



Examining the Sowing Dates and Nitrogen Fertilization for Enhancing Growth and Yield Attributes of Barley (*Hordeum vulgare* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/ijpss/2026/v38i106391>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/168403>

Original Research Article

Received: 26/08/2026

Accepted: 22/10/2026

Published: 28/10/2026

Abstract

Barley growth and yield attributes depend partly on sowing date and nitrogen supply, but their combined response in variety BH 393 under Sri Ganganagar conditions required evaluation. A field experiment was conducted during 2025–26 at the Agricultural Research Farm, Tanta University, Sri Ganganagar, Rajasthan, India. Treatments comprised three sowing dates (5 November, 20

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November and 5 December) and three nitrogen levels (75%, 100% and 125% of the recommended nitrogen dose), arranged in a factorial randomised block design with three replications. Plant height, dry matter accumulation, tillers per square metre, grains per ear head and test weight were assessed. Sowing on 20 November recorded the highest plant height (104.56 cm), dry matter accumulation (65.38 g plant⁻¹), tiller density (208 m⁻²) and grains per ear head (37.56). Across the nitrogen treatments, 125% of the recommended dose produced the highest numerical values for plant height (107.54 cm), dry matter accumulation (66.82 g plant⁻¹), tiller density (202 m⁻²) and grains per ear head (40.56). Both experimental factors significantly affected several growth and yield attributes, whereas their effects on test weight were non-significant. The sowing date × nitrogen interaction was significant for tiller density but not for the other recorded traits. Under the specific conditions evaluated, sowing on 20 November and higher nitrogen supply were associated with improved vegetative growth and selected yield attributes. These findings apply to the tested cultivar, location and growing season.

Keywords: Barley; sowing date; nitrogen; RDN; growth; yield attributes.

1. Introduction

Barley (*Hordeum vulgare* L.) is a staple grain used in animal feed, and its importance in malt beverages contributes to its significance in certain regions. Barley is one of the oldest domesticated cereal crops known to humanity and occupies an important place among the world's food grains. Globally, barley ranks fourth among major cereal crops, after wheat, rice and maize (Kebede et al., 2019). It belongs to the family Poaceae and is considered a highly adaptable cereal crop due to its ability to grow successfully under diverse climatic and soil conditions. Barley, being rich in carbohydrates (69.6%), fibre and antioxidants, is a good source of protein (11.5%), calcium, phosphorus and vitamin B. It is low in fat and is cholesterol-free. Because of its wide adaptability, short duration and tolerance to adverse environmental conditions, barley has become an important component of cereal-based farming systems throughout the world. Barley is particularly important in saline and water-scarce soils. Barley ranks fourth among cereal crops in terms of production (Kumar et al., 2022; Rani et al., 2018).

In India, barley was cultivated over an area of 6.05 lakh hectares with an annual production of 18.44 lakh tonnes and a productivity of 3049 kg ha⁻¹ in 2024–25. The primary barley-producing states include Rajasthan, followed by Uttar Pradesh, Haryana, Madhya Pradesh, Himachal Pradesh and Uttarakhand. Barley ranks as the second most important rabi cereal crop in Rajasthan, after wheat, in terms of both cultivation area and production (Ministry of Agriculture and Farmers Welfare, 2026). Official state-level crop estimates are provided by the Directorate of Economics and Statistics, Government of Rajasthan (2026). In the 2024–25 season, barley was grown on 3.3 lakh hectares in Rajasthan, resulting in a total production of 11.02 lakh tonnes and an average grain productivity of 3342 kg ha⁻¹ (Ministry of Agriculture and Farmers Welfare, 2026).

Nitrogen is regarded as one of the most important nutrients for cereal crop production and is often referred to as the “engine of plant growth.” It is an essential constituent of chlorophyll, amino acids, proteins, nucleic acids and enzymes, which are responsible for various physiological and biochemical processes in plants. Adequate nitrogen supply promotes vigorous vegetative growth, higher tillering, larger leaf area and enhanced photosynthetic activity, resulting in increased dry matter production and higher grain yield (Dubey et al., 2018).

In dual-purpose barley, Sharma et al. (2023) documented differences in effective tiller number and grains per spike across nitrogen application rates, while Salve et al. (2026) reported nitrogen-related differences in nutrient uptake and grain-quality characteristics under Rajasthan conditions.

The interaction between sowing date and nitrogen level has a profound influence on crop growth, yield and nutrient uptake. Timely-sown crops generally utilise applied nitrogen more efficiently because favourable environmental conditions support better root development and photosynthetic activity. In contrast, late-sown crops often show a lower response to nitrogen due to shortened growth duration and exposure to terminal heat stress during reproductive stages (Singh et al., 2013).

