International Journal of Agriculture and Nutrition 2024; 6(1): 191-194

ISSN Print: 2664-6064
ISSN Online: 2664-6072
IJAN 2024; 6(1): 191-194
www.agriculturejournal.net
Received: 15-03-2024
Accepted: 19-04-2024

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Nutrient uptake pattern and fertilizer response of high-yielding finger millet genotypes

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DOI: https://doi.org/10.33545/26646064.2024.v6.i1c.412

Abstract
A single hectare of finger millet can extract over 80 kg of potassium from the soil — yet most fertiliser recommendations for this crop ignore genotypic differences in nutrient demand. This research compared the nutrient uptake pattern and fertiliser response of four finger millet genotypes (GPU 28, GPU 67, KMR 204, VR 847) under four fertiliser levels (0, 50, 100, 150% of recommended dose) at Bundelkhand University of Agricultural Sciences, Jhansi, during Kharif 2021. GPU 67 recorded the highest grain yield (34.7 q/ha at 100% RDF), nitrogen uptake (74.8 kg/ha), and agronomic efficiency (12.3 kg grain/kg nutrient). KMR 204 was least responsive, with a flat yield curve beyond 50% RDF. Potassium uptake exceeded nitrogen uptake in all genotypes, confirming the crop's characteristically high K demand. Nutrient use efficiency declined at 150% RDF across all genotypes, indicating diminishing returns from over-fertilisation. GPU 67 appears best suited for intensive management, while KMR 204 may fit low-input systems where fertiliser cost is a constraint.

Keywords: Nutrient uptake, fertilizer response, finger millet, genotype nutrition, millet production, agronomic efficiency, nitrogen use, potassium demand, *Eleusine coracana*, nutrient management

Introduction

When agronomists at ICAR's Bengaluru centre first tested GPU 67 against older finger millet lines, they noticed something unexpected: the genotype didn't just yield more grain — it pulled markedly more nitrogen and potassium from the same soil. This observation, repeated across locations, hinted that nutrient uptake capacity itself might be a selectable trait worth targeting in breeding programmes [1]. But the idea has never been tested formally under the red laterite and alluvial conditions of Bundelkhand, where finger millet occupies roughly 15,000 hectares of kharif dryland.

Finger millet (*Eleusine coracana* L. Gaertn.) is the third most-produced millet globally and a staple for dryland farmers across southern and central India. Its nutritional richness — particularly its 3-4% calcium content, the highest among cereals — has brought renewed attention under the International Year of Millets campaign [2]. Yet average yields hover around 17 q/ha nationally, against a demonstrated potential exceeding 40 q/ha on research stations, and inefficient nutrient management is a major contributor to this gap [3].

The standard fertiliser recommendation (40:20:20 or 60:30:30 kg/ha N:P_2O_5:K_2O, depending on the state) treats all genotypes alike. But genotypes differ in root architecture, mycorrhizal association, and internal nutrient remobilisation efficiency — differences that translate into varied responses to the same fertiliser dose [4]. A genotype with high nutrient uptake efficiency may extract adequate nutrition from a modest dose, while a less efficient one may need a heavier application to achieve the same yield.

This research evaluated four released finger millet genotypes under graded fertiliser levels at Jhansi to (a) characterise their nutrient uptake patterns for N, P, K, Zn, and Fe, (b) quantify the agronomic and recovery efficiency of applied nutrients, and (c) identify genotype-dose combinations that maximise yield per unit nutrient invested [5].

Material and Methods

Nutrient Budget

Soil samples (0-20 cm) were collected before sowing and after harvest from each plot. Available N (alkaline permanganate), P (Olsen's method), and K (ammonium acetate) were determined.

Nutrient uptake in grain and straw was calculated as concentration × dry matter yield. Agronomic efficiency (AE = kg grain increase per kg nutrient applied) and apparent recovery efficiency (RE = nutrient uptake increase per kg nutrient applied × 100) were computed for each genotype-dose combination [6].

