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Assessment of nitrogen content, uptake, quality and economics of finger millet (*Eleusine coracana* G.) as influenced by nitrogen levels and selected varieties

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Abstract
A field study was conducted using FRBD with three finger millet varieties (GN-8, GNN-7 and Local) and three nitrogen levels (0, 30 and 60 kg N ha^{-1}) comprising nine treatment combinations and three replication were used. Results showed that GN-8 recorded significantly higher protein content (7.08%), nitrogen content in grain and straw (1.68% and 0.48%) and total nitrogen uptake (67.43 kg ha^{-1}). GN-8 also achieved the highest net returns (₹ 59,954.11 ha^{-1}) and B: C ratio (2.53). Increasing nitrogen levels significantly improved protein content, nitrogen content and nitrogen uptake by grain and straw. Application of 60 kg N ha^{-1} significantly increased protein content (7.10%), total N uptake (73.82 kg ha^{-1}), net returns (₹ 60,825 ha^{-1}) and B:C ratio (2.56). Overall, the combination of variety GN-8 with 60 kg N ha^{-1} proved most effective in enhancing grain quality, nitrogen uptake and economic profitability of finger millet under semi-arid conditions.

Keywords: Nitrogen, content, uptake, net return, B: C ratio

Introduction

Millets are small-grained coarse cereals traditionally cultivated by smallholders and tribal farmers in tropical regions and are among the oldest crops grown in India (Maitra, 2020) [16]. They are broadly classified into major and minor millets. Finger millet (*Eleusine coracana* G.) is an allotetraploid cereal (2n = 4x = 36, AABB) belongs to the *Poaceae* family and adapted to semi-arid regions due to its C_4 photosynthetic system. Its gluten-free grains are widely used in food and beverages, while the straw serves as feed and thatching material. The crop has excellent storage quality (Ceasar *et al.*, 2018) [4] and a rich nutritional profile, containing high levels of Ca, Fe, Zn, K, Mg, Mn, dietary fibre, phenolic compounds and essential amino acids such as cystine, methionine and tryptophan (Backiyalakshmi *et al.*, 2023) [2]. Finger millet products are reported to reduce blood cholesterol and blood pressure and possess anti-cancer, anti-ageing, anti-diabetic, anti-obesity and anti-anaemic effects. Owing to these benefits, finger millet is considered a "superfood" for combating malnutrition (Gebreyohannes *et al.*, 2024) [9]. The crop is ecologically resilient (Prasanna Kumar *et al.*, 2019) [22], highly responsive to nutrient application (Ramya *et al.*, 2020) [24] and contributes to agro-biodiversity due to its rich varietal base (Brahmachari *et al.*, 2018) [3].

The low productivity of finger millet is mainly attributed to the use of local varieties, poor-quality seed, weak crop establishment under direct sowing and faulty agronomic practices (Maitra *et al.*, 2020) [16]. Although several improved cultivars in India have the potential to yield 3.5-4.0 t ha^{-1} (Prabhakar *et al.*, 2017) [21], their wider adoption is essential to enhance overall production. Significant variation in yield attributes, grain yield and nutrient uptake among varieties has been documented (Simion *et al.*, 2020) [27]. Likewise, efficient nutrient management plays a crucial role in improving finger millet productivity. Nitrogen is an essential macronutrient required in large quantities for plant growth (Dhhwayo and Whhgwin, 1984) [8]. It is often the most yield-limiting nutrient in crop production and is widely applied in annual crops. As a key component of proteins, nitrogen plays a vital role in plant metabolic processes, thereby influencing both productivity and quality in finger millet. Adequate nitrogen application has been reported to enhance growth, dry matter accumulation and yield, particularly under dry or rainfed conditions (Hari Prasanna, 2016) [12]. In view of these factors, a field experiment was conducted during the *kharif*, 2019.

Materials and Methods

The field experiment was conducted at the Instructional Farm, Pacific College of Agriculture, Udaipur, Rajasthan (24°35' N; 73°42' E). The area falls under Agro-climatic Zone IV-A ("Sub-humid Southern Plains and Aravalli Hills"). The climate is sub-humid with hot summers, humid monsoon and cold winters. The region receives about 640 mm annual rainfall, 70-80% during July-September. During kharif 2019, total rainfall was 835.9 mm.

