

Effect of Seed Rate and Nitrogen Nutrition on Rice Fallow Finger Millet- A Review

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Abstract— Finger millet (*Eleusine coracana* (L.)), a climate resilient and nutrient dense cereal, holds significant potential for sustainable intensification of rice fallow systems in India. Its rich profile of calcium, dietary fibre, and essential amino acids makes it a critical crop for addressing nutritional security, particularly in dryland and tribal regions. However, suboptimal agronomic practices, especially with regard to seed rate and nitrogen nutrition, continue to limit its productivity in rice fallow conditions.

This review synthesizes recent research findings to evaluate the influence of seed rate and nitrogen management on the growth, yield attributes, and resource-use efficiency of finger millet. Studies indicate that appropriate seed rate enhances plant population, tillering, and weed suppression, while optimizing nitrogen levels significantly boosts chlorophyll content, dry matter accumulation, grain yield, and nitrogen use efficiency. Findings from trials conducted across diverse agro ecological zones including Zaid and summer seasons demonstrate that both excess and deficient nitrogen applications negatively affect yield and grain quality. Furthermore, the interaction between seed rate and nitrogen shows synergistic effects on canopy architecture, nutrient uptake, and panicle development, particularly under residual soil moisture conditions typical in rice fallows.

Despite extensive field experimentation, region specific recommendations for rice fallow ecosystems remain limited. This review reveals the importance of optimizing both seed rate (typically 6–15 kg/ha) and nitrogen management (60–80 kg N/ha) to unlock the genetic yield potential of finger millet and promote its adoption in underutilized rice fallow areas for greater food and nutritional security.

Keywords— Finger millet; *Eleusine coracana* L.; rice fallow agriculture; seed rate optimization; nitrogen management; nutrient uptake; grain yield; growth attributes; crop productivity.

I. INTRODUCTION

Among small millets finger millet is one of the most nutritious crops, with high levels of methionine, an essential amino acid lacking in diets of millions of poor living on starchy foods. Finger millet has been identified as one of the “future smart food crops” by FAO (Li and Siddique, 2018). Finger millet is known for drought tolerance and can adapt to a wide range of soil and climatic conditions though it prefers fertile, well drained sandy to sandy loam soils, with a pH ranging from 5 to 7 (Triveni *et al.*, 2018). It withstands warming stress, water stress and nutrition stress hence it is called “A climate change compliant crop” (Ferry, 2004). It is an important dryland millet crop and ranks third among the millet crops. In India it is widely cultivated in the states of Karnataka, Tamil Nadu, and Andhra Pradesh, often as a rice fallow crop utilizing the residual soil moisture after the harvest of transplanted paddy. In India finger millet occupies an area of 1.03 million hectares with a production of 1.30 million metric tonnes with an average national productivity of 1336 kg ha⁻¹ (Department of Agriculture and Farmers Welfare, Govt. of India 2023-24). In Andhra Pradesh, it is an important millet crop cultivated in tribal and rainfed regions. It accounts

for 0.27 lakh hectares of finger millet were planted, yielding 0.34 lakh tonnes of production and 1261 kg ha⁻¹ of productivity in Andhra Pradesh (Directorate of Economics and Statistics, Andhra Pradesh, Government of Andhra Pradesh 2024).

Finger millet grain contains 9.8% proteins, 4.3% crude fiber, 81.5% carbohydrates, 2.7% minerals, 1.37% ash and 0.33% calcium (Amir Gull *et al.*, 2014). It also contains vitamin A, D, iron, phosphorous and dietary fibre. It is having low glycemic index and free from gluten which makes it suitable for people suffering from digestive problems, diabetes, hypertension and obesity. Silage is prepared from the green straw of finger millet. It is an eco-friendly crop which requires less nutrients. Rice-fallow finger millet makes efficient use of the remaining soil moisture and nutrients during the fallow period after rice, thus increasing yield. When traditional crops fail in rice fallows, particularly in north coastal Andhra Pradesh, farmers are interested in growing finger millet in these areas and are looking for a decent package to follow. Since nitrogen and the ideal plant population are the two most important production elements, optimizing the N dose and seed rate is crucial for rice fallow finger millet.

