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Effect of potassium levels on soil properties and nutrient availability under Kodo millet (*Paspalum Scrobiculatum* L.)

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ABSTRACT

A field experiment entitled “Effect of Potassium Levels on Soil Properties and Nutrient Status of Kodo Millet (*Paspalum scrobiculatum* L.)” was conducted during Kharif 2025 at the College of Agriculture, Shivamogga, Karnataka, to evaluate the influence of graded levels of potassium on soil physico-chemical properties and nutrient availability. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and seven treatments comprising absolute control, recommended dose of fertilizers (RDF) and different levels of potassium applied along with RDF. The results revealed that soil pH, electrical conductivity, organic carbon, exchangeable calcium and magnesium, and available micronutrients were not significantly influenced by potassium application. However, available phosphorus, potassium and sulphur in soil were significantly affected by the treatments. Application of potassium along with RDF improved the availability of these nutrients and enhanced the overall soil fertility status. Higher potassium levels maintained greater available potassium throughout the crop growth period, while moderate potassium supplementation along with RDF was found effective in improving the availability of phosphorus and sulphur. Thus, potassium application beyond RDF improved soil nutrient availability without adversely affecting the physico-chemical properties of soil, indicating its potential role in sustaining soil fertility under kodo millet cultivation.

Keywords: Kodo millet, Potassium levels, Soil properties, Nutrient availability, Soil fertility, Available potassium, Phosphorus and sulphur

Introduction

In recent years, millets have gained significant attention as an important alternative to major cereal crops due to their nutritional value and adaptability to adverse climatic conditions. Millets have been cultivated since ancient civilizations and were among the earliest crops grown during the early plough-based agricultural era. Traditionally, millets were classified into major and minor groups based on the extent of cultivation and seed size. Sorghum and pearl millet are categorized as major millets, whereas finger millet, foxtail millet, proso millet, barnyard millet, kodo millet, little millet, and browntop millet are considered minor or small millets. However, with the growing recognition of their rich nutritional composition, millets are now widely referred to as *nutri-cereals*. These crops serve as staple foods in many countries of the semi-arid tropics, particularly in Asia and Africa, where low rainfall and poor soil fertility limit the cultivation of other major food crops. In such regions, millets continue to play a crucial role in ensuring food and nutritional security, providing essential carbohydrates, protein, vitamins, minerals, and dietary fibre.

Kodo millet is well known for its remarkable drought tolerance compared to other millets. It can grow successfully on marginal soils and produce economically viable grain yields even under adverse environmental conditions. The crop requires relatively less water

and exhibits excellent drought tolerance, making it suitable for rainfed agriculture. Kodo millet can thrive in low-fertility soils because its nutrient requirement is minimal, and excessive nutrient application may even lead to lodging. It has the ability to produce relatively high yields within a short duration, which adds to its economic importance. Among the small millets, it is considered one of the hardiest crops and is generally cultivated during the kharif season with the onset of the monsoon.

Potassium is an essential nutrient element required by all living organisms, including plants and animals, and its importance in Indian agriculture has increased with the intensification of farming systems. It exists in plants as a monovalent cation (K^+) and is present in the highest concentration in the cell sap; therefore, it is often referred to as the “master cation.” Potassium is highly mobile within the plant and plays a crucial role in several physiological and biochemical processes. It is involved in water relations, enzyme activation, osmotic regulation, energy transfer, translocation of assimilates, photosynthesis, and protein synthesis (Mengel and Kirkby, 1978) [1]. Nearly sixty enzymes require potassium for their activation. In addition to its role in metabolic processes such as grain and seed formation, potassium improves the quality of agricultural pro

duce, enhances plant strength and reduces lodging in cereal crops, and increases resistance to pests and diseases.

In rainfed regions, the yield potential of small millets, including kodo millet, remains relatively low due to limited fertilizer use and inadequate crop management practices. Although kodo millet is often considered a low-input crop, improved cultivars respond favourably to balanced nutrient management. Balanced application of nitrogen (N), phosphorus (P) and potassium (K) is essential for achieving optimum crop growth and productivity. Nitrogen promotes vegetative growth and chlorophyll synthesis, phosphorus supports root development and energy transfer, while potassium regulates enzyme activation, water relations, photosynthesis, assimilate translocation and stress tolerance. The application of only nitrogen and phosphorus without adequate potassium may result in nutrient imbalance, reduced nutrient use efficiency, poor translocation of photosynthates, lower drought tolerance and suboptimal yield realization.

