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Influence of nitrogen management on yield and economics of pearl millet (*Pennisetum glaucum* L.) varieties

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Abstract

A field experiment was conducted during *Kharif* season 2025 at Crop research farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.36 %), Available N (171.48 kg/ha), Available P (15.2 kg/ha) and available K (232.5 kg/ha). To determine the “Effect of Nitrogen Management on growth and yield of Pearl millet (*Pennisetum glaucum* L.) Varieties” to study the response of Nitrogen levels. The experiment was laid out in Randomized Block Design. The treatment comprised of 3 levels of Nitrogen and Biofertilizers along with different Varieties. There were 9 treatments which were replicated thrice, divided into Twenty-nine plots. The results revealed that significantly higher yield attributes of Pearl millet at harvest *i.e.*, length of ear head/m² (24.22 cm), Number of grains/head (1482.85), grain yield (3.83 t/ha) and stover yield (7.55 t/ha) were recorded in treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS) compared to other treatments. Whereas, maximum gross return (INR 1,39,125.40/ha), net return (INR 1,02,081.40 /ha) and B:C ratio (2.76) were also recorded in treatment - 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS).

Keywords: Biofertilizers, Nitrogen, Pearl Millet, Varieties, Yield and Economics

Introduction

Pearl millet (*Pennisetum glaucum* L.) is the sixth most important cereal crop in the world and the fourth most important food grain crop in India after rice, wheat, and maize. In India, it is popularly known as Bajra or Bajri and is also referred to as cattail, bulrush, or spiked millet because of its characteristic ear head. The crop originated in tropical western Africa and belongs to the family *Poaceae*. Among the cultivated species, *Pennisetum glaucum* (2n = 14) is primarily grown for grain production, whereas *Pennisetum purpureum* (2n = 28) is cultivated mainly for green and dry fodder.

Pearl millet is an important dual-purpose crop, serving as a staple food for millions of people while also providing valuable fodder for livestock. As a C4 plant, it possesses high photosynthetic efficiency, enabling greater dry matter production with fewer inputs and making it highly suitable for cultivation under drought-prone and marginal environments. This characteristic ensures better economic returns for farmers, particularly in arid and semi-arid regions (Reddy *et al.* 2022) ^[1]. Owing to its exceptional tolerance to drought, high temperatures, and poor soil conditions, pearl millet is considered one of the most resilient cereal crops and has significant potential for sustaining food security under changing climatic conditions.

Pearl millet contributes approximately 10.7 per cent of India's total food grain production. The major pearl millet-growing states include Rajasthan, Uttar Pradesh, Haryana, Gujarat, Maharashtra, Punjab, and Tamil Nadu, where the crop is cultivated during both the kharif and summer seasons. Rajasthan is the leading producer, contributing nearly 45 per cent of the country's total production, followed by Uttar Pradesh (19%), Haryana (9%), Gujarat (9%), Maharashtra (6%), and Tamil Nadu (2%) (Directorate of Millets Development, 2021-22; Project Coordinator Review, 2022) ^[2, 3].

In Maharashtra, pearl millet is predominantly cultivated in the hilly and drought-prone regions of the central plateau on relatively poor soils. Major cultivating districts include Beed, Nashik, Dhule, Satara, Pune, Sangli, Aurangabad, Solapur, Jalgaon, and Ahmednagar. The crop occupies about 1.035 million hectares in the state, producing approximately 1.123 million tonnes with an average productivity of 1,086 kg/ha (Areshwar *et al.* 2018) ^[4]. At the national level, pearl millet was cultivated over 7.41 million hectares during 2020-21, producing 9.35 million tonnes with an average productivity of 1,391 kg/ha. According to the Government of India (2022) ^[5], the crop currently occupies around 7.8 million hectares, with a production of 9.25 million tonnes and an average productivity of 1,270 kg/ha.