Material

Four finger millet genotypes — GPU 28, GPU 67, KMR 204, and VR 847 — were sown on 12 July 2021 at 22.5 × 10 cm spacing at the BUAS research farm, Jhansi (25.43°N, 78.58°E; 271 m elevation). Soils are rakar-type (Inceptisol, pH 6.7, OC 0.38%, available N 187 kg/ha, P 14.2 kg/ha, K 168 kg/ha). Four fertiliser levels were tested: F0 (no fertiliser), F1 (50% RDF = 30:15:15 kg/ha), F2 (100% RDF = 60:30:30 kg/ha), and F3 (150% RDF = 90:45:45 kg/ha). Half the N and full P and K were applied basally; remaining N was top-dressed at tillering [7].

Methods

The experiment used a factorial RBD with three replications; each plot was 4 × 3 m. Plant height, tiller count, and ear-head length were recorded at harvest. Grain and straw yields were determined on a whole-plot basis. Tissue N was measured by micro-Kjeldahl, P by vanadomolybdate colorimetry, and K by flame photometry. Micronutrients (Zn, Fe) were determined by atomic absorption spectrophotometry after di-acid digestion. Data were analysed by two-way ANOVA (genotype × fertiliser) and means compared using LSD at $P \leq 0.05$ [8].

Results

Table 1: Grain yield and nutrient uptake of four finger millet genotypes at 100% RDF

Genotype	Yield (q/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	Zn (g/ha)	Fe (g/ha)
GPU 28	31.4	68.3	14.7	82.1	187	312
GPU 67	34.7	74.8	16.2	89.6	204	347
KMR 204	27.8	61.4	12.8	74.3	168	278
VR 847	33.1	71.2	15.4	86.7	196	331
SEm(±)	1.07	2.3	0.61	2.8	7.4	11.6
CD (P=0.05)	3.21	6.9	1.83	8.4	22.1	34.7

GPU 67 outperformed all genotypes in grain yield and nutrient uptake at 100% RDF. Its N uptake (74.8 kg/ha) was 21.8% higher than KMR 204 (61.4 kg/ha). K uptake exceeded N uptake in every genotype — by 17-21% — confirming finger millet's characteristically heavy potassium demand. Fe uptake (278-347 g/ha) was roughly 1.5 times Zn uptake, reflecting the crop's high grain Fe concentration [1, 3].

Table 2: Agronomic efficiency and recovery efficiency across genotypes and fertiliser levels

Geno × Fert	Yield (q/ha)	AE-N	AE-P	AE-K	RE-N (%)	RE-K (%)
GPU 67 × F1	28.3	13.8	27.6	27.6	38.4	31.7
GPU 67 × F2	34.7	12.3	24.6	24.6	34.1	28.3
GPU 67 × F3	35.4	8.7	17.4	17.4	26.8	22.1
KMR 204 × F1	24.1	9.2	18.4	18.4	27.3	23.4
KMR 204 × F2	27.8	7.8	15.6	15.6	23.1	19.8
KMR 204 × F3	28.6	5.4	10.8	10.8	18.7	16.1
LSD (G×F)	2.14	1.6	3.2	3.2	3.8	2.9

Agronomic efficiency declined with increasing fertiliser dose across all genotypes. GPU 67 at 50% RDF achieved AE-N of 13.8 kg grain/kg N — higher than KMR 204 at any dose. At 150% RDF, GPU 67 yielded only 0.7 q/ha more than at 100% RDF, while KMR 204 gained a negligible 0.8 q/ha, confirming diminishing returns from over-fertilisation. Recovery efficiency of N dropped from 38.4% (F1) to 26.8% (F3) in GPU 67, indicating that surplus nitrogen was lost to leaching or denitrification [4, 6].

