International Journal of Research in Agronomy 2025; 8(9): 686-689

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 686-689
Received: 13-06-2025
Accepted: 17-07-2025

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The effect of levels and sources of nitrogen on growth and yield of finger millet (*Eleusine coracana* L.)

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9j.3835

Abstract
Ensuring the future readiness of finger millet [*Eleusine coracana* (L.)] cultivation through sustainable production requires integrated nutrient management strategies capable of supporting crop productivity and soil health under rainfed and marginal conditions. A field investigation was conducted during the *kharif* 2024 season at the Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Maharashtra, to evaluate the effect of levels and sources of nitrogen on the growth and yield of finger millet. The experiment adopted a split-plot design with four main plot treatments of nitrogen fertilizer levels (F_0: 0% RDF (No fertilizer), F_1: 50% N+ Full dose of P_2O_5 and K_2O, F2: 75% N + Full dose of P_2O_5 and K_2O and F3: 100% N + Full dose of P_2O_5 and K_2O and four subplot treatments representing different nitrogen sources: N0: control, N_1: 0.5% Nano nitrogen, N_2: 0.5% Conjugated nitrogen and N_3: *Acetobacter* biofertilizer. The result revealed that, the application of the full recommended dose of fertilizer (F_3: 100% N + Full dose of P_2O_5 and K_2O), significantly enhanced key plant growth parameters including plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1}. Yield components such as earhead number, grain yield per hectare and protein content were similarly maximized in these treatments, with nutrient uptake and use efficiency also reaching their higher values under integrated nitrogen management. Among nitrogen sources Notably, the treatment (N_2: 0.5% conjugated nitrogen) foliar spray resulted in the higher growth, yield, nutrient use indices and profitability. The study strongly suggests that, optimizing nitrogen levels and nitrogen sources application especially through precision foliar delivery can meaningfully improve finger millet productivity and economics, while supporting sustainable soil management.

Keywords: Finger millet, nitrogen management, growth and yield, nano fertilizer, conjugated nitrogen, *Acetobacter*, nutrient uptake

Introduction

Finger millet (*Eleusine coracana* L.), locally known as "ragi," is a vital cereal crop that has supported food and nutritional security in semi-arid and rainfed regions for centuries. As one of the world's oldest domesticated grains, finger millet thrives under a wide range of agro-climatic conditions from the lowlands of southern India to the elevated terrains of the Himalayas thanks to its robust tolerance to drought, marginal soils and variable rainfall. India ranks as a leading producer of finger millet, contributing significantly to global output, with Karnataka at the forefront in both area and productivity. Despite its resilience and adaptability, maximizing the yield potential and nutritional quality of finger millet remains a challenge, particularly in regions with sandy loam soils and moderate fertility, such as the Konkan tract of Maharashtra. Here, traditional cultivation often depends on limited and imprecise fertilizer application, resulting in suboptimal productivity and profitability for farmers. Modern approaches such as high-efficiency fertilizers, biofertilizers and nano-enabled nutrient formulations are drawing increasing attention as potential tools to reconcile productivity with environmental sustainability.

India's substantial progress in food grain self-sufficiency is underscored by a record production of 329.7 million tons in 2022–23, as per the Economic Survey 2023–24 [4]. While rice, wheat and maize dominate, millets particularly finger millet are now recognized as potential agents for further raising food grain output, especially given the country's prime status in global millet production. India alone contributes approximately 15% of the world's millet output and holds the top position in the cultivation of finger millet, barnyard millet, kodo millet and little millet, with key growing states including Karnataka, Maharashtra, Rajasthan, Uttar Pradesh, Tamil Nadu and Andhra Pradesh (ASSOCHAM, 2022) [10]. Historically, millets have been embedded in Indian cuisine, with references in Vedic texts like the Yajurveda, highlighting both their cultural and nutritional importance.

Nutritionally, finger millet stands out for its high calcium content and fiber, in addition to noteworthy carbohydrate (72–79.5%) and protein levels (5.6–12.7%) (Pore and Magar, 1979; Joshi and Katoch, 1990; Bhatt *et al*., 2003; Vijayakumari *et al*., 2003) [14, 7, 1, 18]. Its drought resistance, rapid recovery from moisture stress and suitability for a wide range of soils and climatic conditions including waterlogged, saline, hilly and drought-prone settings make it an economically and ecologically sustainable crop.

This study is situated within the broader context of sustainable agriculture, in which finger millet assumes new importance amid rising environmental challenges such as climate change, water scarcity and the harmful effects of excessive agrochemical use(Saleh *et al*., 2013; Kim *et al*., 2018) [15, 8]. Attention is increasingly turning to innovative nutrient sources especially nano-fertilizers and biofertilizers that promise to enhance yield and quality while improving nutrient use efficiency and reducing environmental harm (Elgadir *et al*., 2015; Chaitra *et al*., 2021) [5, 2]. The use of chitosan-based nano urea and nitrogen-fixing bacteria like *Acetobacter* is a step toward advancing both productivity and sustainability, addressing the challenges of nutrient-poor sandy loam soils prevalent in regions like the Konkan.

