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Morphological response of Proso millet (*Panicum miliaceum* L.) to different nitrogen levels under semi-arid conditions

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Abstract

A field experiment was conducted during the Kharif 2025 season at the Agricultural Research Farm, Faculty of Agricultural Sciences, Mandsaur University, Mandsaur (M.P.), India, to evaluate the morphological response of Proso Millet (*Panicum miliaceum* L.) variety GPUP-8 to different nitrogen levels under semi-arid conditions. The experiment was laid out in a Randomized Block Design with nine nitrogen treatments and three replications. The crop was sown at a spacing of 25 cm × 15 cm using a seed rate of 8-12 kg ha⁻¹. Nitrogen application significantly influenced vegetative growth parameters. The highest plant height at 60 DAS (92.16 cm), number of tillers per plant (10.80), panicles per plant (5.30), panicle length (16.70 cm), and grains per panicle (5.30) were recorded at 90 kg N ha⁻¹, whereas the control showed the lowest values (45.03 cm, 3.20 tillers, 2.10 panicles per plant). Morphological enhancement directly correlated with increased nitrogen levels up to 90 kg N ha⁻¹. These results indicate that nitrogen at 90 kg ha⁻¹ optimally improves vegetative growth and panicle development of Proso Millet under semi-arid conditions, contributing to higher productivity and profitability.

Keywords: Kharif, nitrogen, Proso millet, semi-arid conditions and vegetative growth

Introduction

Proso millet (*Panicum miliaceum* L.) is a short-duration cereal crop belonging to the family Poaceae and is widely cultivated in semi-arid and arid regions of India. It is valued for its adaptability to marginal soils, drought tolerance, and relatively low input requirement, making it an important crop for food security and nutritional purposes (Kumar *et al.*, 2018) [12]. Proso millet is rich in carbohydrates, proteins, and micronutrients, and its grains are used for human consumption, as animal feed, and for various industrial applications, (Chaudhry and Tiku, 2025) [3]. In Madhya Pradesh, proso millet is traditionally cultivated during the Kharif season on limited acreage, yet it has significant potential for productivity enhancement under proper nutrient management. Nitrogen is one of the most critical nutrients influencing vegetative growth and development in proso millet. Being a major constituent of chlorophyll and amino acids, nitrogen regulates processes such as photosynthesis, tillering, and panicle formation (Singh *et al.*, 2015) [16]. In semi-arid environments, inadequate nitrogen supply often limits growth, whereas excessive nitrogen can lead to lodging and reduced nutrient use efficiency, Arreyndip *et al.*, (2025) [1]. Therefore, optimizing nitrogen levels is essential for improving morphological traits, including plant height, number of tillers, panicle length, and grain formation, which ultimately affect crop performance and productivity, Bhavani *et al.*, (2021) [12]. Several studies have demonstrated that appropriate nitrogen application enhances vegetative growth and panicle development in small millets, thereby improving overall yield (Gong *et al.*, 2021) [6]. However, limited research has been conducted on the morpho-physiological response of proso millet to different nitrogen levels under semi-arid conditions of the Malwa region. Considering this, the present study was undertaken to evaluate the morphological response of proso millet to varying nitrogen levels, aiming to identify the optimum dose for improved growth and productivity under semi-arid conditions.

Materials and Methods

Experimental Site

The field experiment was conducted during the Kharif season of 2025 at the Agricultural Research Farm, Faculty of Agricultural Sciences, Mandsaur University, Mandsaur (M.P.), India, located in the western Malwa region. The site represents a semi-arid agro-climatic condition with average annual rainfall of 850-900 mm, predominantly received during the Kharif season. The soil of the experimental field was sandy loam in texture, well-drained, slightly alkaline in reaction (pH 7.2), with low organic carbon (0.45%), and medium available nitrogen (215 kg ha⁻¹), phosphorus (18 kg ha⁻¹), and potassium (225 kg ha⁻¹). Proso millet (*Panicum miliaceum* L.) variety GPUP-8 was used in the study. This variety is widely adapted to semi-arid conditions and is known for its short duration and high yield potential. The experiment was laid out in a Randomized Block Design (RBD) with nine nitrogen levels as treatments and three replications, resulting in a total of 27 plots. The treatments included nitrogen levels of 0 (control), 15, 30, 45, 60, 75, 90, 105, and 120 kg N ha⁻¹. Proso millet was sown at a spacing of 25 cm × 15 cm using a seed rate of 8-12 kg ha⁻¹. Gross plot size was 16.8 m² (4.0 × 4.2 m) and net plot size was 9.0 m² (3.0 × 3.0 m), with 1.0 m spacing maintained between plots and replications. Nitrogen was applied in the form of urea, with half the dose applied at sowing and the remaining half at 25 DAS. Recommended doses of phosphorus (40 kg P₂O₅ ha⁻¹) and potassium (25 kg K₂O ha⁻¹) were applied uniformly across all treatments. Standard agronomic practices, including irrigation, weed control, and plant protection, were followed uniformly for all plots to avoid confounding effects.

