed that higher plant height (108.4 cm), Dry matter production (4644 kg/ha), Grain yield (827 kg/ha) and haulm yield (2664 kg/ha) was obtained with the application of 75% RDF with 25% N equivalent of vermicompost. Higher net gain and added cost was recorded in the application of 100% RDF + FYM @12.5 t/ha conversely higher gross return and added return was observed in the application of 75% RDF with 25% N equivalent of vermicompost.

Key words: Farmyard manure, Nitrogen equivalent, Parametric budgeting, Sensitivity analysis, Sustainable, Vermicompost.

INTRODUCTION

Pigeonpea is a versatile edible legume crop cultivated in most of the agro-climatic zones across the country and it is considered as the fifth prominent pulse crop in the world and second most important legume crop in India after chick pea. Globally, red gram cultivation spans across a total area of 63.57 million hectares yielding a total production of 54.75 million tonnes and total productivity of 861.25 kg per hectare. India stands at the forefront of red gram production worldwide, with 42.2 lakh tonnes cultivated across 49.0 million hectares, achieving a productivity of 861 kg per hectare (Sowmyasri *et al*., 2023).

Adequate nutrition is fundamental to human health and malnutrition can result in significant long-term consequences. The accessibility of nutritious diets is severely constrained by economic limitations which restrict the availability and consumption of nutrient-rich foods. The Indian Council of Medical Research (ICMR) has recommended about 0.8 to 1 gram of protein for per kg weight of the body. Among the other legume crops, pigeonpea has unique ability of combining optimal nutritional profiles which has high protein content compared to the cereals contains 21 % of protein (Umesha *et al.,* 2017) which helps to meet the nutritional security of the general population.

As the global population continues to grow the demand for food production rises correspondingly leading to an increasing demand for higher crop yield which forced the farmers to use excessive plant nutrients which results higher application of inorganic fertilizers. The use of chemical fertilizers in worldwide is estimated around 1.9 × 1011 tonnes (Wan *et al.,* 2021) and excessive utilization of chemical fertilizers may cause huge environmental cause, where the chemicals fertilizers contain high concentration of radio nuclides and heavy metals like cadmium and chromium which causes severe soil degradation. Completely eliminating chemical fertilizers is impractical but the application can be optimized through Integrated Nutrient Management practices (INM). This research focuses on INM strategies that combine organic sources such as farmyard manure and vermicompost with synthetic

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fertilizers to enhance nutrient efficiency and minimize environmental impact of using harmful chemicals.

MATERIALS AND METHODS

A field trail was carried out at the Instructional farm of Karunya Institute of Technology and Sciences, Coimbatore during the late *rabi* season of 2024-25. The farm is located at an elevation of 474 meters above mean sea level, positioned at latitude 17°22′N and longitude 77°58′E, in the Western Zone of Tamil Nadu (Fig 1). The soil sampled from the experimental site resulted an alkaline with the pH of 8.1 and an electrical conductivity (EC) of 0.28 dS/m with low level of available nitrogen (255 kg/ha), medium level of available phosphorus (15.7 kg/ha) and high level of available potassium (185 kg/ha). The study was conducted in randomized block design, with 11 different treatments *i.e.* T1 - 75% RDF + 25% N equivalent as FYM, T2 - 75% RDF + 25% N equivalent as Vermi compost, T3 - 50% RDF + 50 % N equivalent as FYM, T4 - 50% RDF + 50 % N equivalent as Vermicompost, T5 - 25% RDF +75% N equivalent as FYM, T6 - 25% RDF + 75% N equivalent as Vermicompost, T7 - 100% N equivalent of FYM, T8 - 100% N equivalent of Vermicompost, T9 - 100% RDF + FYM @12.5 t ha^{-1}, T10 - 100% RDF alone, T11 - Control and it was replicated thrice.

The estimation of nutrient content of both farmyard manure and vermicompost were given in Table 1. Organic manures and synthetic fertilizers utilized in this experiment were applied as a basal dose during the final ploughing with the specific treatment rates assigned to each experimental plot. The application rates of organic manures are detailed in Table 2.

