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Nutrient Balance and Nutrient Use Efficiency of Irrigated Pigeon Pea [*Cajanus cajan* (L.) Millsp.] under Various Integrated Nutrient Management Practices

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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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Original Research Article

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ABSTRACT

Aims: To evaluate the nutrient balance and nutrient use efficiency of irrigated pigeon peas under various integrated fertilizers

Place and Duration of Study: The field trial was conducted at Instructional Farm (North), Karunya Institute of Technology and Sciences, Coimbatore.

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Methodology: During the growth phase of the pigeon pea crop, the soil's nitrogen, phosphorus, and potassium levels were monitored to assess their essential nutrient balance. This evaluation was conducted for each treatment, considering the specific nutrient application given to the crop. Additionally, the total quantity of nutrient uptake and the efficiency of nitrogen, phosphorus, and potassium utilization were calculated.
Results: Higher availability of nutrients and nutrient uptake at harvest and the maximum values of computed balance and gain values in the nutrient balance studies and agronomic efficiency were observed in the integrated application of 75% RDF + 25% N eq as vermicompost (T_2)
Conclusion: The integrated application of 75% RDF + 25% N eq as vermicompost (T_2) resulted in maximum available nutrients, plant uptake, agronomic efficiency and computed balance nutrient gain.

Keywords: Farmyard manure; vermicompost; nutrient balance.

1. INTRODUCTION

Pulses play a crucial role in agriculture, contributing to a larger portion of exports and offering considerable economic benefits to the country. Globally, pulses are cultivated around 93.18 MT ha^{-1} with a production of 89.82 MT ha^{-1}. India ranks first in area (31%), production (28%) and import (14%) of the world pulse consumption [1]. Among the pulses, pigeon pea ranks as the sixth most significant grain legume crop and cultivated across the semi-arid tropics of Asia, Africa, and the Caribbean countries. Due to the availability of extra short, short, medium and perennial duration verities of red gram it can be successfully accommodated in a diverse range of cropping systems [2]. In India, red gram is popularly known as pigeon pea, Congo pea, gung pea, no-eye pea, toor dal and arhar dal etc. The natural distribution of pigeon peas is within the latitude range of 14° to 28° N, which represents the primary geographic region for the world's pigeon pea production [3]. Pigeon pea has the unique ability to combine optimal nutritional profiles which have a high protein content compared to cereals (average 25 g/100 g) [4] and it is considered a cost-effective source of protein, carbohydrates, minerals, and vitamins, including b-complex, especially in vegetarian diets [5]. Globally, red gram cultivation spans an area of 63.57 million hectares, yielding a total production of 54.75 million tones and productivity of 861.25 kg ha^{-1}. India stands at the forefront of red gram production worldwide, with 42.2 lakh tones cultivated across 49.0 million hectares, achieving productivity of 861 kg ha^{-1}[6]. The major cultivating regions of pigeon peas in India are Maharashtra, Uttar Pradesh, Karnataka, Madhya Pradesh, Gujarat, Andhra Pradesh, and Haryana. Maharashtra leads in pigeon pea production, accounting for 26.29% of the total yield with a production of 0.71 million tons from an area of 1.05 million hectares, with a productivity rate of 0.68 tons ha^{-1} [7].

Farmers apply an enormous amount of synthetic fertilizers in the soil to meet the increasing demands of the growing population. The excessive utilization of chemical fertilizers will cause serious environmental impacts which will degrade the soil fertility. The major utilization of chemicals in agricultural systems can be decreased through the integrated use of fertilizers along with available manures and crop residues. Integrated nutrient management involves maintaining soil fertility and plant nutrient availability at optimal levels to sustain desired productivity by maximizing the advantages of all available sources of organic, inorganic, and biological fertilizers. A nutrient balance sheet for agriculture is a tool used to track the inputs and outputs of nutrients within a farming system. It helps to understand the nutrient dynamics of their soil and crops and also helps to understand fertilization and soil management practices. This comprehensive approach ensures that farming not only becomes more productive and profitable but also engages in environmental sustainability and responsibility.

2. MATERIALS AND METHODS

A field experiment was carried out at the instructional farm of Karunya Institute of Technology and Sciences, Coimbatore during the late *rabi* season of 2023. The farm is located at an elevation of 474 meters above mean sea level, positioned at latitude 10° 56' N and longitude 76° 44' E, in the western zone of Tamil Nadu. The study was conducted using a randomized block design, which included eleven different treatments with three replication as follows: T_1 - 75% RDF + 25% N equivalent as FYM, T_2 - 75% RDF + 25% N equivalent as

Vermi compost, T_3 - 50% RDF + 50 % N equivalent as FYM, T_4 - 50% RDF + 50 % N equivalent as Vermicompost, T_5 - 25% RDF +75% N equivalent as FYM, T_6 - 25% RDF + 75% N equivalent as Vermicompost, T_7 - 100% N equivalent of FYM, T_8 - 100% N equivalent of Vermicompost, T_9 - 100% RDF + FYM @12.5 t ha^{-1}, T_{10} - 100% RDF alone, T_{11} – Control.