At present, nutrient recommendations for kodo millet primarily focus on nitrogen and phosphorus, while specific potassium recommendations are generally lacking. Continuous cultivation under such unbalanced fertilization practices may lead to depletion of soil potassium reserves and reduced crop productivity over time. Therefore, evaluating appropriate potassium levels under the existing N and P fertilization regime is essential for developing a balanced nutrient management strategy for sustainable production of kodo millet. Keeping the above facts in view, the investigation was carried out to study the effect of potassium levels on soil properties and nutrient availability under kodo millet (*Paspalum scrobiculatum*).

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Methodology

Before initiation of the experiment, a representative composite soil sample was collected from the experimental field, air-dried under shade, processed and passed through a 2 mm sieve for characterization. The experimental soil was sandy loam in texture and acidic in reaction, with a pH of 5.31, electrical conductivity of 0.131 dS m⁻¹ at 25 °C and organic carbon content of 3.38 g kg⁻¹. The soil contained 289.32 kg ha⁻¹ available N, 86.32 kg ha⁻¹ of available P₂O₅ and 280.44 kg ha⁻¹ of available K₂O. Exchangeable Ca and Mg were 1.98 and 0.94 cmol(p⁺) kg⁻¹, respectively, while available S 12.08 mg kg⁻¹. The DTPA-extractable Zn, Cu, Mn and Fe contents were 1.20, 2.78, 12.24 and 28.15 mg kg⁻¹, respectively.

The experiment was laid out in a Randomized Complete Block Design with seven treatments and three replications. Kodo millet (*Paspalum scrobiculatum* L.) cv. TNAU 86 was used as the test crop. The gross plot size was 4.5 m × 3.0 m, with a row spacing of 22.5 cm and a seed rate of 12.5 kg ha⁻¹. The recommended dose of fertilizer was 20:20:00 kg N: P₂O₅: K₂O ha⁻¹, with FYM applied at 2.5 t ha⁻¹. The treatments comprised an absolute control (T₁), RDF (T₂), RDF + K₂O at 10, 15, 20, 25 and 30 kg ha⁻¹ (T₃, T₄, T₅, T₆ and T₇ respectively).

Table 1. Initial soil properties of the experimental field

Physico - chemical properties	
pH (1:2.5)	5.31
Electrical conductivity (dS m ⁻¹)	0.131
Organic carbon (g kg ⁻¹)	3.38
Textural class	Sandy loam
Available macronutrient status	
Available N (kg ha ⁻¹)	289.32
Available P ₂ O ₅ (kg ha ⁻¹)	86.32
Available K ₂ O (kg ha ⁻¹)	280.44
Available S (mg kg ⁻¹)	12.08
Exchangeable Ca [cmol (p ⁺) kg ⁻¹]	1.98
Exchangeable Mg [cmol (p ⁺) kg ⁻¹]	0.94
Micronutrient status (mg kg⁻¹)	
DTPA - Extractable Zn	1.20
DTPA - Extractable Cu	2.78
DTPA - Extractable Mn	12.24
DTPA - Extractable Fe	28.15

Soil samples were collected from the experimental plots at 0–15 cm depth before sowing and after harvest to assess the changes in soil physico-chemical and nutrient properties due to potassium application. The collected samples were shade-dried, gently powdered, passed through a 2 mm sieve and stored for further analysis. Soil pH was determined in a 1:2.5 soil-to-water suspension, while electrical conductivity was measured in the same extract using a conductivity meter. Organic carbon was estimated by the Walkley and Black method (1934) [2]. Available nitrogen was determined by the alkaline potassium permanganate method (Subbaiah and Asija, 1956) [3], available phosphorus by Bray's method as described by Jackson, (1973) [4], and available potassium by extraction with neutral normal ammonium acetate followed by flame photometric determination (Jackson, 1973) [4]. Exchangeable calcium and magnesium were determined using neutral normal ammonium acetate extraction followed by EDTA titration (Jackson, 1973) [4], while available sulphur was estimated by the calcium chloride extraction and turbidimetric method (Black, 1965) [5]. DTPA-extractable iron, manganese, zinc and copper

were determined using DTPA extraction followed by estimation using an atomic absorption spectrophotometer (Lindsay *et al.*, 1978) [6].