Nitrogen availability is the nutrient that most frequently restricts crop production, making it a crucial component of agricultural productivity. Increased levels of N application lead to increased yield attributes and grain yield (Chakraborty *et al.*, 2002). Applying the proper amount of N fertilizer is crucial for achieving the highest possible finger millet production. Variations in seed rates and nitrogen application dosages in rice fallow finger millet can impact crop growth, yield, and economics. To maintain production and profits in finger millet generally, it is essential to optimize seed rate and nitrogen application. This review aims to synthesize and evaluate current research on the effects of seed rate and nitrogen nutrition on the performance of finger millet in rice fallow systems, with the objective of identifying optimal agronomic practices and highlighting future research needs.

II. THE ROLE OF SEED RATE AND NITROGEN NUTRITION IN RICE FALLOW FINGER MILLET:

Application of the right dose of N fertilizer is important to obtain optimum yield of finger millet and thus makes its cultivation profitable. Many of the soils where finger millet is grown are deficient in N (Sagar Maitra *et al.*, 2020). Nitrogen plays a crucial role in the process of photosynthesis, synthesis of chlorophyll, amino acids and other organic compounds which contribute to building units of proteins in plants. With increase in nitrogen application, the availability of nutrients will be higher in soil and there by uptake of nutrients will be higher (Gupta *et al.*, 2012).

Adequate seed rate ensures the right number of plants per unit area. This prevents under population which leads to low yield or overcrowding which leads to competition for nutrients, water and light. Finger millet yield depends on the number of productive tillers and panicles. Optimum seed rate ensures highest grain yield and biomass yield (Nigus *et al.*, 2018). Increasing seed rate increases plant density but decreases panicle weight beyond optimum levels. Higher seed rate gave higher quantitative yield attributes such as straw yield, panicle yield and grain yield. Bellatore *et al.* (1985) and Kumpawt *et al.* (1998) reported increased in straw yield with increased seed rate. Kumar *et al.* (2008) observed that seed rate increases plant density, and can compensate for reduction in plant productivity. Spanner *et al.* (2005) found that grain yield increased significantly with increasing seed rate.

III. EFFECT OF SEED RATE ON FINGER MILLET PERFORMANCE:

Optimizing seed rate is critical for enhancing the performance of finger millet, especially under resource constrained conditions like rice fallows. Chaturvedi *et al.* (2025) revealed that seed rate of 1.5 kg ha⁻¹ strongly influences growth traits increases plant height (128.87cm), total number of tillers (78.88 m⁻²), leaf area (61.80 cm²) and dry matter accumulation per plant (27.21g). Seed rate significantly affects germination, early seedling vigour, intra-plant competition, and ultimately influences the crop's productivity and resource-use efficiency. Nigus *et al.* (2018) revealed that 15 kg ha⁻¹ of seed rate recorded highest grain yield (2214.4 kg ha⁻¹) and biomass yield (12889 kg ha⁻¹).

Dereje *et al.* (2017) conducted experiment over two years at two locations and evaluated finger millet response to three seed rates (5,15,25 kg ha⁻¹) and concluded that 15 kg ha⁻¹ is the most suitable seed rate for highest grain yield (1926.8 kg ha⁻¹). Bitew *et al.* (2014) conducted field experiment on effect seed rate on the growth, yield and yield component of finger millet and concluded that 10 kg ha⁻¹ seed rate gave optimal grain yield. Opale *et al.* (2013) conducted field experiment and evaluated seeding rate of 3.2,6.0 and 9.0 kg ha⁻¹ and stated that high seeding rate (6.0 kg ha⁻¹) increased leaf dry weight and grain yield. Gani *et al.* (2016) conducted field experiment and evaluated three seed rates (3,6 and 9 kg ha⁻¹) and stated that the seed rate (6.0 kg ha⁻¹) gave highest grain yield ha⁻¹. Hulakund *et al.* (2024) concluded that seed rate of 7.5 kg ha⁻¹ optimizes the yield (585.6 kg ha⁻¹) and nutrient uptake.