Nitrogen is a cornerstone nutrient in cereal crop production, directly influencing vegetative vigor, grain development and protein content. However, the efficiency of conventional nitrogen use is frequently undermined by losses through leaching, volatilization and poor synchronization with crop demand especially in light-textured, rainfed soils. Recent innovations, including slow-release nano-urea formulations and microbial bio-inoculants such as *Acetobacter*, offer a pathway to enhance nutrient availability and plant uptake efficiency, as well as to bolster soil health.

The imperative for balanced, site-specific nutrient management strategies is further underscored by global concerns about fertilizer overuse, soil degradation and climate vulnerability. Employing precise fertilizer recommendations and yield targets can support both the productivity and sustainability of finger millet systems. This research, focused on dissecting the effects of nitrogen sources and application levels on growth, yield, nutrient dynamics and economic returns in finger millet, aims to provide actionable insights for advancing sustainable cereal production benefiting farmers in the Konkan region and across similar agro-ecological zones.

Materials and Methods

A field experiment entitled "The effect of levels and sources of nitrogen on growth and yield of finger millet (*Eleusine coracana* L.)" was conducted at the Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Dist. Ratnagiri, during the *kharif* 2024 season. The site is geographically located at in the subtropical region at 17°45'55" N latitude and 73°10'26" E longitude, with an elevation of approximately 157.8 meters above mean sea level. The experimental field exhibited a well-drained sandy clay loam textured soil. It contained medium levels of available nitrogen (203.47 kg ha^{-1}), phosphorus (15.2 kg ha^{-1}) and potassium (220.26 kg ha^{-1}), exhibited a moderate organic carbon content (11.30 g kg^{-1}) and was acidic in reaction with a pH of 5.50.

The experimental design laid out on Split Plot Design with three replications, consisting of 16 treatment combinations. The main plot treatments included four nitrogen levels:F_0 – 0% RDF (No fertilizer), F_1 – 50% nitrogen with full P_2O_5 and K_2O, F_2 – 75% nitrogen with full P_2O_5 and K_2O, F_3 – 100% nitrogen with full P_2O_5 and K_2O. The sub-plot treatments involved different nitrogen sources: N_0 – Control (no foliar spray), N_1 – 0.5% Nano nitrogen, N_2 – 0.5% Conjugated nitrogen, N_3 – 0.5% *Acetobacter* foliar spray. Each plot had a gross size of 4.50 m × 3.60 m and a net plot size of 4.20 m × 3.20 m, maintaining a spacing of 20 cm × 15 cm between the hills. The finger millet variety used was Dapoli-2 and seedlings were transplanted at one per hill. The recommended fertilizer dose was 80:40:40 kg ha^{-1} of $N:P_2O_5:K_2O$, applied through urea, single super phosphate and muriate of potash. Nitrogen was applied in split doses at the time of transplanting, 30 and 60 days after transplanting depending on treatment and foliar applications of nano nitrogen, conjugated nitrogen and *acetobacter* were done at critical growth stages i.e.30 and 60 days after transplanting.

Results and Discussion

Growth studies

Effect of nitrogen levels

The data given in the Table 1 indicates that, the plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1} (g) were significantly influenced due to nitrogen levels at harvest. The treatment 100% N + Full dose of P_2O_5 and K_2O (F_3) recorded the significantly higher plant height (107.78 cm), number of functional leaves hill^{-1} (10.95), number of tillers hill^{-1} (2.95) and dry matter accumulation hill^{-1} (42.31g) over rest of the treatments. Similar finding align with those reported by Krishna *et al.* (2020) [11] who observed that, the high nitrogen levels enhanced plant height, number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1} in finger millet. Also Niharika *et al.* (2021) [13] who noted that, the application of 100 per cent RDF recorded significantly higher plant height, number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1} of finger millet.

Effect of nitrogen sources

The data given in the Table 1 indicates that, the plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1} (g) were significantly influenced due to nitrogen sources at harvest. The treatment 0.5% conjugated nitrogen (N_2) recorded the significantly higher plant height (104.02 cm), number of functional leaves hill^{-1} (10.13), number of tillers hill^{-1} (3.05) and dry matter accumulation hill^{-1} (35.23 g) over rest of the treatments. Similar result reported by Gughe *et al.* (2024) who observed that, spraying of 120 ppm conjugated nitrogen produced higher number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1} in okra. Additionally Satadal *et al.* (2022) [16] who noted that, the application of nano urea recorded significantly higher plant height, number of functional leaves hill^{-1}, number of tillers hill^{-1} and dry matter accumulation hill^{-1} of finger millet.

Table 1: Growth parameters as influenced periodically by nitrogen levels and nitrogen sources during *kharif season* 2024-25.

