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Effect of nitrogen management on growth and yield of pearl millet (*Pennisetum glaucum* L.) hybrids

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Abstract

A field experiment was conducted during *Zaid* season 2025 at CRF (Crop Research Farm), Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, (U.P.). The experiment was laid out into Randomized Block Design with 12 treatment combination replicated thrice. The experiment consisted of six pearl millet hybrids *viz.* 86 M 25, 86 M 15, PA 9666, RBX 6066, US 7306, and MP 7793 and two different sources of nitrogen *viz.* 100% Recommended Dose of Nitrogen through Urea and 50% RDN (Recommended Dose of Nitrogen) through urea along with 4% Nano urea. The results revealed that treatment T₃ (86 M 15 + 100% RDN) recorded highest plant height (168.10 cm), highest dry weight (80.23 g), maximum number of earhead/m² (71), maximum number of grains/car head (3120.33), highest test weight (16.55 g), highest grain yield (3.48 t/ha), and highest stover yield (4.74 t/ha).

Keywords: Hybrids, nitrogen, nano urea, grain yield, and stover yield

Introduction

Pearl millet (*Pennisetum glaucum* L.), commonly known as Bajra, is one of the most important millet crops cultivated in India (Satyavathi *et al.*, 2021) ^[12]. It belongs to the family Poaceae and genus *Pennisetum*, and is believed to have originated in the central tropical region of Africa. The crop is well adapted to hot, arid, and semi-arid climates and is predominantly grown during the kharif season for both grain and fodder purposes (Sanjana *et al.*, 2021) ^[11].

In India, the major pearl millet-producing states include Rajasthan (46%), Maharashtra (19%), Gujarat (11%), Uttar Pradesh (8%), and Haryana (6%). It ranks as the fourth most important cereal crop in the country after rice, wheat, and sorghum (Saroy *et al.*, 2024). India is the largest producer of pearl millet globally, and the crop plays a significant role in ensuring food and nutritional security, particularly among resource-poor farming communities in arid and semi-arid regions (Satyavathi *et al.*, 2021) ^[12].

Nutritionally, pearl millet grains are a rich source of protein (9-15%), fat (approximately 5%), carbohydrates (around 67%), and mineral matter (2-7%). They also provide high energy value (>360 kcal per 100 g) and contain comparatively higher levels of essential micronutrients such as iron (Fe), zinc (Zn), and calcium (Ca) than many other cereals. Moreover, pearl millet demonstrates remarkable resilience under adverse environmental conditions, including low soil fertility, extreme temperatures, and prolonged drought (Jan *et al.*, 2015) ^[5]. Its ability to produce satisfactory grain yields under such stress conditions accounts for its widespread cultivation in arid and semi-arid agro-ecological zones (Yadav *et al.*, 2017) ^[16].

Plant nutrition plays a crucial role in the successful cultivation of pearl millet, significantly influencing its productivity. Among essential nutrients, nitrogen is considered one of the most important macronutrients required for proper plant growth, development, and yield formation (Tremblay *et al.*, 2011) ^[15]. It serves as a fundamental element in enhancing crop growth rates and achieving optimum grain yield. Crop growth and development are also strongly affected by environmental factors, particularly temperature. The application of higher levels of nitrogenous fertilizers in pearl millet has been reported to effectively improve growth and development, primarily by increasing the rate of photosynthesis (Fayyaz-ul-Hassan *et al.*, 2005) ^[3].

Nutrient losses from agricultural fields through leaching and gaseous emissions significantly contribute to environmental pollution and climate change. Such losses can be mitigated by the use of nano urea, which is reported to have minimal residual effects. In India, urea accounts for approximately 82% of the total nitrogenous fertilizers consumed, and its usage has increased exponentially over time. It was projected that urea consumption would reach about 35 million tonnes during 2020-21. However, only 30-50% of the applied nitrogen from urea is effectively utilized by crops, while the remaining portion is lost due to rapid chemical transformations, including leaching, volatilization, and surface runoff, resulting in low nitrogen use efficiency. Furthermore, excessive application of urea contributes to the emission of greenhouse gases, particularly nitrous oxide, thereby accelerating global warming (Manjunath *et al.*, 2025) [9].