The APK-1 (Aruppukkottai) variety of red gram, was sown at a spacing of 45 cm x 20 cm with the seed rate of 15 kg ha^{-1}. Before the sowing of crop, the nitrogen equivalent for all the treatments was calculated and applied accordingly. Organic manures namely FYM and vermicompost were also applied before the sowing as per their treatments. Initially the soil samples were collected and analyzed for available nitrogen (255 kg ha^{-1}), available phosphorus (15.2 kg ha^{-1}) and available potassium (187 kg ha^{-1}) by Alkaline permanganate method [8], Olsen's method [9] and Flame photometer method [10] respectively**.** Similarly, the total nutrient uptake of nitrogen, phosphorous and potassium uptake was analyzed using Micro kjeldahl [11], Colorimetric Estimation [12] and Flame photometric method [10] respectively. The nutrient's computed balance was derived from total quantity of the nutrient added it was subtracted from the total quantity of the nutrient removed. The nutrient balance was computed from the soil nutrient status at harvest was subtracted from the nutrient status at initial and the nutrient balance (either positive or negative) was expressed in kg ha^{-1} [13]. Agronomic efficiency (AE) as calculated by Grain yield in fertilized plot (kg ha^{-1}) - Grain yield in unfertilized plot (kg ha^{-1}) divided by Quantity of fertilizer N applied (kg ha^{-1}).

Map 1. Study area

3. RESULTS AND DISCUSSION

3.1 Nutrient Balance Studies

The nutrient balance refers to the difference between the nutrients applied to soil, primarily through sources like organic manure and fertilizers, and the nutrients utilized by crops (uptake). The nutrient balance sheet of nitrogen, phosphorous and potassium was given in Tables 1,2 and 3 respectively. There was a slight positive rise in the levels of nitrogen (N), phosphorus (P), and potassium (K) after the experiment in some of the treatments compared to the initial soil values measurements. The higher availability of NPK in the soil after post-harvest was recorded in the application of 75% RDF + 25% N eq as vermicompost (T_2) followed by the application of 75% RDF + 25% N eq as FYM(T_1). The maximum estimated balance value of N was recorded in the application of 25% RDF + 75% N eq as vermicompost (T_2), value of P was recorded in the application of 100% RDF (T_{10}) and value of K was observed in the application of 25% RDF + 75% N eq as farmyard manure (T_1). The highest gain in soil nitrogen and phosphorous was reported with the application of 75% RDF + 25 % of vermicompost (T_2) followed by application of 75% RDF + 25 % of farmyard manure (T_2). In potassium budgeting, post-harvest soil values had levels a negative value in the nutrient balance sheet. The above results were due to the improved soil physical properties and slow microbial decomposition of humus from the organic manures which gradually increased nutrient availability during the crop growth that resulted in better nutrient uptake by the plants. The finding was similar to the results of Singh et al., [14] and Babu et al., [15]. The available nutrients of soil at harvest stage were graphically in Fig. 1.

3.2 Agronomic Efficiency

The agronomic efficiency of various nutrients was given in Tables 2,3,4. In nitrogen status, application of 75% RDF + 25% of N equivalent as vermicompost (T_2) recorded maximum agronomic efficiency followed by the application of 75% RDF + 25% of N eq as farmyard manure (T_1). The lowest agronomic efficiency takes place in the application 25% RDF with 75% of N eq as farmyard manure (T_5). Regarding phosphorous levels fertilizer, application of 100% N eq as farmyard manure (T_7) recorded maximum agronomic efficiency followed by the application of 100% N eq as vermicompost (T_8). The lowes

Table 1. Nutrient balance sheet of Nitrogen (N) (Kg ha^{-1})