The soil was "clay loam" (35.6% sand, 37.4% silt and 26.3% clay) with bulk and particle densities of 1.30 and 2.65 Mg m^{-3} and porosity of 50.94%. It had pH (8.20), EC (0.77 dS m^{-1}) and 0.61% organic carbon. Available nutrients were: N (248.10 kg ha^{-1}), P (20.60 kg ha^{-1}) and K (355.90 kg ha^{-1}).

The experiment included nine treatment combinations of three varieties (Local, GNN-7 and GN-8) and three nitrogen levels (0, 30, 60 kg N ha^{-1}) in a factorial RBD with three replications. Twenty-seven plots were laid out (4.3 x 3.3 = 14.19 m^2 gross; 4 x 3 = 12 m^2 net plot size). Furrows were opened at 25 cm spacing and sowing was done manually at a depth of 2-3 cm using a uniform seed rate of 8 kg ha^{-1}. Seeds were obtained from verified sources and treatments were imposed as per standard procedures.

Observations were recorded following standard methods

Protein content (%): The protein content (%) in grains was determined by multiplying grain nitrogen content (%) with a conversion factor 6.25 (A.O.A.C.).

Total N uptake by the crop: The total uptake of N by the crop was estimated by using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content in seed (\%)} \times \text{Seed yield (kg ha}^{-1}) + \text{Nutrient content in straw (\%)} \times \text{Straw yield (kg ha}^{-1})}{100}$$

Net returns: To find out the most profitable treatment, economics of different treatments was worked out in terms of net returns by subtracting the cost of treatment and the cost of cultivation from gross income obtained.

Net returns (Rs. ha^{-1}) = Gross returns - Total cost of cultivation

Benefit- cost ratio: This was calculated by dividing net returns with cost of cultivation for each treatment to see the economic viability of the treatments.

$$\text{B:C ratio} = \frac{\text{Net returns (Rs ha}^{-1})}{\text{Total cost of cultivation (Rs ha}^{-1})}$$

Statistical analysis: Data collected during the present investigation were subjected to statistical analysis by adopting appropriate method of analysis of variance as described by Cochran and Cox (1967) [7]. Wherever the variance ratio (F-values) were found significant at 5 percent level of probability, the critical difference (CD) values were computed for making comparison among the treatment means. To assess the relationship between various characters, correlation coefficient was worked out in order to establish cause and effect relations. All the statistical estimates were computed by standard statistical procedures (Panse and Sukhatme, 1995) [20].

Results and discussion

Protein Content in Grain

Protein content varied significantly among varieties (Table 1). GN-8 recorded the highest protein content (7.08%) followed by the GNN-7 over local variety. The superior protein content in GN-8 can be attributed to its higher nitrogen accumulation in grains as the protein content is directly influenced by grain N concentration. The strong positive correlation between protein content and grain N content (r = 0.991) further supported this relationship. Similar varietal differences were reported by Kumari *et al.*, (2018) [15].

Application of significantly increased protein content over the control and 30 kg N ha^{-1} remained at par. The increase in protein content under higher N supply is due to enhanced synthesis of amino acids, continued nitrogen availability during grain filling and subsequent protein accumulation. These findings align with those of Rao *et al.* (1989) [25], who observed increased protein content with nitrogen fertilization.

Nitrogen Content in Grain and Straw

Varieties did not differ significantly in N content of grain. However, GN-8 recorded significantly higher N content in straw (Table 1). Increased nitrogen content in GN-8 may be linked to its greater biomass accumulation and improved nutrient absorption efficiency. Similar type of variation in N content was noted by Maitra *et al.* (1999) [17], Gupta *et al.* (2012) [11] and Radha *et al.* (2020) [23]. Nitrogen levels had a consistent positive effect on N content in both grain and straw. Increasing N from 0 to 60 kg ha^{-1} significantly enhanced N content, better nitrogen nutrition and assimilation in plants. Similar increases in tissue N content due to nitrogen fertilization have been reported by Rao *et al.* (1986) [26], Jagathjothi *et al.* (2010) [13], Pallavi *et al.* (2015) [18] and Radha *et al.* (2020) [23].