In contrast, nano urea exhibits higher nitrogen use efficiency and is considered environmentally sustainable. It is often referred to as a “smart fertilizer” due to its ability to reduce nitrous oxide emissions, a major contributor to the contamination of soil, air, and water resources, as well as to global warming. These characteristics make nano urea a promising alternative to conventional urea (Kanno *et al.*, 2022) [6]. Owing to its nanoscale size and high surface area-to-volume ratio, nano urea particles are readily available for plant uptake. Its application has been reported to enhance chlorophyll content and photosynthetic activity in leaves, along with increased root biomass and a greater number of effective tillers or branches, ultimately leading to improved crop yields. Furthermore, nano urea enhances the efficiency of bulk nitrogen fertilizers. It is required in smaller quantities compared to conventional nitrogenous fertilizers such as urea, making it easier to store and transport. The portability of nano urea bottles, as opposed to bulky urea bags, significantly reduces logistical and warehousing costs (Meena and Verma, 2022) [10].

In recent years, the development of high-yielding pearl millet hybrids has opened new avenues for enhancing crop productivity. Improvement in crop productivity is essential for meeting the growing food demand and enhancing the livelihood of farming communities. Pearl millet has the potential to produce an economical grain yield of about 600-700 kg/ha even under marginal lands and low-input management conditions. Moreover, the cultivation of short-duration hybrids (80-85 days maturity) during the summer season under irrigated conditions and optimum nutrient management can achieve grain yields ranging from 4000 to 5000 kg/ha (Chaudhari *et al.*, 2018) [2]. This indicates the immense yield potential of pearl millet when suitable agronomic practices are adopted. Hence, increasing pearl millet production largely depends on the cultivation of high-yielding hybrids and varieties with better drought tolerance, disease resistance, and higher fertilizer responsiveness. Sharma (2014) [14] also reported that hybrid cultivars were more profitable than traditional open-pollinated varieties (OPVs) in the arid regions of Rajasthan. Therefore, the evaluation and selection of region-specific hybrid cultivars suitable for varying agro-climatic conditions are important strategies for enhancing pearl millet productivity and profitability.

Materials and Methods

The field experiment was conducted during the *Zaid* season of 2025 at the Crop Research Farm, Department of

Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, located, Prayagraj, (U.P.). The Crop Research Farm is located at 25°24'42" N latitude and 81°50'56" E longitude and 98 meters altitude from sea level. This area is situated on the right side of the river *Yamuna* and opposite side of Prayagraj-Rewa Road, approximately 6 km from Prayagraj city. The soil of the experimental field was sandy loam in texture with pH (7.2), organic carbon (0.4%), and available nitrogen, phosphorus, and potassium status of (186), (24), and (90) kg/ha, respectively.

The experiment was laid out in a Randomized Block Design (RBD) with 12 treatments and 3 replications. The experiment consisted of six pearl millet hybrids *viz.* 86 M 25, 86 M 15, PA 9666, RBX 6066, US 7306, and MP 7793 and two different sources of nitrogen *viz.* 100% Recommended Dose of Nitrogen through Urea and 50% RDN (Recommended Dose of Nitrogen) through urea along with 4% Nano urea. The treatment combinations are, T₁ (86 M 25 + 100% Recommended Dose of Nitrogen), T₂ (86 M 25 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), T₃ (86 M15 + 100% Recommended Dose of Nitrogen), T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), T₅ (PA 9666 + 100% Recommended Dose of Nitrogen), T₆ (PA 9666 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), T₇ (RBX 6066 + 100% Recommended Dose of Nitrogen), T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), T₉ (US 7306 + 100% Recommended Dose of Nitrogen), T₁₀ (US 7306 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), T₁₁ (MP 7793 + 100% Recommended Dose of Nitrogen), T₁₂ (MP 7793 + 50% Recommended Dose of Nitrogen + 4% Nano Urea).

Recommended agronomic practices were followed throughout the crop growth period. The field was prepared by proper ploughing and leveling, and sowing was done on (25 March 2025) with a spacing of 45 cm × 10 cm using a seed rate of 5 kg/ha. Fertilizers were applied as per treatment requirements through suitable sources of nitrogen, phosphorus, and potassium. Irrigation, weeding, and plant protection measures were carried out uniformly in all plots. Observations on growth parameters such as plant height, dry weight, crop growth rate, and relative growth rate were recorded at different growth stages. Yield attributes including number of ear head/m², ear head length, grains/earhead, test weight, grain yield, and stover yield were recorded at harvest. Plant and soil samples were analyzed using standard laboratory procedures.