In the Agra region of Uttar Pradesh, pearl millet plays an important role in both human and animal nutrition and forms an integral component of sustainable cropping systems. The pearl millet-lentil cropping sequence is particularly popular because it requires relatively low water and labour inputs compared to many other cropping systems. In most cases, chemical fertilizers are applied only to the pearl millet crop, while the succeeding lentil crop benefits from the residual nutrients. Continuous cultivation, however, has resulted in the depletion of both macro and micronutrients in the soil, leading to declining soil fertility and reduced crop productivity. Therefore, balanced nutrient management has become essential for maintaining sustainable yields.

Among all plant nutrients, nitrogen is considered the most important for crop growth and development. It is a vital component of amino acids, proteins, nucleic acids (DNA and RNA), enzymes, vitamins, hormones, alkaloids, and several other cellular constituents. Adequate nitrogen availability promotes vigorous vegetative growth, enhances chlorophyll formation, and imparts a healthy dark green colour to plants. Proper and judicious nitrogen fertilization not only increases grain yield but also improves forage quality by enhancing protein content (Ayub *et al.*, 2007) ^[6]. Although pearl millet is traditionally regarded as a crop capable of producing satisfactory yields under low nitrogen conditions (Gascho, 1995) ^[7], several studies have demonstrated that nitrogen application significantly improves its productivity and nutrient use efficiency (Singh *et al.*, 2010; Srinivasarao *et al.*, 2013) ^[8, 9].

Recent advances in nanotechnology have introduced nano urea as an innovative liquid nitrogen fertilizer that enhances nitrogen use efficiency while minimizing nutrient losses and environmental pollution. Nano urea provides nitrogen directly to plants in a more efficient manner than conventional urea, thereby reducing fertilizer requirements and improving crop performance. Nano fertilizers also increase nutrient use efficiency, promote photosynthesis through enhanced metabolic activity, improve dry matter accumulation, and ultimately increase crop yield and quality. Their application supports precision agriculture by enabling targeted nutrient management and reducing cultivation costs (Qureshi *et al.* 2018) ^[10].

Another sustainable approach to nutrient management involves the use of beneficial microorganisms such as *Azotobacter*. These free-living nitrogen-fixing bacteria improve soil fertility by fixing atmospheric nitrogen and promoting plant growth through the production of growth-promoting substances. Their beneficial effects extend beyond biological nitrogen fixation, as they also enhance

nutrient availability, improve root development, and stimulate overall plant growth. The use of *Azotobacter* can reduce dependence on chemical nitrogen fertilizers, lower production costs, minimize nitrate leaching into groundwater, and reduce emissions of nitrous oxide, a greenhouse gas with a global warming potential nearly 300 times greater than carbon dioxide (Singh *et al.*, 2016) ^[11, 12].

Considering the importance of pearl millet in ensuring food and fodder security, along with the need for sustainable nutrient management, integrating nitrogen fertilization with innovative inputs such as nano urea and biofertilizers like *Azotobacter* offers a promising strategy for improving crop productivity, nutrient use efficiency, and environmental sustainability.