The data obtained from the experiment were subjected to analysis of variance appropriate for the Randomized Complete Block Design following the procedure described by Gomez and Gomez (1984) [7]. The significance of treatment effects was tested using the *F*-test at 5 per cent probability level. The standard error of mean (Sem ±) was calculated for each parameter, and the critical difference (CD) at 5 per cent probability was worked out wherever the treatment effect was significant. Non-significant treatment effects were denoted as NS.

Results and Discussion

Soil pH, electrical conductivity and organic carbon

Soil pH, EC and organic carbon after harvest were not significantly influenced by different levels of potassium application (Table 2). Soil pH ranged from 5.33 to 5.54, electrical conductivity ranged from 0.16 to 0.18 dS m⁻¹, and organic carbon from 3.30 to 3.54 g kg⁻¹. The absence of significant changes indicates that application of potassium at

different levels did not markedly modify the basic chemical properties of soil during one cropping season. Similar observations were reported by Chand *et al.* (2006) [8] and Hussain *et al.* (2015) [9]. Sharieff *et al.* (1984) [10] reported that balanced nutrient management, enhances soil OC through improved residue quality and microbial biomass activity.

Available nitrogen

Available nitrogen content of soil after harvest differed significantly among the treatments. The significantly higher available nitrogen ($281.32 \text{ kg ha}^{-1}$) was recorded in T₂ (RDF = 20:20:00 N: P₂O₅: K₂O kg ha⁻¹), which was on par with T₃ (RDF + 10 kg K₂O ha⁻¹) ($279.31 \text{ kg ha}^{-1}$) and significantly superior to the remaining treat-

ments. The comparatively lower available nitrogen ($265.24 \text{ kg ha}^{-1}$) observed in T₅ (RDF + 20 kg K₂O ha⁻¹) may be attributed to enhanced crop growth and greater nitrogen uptake under optimum potassium supply. Potassium plays a vital role in root development, nutrient transport and efficient utilization of nutrients, resulting in increased removal of nitrogen by the crop and consequently lower residual nitrogen in the soil after harvest. The improved nutrient use efficiency and higher biomass production under optimum potassium nutrition might have contributed to greater depletion of available soil nitrogen (Rout *et al.*, 2017 [11], Divyashree *et al.*, 2018 [12], [11]. Similar findings indicating reduced residual soil nitrogen were reported by Dwivedi *et al.* (2016) [13].

Table 2. Effect of potassium levels on physico chemical properties of soil at harvest

Treatments	pH	EC (dS m ⁻¹)	Organic Carbon (g/kg)
T ₁ : Absolute control	5.46	0.16	3.30
T ₂ : RDF (20:20:00 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹)	5.51	0.16	3.36
T ₃ : RDF + 10 kg K ₂ O ha ⁻¹	5.46	0.17	3.39
T ₄ : RDF + 15 kg K ₂ O ha ⁻¹	5.54	0.16	3.42
T ₅ : RDF + 20 kg K ₂ O ha ⁻¹	5.50	0.17	3.54
T ₆ : RDF + 25 kg K ₂ O ha ⁻¹	5.33	0.17	3.51
T ₇ : RDF + 30 kg K ₂ O ha ⁻¹	5.39	0.18	3.37
S. Em. ±	0.050	0.006	0.052
CD @5%	NS	NS	NS

Available phosphorus

The post-harvest soil available phosphorus was significantly influenced by potassium application. Among the treatments, T₅ (RDF + 20 kg K₂O ha⁻¹) recorded significantly higher available P₂O₅ content (86.79 kg ha^{-1}) followed by T₆ (RDF + 25 kg K₂O ha⁻¹) (84.57 kg ha^{-1}) and lowest was recorded in absolute control (79.00 kg ha^{-1}). The increased availability of phosphorus under optimum potassium application may be due to improved nutrient interaction and enhanced nutrient recycling within the soil-plant system. Better root proliferation and increased biological activity in the rhizosphere under balanced nutrient supply may have contributed to greater phosphorus availability in the soil. In addition, efficient utilization of applied nutrients and reduced nutrient losses might have helped maintain higher residual phosphorus levels after harvest. Similar results were reported by Jat *et al.* (2014) [14] and Asodariya *et al.* (2023) [15].