The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate to the experimental design as described by Gomez and Gomez (1984). Treatment means were compared using the critical difference (CD) test at 5% level of significance. Economic analysis of treatments was carried out by calculating gross returns, net returns, and benefit-cost ratio based on prevailing market prices.

Result and Discussion

Growth Attributes

Plant height (cm)

At 80 DAS, significantly highest plant height (35.56 cm) was recorded in treatment T₃ (86M15 + 100% Recommended Dose of Nitrogen). And the T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea)

statistically at par with treatment T₃ (86M15 + 100% RDN). The lowest plant height (151.53 cm) was recorded in treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea).

The results indicated that Adequate nitrogen supply promotes photosynthetic activity and synthesis of proteins, which ultimately enhances plant growth and development. The superior performance of hybrid 86 M15 under 100% RDN and nano-urea treatments indicates better nitrogen use efficiency and adaptability of the hybrid under integrated nitrogen management practices. Similar findings were reported by Yadav *et al.*, (2023) ^[17] and Kumar *et al.*, (2025) ^[8] who observed increased plant height with integrated nitrogen management and nano-urea application in pearl millet.

Plant Dry Weight (g)

At 80 DAS, significantly highest plant dry weight (80.23 g) was recorded in treatment T₃ (86M15 + 100% Recommended Dose of Nitrogen). And the T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) statistically at par with treatment T₃ (86M15 + 100% Recommended Dose of Nitrogen). The lowest plant dry weight (66.47 g) was recorded in treatment T₇ (RBX 6066 + 100% Recommended Dose of Nitrogen).

The increase in dry weight under higher nitrogen application and nano urea supplementation might be due to improved nutrient uptake efficiency and better translocation of photosynthates from source to sink. These findings are in agreement with the reports of Yadav *et al.*, (2023) ^[17] and Kumar *et al.*, (2025) ^[8] who observed enhanced dry matter accumulation with adequate nitrogen nutrition and nano nitrogen application in pearl millet.

Crop Growth Rate (CGR) (g/m²/day)

At 60-80 DAS, significantly highest CGR (27.59 g/m²/day) was recorded in treatment T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea). And treatment T₁ (86 M 25 + 100% Recommended Dose of Nitrogen), treatment T₂ (86 M 25 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), treatment T₃ (86M15 + 100% Recommended Dose of Nitrogen), treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) treatment T₉ (US 7306 + 100% Recommended Dose of Nitrogen), treatment T₁₀ (US 7306 + 50% Recommended Dose of Nitrogen + 4% Nano Urea), treatment T₁₁ (MP 7793 + 100% Recommended Dose of Nitrogen), and treatment T₁₂ (MP 7793 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) statistically at par with treatment T₃ (86M15 + 100% RDN). The lowest CGR (22.78 g/m²/day) was recorded in T₅ (PA 9666 + 100% Recommended Dose of Nitrogen).

Crop growth rate (CGR) of pearl millet increased significantly with nitrogen application due to enhanced photosynthetic efficiency and biomass accumulation during active growth stages. The highest CGR was observed under 100% Recommended Dose of Nitrogen (RDN), which remained statistically at par with 50% RDN + 4% nano-urea, indicating improved nitrogen use efficiency through nano-fertilizer application. These findings are in agreement with studies reporting significant improvement in growth rate under optimum and integrated nitrogen management Yadav *et al.*, (2023) ^[17] and Kumar *et al.*, (2025) ^[8].

Relative Growth Rate (RGR) (g/g/day)

At 60-80 DAS, RGR was recorded non significant. RGR further declined and remained almost constant (0.02 g/g/day) across all treatments.

Relative growth rate (RGR) of pearl millet was not significantly affected by nitrogen management at any growth stage, indicating that RGR is largely governed by internal physiological processes rather than external nutrient supply. The decline in RGR with crop age reflects reduced growth efficiency due to increased structural biomass and lower proportion of actively growing tissues.