Materials and Methods

An experiment was conducted during the *Kharif* season 2025. In the alluvial soil at the Crop Research Farm, Department of Agronomy, NAI, SHUATS, Prayagraj, U.P. It is situated 98 meters above mean sea level at latitude 25° 24' 42" N, longitude 81° 50' 56" E. About five kilometers from Prayagraj city, this location lies on the right bank of the Yamuna River beside Prayagraj Rewa Road. At a depth of 0-30 cm, a composite soil sample was taken. It underwent crushing, air drying, and physical and chemical testing. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.36 %), Available N (171.48 kg/ha), Available P (15.2 kg/ha) and available K (232.5 kg/ha). The seeds were sown on 12th August 2025, with spacing 45 cm x 15 cm in line sowing. The experiment was laid out in a Randomized block design with nine treatments replicated thrice. The treatment details are as follows: T₁ - MPMH21 + 100% RDN, T₂ - MPMH21 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS, T₃ - MPMH21 + *Azotobacter* seed inoculation + 4% Nano urea spray at 45 DAS, T₄ - 86 M 90 + 100 % RDN + *Azotobacter* seed inoculation, T₅ - 86M90+75 % RDN + 4% Nano urea spray at 30 and 45 DAS, T₆ - 86M90+A *zotobacter* seed inoculation + 4% Nano urea spray at 45 DAS, T₇ - MD1722 + 100% RDN, T₈ - MD1722 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS, T₉ - MD1722 + *Azotobacter* seed inoculation + 4% Nano urea spray at 45 DAS. To apply nutrients as a spreading method, 4-5 cm deep furrows were dug along the seed rows using a hand hoeing. Ten days after sowing, the gaps were filled by transplanting once germination took place. Whereas necessary, seeds were trimmed out to maintain 45 cm x 15 cm spacing. In order to reduce crop density, weed competition, intercultural operations were carried out between 25- and 45-days intervals. On 25th October 2025, harvesting of the crop was done. At regular intervals from germination to harvest. At harvest, yield metrics such as Ear head length (cm), No. of Grains/ear head, test weight (g), seed yield (kg/ha), straw yield (kg/ha), and harvest index (%) were measured at 20, 40, 60 and 80 DAS. Whereas, Economics analysis *i.e.* cost of cultivation, gross return, net return and benefit cost ratio was observed. Analysis of variance (ANOVA), as it relates to randomized block design, was used to statistically examine the observed data of nine treatments (Gomez and Gomez, 1984 and Mohan *et al.* 2024) ^[13].

Result and Discussion

Post-Harvest Observations

Length of Ear head (cm)

Significantly higher ear head length (24.22 cm) was observed in treatment 5 (86M90 + 75% RDN + 4% Nano

urea spray at 30 and 45 DAS). However, 3 (MPMH21 + *Azotobacter* seed inoculation + 4% Nano urea spray at 45 DAS) and treatment 4 (86M90 + 100% RDN) was found to be statistically at par with the treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). The increase in ear head density with higher nitrogen levels may be attributed to enhanced tillering capacity and improved survival of tillers. Nitrogen plays a vital role in promoting vegetative growth, leading to increased formation of tillers, many of which develop into productive ear heads. NPK application can be attributed to a general development in plant growth as replicated by increased dry matter accumulation, which may be due to an increased availability of nutrients to plants at the flowering stage, which might take greater effective tiller formation and ultimately increased ear head length. The increase in ear head length (cm) may be attributed to physiological and metabolic processes with increases in tiller initiation and survival. Sharma *et al.* (2012)^[14] and Sharma *et al.* (2008)^[15].

Number of grains/ear head

Significantly maximum number of grains/ear head (1482.85) was observed in treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). However, treatment 6 (86M90 + *Azotobacter* seed inoculation + 4% Nano urea spray at 45 DAS), treatment 7 (MD1722 + 100% RDN), and treatment 8 (MD1722 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS) were found to be statistically at par with the treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). The improvement in grain number with higher nitrogen application may be attributed to enhanced vegetative growth and better development of reproductive structures. Adequate nitrogen supply during critical growth stages promotes panicle development, floret initiation, and reduces floret abortion, thereby increasing the number of grains per ear head. These results are in agreement with Chouhan *et al.* (2015)^[16], who reported that nitrogen plays a vital role in reproductive development and yield formation in cereals.

Test weight (g)

Highest test weight (8.21 g) was recorded in Treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). However, there was no significant difference among the treatments. Test weight was not influenced by the application of different Varieties and nitrogen effect which might be due to characters highly influenced by its genetic make-up. Optimal nitrogen (N) management significantly increases pearl millet test weight (1000-grain weight) by enhancing plant physiological processes, with top results often found using 75-100% recommended dose of nitrogen (RDN) combined with organic manures, reaching test weights around Nitrogen boosts grain filling through improved photosynthesis and nutrient uptake was similar to Arshad *et al.* (2016)^[17].