The APK-1 variety of red gram was sown on December 6, 2024, with a spacing of 45 × 20 cm. A seed rate of 15 kg/ha was used in the gross plot size measured 7.2 m × 6 m. The seeds were treated with *rhizobium* before sowing and the initial irrigation was applied immediately after sowing, followed by a second irrigation at 3 days after sowing (DAS). Subsequent irrigations were carried out during critical growth stages, including bud initiation, 50% flowering and pod development, to ensure optimal crop growth and yield. Two hand weeding practices were done to suppress the weed. The growth and yield characters of plant were measured at the time of harvest with standardized procedures. The collected data were subsequently analysed using the analysis of variance (ANOVA) method (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth and yield parameters

The plant height, dry matter production (DMP), grain yield and haulm yield are presented in Table 3. The application of 75% RDF with 25% nitrogen equivalent of vermicompost recorded higher plant height (108.4 cm) and DMP (2664 kg/ha) whereas, the lowest plant height (65.1 cm) and DMP (1358) was recorded in the control. Similarly, the higher grain yield of 827 kg/ha and haulm yield of 2664 kg/ha was recorded in the treatment with the application of 75% RDF with 25% N equivalent of vermicompost. This might be due to the application of the organic manure vermicompost, which rich in essential nutrients. The beneficial microorganisms present in the vermicompost would have enhanced soil structure, microbial activity and nutrient retention and this balanced nutrient availability and enhanced soil health provided by vermicompost supported optimal physiological processes in plants. Which would have resulted in better root development and increased microbial activity collectively

Table 1: Experiment methods used to estimate the nutrient content of organic manures.

Nutrients	Estimation methods	FYM	Vermicompost
Nitrogen	Kjeldahl method (Bermar 1960)	0.48	1.62
Phosphorous	Triple acid method (Ruttenberg 1992)	0.16	1.14
Potassium	Flame photometry method (Dippel 1954)	0.53	1.76

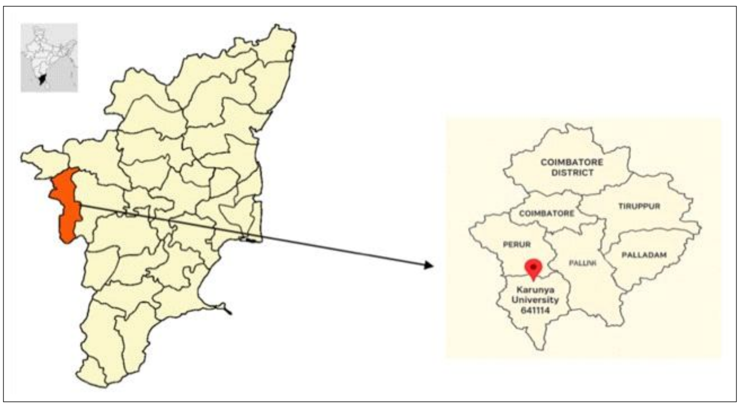

Fig 1: Site map the experimental study.

promoting superior plant growth and development (Jeyajothi *et al.,* 2023; Kumar *et al*., 2020 and Cathrine *et al*., 2025).

The application of synthetic fertilizers with organic inputs has enhanced nutrient availability ensuring sustained plant development. This approach underscored the long-term benefits of organic inputs in maintaining soil fertility and providing a steady nutrient supply which is vital for sustaining crop productivity. These findings were also agreed with the research findings of Verma *et al*. (2022) and Devaraj *et al*. (2023).

Effect of integrated nutrient management on nutrient uptake (kg/ha) at harvest

The plant nutrient uptake were presented in Fig 2. The application of 75% RDF combined with 25% N equivalent from vermicompost resulted in higher nutrient absorption of nitrogen (43.5 kg/ha), phosphorous (25.8 kg/ha) and potassium (20.8 kg/ha) followed by the application of 75% RDF + 25% N equivalent from FYM. This nutrient combination enhanced the soil moisture retention and provided a slow and steady release of nutrients which aligned well with the nutrient demands of pigeonpea throughout its growth cycle. When used in combination with synthetic fertilizers, they created a balanced nutrient supply leading to a better plant growth and higher nutrient uptake. These results were corroborated with the findings of Kumawat *et al*. (2012), Monga *et al*. (2022) and Kharabe *et al*. (2021).