Nitrogen Uptake by Grain and Straw

Varieties **GN-8 and GNN-7** were at par and recorded significantly higher N uptake by grain and straw compared to the local variety (Table 1). The higher uptake in GN-8 is associated with its greater dry matter production as nutrient uptake is a function of biomass and nutrient concentration. The results are in close conformity with the findings of Pallavi *et al.* (2015) [18], Radha *et al.* (2020) [23] and Panda *et al.* (2021) [19]. This relationship supported by the strong correlation between dry matter accumulation and total N uptake (r = 0.997).

Nitrogen uptake increased significantly with higher nitrogen levels. Application of 30 kg N ha^{-1} increased N uptake by grain by 53.29%, while 60 kg N ha^{-1} further enhanced uptake by 9.64% over 30 kg N ha^{-1}. Straw N uptake increased by 79.83% at 60 kg N ha^{-1} over control. These improvements can be attributed to increased nitrogen availability, enhanced root activity and greater vegetative growth. A positive correlation between grain yield and N uptake (r = 0.905) supports the role of applied nitrogen in boosting uptake efficiency by Singh (2015) [29] and Panda *et al.* (2021) [19].

Economics

Variety GN-8 recorded the highest net returns (₹59,954.11 ha^{-1}) and B:C ratio (2.53) due to its higher yield and nutrient uptake efficiency, aligning with the findings of Giribabu (2010) [10]. Among nitrogen levels, 60 kg N ha^{-1} produced the maximum net returns (₹60,825 ha^{-1}) and the highest B:C ratio (2.56), performing significantly better than the control and at par with 30 kg N ha^{-1}, consistent with Chandraprabha *et al.* (2024) [5].

Table 1: Effect of varieties and nitrogen level on N content and uptake by grain and straw

Treatment	Yield (q ha^{-1})		Nitrogen content (%)		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})	Protein content (%)	Net returns (Rs. ha^{-1})	B:C ratio
	Grain	Straw	Grain	Straw	Grain	straw				
Varieties										
Local	19.84	53.10	1.50	0.39	20.88	25.77	46.65	6.26	32571.22	1.45
Gnn-7	24.83	64.84	1.58	0.42	31.72	32.44	64.16	6.86	45409.44	1.94
Gn-8	30.50	72.02	1.63	0.48	33.38	34.05	67.43	7.08	59954.11	2.53
SEm(±)	0.68	1.51	0.05	0.01	0.68	0.82	1.64	0.18	1197.47	0.07
CD (p= 0.05)	2.07	4.56	Ns	0.05	2.05	2.48	4.96	0.55	3620.927	0.21
Nitrogen level										
0	18.82	51.24	1.44	0.34	16.94	20.88	37.82	6.03	29803	1.33
30	25.46	66.13	1.61	0.45	32.77	33.83	66.60	7.08	47306.77	2.04
60	30.88	72.58	1.66	0.52	36.27	37.55	73.82	7.10	60825	2.56
SEm(±)	0.68	1.51	0.05	0.01	0.68	0.82	1.64	0.18	1197.47	0.07
CD (p=0.05)	2.07	4.56	0.17	0.05	2.05	2.48	4.96	0.55	3620.927	0.21