Results and Discussion

Plant height (cm)

Plant height increased progressively with crop growth and varied considerably in different nitrogen levels at 30, 45 and 60 DAS as depicted in Table 1 and graphically illustrated in Fig 1. At 30 DAS, the highest plant height was observed in T₇: 110 kg N ha⁻¹ (41.60 cm), followed by T₃: 60 kg N ha⁻¹ (39.23 cm), T₅: 90 kg N ha⁻¹ (39.23 cm) and T₈: 120 kg N ha⁻¹ (39.20 cm). The lowest plant height was recorded in T₄: 75 kg N ha⁻¹ (32.60 cm), while the control (T₉: 0 kg N ha⁻¹) produced 37.20 cm plant height. At 45 DAS, maximum plant height was recorded in T₅: 90 kg N ha⁻¹ (73.53 cm), followed by T₇: 110 kg N ha⁻¹ (71.33 cm), T₈: 120 kg N ha⁻¹ (70.03 cm) and T₆: 100 kg N ha⁻¹ (69.34 cm). The minimum value was noted in T₉: control (40.03 cm), whereas lower nitrogen levels such as T₁: 30 kg N ha⁻¹ (45.33 cm) and T₂: 45 kg N ha⁻¹ (48.63 cm) showed comparatively reduced growth. At 60 DAS, the tallest plants were again recorded in T₅: 90 kg N ha⁻¹ (92.16 cm), closely followed by T₈: 120 kg N ha⁻¹ (90.66 cm), T₇: 110 kg N ha⁻¹ (78.26 cm) and T₆: 100 kg N ha⁻¹ (76.26 cm). The lowest plant height (45.03 cm) was found in control, while lower nitrogen doses such as T₁: 30 kg N ha⁻¹ (50.03 cm) and T₂: 45 kg N ha⁻¹ (55.13 cm) resulted in comparatively shorter plants. This improvement in plant height at optimum nitrogen levels may be associated with increased nutrient uptake, improved physiological activity and greater accumulation of photosynthates, which

ultimately promote stem elongation and overall plant growth. The present results are in partial agreement with Claudir *et al.*, (2015) ^[4], Santra *et al.*, (2019) ^[15], Gong *et al.*, (2021) ^[6].

Number of tillers

The data for number of Tillers as clearly stated in Table 2 and graphically illustrated in Fig 2. Number of tillers per plant increased with increasing nitrogen levels and reached the maximum in T₅: 90 kg N ha⁻¹ (10.80), followed by T₈: 120 kg N ha⁻¹ (9.40), T₇: 110 kg N ha⁻¹ (8.60) and T₆: 100 kg N ha⁻¹ (8.00). Lower nitrogen levels such as T₁: 30 kg N ha⁻¹ (4.90) and T₂: 45 kg N. The reduced tiller formation under these treatments may be attributed to limited nutrient availability, which restricted vegetative growth and shoot development. These findings partially supports the results reported by Joshi *et al.*, (2018) ^[11], Dey *et al.*, (2022) ^[5] and Palchetti *et al.*, (2023) ^[13].

Number of panicles per plant

The highest number of panicles were recorded in T₅: 90 kg N ha⁻¹ (5.30), followed by T₈: 120 kg N ha⁻¹ (5.00), T₇: 110 kg N ha⁻¹ (4.50) and T₆: 100 kg N ha⁻¹ (4.30) whereas, the lowest value was observed in the control (2.10). Moderate nitrogen levels such as T₃: 60 kg N ha⁻¹ (3.60) and T₄: 75 kg N ha⁻¹ (4.00) resulted in intermediate values. Moderate nitrogen levels such as T₃ (60 kg N ha⁻¹) and T₄ (75 kg N ha⁻¹) produced intermediate values, whereas the lowest number of panicles was recorded in the control treatment T₉. This may be due to poor tiller development and reduced photosynthetic activity under nitrogen-deficient conditions, which limited the formation of reproductive structures. The present study is in agreement with Gong *et al.*, (2021) ^[6], Kumar *et al.*, (2020) ^[9] and Kaleri *et al.*, (2025) ^[8].