Agronomic use efficiency of nitrogen, phosphorous and potassium

Agronomic use efficiency (AUE) is the asant of additional grain harvested per kilogram of N, P and K fertilizer applied. The AUE of the pigeonpea was significantly influenced by various treatment combinations (Fig 3). Among the

Table 2: Nutrient content of organic manures applied on dry weight basis.

Treatment	Particulars	Quantity (kg/ha)	N(kg/ha)	P(kg/ha)	K(kg/ha)
T_1- 75% RDF + 25% N equivalent as FYM	FYM	1302	6.24	2.08	6.9
	Vermicompost	-	-	-	-
T_2- 75% RDF + 25% N equivalent as Vermicompost	FYM	-	-	-	-
	Vermicompost	386	6.25	4.4	6.79
T_3- 50% RDF + 50 % N equivalent as FYM	FYM	2604	12.49	41.6	13.8
	Vermicompost	-	-	-	-
T_4- 50% RDF + 50 % N equivalent as Vermicompost	FYM	-	-	-	-
	Vermicompost	772	12.50	8.80	13.58
T_5- 25% RDF +75% N equivalent as FYM	FYM	3906	18.70	62.4	20.7
	Vermicompost	-	-	-	-
T_6- 25% RDF + 75% N equivalent as Vermicompost	FYM	-	-	-	-
	Vermicompost	1157	18.74	13.18	20.36
T_7- 100% N equivalent of FYM	FYM	5208	24.99	83.32	27.60
	Vermicompost	-	-	-	-
T_8- 100% N equivalent of Vermicompost	FYM	-	-	-	-
	Vermicompost	1543	24.99	17.59	27.15
T_9- 100% RDF + FYM @12.5 t/ha	FYM	12500	60	20	66.25
	Vermicompost	-	-	-	-
T_{10}- 100% RDF alone	FYM	-	-	-	-
	Vermicompost	-	-	-	-
T_{11}- Control		-	-	-	-

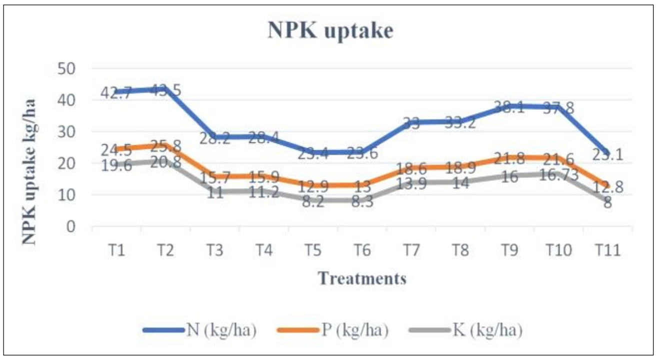

Fig 2: Nutrient uptake of pigeonpea at harvest under various integrated nutrient management practices.

treatments, the higher AUE of nitrogen was recorded with the application of 75% RDF + 25% N equivalent as vermicompost followed by 75% RDF + 25% N equivalent as FYM and the lowest was observed with 25% RDF + 75% N equivalent as FYM. Whereas, in phosphorus, the application of 100% N equivalent as FYM resulted in the higher AUE. The lower AUE of phosphorus was recorded with the application of 25% RDF + 75% N equivalent as FYM. As far as potassium is concerned, the higher agronomic efficiency was achieved with the application of 100% RDF + 12.5 t/ha of FYM and lowest was observed in 25% RDF + 75% N equivalent as FYM. This suggested that supplementing chemical fertilizers with organic amendments enhanced nutrient availability and its uptake, leading to improved plant growth and yield. The lower agronomic efficiency showed that a higher reliance on organic sources alone may not be

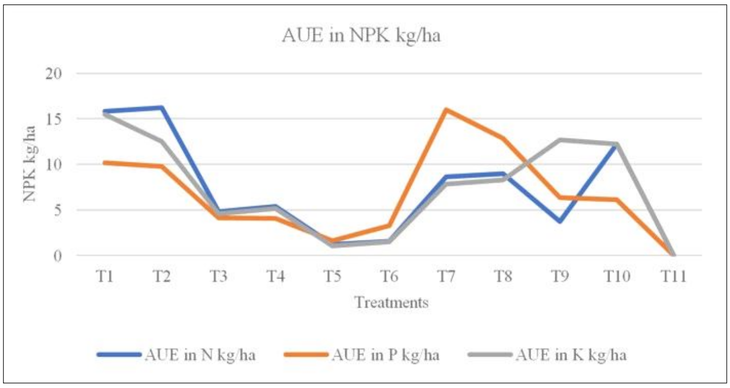

Fig 3: Effect of integrated nutrient management practices on agronomic use efficiency of NPK.