Treatments	Available of N Kg ha^{-1} (A)	N applied to the crop Kg ha^{-1} (B)	N removal Kg ha^{-1} (C)	Computed balance (B-C)	Available N at harvest Kg ha^{-1} (D)	Net gain or loss (D-A)
T1	255	25.10	42.74	-17.64	274.45	19.45
T2	255	25.00	43.51	-18.51	280.38	25.38
T3	255	24.90	28.25	-3.35	146.83	-108.17
T4	255	25.01	28.43	-3.42	150.93	-104.07
T5	255	25.05	23.42	1.63	111.44	-143.56
T6	255	25.60	23.65	1.95	115.32	-139.68
T7	255	25.00	33.03	-8.03	183.84	-71.16
T8	255	24.99	33.25	-8.26	192.49	-62.51
T9	255	85.00	38.14	46.86	242.86	-12.14
T10	255	25.00	37.85	-12.85	223.78	-31.22
T11	255	-	23.14		100.37	-154.63

Table 2. Nutrient balance sheet of phosphorous (P) (Kg ha^{-1})

Treatments	Available of N Kg ha^{-1} (A)	P applied to the crop Kg ha^{-1} (B)	P removal Kg ha^{-1} (C)	Computed balance (B-C)	Available P at harvest Kg ha^{-1} (D)	Net gain or loss (D-A)
T1	15.2	39.0	24.58	14.5	34.94	19.74
T2	15.2	41.4	25.87	15.53	35.42	20.22
T3	15.2	29.1	15.75	13.35	23.87	8.67
T4	15.2	33.3	15.95	17.35	24.06	8.86
T5	15.2	18.8	12.98	05.82	20.26	5.06
T6	15.2	12.2	13.05	-0.85	20.44	5.24
T7	15.2	8.33	18.65	-10.32	27.54	12.34
T8	15.2	17.5	18.96	-1.46	27.87	12.67
T9	15.2	50.0	21.89	28.11	31.56	16.36
T10	15.2	50.0	21.66	28.34	31.25	16.05
T11	15.2	-	12.87		20.08	4.88

Table 3. Nutrient balance sheet of potassium (K) (Kg ha^{-1})

Treatments	Available of P Kg ha^{-1} (A)	K applied to the crop Kg ha^{-1} (B)	K removal Kg ha^{-1} (C)	Computed balance (B-C)	Available K at harvest Kg ha^{-1} (D)	Net gain or loss (D-A)
T1	185	25.65	19.64	6.01	180.14	-4.86
T2	185	32.45	20.84	11.61	183.64	-1.36
T3	185	26.30	11.08	15.22	116.43	-68.57
T4	185	26.10	11.24	14.86	121.84	-63.16
T5	185	29.20	8.21	20.99	99.67	-85.33
T6	185	26.20	8.38	17.82	100.88	-84.12
T7	185	27.60	13.94	13.66	138.94	-46.06
T8	185	27.10	14.03	13.07	145.56	-39.44
T9	185	25.00	16.94	8.06	165.35	-19.65
T10	185	25.00	16.73	8.27	161.66	-23.34
T11	185	-	8.05		96.43	-88.57

Table 4. Agronomic efficiency of nitrogen (N)

Treatments	Treated plot yield Kg ha^{-1}	Control yield Kg ha^{-1}	Treated yield - control plot yield Kg ha^{-1}	N applied to the crop Kg ha^{-1}	Agronomic efficiency N
T1	819	421	397	25	15.85
T2	827	421	405	25	16.22
T3	542	421	120	25	4.84
T4	556	421	134	25	5.39
T5	452	421	30	25	1.23
T6	461	421	39	25	1.55
T7	638	421	216	25	8.66
T8	646	421	224	25	8.98
T9	738	421	316	85	3.72
T10	727	421	305	25	12.23
T11	421	421	-	-	-

Table 5. Agronomic efficiency of phosphorous (P)

Treatments	Treated plot yield Kg ha^{-1}	Control yield Kgha^{-1}	Treated yield - control plot yield Kg ha^{-1}	P applied to the crop Kg ha^{-1}	Agronomic efficiency P
T1	819	421	397	39.08	10.18
T2	827	421	405	41.40	9.79
T3	542	421	120	29.10	4.14
T4	556	421	134	33.30	4.05
T5	452	421	30.8	18.80	1.64
T6	461	421	39.6	12.20	3.25
T7	638	421	216	08.33	25.99
T8	646	421	224	17.5	12.83
T9	738	421	316	50.0	6.33
T10	727	421	305	50.0	6.12
T11	421	421	-	-	-

Table 6. Agronomic efficiency of potassium (K)

Treatments	Treated plot yield Kg ha^{-1}	Control yield Kg ha^{-1}	Treated yield - control plot yield Kg ha^{-1}	K applied to the crop Kg ha^{-1}	Agronomic efficiency K
T1	819	421	397	25.65	15.51
T2	827	421	405	32.45	12.50
T3	542	421	120	26.30	4.59
T4	556	421	134	26.10	5.16
T5	452	421	30.8	29.20	1.05
T6	461	421	39.6	26.20	1.51
T7	638	421	216	27.60	7.84
T8	646	421	224	27.10	8.28
T9	738	421	316	25.00	12.66
T10	727	421	305	25.00	12.23
T11	421	421	-	-	-