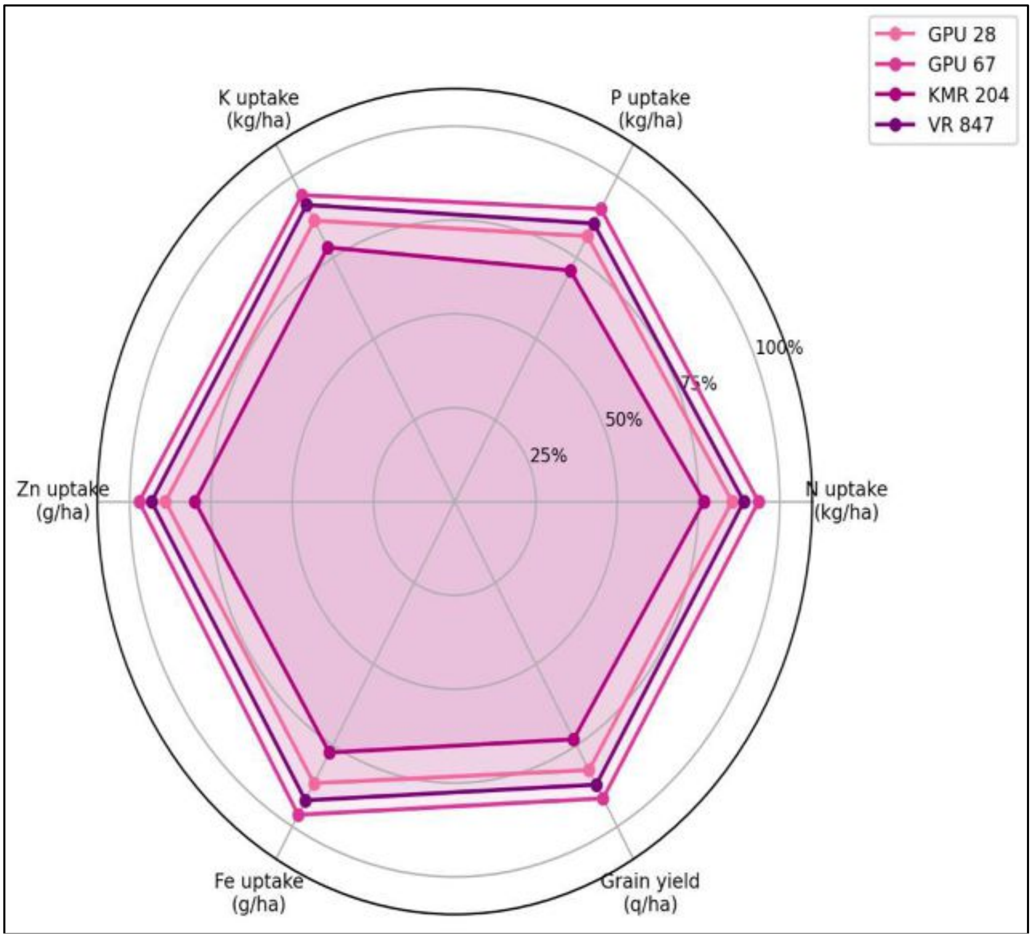

Fig 1: Radar chart comparing nutrient uptake profiles of four finger millet genotypes at 100% recommended fertiliser dose