Grain Yield (t/ha)

Significantly higher grain yield (3.83 t/ha) was recorded in treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). However, treatment 6 (86M90 + *Azotobacter* seed inoculation + 4% Nano urea spray at 45 DAS) was found to be statistically at par with the treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). Applying nitrogen might be applied to improve

vegetative development, probably uptake and utilization of other elements fascinated by its wide root system developed by NPK imitation. The increase in grain yield with higher nitrogen levels can be attributed to enhanced vegetative growth, improved leaf area index, and higher photosynthetic activity, which ultimately led to better assimilate production and translocation towards reproductive organs. Nitrogen also plays a crucial role in the formation of yield-attributing characters such as number of effective tillers, earhead length, and grain weight. Similar findings were previously published by Sharma *et al.*, (2012)^[14] and Singh *et al.*, (2016)^[11].

Stover yield (t/ha)

Significantly higher stover yield (7.55 t/ha) was recorded in treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). However, treatment 6 (86M90 + *Azotobacter* seed inoculation + 4% Nano urea spray at 45 DAS), treatment 7 (MD1722 + 100% RDN), and treatment 8 (MD1722 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS) were found to be statistically at par with the treatment 5 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS).

The significantly higher stover yield recorded under Treatment 5 (86M90 + 75% RDN + 4% nano urea spray at 30 and 45 DAS) may be attributed to the improved nitrogen availability throughout the crop growth period. The enhanced nitrogen use efficiency of nano urea, coupled with a reduced basal nitrogen dose, could have contributed to greater stover production while minimizing nitrogen losses through volatilization and leaching. Similar findings have been reported by Srivastava *et al.* (2023)^[18]. Who observed significantly higher stover yield in Pearl millet. The combined application of 75% recommended nitrogen dose (RDN) and foliar nano urea sprays at critical growth stages likely enhanced photosynthetic efficiency, chlorophyll synthesis, and vegetative growth, resulting in greater biomass accumulation. Nano urea, owing to its higher nutrient use efficiency and gradual nitrogen release, may have supplemented the crop's nitrogen requirement effectively while minimizing nitrogen losses Vasanth *et al.* (2025)^[19]. These findings indicate that nano urea, either in combination with reduced fertilizer nitrogen or with biofertilizer inoculation, has the potential to maintain stover yield while reducing dependence on conventional nitrogen fertilizers Hemanth *et al.* (2025)^[20].

Harvest Index (%)

Highest harvest index (33.89 %) was recorded in Treatment 6 (86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS). However, there was no significant difference among the treatments. Application of different varieties and Nitrogen management could be attributed to increase vegetative growth, possibly the result of effective uptake and utilization of other nutrients absorbed through its extensive root system developed under different fertilization. The biological yield is a function of grain and straw yield. Thus, a significant increase in biological yield with the application of different potassium could be attributed to the increased grain and straw yield attributes and yield. The increase in grain and stover yields may be attributed to role of varieties as a catalyst or stimulant in most of the physiological and metabolic processes and metal

activator or enzymes resulting in increased growth and development of plant. Similar results were also reported by Kumar *et al.*, (2018) ^[21].

Economics

Observations regarding economics of different treatments of pearl millet are given in table 3.

Cost of cultivation (INR/ha)

The cost of cultivation varied among the different treatments. The maximum cost of cultivation (INR. 38,144.00/ha) was recorded under Treatment 9 (MD1722 + *Azotobacter* seed inoculation + 4% nano urea spray at 45 DAS), whereas the minimum cost of cultivation (INR. 36,444.00/ha) was recorded under Treatment 1 (86M90 + 100% RDN).

Gross return (INR/ha)

The highest gross return (INR. 139,125.40/ha) was obtained under Treatment 5 (86M90 + 75% RDN + 4% nano urea

spray at 30 and 45 DAS), which was superior to all other treatments.