Yield Attributes and Yield

Number of earheads per m²

Significantly maximum number of earheads per m² (71.00) was recorded in treatment T₃ (86 M15 + 100% Recommended Dose of Nitrogen). And the treatment T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) statistically at par with treatment T₃ (86M15 + 100% RDN). The lowest number of earheads per m² (63.66) was observed in treatment T₇ (RBX 6066 + 100% Recommended Dose of Nitrogen).

The increased number of earheads under higher nitrogen supply and nano urea application might be due to enhanced vegetative growth, improved tillering and better nutrient utilization efficiency. Similar findings were reported by Kumar *et al.*, (2025) ^[8] and Karnot *et al.*, (2024) ^[7], who observed significant improvement in earhead formation with adequate nitrogen fertilization.

Ear head length (cm)

Significantly highest ear head length was recorded in treatment T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea). And the treatment T₃ (86 M15 + 100% Recommended Dose of Nitrogen) which was statistically at par with T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea). The lowest ear head length (17.60 cm) was recorded in treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea). Improvement in earhead length may be attributed to better nitrogen availability, which enhanced cell elongation, photosynthesis and assimilate translocation towards reproductive organs. Similar observations were also reported by Yadav *et al.*, (2023) and Shahin *et al.*, (2013) ^[13].

Number of grains per ear head

The maximum number of grains per ear head (3120.33) was recorded in treatment T₃ (86 M15 + 100% Recommended Dose of Nitrogen). And the treatment T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) statistically at par with treatment T₃ (86M15 + 100% RDN). The minimum number of grains per ear head (2346.00) was observed in treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea).

Higher grain number may be due to improved nitrogen nutrition, which enhanced spike development, pollination efficiency and grain filling. These findings are in agreement with the reports of Kumar *et al.*, (2025) ^[8] and Karnot *et al.*, (2024) ^[7].

Test weight (g)

Test weight was recorded non-significant. Higher test weight (16.55 g) was recorded in treatment T₃ (86 M15 +

100% Recommended Dose of Nitrogen). And the lower test weight was recorded in treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea).

The slight variation in test weight among treatments might be due to genotypic characteristics and differential assimilate partitioning during grain development.

Grain Yield (t/ha)

Significantly highest grain yield (3.48 t/ha) was recorded in treatment T₃ (86 M15 + 100% Recommended Dose of Nitrogen). And the treatment T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) statistically at par with treatment T₃ (86M15 + 100% RDN). The minimum grain yield (1.79 t/ha) was observed in treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea).

The increase in grain yield under higher nitrogen levels and nano urea application may be attributed to improved nitrogen availability, enhanced photosynthetic activity and better assimilate translocation towards grain formation. Similar findings were reported by Karnot *et al.*, (2024) [7] and Bharathi *et al.*, (2024) [1], who observed higher grain yield with balanced nitrogen nutrition in pearl millet.

Stover Yield (t/ha): Significantly maximum stover yield (4.74 t/ha) was recorded in treatment T₃ (86 M15 + 100%

Recommended Dose of Nitrogen). And the treatment T₄ (86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea) statistically at par with treatment T₃ (86M15 + 100% RDN). The minimum stover yield (2.44 t/ha) was observed in treatment T₈ (RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea).

Higher stover yield may be due to enhanced vegetative growth and dry matter accumulation under adequate nitrogen supply. Nitrogen promotes cell division, leaf area expansion and biomass production, resulting in increased fodder yield. Similar results were also reported by Karnot *et al.*, (2024).

Harvest Index (%)

Significantly highest harvest index (46.53%) was recorded in treatment T₂ (86 M25 + 50% RDN + 4% Nano-urea). The lowest harvest index (39.27%) was observed in treatment T₅ (PA 9666 + 100% RDN).

Higher harvest index under nano urea integrated treatments indicates efficient partitioning of assimilates from source to sink, resulting in better grain production relative to total biomass. Variation in harvest index among hybrids may also be attributed to genetic differences in dry matter partitioning efficiency. Similar findings were reported by Bharathi *et al.*, (2024).