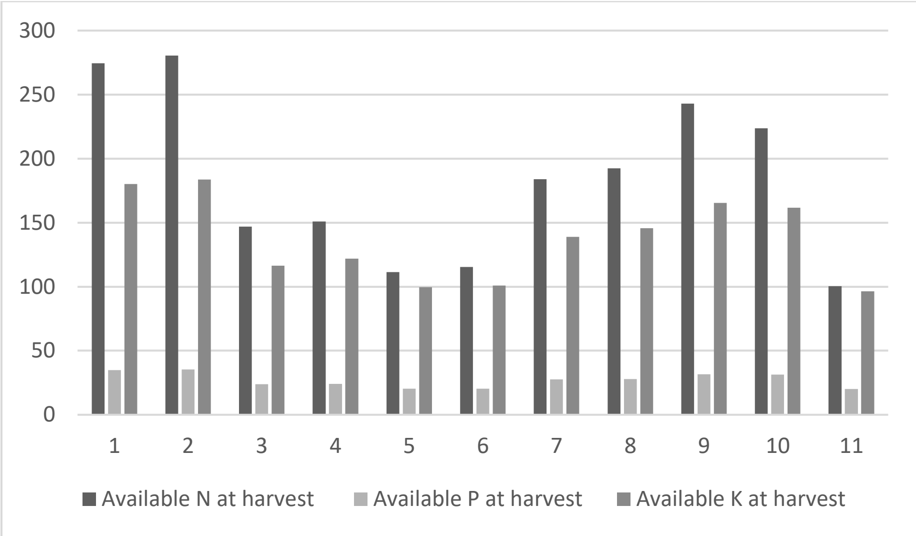

Fig. 1. Available nutrients in soil at harvest

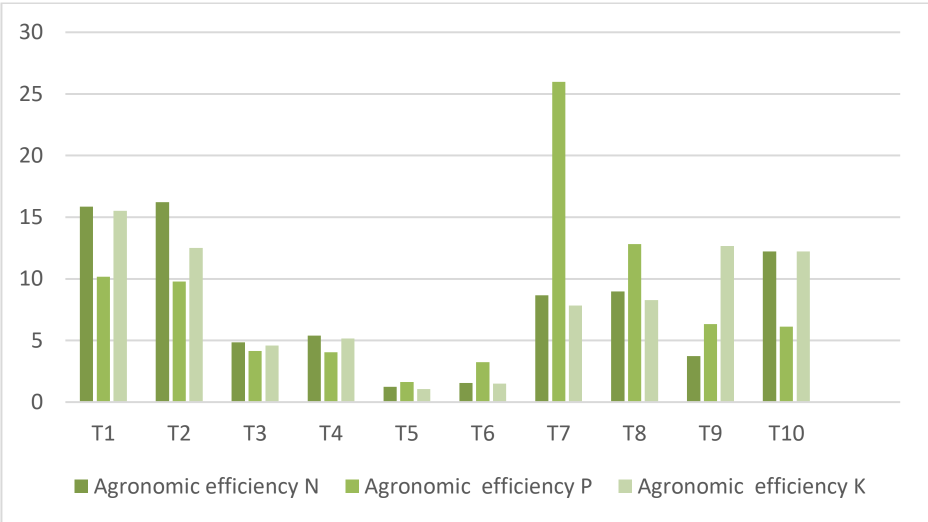

Fig 2. Agronomic use efficiency of nutrients

agronomic efficiency takes place in the application 25% RDF with 75% of N eq as farmyard manure (T_8). Potassium fertilizer, application of 100% RDF (T_9) + 12.5t of FYM recorded maximum agronomic efficiency followed by the application of 100% RDF (T_{10}). The lowest agronomic efficiency takes place in the application 25% RDF + 75% of N eq as farmyard manure (T_5). The agronomic efficiency of nitrogen, phosphorous and potassium were graphically presented in Fig. 2

4. CONCLUSION

In the integrated nutrient management of pigeon pea higher uptake of NPK, maximum availability of nutrients after the post-harvest analysis and the maximum gain of N and P was recorded in the integrated application of 75 % RDF + 25 % N eq as vermicompost (T_2). Maximum agronomic efficiency and physiological values in N were recorded with the application of 75% RDF + 25% N eq as vermicompost (T_2) and in potassium fertilizer applied in 100% RDF + 12.5t of FYM (T_9).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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