TABLE 1
SUMMARY OF RESEARCH ON THE EFFECT OF SEED RATE ON FINGER MILLET PERFORMANCE

Study (Author, Year)	Location / Context	Seed Rates Evaluated (kg ha ⁻¹)	Optimal Seed Rate Identified (kg ha ⁻¹)	Key Outcome / Yield at Optimal Rate
Chaturvedi <i>et al.</i> (2025)	Not specified	1.5	1.5	Max. plant height, tillers, leaf area, dry matter.
Nigus <i>et al.</i> (2018)	Not specified	15	15	Highest grain yield (2214.4 kg ha ⁻¹) & biomass.
Dereje <i>et al.</i> (2017)	Two locations over 2 years	5, 15, 25	15	Most suitable for highest grain yield (1926.8 kg ha ⁻¹).
Bitew <i>et al.</i> (2014)	Field experiment	Varied	10	Gave optimal grain yield.
Opale <i>et al.</i> (2013)	Field experiment	3.2, 6.0, 9.0	6	Increased leaf dry weight and grain yield.
Gani <i>et al.</i> (2016)	Field experiment	3, 6, 9	6	Gave the highest grain yield per hectare.
Hulakund <i>et al.</i> (2024)	Not specified	7.5	7.5	Optimized yield (585.6 kg ha ⁻¹) and nutrient uptake.
Reported Range	Across diverse agro-ecologies	1.5 - 25	15-Jun	Most common optimal range for grain yield.

Note: Data presented in this table are synthesized from the experimental results of the referenced studies reviewed in the preceding text.

IV. EFFECT OF NITROGEN NUTRITION ON THE PERFORMANCE OF FINGER MILLET:

Nitrogen is a key macronutrient in plant nutrition, playing a crucial role in various physiological and biochemical processes. Nitrogen fertilizer is one of the most yield limiting nutrients for crop production and it is applied in large quantity for most annual crops (Huber and Thompson, 2007). In finger millet (*Eleusine coracana* L.), nitrogen influences growth, dry matter production and yield under rainfed conditions (Hari Prasanna *et al.*, 2016). The significant improvement in yield attributes was observed with application of 90 kg N ha⁻¹ over that of lower levels ultimately increase yield. Increased uptake of N with increased levels of N application has been reported by (Sudhakar Rao *et al.*, 1991). Optimizing nitrogen levels is especially important in marginal environments like rice fallows, where soil fertility is typically low and moisture availability is limited. The studies on N fertilization indicate that higher grain yield was obtained with application of N ranging from 0 to 90 kg (Bekele *et al.*, 2016, Nigade *et al.*, 2011).

Ramyasri *et al.* (2019) concluded that application of 80 kg N ha⁻¹ increases plant height (153.9 cm), dry matter production (3590 kg), panicles m⁻²(70), panicle length (16.3 cm), test weight (2.68 g), grain yield (1684 kg ha⁻¹), straw yield (3101 kg ha⁻¹). Bhomte *et al.* (2016) concluded that plant height (80.8 cm) was found to be increased with increased levels of nitrogen (20, 40, 60 and 80 kg ha⁻¹). Bekele *et al.* (2016) stated that the highest plant height (70.75 cm) of finger millet was reported with 69 kg N ha⁻¹. Navya Jyothi *et al.* (2016) stated that application of 50 kg N ha⁻¹ increases tillers plant⁻¹ (2.56), dry matter production (4069 kg ha⁻¹). Rashmi Yadav *et al.* (2010) concluded that application of 60 kg N ha⁻¹ increases tillers plant⁻¹ (2.9), test weight (4.5 g).

