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Integrated nutrient management for sustainable production of finger millet in tribal areas

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Abstract

Finger millet's yield potential remains untapped in tribal areas where fertiliser access is limited. This research evaluated integrated nutrient management (INM) for finger millet at Kyoto University, Japan, during 2021-2022 kharif seasons. Six treatments were tested: unfertilised control, 100% RDF (60-30-30 kg NPK ha⁻¹), FYM alone (10 t ha⁻¹), 50% RDF + FYM, 75% RDF + FYM, and 75% RDF + VC (5 t ha⁻¹). The 75% RDF + FYM treatment recorded the highest grain yield (2,925 kg ha⁻¹), 34.2% above 100% RDF. Soil available N and K increased progressively under organic-amended treatments. INM offers a practical, low-cost strategy for finger millet in resource-limited settings.

Keywords: Finger millet, integrated nutrient management, farmyard manure, vermicompost, tribal agriculture, soil fertility, *Eleusine coracana*, nutrient use efficiency

Introduction

Finger millet (*Eleusine coracana* L. Gaertn.) was domesticated around 3000 BCE and remains the fourth most important millet globally, grown on about 4.5 million hectares by smallholders on marginal soils ^[1, 2, 3]. Its grain contains 7-11% protein and 344 mg calcium per 100 g with a low glycaemic index ^[4]. In tribal areas, yields typically range 800-1,500 kg ha⁻¹ well below the attainable 3,000-4,000 kg ha⁻¹ ^[5]. The main constraint is inadequate nutrients: inorganic fertiliser adoption is low due to cost and distance from markets ^[6]. Organic resources like FYM and vermicompost can supply nutrients and improve soil, but alone rarely meet full crop demand ^[7, 8].

Integrated nutrient management combining reduced inorganic fertiliser with organic amendments can bridge this gap while keeping costs accessible ^[9, 10]. This research compared INM options for finger millet to identify combinations that maximise yield and improve soil fertility with reduced synthetic fertiliser dependence.

Materials and Methods

Research area description

The experiment was at the Takaragaike Experimental Farm (35°03'N, 135°47'E, 82 m a.s.l.) of Kyoto University. Soil: Andisol, sandy loam, pH 5.8, organic C 1.87%, available N 218, P 14.3, K 142 kg ha⁻¹. Mean annual rainfall 1,491 mm (June-September peak).

Seasonal conditions and soil properties

The 2021 kharif season received 687 mm rainfall (mean 25.4 °C); 2022 was drier (621 mm) but warmer (26.1 °C). Pre-experiment soil (0-20 cm): bulk density 1.18 g cm⁻³, CEC 18.4 cmol(+) kg⁻¹. FYM contained 0.58% N, 0.27% P₂O₅, 0.53% K₂O; vermicompost had 1.42% N, 0.83% P₂O₅, 0.91% K₂O.

Materials

Finger millet variety GPU-28 was direct-seeded at 10 kg ha⁻¹ in 30 cm rows on 20 June 2021 and 18 June 2022, thinned to 10 cm at 21 DAS. RDF: 60-30-30 kg N-P₂O₅-K₂O ha⁻¹ (urea, SSP, MOP). FYM (10 t ha⁻¹) and VC (5 t ha⁻¹) were incorporated 10 days before sowing.

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Methods

A randomised complete block design with four replications was used. Plots measured 4 m × 3 m. Grain and straw yields were recorded from 6 m² net plots. Post-harvest soil samples (0-20 cm) were analysed for available N (alkaline KMnO₄), P (Olsen),

and K (NH₄OAc). Nutrient uptake was calculated from tissue N, P, K concentrations and dry matter. Data were analysed by ANOVA in R 4.2 with Tukey's HSD at $P \leq 0.05$.