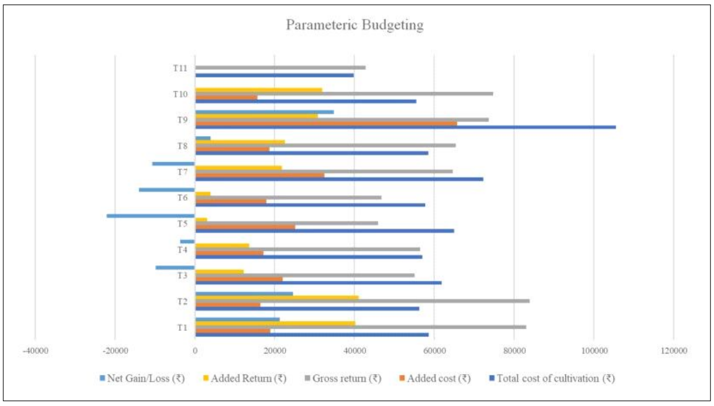

Fig 4: Partial budgeting on the various integrated nutrient management practices.

Table 3: Effects of INM in growth and yield parameters of pigeonpea.

Treatments	Plant height (cm)	DMP(kg/ha)	Grain yield (kg/ha)	Haulm yield (kg/ha)
T_1- 75% RDF + 25% N equivalent as FYM	107.4	4537	819	2541
T_2- 75% RDF + 25% N equivalent as vermicompost	108.4	4644	827	2664
T_3- 50% RDF + 50% N equivalent as FYM	75.5	3098	542	1719
T_4- 50% RDF + 50% N equivalent as vermicompost	75.9	3161	556	1752
T_5- 25% RDF +75% N equivalent as FYM	65.6	2583	452	1454
T_6- 25% RDF + 75% N equivalent as vermicompost	66	2676	461	1472
T_7- 100% N equivalent of FYM	86	3580	638	1998
T_8- 100% N equivalent of vermicompost	86.6	3655	646	2031
T_9- 100% RDF + FYM +12.5 t/ha	97.6	4114	738	2295
T_{10}- 100% RDF alone	96.5	4075	727	2276
T_{11}- Control	65.1	2368	421	1358
Mean	84.6	3499	621	1960
SE(d)	4.5	200	38.8	116
CD (p=0.05)	9.5	418	80.9	243.7

Table 4: Effect of integrated nutrient management on parametric budgeting.

Treatments	GY1	GR2	MC3	LC4	ICC5	TVC6 (3+4+5)	RAVC7 (2-6)	RMC8 (2-4/4)	RLC8 (2-3/4)	MBCR10 (2/6)	BEP11	Increase over BEP %
T_1	820	82984	32862	25100	1691	59653	58833	1.76	2	1.39	1054	-22.23
T_2	827	83893	30467	25100	1621	57188	56361	1.93	2.1	1.47	1028	-19.59
T_3	543	55023	35996	25100	1782	62878	62335	0.83	0.8	0.88	1088	-50.11
T_4	557	56421	31205	25100	1642	57947	57390	1	1	0.97	1036	-46.26
T_5	453	45943	39127	25100	1873	66100	65647	0.53	0.3	0.7	1122	-59.64
T_6	462	46836	31941	25100	1664	58705	58243	0.68	0.6	0.8	1044	-55.77
T_7	638	64606	46430	25100	2086	73616	72978	0.85	0.7	0.88	1201	-46.9
T_8	646	65434	32680	25100	1685	59465	58819	1.23	1.3	1.1	1052	-38.62
T_9	738	74702	29728	25100	1599	56427	55689	1.67	1.8	1.32	1020	-27.68
T_{10}	728	73712	79728	24400	3037	107165	106437	0.62	-0.2	0.69	1555	-53.17
T_{11}	422	42808	17880	21900	1160	40940	40518	1.17	1.1	1.05	431	-2.08

GY- Grain yield; RAVC- Return above variable cost; RLC- Return on labour cost; GR- Gross return; RMC- Return on material cost; MBRC- Marginal BC ratio; MC- Material cost; ICC- Interest on special capital; BEP- Break-even point; LC- Labour cost; TVC- Total variable cost.