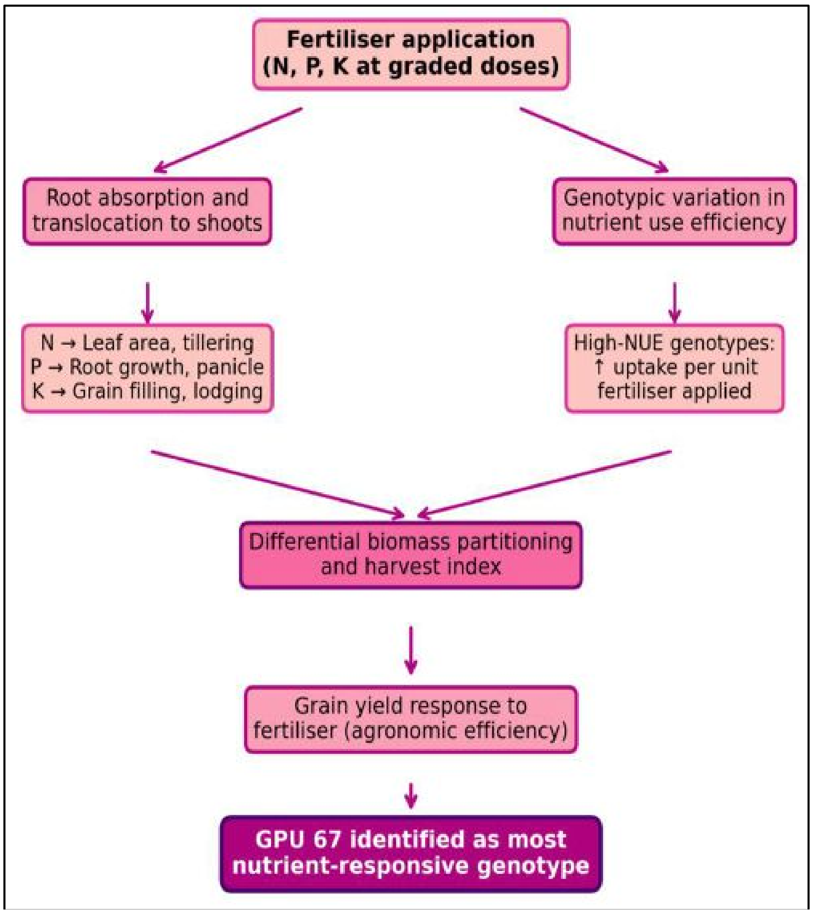

Fig 2: Mechanism diagram showing the pathway from fertiliser application through genotypic nutrient use efficiency to yield response in finger millet

Discussion

GPU 67's superior nutrient uptake aligns with its known vigorous root system and higher mycorrhizal colonisation reported by Ramakrishnan *et al*. (2019) [1]. A larger root network accesses a wider soil volume, absorbing more N and K per unit time — a trait that translates directly into higher tissue concentrations and ultimately greater biomass. The 21.8% N uptake advantage over KMR 204 parallels the 24.8% grain yield difference, suggesting that N acquisition is a key yield determinant in these genotypes.

The high K uptake (74-90 kg/ha) underscores a nutritional reality often overlooked in finger millet agronomy: current K recommendations (20-30 kg/ha K_2O) supply only a fraction of what the crop removes. Over repeated cycles without adequate K replenishment, soil K reserves will decline, eventually limiting yield even in genotypes with high uptake capacity [9, 10].

The diminishing AE at 150% RDF is a practical warning against blanket over-fertilisation. GPU 67 gained less than 1 q/ha from the extra 50% dose, while the additional fertiliser cost (approximately Rs 2,400/ha) far exceeded the marginal revenue. KMR 204's flat response beyond 50% RDF suggests that its yield ceiling is determined by non-nutritional factors — probably limited tillering capacity and smaller ear-head size — that can't be overcome by adding more fertiliser [5, 11].

Conclusion

GPU 67 emerged as the most nutrient-responsive finger millet genotype, combining the highest grain yield (34.7 q/ha), greatest N and K uptake, and best agronomic efficiency at 100% RDF. KMR 204, by contrast, showed low responsiveness beyond 50% RDF, making it better suited for low-input dryland systems.

Potassium uptake exceeded nitrogen uptake in all genotypes, highlighting the need to revise K recommendations upward for high-yielding finger millet production. The sharp decline in nutrient use efficiency at 150% RDF confirms that over-fertilisation wastes resources without meaningful yield gain.

Genotype-specific fertiliser scheduling — rather than blanket recommendations — should be the target for extension advice in finger millet-growing regions of Bundelkhand.

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