Results

Table 1: Grain yield, straw yield, and yield attributes of finger millet under INM treatments (mean±SE, two seasons pooled)

Treatment	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Ear length (cm)	Fingers per ear	Test wt (g)
T ₁ : Control	1275±87e	2140±142e	5.8±0.3d	4.2±0.3c	2.61±0.08c
T ₂ : 100% RDF	2235±108c	3580±168c	7.4±0.4bc	5.8±0.4b	2.84±0.06b
T ₄ : 50%RDF+FYM	2470±118bc	3890±172bc	7.9±0.4ab	6.1±0.4ab	2.91±0.05ab
T ₅ : 75%RDF+FYM	2925±134a	4510±186a	8.7±0.5a	6.8±0.4a	3.04±0.06a
T ₆ : 75%RDF+VC	2825±127ab	4320±178ab	8.4±0.4a	6.6±0.5a	2.98±0.07a

The 75% RDF + FYM treatment recorded the highest grain yield of 2,925 kg ha⁻¹, followed by 75% RDF + VC at 2,825 kg ha⁻¹ (Figure 1, Table 1). Both surpassed 100% RDF (2,235 kg ha⁻¹)

by 30.9% and 26.4%. FYM alone yielded 1,715 kg ha⁻¹; the control 1,275 kg ha⁻¹.

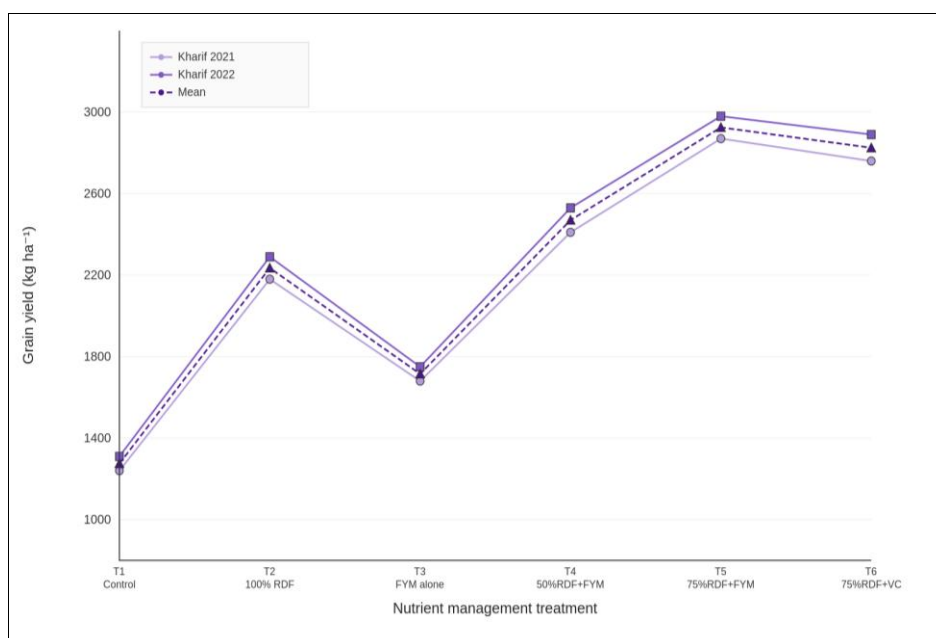


Fig 1: Grain yield of finger millet across INM treatments in kharif 2021, 2022, and their mean