Treatment	Growth parameters at harvest			
	Plant height (cm)	Number of functional leaves $hill^{-1}$	Number of tillers $hill^{-1}$	Dry matter accumulation $hill^{-1}$ (g)
A) Main plot - Nitrogen fertilizer level				
F_0: 0% RDF (No fertilizer)	89.08	7.41	2.28	34.63
F_1: 50% N+ Full dose of P_2O_5 and K_2O	97.16	8.98	2.63	36.76
F_2: 75% N + Full dose of P_2O_5 and K_2O	101.19	10.14	2.68	37.73
F_3: 100% N + Full dose of P_2O_5 and K_2O	107.78	10.95	2.95	42.31
S.E.(m)±	0.25	0.42	0.03	0.65
C.D.at 5%	0.87	1.45	0.11	2.23
B) Sub plot - Nitrogen sources				
N_0: Control	93.60	7.81	2.28	29.97
N_1: 0.5% Nano nitrogen	100.49	9.74	2.82	41.10
N_2: 0.5% Conjugated nitrogen	104.02	10.13	3.05	45.12
N_3: 0.5% *Acetobacter*	97.10	9.79	2.40	35.23
S.E.(m)±	0.75	0.46	0.06	0.58
C.D.at 5%	2.18	1.33	0.18	1.68
Interaction effect				
S.E.(m)±	1.50	0.91	0.13	1.15
C.D. at 5%	N.S.	N.S.	N.S.	N.S.
General mean	98.80	9.37	2.64	37.86

Table 2: Yield parameters of finger millet as influenced periodically by nitrogen levels and nitrogen sources during *kharif* season 2024-25.

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
A) Main plot - Nitrogen fertilizer level			
F_0: 0% RDF (No fertilizer)	1108.75	1577.05	2685.81
F_1: 50% N+ Full dose of P_2O_5 and K_2O	1331.35	1903.89	3235.24
F_2: 75% N + Full dose of P_2O_5 and K_2O	1521.70	2149.57	3671.27
F_3: 100% N + Full dose of P_2O_5 and K_2O	1776.54	2530.55	4307.08
S.E.(m)±	11.34	18.05	27.55
C.D.at 5%	39.22	62.46	95.31
B) Sub plot - Nitrogen sources			
N_0: Control	1118.80	1591.92	2710.72
N_1: 0.5% Nano nitrogen	1609.38	2304.11	3913.48
N_2: 0.5% Conjugated nitrogen	1687.00	2380.39	4067.39
N_3: 0.5% *Acetobacter*	1323.16	1884.65	3207.81
S.E.(m)±	44.98	67.51	111.65
C.D.at 5%	131.26	197.02	325.82
Interaction effect			
S.E.(m)±	89.95	135.02	223.29
C.D. at 5%	N.S.	N.S.	N.S.
General mean	1434.59	2040.26	3474.85

2. Yield studies

Effect of nitrogen levels

The data given in the Table 2 indicates that, grain yield (kg/ha), straw yield (kg/ha) and biological yield (kg/ha) were significantly influenced due to nitrogen levels at harvest. The treatment 100% N + Full dose of P_2O_5 and K_2O (F_3) recorded the significantly higher grain yield (1776.54 kg/ha), straw yield (2530.55 kg/ha) and biological yield (4307.08 kg/ha) over rest of the treatments. Similar finding align with those reported by Kiranmai *et al.* (2015) [9] who observed that, the high nitrogen levels enhanced grain yield, straw yield and biological yield in finger millet. Also Chavan *et.al.* (2019) [3] who noted that, the application of 100 per cent RDF recorded significantly higher grain yield, straw yield and biological yield of finger millet.

Effect of nitrogen sources

The data given in the Table 2 indicates that, grain yield (kg/ha), straw yield (kg/ha) and biological yield (kg/ha) were significantly influenced due to nitrogen sources at harvest. The treatment 0.5% conjugated nitrogen (N_2) recorded the significantly higher grain yield (1687.00 kg/ha), straw yield (2380.39 kg/ha) and biological yield (4067.39 kg/ha) over rest of the treatments. Similar result reported by Sneha *et al.*(2022) who observed that, spraying of nano nitrogen produced higher grain yield, straw yield and biological yield. Additionally, Kumar *et.al.* (2023) [12] who noted that, the application of nano urea recorded significantly higher grain yield, straw yield and biological yield of finger millet.

Conclusion

The experiment could be concluded that, among the different nitrogen levels and sources, the treatment with 100 per cent recommended dose of nitrogen along with full dose of P_2O_5 and K_2O (F_3) demonstrated significantly superior performance in terms of plant growth attributes and yield parameters of finger millet crop. It is concluded that, application of 100 per cent RDF (80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}) through soil and foliar application of 0.5 per cent conjugated nitrogen (N_2) be used for obtaining higher growth and yield of finger millet cultivation under Konkan conditions.

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