



Effect of biochar and nutrients on nitrogen, phosphorus and potassium uptake by pigeonpea (*Cajanus Cajan* (L.) Millsp.)

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Abstract

A field experiment was conducted during *kharif* 2025-26 at the Diggi Block, College of Agriculture, Bheemaranagudi, University of Agricultural Sciences, Raichur, Karnataka, India, to study the effect of biochar, alone and in combination with farmyard manure (FYM) and vermicompost, on the uptake of nitrogen, phosphorus and potassium by pigeonpea (*Cajanus cajan* (L.) Millsp., cv. GRG-152). Ten nutrient management treatments were evaluated in a Randomized Complete Block Design (RCBD) with three replications and nutrient uptake was recorded at harvest. Application of the recommended dose of chemical fertilizer (RDCF) together with vermicompost @ 2.5 t ha⁻¹ and biochar @ 2.5 t ha⁻¹ (T₈) recorded significantly the higher nitrogen (54.9 kg ha⁻¹), phosphorus (11.9 kg ha⁻¹) and potassium uptake (51.5 kg ha⁻¹), being on par with RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹ (T₇), 75 % RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ (T₁₀) and RDCF + Vermicompost @ 2.5 t ha⁻¹ (T₂). Significantly the lower uptake of nitrogen (33.2 kg ha⁻¹), phosphorus (9.6 kg ha⁻¹) and potassium (32.4 kg ha⁻¹) was recorded with the sole application of biochar @ 1.25 t ha⁻¹ (T₃). The results indicate that the conjunctive use of biochar with vermicompost and recommended chemical fertilizer improved nutrient availability and uptake efficiency of rainfed pigeonpea and can be recommended as a sustainable nutrient management practice for enhancing nutrient use efficiency in pigeonpea-growing tracts of the semi-arid tropics.

Keywords: Pigeonpea, biochar, vermicompost, nitrogen uptake, phosphorus uptake, potassium uptake

Introduction

Pigeonpea (*Cajanus Cajan* (L.) Millsp.) is the second most important pulse crop of India after chickpea, cultivated over 4.04 million hectares with a production of about 3.9 million tonnes and an average productivity of 861 kg ha⁻¹ (Anonymous, 2024) [2]. Being a deep-rooted legume with an efficient symbiotic nitrogen-fixing system, pigeonpea occupies a unique niche in rainfed cropping systems, but its productivity remains constrained by low and imbalanced nutrient availability, particularly under the low organic carbon status typical of semi-arid Alfisols (Egbe and Kalu, 2006) [6].

Nutrient uptake by a crop is a resultant of nutrient availability in the soil, root proliferation and the efficiency of the applied nutrient sources and serves as a key physiological indicator of the adequacy of a nutrient management practice. While chemical fertilizers supply nutrients in a readily available form, their efficiency is often compromised by leaching, fixation and volatilization losses, particularly under coarse-textured or alkaline soils (Liu *et al.*, 2024) [12]. Organic manures such as farmyard manure (FYM) and vermicompost not only supply macro- and micro-nutrients but also improve soil microbial activity and enzyme function, thereby enhancing nutrient mineralization and root absorption (Subbarayappa *et al.*, 2009) [17]. Biochar, a porous and highly stable carbonaceous material produced through pyrolysis of biomass under limited-oxygen conditions (Amonette and Joseph, 2009) [1], has been shown to improve the cation exchange capacity, water-

holding capacity and nutrient retention of soil, thereby reducing nutrient losses and improving the synchrony between nutrient release and crop demand (Glaser *et al.*, 2002; Chan *et al.*, 2008) [4, 7].

Although the individual and combined effects of biochar, FYM and vermicompost on soil fertility and nutrient dynamics have been documented in several crops, information on their integrated effect on nitrogen, phosphorus and potassium uptake by pigeonpea under the rainfed conditions of northeastern Karnataka is limited. The present investigation was therefore undertaken to assess the effect of biochar, alone and in conjunction with FYM, vermicompost and chemical fertilizer, on the nutrient (N, P and K) uptake of pigeonpea.