Panicle length (cm)

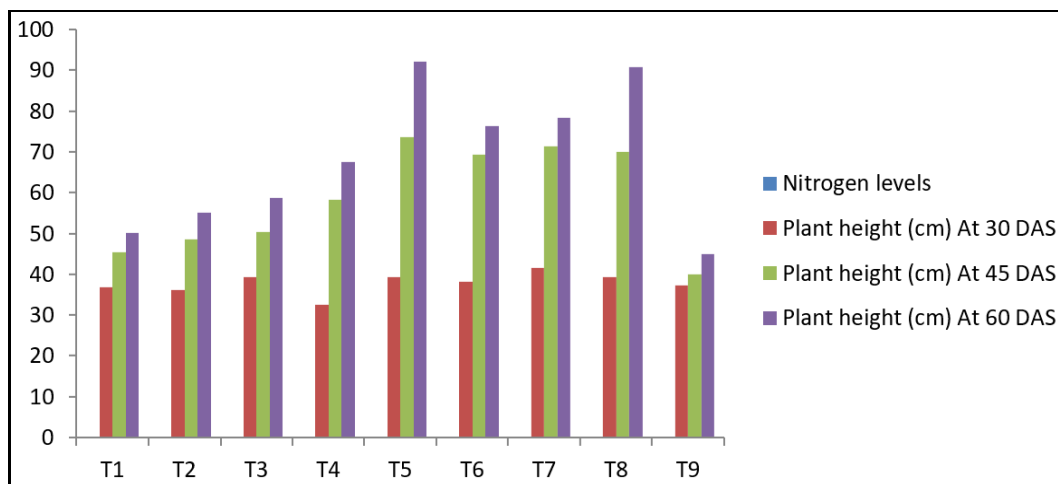
Panicle length also responded to nitrogen fertilization, with the longest panicle observed in T₅: 90 kg N ha⁻¹ (16.70 cm), followed by T₇: 110 kg N ha⁻¹ (15.73 cm), T₂: 45 kg N ha⁻¹ (15.40 cm) and T₆: 100 kg N ha⁻¹ (15.26 cm). The shortest panicle length was recorded in the control (11.13 cm), while comparatively lower values were also observed in T₄: 75 kg N ha⁻¹ (13.80 cm) and T₈: 120 kg N ha⁻¹ (13.70 cm). Limited nitrogen supply in these treatments might have reduced the metabolic activities required for proper development and elongation of panicles. Similar findings regarding improved improved panicle length was in accordance with Nandini *et al.*, (2018) ^[11], Sachin *et al.*, (2023) ^[14] and Zheng *et al.*, (2024) ^[17].

Number of grains per panicle

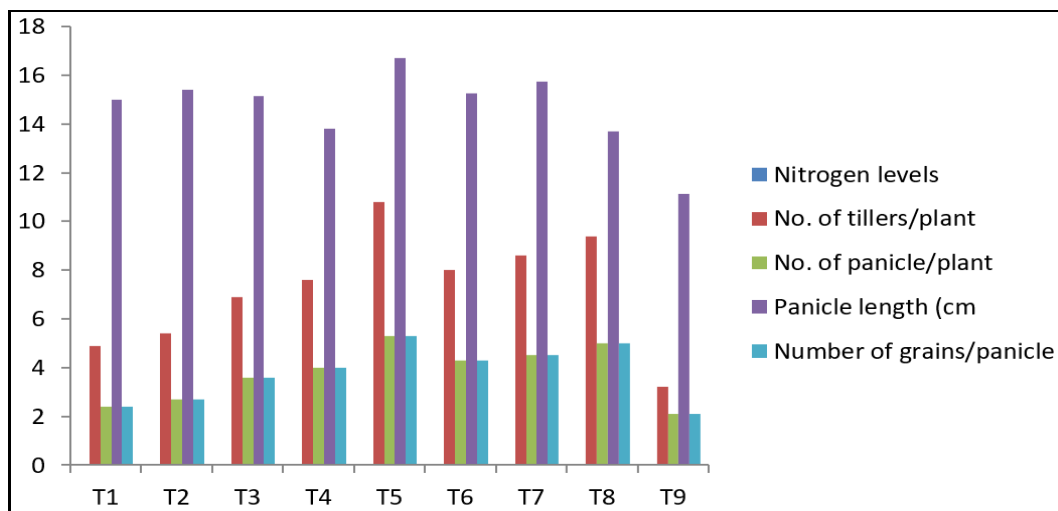
The number of grains per panicle followed a pattern similar to the number of panicles, with the maximum recorded in T₅: 90 kg N ha⁻¹ (5.30), followed by T₈: 120 kg N ha⁻¹ (5.00), T₇: 110 kg N ha⁻¹ (4.50) and T₆: 100 kg N ha⁻¹ (4.30) whereas, the lowest (2.10) was in control. This may be due to poor vegetative growth and reduced nutrient availability, which ultimately limited the development of reproductive organs and grain setting. Similar trend was noticed by Mao *et al.*, (2024) ^[10] and Nandini *et al.*, (2025) ^[12].