Available potassium

Available potassium content of soil differed significantly among the treatments at 30, 60, 90 DAS and at harvest. The available potassium content increased progressively with increasing levels of potassium application. Among the treatments, T₇ (RDF + 30 kg K₂O ha⁻¹) recorded the highest available potassium content at all growth stages ($299.56, 278.29, 275.08, 268.44 \text{ kg ha}^{-1}$ at 30, 60, 90DAS and at harvest respectively), whereas the lowest values were recorded in the absolute control. The higher availability of potassium under T₇ was due to the direct addition of potassium through fertilizer application, resulting in increased concentration of exchangeable and soil solution potassium. The higher residual potassium content at harvest under T₆ and T₇ indicates that potassium application exceeded crop demand, resulting in greater potassium retention in the soil. Wherever there was no application of potassium, the depletion of potassium was observed. Available K was depleted with either no K (T₁ & T₂) or reduced dose of K fertilizer. Similar findings were reported by Srinivasa *et al.* (2019) [16] and Sundares and Basavaraja (2017) [17].

Table 3. Effect of potassium levels on available nitrogen and available phosphorus at harvest

Treatments	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)
T ₁ : Absolute control	221.21	71.88
T ₂ : RDF (20:20:00 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹)	281.32	79.00
T ₃ : RDF + 10 kg K ₂ O ha ⁻¹	279.31	80.35
T ₄ : RDF + 15 kg K ₂ O ha ⁻¹	273.22	84.02
T ₅ : RDF + 20 kg K ₂ O ha ⁻¹	265.24	86.79
T ₆ : RDF + 25 kg K ₂ O ha ⁻¹	269.11	84.57
T ₇ : RDF + 30 kg K ₂ O ha ⁻¹	276.29	83.97
S. Em. ±	4.833	2.331
CD @5%	14.894	7.182

(continued on next page)

Table 4. Effect of potassium levels on available potassium at different growth stages of kodo millet

Treatments	Avail K ₂ O (kg ha ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest
T ₁ : Absolute control	256.56	227.20	217.92	206.08
T ₂ : RDF (20:20:00 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹)	267.73	244.31	232.80	225.08
T ₃ : RDF + 10 kg K ₂ O ha ⁻¹	283.72	260.28	248.40	243.88
T ₄ : RDF + 15 kg K ₂ O ha ⁻¹	290.17	263.33	254.48	248.32
T ₅ : RDF + 20 kg K ₂ O ha ⁻¹	293.72	269.05	261.28	254.24
T ₆ : RDF + 25 kg K ₂ O ha ⁻¹	297.52	273.38	268.92	262.40
T ₇ : RDF + 30 kg K ₂ O ha ⁻¹	299.56	278.29	275.08	268.44
SEm±	6.998	6.919	6.275	6.843
CD @ 5%	21.562	21.320	19.338	21.085

Table 5. Effect of potassium levels on exchangeable calcium, exchangeable magnesium and available sulphur at harvest

Treatments	Exch. Ca	Exch. Mg	Avail. S
	(cmol (p ⁺) kg ⁻¹)		
T ₁ : Absolute control	1.80	0.82	10.38
T ₂ : RDF (20:20:00 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹)	1.82	0.84	11.26
T ₃ : RDF + 10 kg K ₂ O ha ⁻¹	1.85	0.85	12.20
T ₄ : RDF + 15 kg K ₂ O ha ⁻¹	1.86	0.87	12.34
T ₅ : RDF + 20 kg K ₂ O ha ⁻¹	1.88	0.89	12.57
T ₆ : RDF + 25 kg K ₂ O ha ⁻¹	1.84	0.85	12.51
T ₇ : RDF + 30 kg K ₂ O ha ⁻¹	1.81	0.83	12.46
S. Em. ±	0.042	0.024	0.167
CD @5%	NS	NS	0.514

Exchangeable calcium

The post-harvest soil exchangeable calcium content under kodo millet plots varied non significantly and ranged from 1.80 to 1.88 cmol (p⁺) kg⁻¹ among different levels of K and RDF. The higher value of 1.88 cmol (p⁺) kg⁻¹ was observed in T₅ (RDF + 20 kg K₂O ha⁻¹), while the lower exchangeable Ca (1.81 cmol (p⁺) kg⁻¹) was recorded in T₇ (RDF + 30 kg K₂O ha⁻¹). This may be attributed to the moderate levels of potassium applied, which were insufficient to induce a marked antagonistic effect on calcium availability. Ahmad and Maathuis (2014) [18] also reported that adequate potassium fertilization generally does not adversely affect calcium availability under balanced fertilization.