Materials and Methods

Experimental site

A field experiment was conducted during *kharif* 2025-26 at the Diggi Block of the College of Agriculture, Bheemaranagudi, University of Agricultural Sciences, Raichur, situated in the North Eastern Dry Zone of Karnataka (Zone-II) at 16.72° N latitude and 76.79° E longitude, at an altitude of 412 m above mean sea level. The soil of the experimental site was red sandy loam (*Alfisol*), slightly alkaline in reaction (pH 7.54), medium in available nitrogen (250.9 kg ha⁻¹), available phosphorus (33.4 kg ha⁻¹) and available potassium (415.2 kg ha⁻¹).

Treatments and experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with ten treatments replicated thrice. The treatments comprised: T₁ - RDCF + FYM @ 6 t ha⁻¹; T₂ - RDCF + Vermicompost @ 2.5 t ha⁻¹; T₃ - RDCF + Biochar @ 1.25 t ha⁻¹; T₄ - RDCF + Biochar @ 2.5 t ha⁻¹; T₅ - RDCF + FYM @ 6.0 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹; T₆ - RDCF + FYM @ 6.0 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹; T₇ - RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹; T₈ - RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹; T₉ - 75 % RDCF + FYM @ 6 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ and T₁₀ - 75 % RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹, where RDCF refers to the recommended dose of chemical fertilizer (25:50:125 kg N: P₂O₅: K₂O ha⁻¹). The pigeonpea variety GRG-152 was sown at 90 cm × 30 cm spacing, with a gross plot size of 7.2 m × 4.5 m and a net plot size of 3.6 m × 3.3 m.

Nutrient uptake and statistical analysis

At harvest, plant samples (grain and stalk) from the net plot area were oven-dried at 65 ± 5°C to a constant weight and ground for chemical analysis. Nitrogen content was estimated by the micro-Kjeldahl method, phosphorus by the vanadomolybdo-phosphoric yellow colour method using a spectrophotometer and potassium by flame photometry, following the standard procedures outlined by Jackson (1973) and Piper (1966) [9, 15]. The nutrient content (%) was multiplied by the respective dry matter yield (kg ha⁻¹) to arrive at total nitrogen, phosphorus and potassium uptake (kg ha⁻¹). The data generated were statistically analysed by Fisher's method of analysis of variance as outlined by Panse and Sukhatme (1967) [14]. The level of significance used in the 'F' test was 5 per cent probability and wherever the 'F' test was significant, the critical difference (C.D.) was worked out to compare treatment means.

Results and Discussion

Nitrogen uptake (kg ha⁻¹)

Data on nitrogen uptake by pigeonpea at harvest, as influenced by different nutrient management practices, are presented in Table 1 and Fig. 1. Significantly higher nitrogen uptake (54.9 kg ha⁻¹) was recorded with the treatment RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹, which was on par with RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹ (52.7 kg ha⁻¹), 75 % RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ (51.6 kg ha⁻¹) and RDCF + Vermicompost @ 2.5 t ha⁻¹ (51.2 kg ha⁻¹). While, the significantly lower nitrogen uptake (41.6 kg ha⁻¹) was observed with RDCF + Biochar @ 1.25 t ha⁻¹.

The higher nitrogen uptake may be attributed to improved nitrogen availability, vigorous plant growth and greater dry matter production under favourable nutrient management. Organic amendments may have supplied nitrogen through decomposition and mineralization, while biochar could have improved nutrient retention in the soil and supported efficient nutrient uptake. Greater biomass production and seed and stalk yield may have increased the crop demand for nitrogen, resulting in higher overall uptake. In the present investigation, nitrogen uptake ranged from 33.2 to 54.9 kg ha⁻¹, with significant differences among the nutrient management practices. Jat and Ahlawat (2010) [10] reported improved NPK uptake in pigeonpea with FYM application. Badu *et al.* (2019) [3] also observed increased nitrogen

uptake with the combined application of biochar and nitrogen fertilizer. Similarly, Niranjan *et al.* (2020) [13] recorded higher nutrient uptake with integrated application of RDF and biochar, associated with improved crop growth and biomass production. Thus, the higher nitrogen uptake may be attributed to improved nutrient availability, greater biomass production and efficient utilization of applied nitrogen.