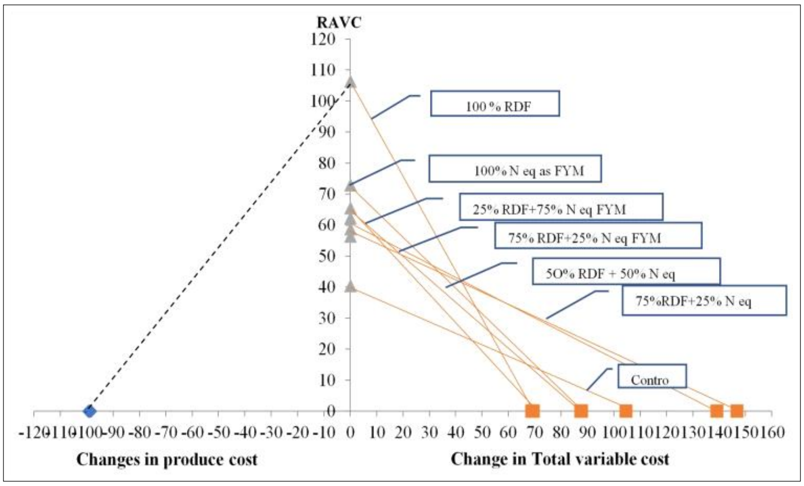

Fig 5: Sensitive analysis as impacted by various integrated nutrient management practices.

sufficient to meet the crop's immediate nutrient demand due to the initial slower nutrient release from organic manures (Salim and Raza 2020).

Partial budgeting on the various integrated nutrient management of pigeonpea

Partial budgeting is used to calculate the expected change in profit for a proposed change in farm business. From the results of the experiment, the higher cost of cultivation, net gain and added cost was recorded in the application of 100% RDF + FYM @12.5 t/ha (Fig 4). Whereas, the integrated application 75% RDF + 25% N equivalent as Vermicompost recorded higher gross return and added return among the other nutrient management practices. The cost of cultivation and added expenses were associated with the combination of organic and inorganic nutrient sources particularly when organic inputs were used in larger quantities but when the vermicompost and other organic inputs are purchased externally the cost of cultivation remains high but this can be minimized by producing organic inputs in-situ using farm waste materials available within the farm itself which helps the farmer to reduce the cost of cultivation. This result was also documented by Yadav *et al.* (2021), Gupta *et al.* (2022) and Kharte *et al.* (2022).

Parametric budgeting and sensitive analysis

Parametric budgeting is an economic evaluation method used for estimating costs and financial requirements based on various parameters such as crop type, farm size, input costs, labour cost, *etc*. The impact of integrated nutrient management practices on parametric budgeting and sensitive analysis in the current study is illustrated in Table 4 and Fig 5. The higher return above variable cost (RAVC) was registered in the sole application of 100% RDF was ₹ 1,06,437/ha and the higher return on labour cost (RLC) was recorded in the application of 75% RDF with 25% N equivalent of vermicompost was ₹ 2.1/ha. The percentage increase over Break even point (-0.2%) was higher in control plot which indicates the untreated plots with lower input costs has struggled to generate significant financial gains that shows the importance of proper fertilization strategies to improve the economic benefits in the cultivation practices. Similar findings were reported by Makowski *et al.* (2006) in mustard crop and Srinithi *et al*. (2023) in finger millet crop.

CONCLUSION

Based on the experimental findings, integrating 75% RDF with 25% nitrogen equivalent from vermicompost proved to be an effective strategy. This combination not only enhanced the productivity of pigeonpea but also improved nutrient use efficiency and provided better economic returns. Therefore, partial substitution of chemical fertilizers with vermicompost can be considered as a sustainable approach for pigeonpea cultivation.

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Conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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