Net return (INR/ha)

The maximum net return (INR.102,081.40/ha) was also recorded under Treatment 5 (86M90 + 75% RDN + 4% nano urea spray at 30 and 45 DAS), indicating its economic superiority over the remaining treatments.

Benefit-Cost Ratio (B)

The highest benefit-cost ratio (2.76) was recorded under Treatment 5 (86M90 + 75% RDN + 4% nano urea spray at 30 and 45 DAS), demonstrating its greater economic viability compared to the other treatments. The higher gross return, net return, and benefit-cost ratio observed under Treatment 5 may be attributed to its higher grain and stover yields, which resulted from improved nutrient availability, enhanced assimilation rate, and better metabolic activities in the plants. These findings are in agreement with those reported by Kumar and Bobra (2014) ^[22].

Table 1: Effect of Nitrogen management on yield attributes and yield of Pearl millet varieties.

S. No.	Treatments	Length of ear head/cm	Grains/ear head (no.)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
1	MPMH21 + 100% RDN	19.92	1081.74	5.93	2.39	4.79	29.50
2	MPMH21 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS	20.97	1139.65	6.31	2.24	5.18	30.54
3	MPMH21 + <i>Azotobacter</i> seed inoculation + 4% Nano urea spray at 45 DAS	22.07	1108.55	6.76	2.75	5.52	31.63
4	86M90 + 100% RDN	23.46	1272.40	6.94	3.36	7.13	32.04
5	86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS	24.22	1482.85	8.21	3.83	7.55	33.62
6	86M90 + <i>Azotobacter</i> seed inoculation + 4% Nano urea spray at 45 DAS	21.67	1349.40	7.66	3.71	7.24	33.89
7	MD1722 + 100% RDN	21.14	1443.78	8.14	3.38	6.89	32.98
8	MD1722 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS	20.80	1393.24	8.12	3.41	7.13	32.34
9	MD1722 + <i>Azotobacter</i> seed inoculation + 4% Nano urea spray at 45 DAS	19.31	1281.70	5.71	3.07	6.13	33.56
	F-test	S	S	NS	S	S	NS
	SEm(+)	0.80	24.50	1.31	0.12	0.21	1.77
	CD (P= 0.05)	2.42	71.86	-	0.36	0.62	-

Table 2: Effect of Nitrogen management on economics of Pearl millet varieties.

S. No.	Treatments	Cost of cultivation (INR/ha)	Gross returns (INR /ha)	Net returns (INR /ha)	Benefit-cost ratio (B:C)
1	MPMH21 + 100% RDN	36,544.00	87365.94	50821.94	1.39
2	MPMH21 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS	37,044.00	85236.56	48192.56	1.30
3	MPMH21 + <i>Azotobacter</i> seed inoculation + 4% Nano urea spray at 45 DAS	37,544.00	100519.20	62975.20	1.68
4	86M90 + 100% RDN	36,444.00	124781.00	88337.00	2.42
5	86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS	37,044.00	139125.40	102081.40	2.76
6	86M90 + <i>Azotobacter</i> seed inoculation + 4% Nano urea spray at 45 DAS	37,544.00	134535.31	96991.31	2.58
7	MD1722 + 100% RDN	37,144.00	124132.54	86988.54	2.34
8	MD1722 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS	37,644.00	125923.83	88279.83	2.35
9	MD1722 + <i>Azotobacter</i> seed inoculation + 4% Nano urea spray at 45 DAS	38,144.00	112192.67	74048.67	1.94

Note: Price of Grain yield - INR 26500/t or INR 26.50 kg (MSP) and price of stover yield - INR 5000/t or INR 5.00 kg

Conclusion

It is concluded that application of 86M90 + 75% RDN + 4% Nano urea spray at 30 and 45 DAS in treatment -5 was

recorded highest Grain yield, gross return, net return and benefit cost ratio in Pearl millet crop which performed better in terms of yield and economic returns.

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