Exchangeable magnesium

The post-harvest soil exchangeable magnesium content under kodo millet varied narrowly from 0.82 to 0.89 cmol (p⁺) kg⁻¹. The higher exchangeable Mg (0.89 cmol (p⁺) kg⁻¹) was recorded in T₅ (RDF + 20 kg K₂O ha⁻¹), while lower exchangeable Mg (0.83 cmol (p⁺) kg⁻¹) was recorded in T₇ (RDF + 30 kg K₂O ha⁻¹). A slight numerical decline in Mg was observed at higher potassium levels, though the differences were statistically non-significant. Similar observations were made by Mengel and Kirkby (2001) [1] and Ahmad and Maathuis (2014) [18].

Available sulphur (mg kg⁻¹)

The post-harvest soil sulphur status varied significantly and ranged from 10.38 mg kg⁻¹ to 12.57 mg kg⁻¹ among the treatments. Significantly higher sulphur content (12.57 mg kg⁻¹) was observed in T₅ (RDF + 20 kg K₂O ha⁻¹) and the lowest sulphur content (10.38 mg kg⁻¹) was observed in T₁ (Absolute control) compared to other treatments. This may be attributed to the synergistic interaction between potassium and sulphur in the soil-plant system. Adequate potassium nutrition enhances root growth, nutrient uptake and overall crop vigour, which improves sulphur utilization and contributes to

better sulphur cycling in the soil. Similar findings were reported by Baque *et al.* (2006) [19].

DTPA extractable micronutrients

The post-harvest DTPA extractable micronutrient contents under kodo millet showed only minor variations among treatments and the differences were statistically non-significant. Iron content ranged from 20.97 to 26.42 mg kg⁻¹, zinc from 0.68 to 0.73 mg kg⁻¹, manganese from 10.08 to 12.10 mg kg⁻¹, and copper from 1.85 to 2.60 mg kg⁻¹. The highest values of Fe (26.42 mg kg⁻¹), Zn (0.73 mg kg⁻¹), Mn (12.10 mg kg⁻¹) and Cu (2.60 mg kg⁻¹) were recorded in T₅, whereas the lowest values of Fe (20.97 mg kg⁻¹), Zn (0.68 mg kg⁻¹), Mn (10.08 mg kg⁻¹) and Cu (1.85 mg kg⁻¹) were observed in the absolute control (T₁). However, the variations among treatments were statistically non-significant. Adequate potassium nutrition promotes root growth and root exudation of organic acids, which can enhance the solubility and mobilization of micronutrients such as iron, zinc and manganese in the rhizosphere. Similar findings were reported by Jat *et al.* (2014) [14] and Ramachandrapa *et al.* (2014) [20].

Conclusion

The present investigation revealed that potassium application had a positive influence on post-harvest soil properties under kodo millet. Potassium application improved the availability of phosphorus, potassium and sulphur, while soil pH, EC, organic carbon, exchangeable Ca, Mg and DTPA-extractable micronutrients remained statistically unaffected. Among the different potassium levels, application of 20 kg K₂O ha⁻¹ in addition to RDF maintained a higher residual nutrient status and contributed to better soil fertility after harvest. Soil pH, electrical conductivity and organic carbon were not significantly affected by potassium application, indicating that potassium fertilization did not adversely influence the chemical properties of the soil. Higher potassium levels beyond 20 kg K₂O ha⁻¹ did not result in substantial additional improvement in soil nutrient status. Therefore, application of 20 kg K₂O ha⁻¹ along with the recommended dose of nitrogen and phosphorus can be considered an optimum nutrient man

agement practice for maintaining soil fertility and nutrient availability in kodo millet cultivation under the conditions of the study.

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