Phosphorus uptake (kg ha⁻¹)

Data presented in Table 1 and Fig. 1 revealed that phosphorus uptake at harvest among different treatments, significantly higher phosphorus uptake (11.9 kg ha⁻¹) was recorded in the treatment RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹, followed by RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹ (11.6 kg ha⁻¹), 75 % RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ (11.4 kg ha⁻¹) and RDCF + Vermicompost @ 2.5 t ha⁻¹ (11.3 kg ha⁻¹). While, significantly lower phosphorus uptake was recorded in the treatment RDCF + Biochar @ 1.25 t ha⁻¹ (9.6 kg ha⁻¹).

The higher phosphorus uptake may be attributed to improved phosphorus availability, better root development and greater biomass production under favourable nutrient management. Organic amendments may have contributed to phosphorus availability through improved nutrient cycling, while biochar could have supported phosphorus retention and availability in the soil. Increased plant growth and biomass production would have further enhanced the crop requirement and uptake of phosphorus. In the present investigation, phosphorus uptake ranged from 9.6 to 11.9 kg ha⁻¹, with significant differences among the nutrient management practices. Kumawat *et al.* (2009) [11] reported increased phosphorus content and uptake in mungbean with vermicompost application. Gowthami *et al.* (2019) [8] observed improved phosphorus uptake in groundnut with biochar combined with fertilizer, while Tomar *et al.* (2022) [18] reported higher phosphorus uptake in chickpea with biochar application. Thus, the higher phosphorus uptake may be attributed to improved nutrient availability, enhanced crop growth and efficient utilization of phosphorus.

Potassium uptake (kg ha⁻¹)

Potassium uptake at harvest (Table 1 and Fig. 1) followed a trend similar to nitrogen and phosphorus uptake. Application of RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ resulted in significantly higher potassium uptake (51.5 kg ha⁻¹) compared to all other treatments, followed by RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹ (49.6 kg ha⁻¹), 75 % RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ (48.9 kg ha⁻¹) and RDCF + Vermicompost @ 2.5 t ha⁻¹ (47.8 kg ha⁻¹). While, significantly lower potassium uptake was observed under the treatment RDCF + Biochar @ 1.25 t ha⁻¹ (32.4 kg ha⁻¹).

The higher potassium uptake may be attributed to improved potassium availability, enhanced root activity and greater biomass production under favourable nutrient management. Organic amendments may have contributed nutrients through decomposition and improved the soil environment, while biochar could have enhanced nutrient retention and availability in the root zone. Greater crop growth and biomass production would have increased the demand for

potassium and facilitated its absorption and translocation within the plant. In the present investigation, potassium uptake ranged from 32.4 to 51.5 kg ha⁻¹, with significant differences among the nutrient management practices. Rande *et al.* (2010) [16] reported higher potassium uptake with vermicompost-based nutrient management in wheat. Dhonde *et al.* (2018) [5] observed increased potassium

uptake in sorghum with higher organic nutrient application. Tomar *et al.* (2022) [18] also reported increased potassium uptake in chickpea with biochar application. Thus, the higher potassium uptake may be attributed to improved nutrient availability, enhanced crop growth and efficient utilization of potassium.

Table 1: Nitrogen, phosphorus and potassium uptake by pigeonpea at harvest as influenced by different nutrient management practices