Muneendra Babu *et al.* (2003) concluded that application of 50 kg N ha⁻¹ increases ear head weight (8.5 g). Munirathnam and Kumar (2015) concluded that application of 80 kg N ha⁻¹ increases harvest index (51.3%). Vijayamahantesh *et al.* (2016) revealed that significantly lower weed dry weight o.25 m⁻² (39 g), lowest weed count m⁻²(17.7) of finger millet is recorded when fertilized with 100% N through urea. Krishna *et al.* (2020) reported that increasing nitrogen up to 60 kg/ha enhanced plant height, number of tillers, and biomass accumulation in finger millet during summer. The increased photosynthetic surface area led to better dry matter partitioning. Sneha *et al.* (2024) found that applying 100% recommended dose of fertilizer twice

at 35 and 55 days after sowing recorded significantly higher grain yield (3453 kg ha⁻¹) and straw yield (5035 kg ha⁻¹). Sial *et al.* (2024) concluded that application of 80 kg N ha⁻¹ gave highest number of tillers (5.7 hill⁻¹), number of fingers (7.7 ear head⁻¹), finger length (8.4 cm) and grain yield (2399 ha⁻¹).

TABLE 2
SUMMARY OF RESEARCH ON THE EFFECT OF NITROGEN NUTRITION ON FINGER MILLET PERFORMANCE

Study (Author, Year)	N Rates Evaluated (kg N ha ⁻¹)	Optimal N Rate Identified (kg N ha ⁻¹)	Key Growth & Yield Parameters Enhanced
Ramyasri <i>et al.</i> (2019)	Up to 80	80	Plant height, dry matter, panicles m ⁻² , grain & straw yield.
Bhomte <i>et al.</i> (2016)	20, 40, 60, 80	80 (for height)	Plant height.
Bekele <i>et al.</i> (2016)	Up to 69	69	Plant height.
Navya Jyothi <i>et al.</i> (2016)	50	50	Tillers plant ⁻¹ , dry matter production.
Rashmi Yadav <i>et al.</i> (2010)	60	60	Tillers plant ⁻¹ , test weight.
Muneendra Babu <i>et al.</i> (2003)	50	50	Ear head weight.
Munirathnam & Kumar (2015)	80	80	Harvest index.
Krishna <i>et al.</i> (2020)	Up to 60	60	Plant height, tiller number, biomass.
Sneha <i>et al.</i> (2024)	100% RDF (Split)	100% RDF (Split)	Grain yield (3453 kg ha ⁻¹), straw yield.
Sial <i>et al.</i> (2024)	Up to 80	80	Tillers hill ⁻¹ , fingers earhead ⁻¹ , grain yield.
Satya <i>et al.</i> (2023)	80	80	Plant height, tillers, dry weight, seed & straw yield, HI.
Sanjana <i>et al.</i> (2020)	Up to 120	120	Plant height, tillers, ears, ear weight, grain & straw yield.
Gangothri <i>et al.</i> (2023)	60	60	Plant height, tillers plant ⁻¹ , grain & straw yield, HI.
Ghosh <i>et al.</i> (2024)	60	60	Seed yield (18.59 q ha ⁻¹), straw yield.
Jyostna <i>et al.</i> (2015)	120 (Split)	120 (Split)	Grain yield (+40%), grain quality, soil fertility.
Vamsikrishna <i>et al.</i> (2019)	90	90	Earhead weight.
Synthesized Optimal Range	Varied (0-120)	60 - 80	Consistently improves yield, biomass, and key attributes.

Note: Data presented in this table are synthesized from the experimental results of the referenced studies reviewed in the preceding text.