Table 1: Influence of Nitrogen Levels on Plant height (cm) of Proso Millet

S. No.	Treatment code	Nitrogen levels	Plant height (cm)		
			At 30 DAS	At 45 DAS	At 60 DAS
1	T ₁	30kg N ha ⁻¹	36.80	45.33	50.03
2	T ₂	45 kg N ha ⁻¹	36.03	48.63	55.13
3	T ₃	60 kg N ha ⁻¹	39.23	50.34	58.63
4	T ₄	75 kg N ha ⁻¹	32.60	58.33	67.53
5	T ₅	90 kg N ha ⁻¹	39.23	73.53	92.16
6	T ₆	100 kg N ha ⁻¹	38.23	69.34	76.26
7	T ₇	110 kg N ha ⁻¹	41.60	71.33	78.26
8	T ₈	120 kg N ha ⁻¹	39.20	70.03	90.66
9	T ₉	Control (0kg N ha ⁻¹)	37.20	40.03	45.03
		SE(m)±	0.03	0.04	0.06
		C.D. (p = 0.05)	0.09	0.13	0.18

**Fig 1:** Influence of Nitrogen Levels on Plant height (cm) of Proso Millet**Table 2:** Yield Attributes of Proso Millet under Various Nitrogen Treatments

S. No.	Treatment code	Nitrogen levels	No. of tillers/plant	No. of panicle/plant	Panicle length (cm)	Number of grains/panicle
1	T ₁	30 kg N ha ⁻¹	4.90	2.40	15.00	2.400
2	T ₂	45 kg N ha ⁻¹	5.40	2.70	15.40	2.700
3	T ₃	60 kg N ha ⁻¹	6.90	3.60	15.13	3.600
4	T ₄	75 kg N ha ⁻¹	7.60	4.00	13.80	4.000
5	T ₅	90 kg N ha ⁻¹	10.80	5.30	16.70	5.300
6	T ₆	100 kg N ha ⁻¹	8.00	4.30	15.26	4.300
7	T ₇	110 kg N ha ⁻¹	8.60	4.50	15.73	4.500
8	T ₈	120 kg N ha ⁻¹	9.40	5.00	13.70	5.000
9	T ₉	Control (0kg N ha ⁻¹)	3.20	2.10	11.13	2.100
		SE(m)±	0.029	0.025	0.07	0.025
		C.D. (p = 0.05)	0.087	0.077	0.23	0.077

**Fig 2:** Yield Attributes of Proso Millet under Various Nitrogen Treatments

Conclusion

Based on the experimental findings, it can be concluded that nitrogen application exerted a significant influence on the growth and yield-attributing characters of Proso millet. Among all treatments, T₅: 90 kg N ha⁻¹ consistently recorded superior performance in terms of plant height at different growth stages (30, 45 and 60 DAS), number of tillers per plant, number of panicles per plant, panicle length and number of grains per panicle. The progressive increase in plant height, tiller production and reproductive parameters with increasing nitrogen levels up to 90 kg N ha⁻¹ indicates the crucial role of nitrogen in enhancing vegetative growth, photosynthetic efficiency and nutrient uptake. However, further increase in nitrogen levels beyond 90 kg N ha⁻¹ did not result in proportional improvement and, in some cases, showed a declining trend, suggesting that excessive nitrogen may not be beneficial. Therefore, it can be concluded that application of nitrogen at 90 kg ha⁻¹ is optimal for achieving better growth, improved yield attributes and enhanced productivity of Proso millet under semi-arid conditions.

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