Treatments	Nitrogen uptake (kg ha ⁻¹)	Phosphorus uptake (kg ha ⁻¹)	Potassium uptake (kg ha ⁻¹)
T ₁ : RDCF + FYM @ 6 t ha ⁻¹	39.5	10.0	36.6
T ₂ : RDCF + Vermicompost @ 2.5 t ha ⁻¹	51.2	11.3	47.8
T ₃ : RDCF + Biochar @ 1.25 t ha ⁻¹	33.2	9.6	32.4
T ₄ : RDCF + Biochar @ 2.5 t ha ⁻¹	36.2	9.8	34.4
T ₅ : RDCF + FYM @ 6.0 t ha ⁻¹ + Biochar @ 1.25 t ha ⁻¹	44.1	10.2	38.5
T ₆ : RDCF + FYM @ 6.0 t ha ⁻¹ + Biochar @ 2.5 t ha ⁻¹	44.5	10.6	41.6
T ₇ : RDCF + Vermicompost @ 2.5 t ha ⁻¹ + Biochar @ 1.25 t ha ⁻¹	52.7	11.6	49.6
T ₈ : RDCF + Vermicompost @ 2.5 t ha ⁻¹ + Biochar @ 2.5 t ha ⁻¹	54.9	11.9	51.5
T ₉ : 75 % RDCF + FYM @ 6 t ha ⁻¹ + Biochar @ 2.5 t ha ⁻¹	40.8	10.1	37.4
T ₁₀ : 75 % RDCF + Vermicompost @ 2.5 t ha ⁻¹ + Biochar @ 2.5 t ha ⁻¹	51.6	11.4	48.9
S.Em.±	1.7	0.4	1.6
C.D. (P =0.05)	5.0	1.2	4.6

Note: RDCF: Recommended Dose of Chemical Fertilizer (25:50:125 kg N: P₂O₅: K₂O ha⁻¹); FYM: Farm Yard Manure; S.Em.±: Standard Error of Mean; C.D.: Critical Difference

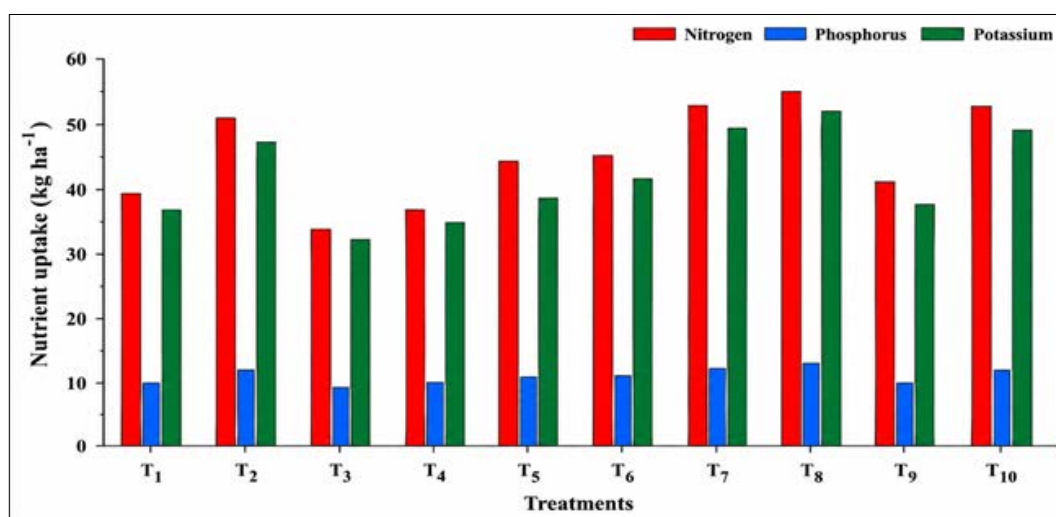


Fig 1: Nitrogen, phosphorus and potassium uptake (kg ha⁻¹) by pigeonpea at harvest as influenced by different nutrient management practices

Conclusion

On the basis of the present investigation, it can be concluded that application of RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ (T₈) significantly improved the uptake of nitrogen, phosphorus and potassium by pigeonpea over the remaining nutrient management practices and was statistically on par with RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 1.25 t ha⁻¹, 75 % RDCF + Vermicompost @ 2.5 t ha⁻¹ + Biochar @ 2.5 t ha⁻¹ and RDCF + Vermicompost @ 2.5 t ha⁻¹. The lowest nutrient uptake was consistently recorded with the sole application of biochar @ 1.25 t ha⁻¹, indicating that biochar alone, without an accompanying readily-available nutrient source, was inadequate for optimum nutrient acquisition by pigeonpea. The conjunctive use of vermicompost and biochar along with the recommended dose of chemical fertilizer can therefore be recommended as a scientifically sound and sustainable nutrient management strategy for enhancing

nutrient uptake and use efficiency in rainfed pigeonpea grown under the semi-arid tropical conditions of northeastern Karnataka.

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