Satya *et al.* (2023) concluded that the higher plant height (79.76 cm), number of tillers plant⁻¹ (7.85 plant⁻¹), plant dry weight (25.92 g plant⁻¹), seed yield (3.25 t ha⁻¹), straw yield (4.81 t ha⁻¹) and harvest index (40.34%) were significantly influenced with application of nitrogen 80 kg ha⁻¹. Sanjana *et al.* (2020) stated that the highest plant height (131.7 cm), number of tillers (4 plant⁻¹), number of ears (97.8 m⁻²), ear head weight (7.11 g), grain yield (2657 kg ha⁻¹) and straw yield (3721 kg ha⁻¹) were recorded with application of N @120 kg N ha⁻¹. Gangothri *et al.* (2023) concluded that application of 60 kg N ha⁻¹ recorded higher plant height (86.27 cm), number of tillers per plant (8.67 plant⁻¹), plant dry weight (23.41), grain yield (2,635.65 kg ha⁻¹), straw yield (4883.10 kg ha⁻¹) and harvest index (35.05). Ghosh *et al.* (2024) revealed that applying 60 kg N ha⁻¹ significantly enhanced seed yield (18.59 q ha⁻¹) and straw yield (26.04 q ha⁻¹) of finger millet, suggesting this rate as optimal for achieving higher productivity in the coastal region of West Bengal. Jyostna *et al.* (2015) stated that applying 120 kg N ha⁻¹ in three splits (25% basal, 50% at 30 days after transplanting, 25% at 45 days after transplanting) significantly increased grain yield (40%), quality of grain and fertility status of irrigated white grain finger millet on sandy loam soils. Vamsikrishna *et al.* (2019) concluded that significantly highest earhead weight (6.1 g) was obtained from application of 90 kg N ha⁻¹.

V. CONCLUSION AND FUTURE PERSPECTIVES:

Based upon the reviewed literature, optimal seed rate (typically 6–15 kg/ha) improves plant population, tillering, canopy structure, and weed suppression in rice fallow finger millet. Nitrogen application (60–80 kg/ha) significantly enhances growth, chlorophyll content, dry matter accumulation, and grain yield. Both over and under application of nitrogen adversely affect yield and grain quality. A synergistic effect of seed rate and nitrogen improves nutrient uptake, panicle development, and resource use efficiency under residual moisture conditions.

TABLE 3
SYNTHESIS OF AGRONOMIC RECOMMENDATIONS FOR RICE FALLOW FINGER MILLET

Agronomic Factor	Optimal Range	Primary Effect / Benefit	Key Consideration for Rice Fallow
Seed Rate	6 - 15 kg ha ⁻¹	• Ensures optimal plant population.	Higher end of range may be beneficial in regions with better residual moisture. Lower rates may suffice in moisture-stressed conditions to reduce competition.
		• Enhances tillering & canopy cover for weed suppression.	
		• Maximizes grain & biomass yield.	
Nitrogen Nutrition	60 - 80 kg N ha ⁻¹	• Boosts chlorophyll synthesis & photosynthesis.	Application must be synchronized with residual soil moisture. Split applications are often crucial for improving Nitrogen Use Efficiency (NUE) in this system.
		• Increases dry matter accumulation & panicle development.	
		• Significantly enhances grain yield & harvest index.	
Synergistic Interaction	Optimal Seed Rate + Optimal N	• Improves nutrient uptake efficiency.	The positive interaction is critical for unlocking full genetic potential under the residual moisture and fertility constraints of rice fallows.
		• Optimizes canopy architecture for light interception.	
		• Leads to superior panicle development and final yield.	

Source: Authors' synthesis based on the consensus and ranges derived from the reviewed literature presented in this article.

To maximize productivity in rice fallows, region specific, integrated agronomic packages and precision nitrogen management are essential. Future research should focus on: (1) developing location-specific recommendations based on soil fertility and residual moisture levels, (2) investigating the interaction effects of seed rate and nitrogen across different cultivars and environments, (3) exploring efficient nitrogen sources and application timings for rice fallow systems, (4) assessing the economic viability of optimized practices for farmer adoption, and (5) integrating seed rate and nitrogen management with other agronomic practices for sustainable intensification of rice fallow finger millet cultivation

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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