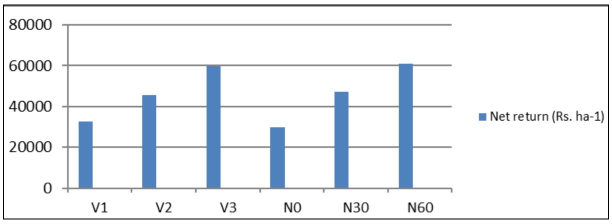

Fig 1: Effect of varieties and nitrogen levels on net return

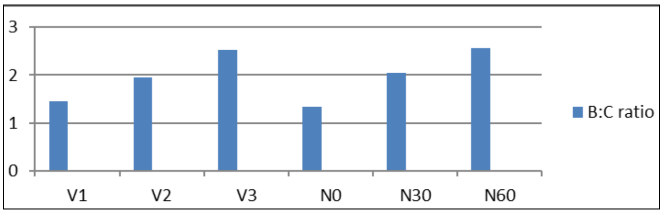

Fig 2: Effect of varieties and nitrogen levels on B: C ratio

Table 2: Economics of treatments

S. No.	Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross returns (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
1.	V_1N_0	1470	4433	41183	21899.67	19283.33	0.88
2.	V_1N_{30}	2000	5523	55523	22278.34	33273.66	1.49
3.	V_1N_{60}	2470	5973	67723	22566.34	45156.66	2.00
4.	V_2N_0	2036	5400	56300	22360	33940	1.51
5.	V_2N_{30}	2320	6350	64350	23120	41230	1.78
6.	V_2N_{60}	3093	7703	85028	23969.67	61058.33	2.54
7.	V_3N_0	2133	5540	58865	22679.34	36185.66	1.59
8.	V_3N_{30}	3320	7966	90966	23549.34	67416.66	2.86
9.	V_3N_{60}	3696	8100	100500	24240	76260	3.14

Table 3: Correlation coefficient between dependent (x) and independent variables (y) in varieties

S. No.	Dependent variables (x)	Independent variables (y)	Correlation coefficient (r)
1.	Number of tillers m^{-1} row length at harvest	Plant height at harvest (cm)	0.974*
2.	DMA (g plant^{-1}) at harvest	Number of tillers m^{-1} row length at harvest	0.949*
3.	DMA (g plant^{-1}) at 85 DAS	Plant height at 85 DAS	0.987*
4.	Effective tillers m^{-1} row length	No of grains per ear	0.998*
5.	Grain yield (kg ha^{-1})	Plant height at harvest (cm)	0.899*
6.	Grain yield (kg ha^{-1})	Number of tillers m^{-1} row length at harvest	0.974*
7.	Grain yield (kg ha^{-1})	DMA (g plant^{-1}) at harvest	0.942*
8.	Grain yield (kg ha^{-1})	Effective tillers m-1 row length	0.907*
9.	Grain yield (kg ha^{-1})	Ear length(cm)	0.996*
10.	Grain yield (kg ha^{-1})	Ear weight (g)	0.907*
11.	Grain yield (kg ha^{-1})	No. of grains per ear	0.987*
12.	Grain yield (kg ha^{-1})	Test weight	0.907*
13.	Grain yield (kg ha^{-1})	N uptake by grain (%)	0.907*

* Significant at 5 percent level of probability

Table 4: Correlation coefficient between dependent (x) and independent variables (y) of nitrogen levels

S. No.	Dependent variables (x)	Independent variables (y)	Correlation coefficient (r)
1.	Grain yield (kg ha^{-1})	N content in grain (%)	0.985*
2.	Grain yield (kg ha^{-1})	N uptake in grains (kg ha^{-1})	0.905*
3.	Protein content (%)	N content in grain (%)	0.991*
4.	Total N uptake by the crop	Biological yield (kg ha^{-1})	
5.	Number of effective tillers m^{-2}	Number of grains spikes^{-1}	0.998*

* Significant at 5 percent level of probability

Conclusion
The study clearly demonstrated that both variety selection and nitrogen fertilization play a crucial role in enhancing the productivity, quality and profitability of finger millet under semi-arid conditions. Among the tested varieties, GN-8 consistently outperformed GNN-7 and the local variety in terms of protein content, nitrogen content, nitrogen uptake, net returns and B:C ratio, highlighting its superior genetic potential and nutrient use efficiency. Application of nitrogen significantly influenced quality and nutrient dynamics, with 60 kg N ha^{-1} recording the highest nitrogen content in grain and straw, maximum total N uptake and the most favorable economic returns. The strong positive correlations between nitrogen availability, dry matter accumulation, N uptake and grain quality further emphasize the importance of adequate nitrogen supply. Based on the findings, the combination of variety GN-8 with 60 kg N ha^{-1} is recommended for achieving higher productivity, better grain quality and improved economic returns in finger millet cultivation under semi-arid conditions.

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Author Contribution
All authors contributed to the design, execution, data analysis, and writing of the manuscript. All authors read and approved the final version.

Conflict of Interest
The authors declare no conflict of interest.

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