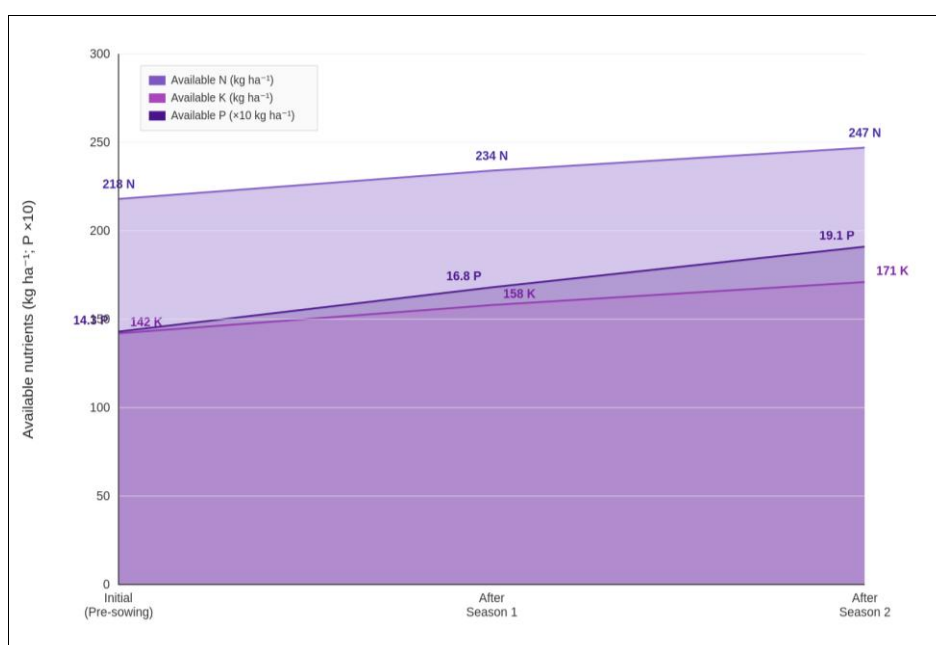


Fig 2: Changes in soil available N, P (×10 scale), and K under 75% RDF + FYM treatment from pre-sowing to post-season 2

Soil available N under 75% RDF + FYM rose from 218 to 247 kg ha⁻¹ (+13.3%) over two seasons (Figure 2). Available P increased 33.6% and K 20.4%. In contrast, 100% RDF maintained N near the initial level while the control declined to

198 kg ha⁻¹ (Table 2). Total nutrient uptake was highest under 75% RDF + FYM (84.7 kg N, 12.8 kg P, 71.3 kg K ha⁻¹). Agronomic N efficiency reached 27.5 kg grain per kg N versus 16.0 under 100% RDF.

Table 2: Post-harvest soil available nutrient status after two seasons of INM (mean±SE, 0-20 cm depth)

Treatment	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)
T ₁ : Control	198±6d	12.8±0.5c	131±5d
T ₂ : 100% RDF	221±7c	15.4±0.6b	146±6c
T ₃ : FYM alone	231±8bc	17.2±0.7ab	159±7b
T ₅ : 75%RDF+FYM	247±9a	19.1±0.8a	171±7a
T ₆ : 75%RDF+VC	242±8ab	18.6±0.7a	168±8ab

Soil available N under 75% RDF + FYM rose from 218 to 247 kg ha⁻¹ (+13.3%) over two seasons (Figure 2). Available P increased 33.6% and K 20.4%. In contrast, 100% RDF maintained N near the initial level while the control declined to 198 kg ha⁻¹ (Table 2). Total nutrient uptake was highest under 75% RDF + FYM (84.7 kg N, 12.8 kg P, 71.3 kg K ha⁻¹). Agronomic N efficiency reached 27.5 kg grain per kg N versus 16.0 under 100% RDF.

Discussion

The 34.2% yield advantage of 75% RDF + FYM over full inorganic RDF aligns with finger millet trials in southern India where similar INM treatments out-yielded sole inorganic application by 20-40%^[11, 12]. The organic component improves not just nutrient supply but also moisture retention and microbial activity in the sandy loam Andisols at this site^[13]. Progressive build-up of available N, P, and K under organic-amended treatments indicates that two seasons of INM measurably shift soil fertility, a benefit inorganic fertiliser alone doesn't provide^[14]. Vermicompost at 5 t ha⁻¹ performed comparably to FYM at 10 t ha⁻¹ due to its higher nutrient concentration, making it attractive where transport costs constrain bulk organic inputs^[15, 16].

Conclusion

Combining 75% of the recommended inorganic fertiliser with 10 t ha⁻¹ FYM produced the highest finger millet grain yield (2,925 kg ha⁻¹) while building soil available N, P, and K over two seasons. Vermicompost at 5 t ha⁻¹ offered a comparable alternative with lower bulk requirement. INM reduced dependence on purchased fertiliser by 25% without sacrificing yield, making it a practical strategy for tribal farming systems with limited market access.

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