Table 1: Effect of Nitrogen management on Plant growth attributes of Pearl millet Hybrids

S. No.	Treatments	Plant Growth Attributes			
		Plant Height (cm) 80 DAS	Dry weight (g) 80 DAS	CGR (g/m ² /day) 60-80	RGR (g/g/day) 60-80
1	86 M 25 + 100% Recommended Dose of Nitrogen	160.46	77.67	27.33	0.02
2	86 M 25 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	159.90	75.40	26.30	0.02
3	86 M15 + 100% Recommended Dose of Nitrogen	168.10	80.23	27.52	0.02
4	86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	166.30	78.73	27.59	0.02
5	PA 9666 + 100% Recommended Dose of Nitrogen	152.86	68.57	22.78	0.02
6	PA 9666 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	154.33	67.20	23.59	0.02
7	RBX 6066 + 100% Recommended Dose of Nitrogen	151.70	66.47	24.30	0.02
8	RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	151.53	66.93	26.85	0.02
9	US 7306 + 100% Recommended Dose of Nitrogen	153.60	71.63	25.15	0.02
10	US 7306 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	153.70	70.10	25.07	0.02
11	MP 7793 + 100% Recommended Dose of Nitrogen	155.50	73.73	24.89	0.02
12	MP 7793 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	155.73	73.83	26.52	0.02
	F- test	S	S	S	NS
	SEm ±	0.7	0.7	1.0	0.0009
	CD (P=0.05)	2.1	2.0	2.9	-

Table 2: Effect of Nitrogen management on Yield Attributes of Pearl millet Hybrids

S. No.	Treatments	Yield Attributes			
		No. of Earhead per m ²	Ear head length (cm)	No. of grains per Ear head	Test weight (g)
1	86 M 25 + 100% Recommended Dose of Nitrogen	68.00	23.93	2973.00	15.27
2	86 M 25 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	68.66	23.66	2964.66	15.03
3	86 M15 + 100% Recommended Dose of Nitrogen	71.00	25.50	3120.33	16.55
4	86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	70.00	25.56	3104.33	15.59
5	PA 9666 + 100% Recommended Dose of Nitrogen	65.33	19.70	2582.00	13.10
6	PA 9666 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	64.33	19.30	2466.00	12.93
7	RBX 6066 + 100% Recommended Dose of Nitrogen	63.66	18.73	2376.66	12.23
8	RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	64.00	17.60	2346.00	11.45
9	US 7306 + 100% Recommended Dose of Nitrogen	66.00	21.26	2743.66	14.11
10	US 7306 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	65.00	20.76	2684.66	13.20
11	MP 7793 + 100% Recommended Dose of Nitrogen	67.66	22.00	2841.66	14.48
12	MP 7793 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	67.00	22.00	2811.00	14.66
	F- test	S	S	S	NS
	SEm ±	0.75	0.4	27.40	1.04
	CD (P=0.05)	2.19	1.2	80.35	-

Table 3: Effect of Nitrogen management on Yield and Harvest Index of Pearl millet Hybrids

S. No.	Treatments	Grain Yield (t/ha)	Stover Yield (t/ha)	Harvest Index (%)
1	86 M 25 + 100% Recommended Dose of Nitrogen	3.23	4.31	42.84
2	86 M 25 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	3.22	3.70	46.53
3	86 M15 + 100% Recommended Dose of Nitrogen	3.48	4.74	42.34
4	86 M15 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	3.39	4.45	43.24
5	PA 9666 + 100% Recommended Dose of Nitrogen	2.25	3.48	39.27
6	PA 9666 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	2.22	2.83	43.96
7	RBX 6066 + 100% Recommended Dose of Nitrogen	1.93	2.78	40.98
8	RBX 6066 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	1.79	2.44	42.32
9	US 7306 + 100% Recommended Dose of Nitrogen	2.43	3.62	40.17
10	US 7306 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	2.26	3.32	40.50
11	MP 7793 + 100% Recommended Dose of Nitrogen	2.50	3.64	40.72
12	MP 7793 + 50% Recommended Dose of Nitrogen + 4% Nano Urea	2.27	3.38	40.18
	F- test	S	S	S
	SEm ±	0.06	0.11	0.78
	CD (P=0.05)	0.18	0.33	2.29

Conclusion

Application of treatment T₃ (86 M 15 + 100% Recommended Dose of Nitrogen) has recorded highest plant height (cm), plant dry weight (g), Number of grains per earhead, grain yield (t/ha) and stover yield (t/ha).

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