Godara et al. (2024) observed sowing-date differences in leaf area index and absorbed photosynthetically active radiation among barley cultivars, including BH 393. Other field studies have identified differences in tillering, dry matter production and yield-related responses across sowing dates (Kharub et al., 2025; Chauhan et al., 2025).

Recent field evidence indicates that barley responses to planting date and nitrogen management are strongly conditioned by the production environment: sowing date can alter crop establishment, biomass production and grain performance, while nitrogen rate and timing influence crop growth, nitrogen-use efficiency and yield components (Moustafa et al., 2021; Sieling & Kage, 2022; Siller et al., 2021). Multi-season studies also show that the agronomic benefit of nitrogen depends on interactions with water availability, management and local yield potential, supporting site-specific optimisation rather than a universally fixed nitrogen strategy (Plaza-Bonilla et al., 2021; Sainju et al., 2013; Siller et al., 2021).

Although previous studies have examined sowing-date and nitrogen-management responses in barley, their results reflect different cultivars, locations and management conditions. The available evidence does not directly establish the combined response of variety BH 393 to the selected sowing dates and nitrogen levels under the specific experimental conditions of Sri Ganganagar, Rajasthan.

Accordingly, the present study evaluated three sowing dates and three levels of the recommended dose of nitrogen to determine their individual and interactive effects on plant height, dry matter accumulation, tiller density, grains per ear head and test weight of barley under the experimental conditions of Sri Ganganagar, Rajasthan.

2. Materials and Methods

2.1 Location of Experimental Site

The experiment was conducted during 2025–26 at the Agricultural Research Farm, Faculty of Agriculture, Tanta University, Sri Ganganagar, Rajasthan, India, located at 28.80° N latitude, 72.2° E longitude and 178 m above mean sea level.

2.2 Experimental Details

The experiment was conducted in a factorial randomised block design (FRBD) with nine treatments and three replications, resulting in a total of 27 plots. Barley (*Hordeum vulgare* L.) variety BH 393 was used with a seed rate of 100 kg ha⁻¹. The recommended fertiliser dose was 80:40:40 kg ha⁻¹ N:P₂O₅:K₂O. The crop was sown at a spacing of 22.5 cm × 10 cm (row × plant).

2.3 Treatment Details

The experiment comprised two factors, namely sowing date and nitrogen level. Factor A consisted of three sowing dates: 5 November (S₁), 20 November (S₂) and 5 December (S₃). Factor B comprised three levels of the recommended dose of nitrogen (RDN): 75% RDN (N₁), 100% RDN (N₂) and 125% RDN (N₃). Thus, a total of nine treatment combinations were evaluated under the factorial randomised block design.

2.4 Statistical Analysis

The data recorded for different growth, yield and yield-attributing parameters were subjected to statistical analysis by analysis of variance (ANOVA) appropriate for a factorial randomised block design (FRBD). The significance of treatment effects was tested at the 5% probability level, and the critical difference (CD) was calculated wherever the treatment effects were significant. The statistical analysis was carried out following the procedure described by Gomez and Gomez (1984).

3. Results and Discussion

3.1 Plant Height (cm)

Plant height was significantly influenced by sowing date and nitrogen level. Among the sowing dates, the maximum plant height (104.56 cm) was recorded with 20 November sowing, followed by 5 November sowing (101.80 cm), whereas the minimum plant height (99.89 cm) was recorded with 5 December sowing. Among the nitrogen levels, 125% RDN recorded the maximum plant height (107.54 cm), followed by 100% RDN (106.39 cm), while the minimum (79.31 cm) was recorded with 75% RDN. The interaction between sowing date and nitrogen level was non-significant.

The higher plant height under 20 November sowing may be attributed to favourable temperature conditions during vegetative growth, which promoted better crop establishment and vegetative development. Higher nitrogen availability also enhanced plant height through its role in cell division, cell elongation and chlorophyll formation. Similar responses in barley plant height to sowing time and nitrogen management have been reported by Singh *et al.* (2013), Al Myali *et al.* (2020) and Sandhu *et al.* (2017).

The observed response is consistent with field studies showing that barley vegetative development can vary with planting date and nitrogen supply, although the magnitude and direction of the response depend on environment, genotype and nitrogen timing (Moustafa *et al.*, 2021; Sieling & Kage, 2022; Siller *et al.*, 2021). Thus, the greater plant height recorded with 20 November sowing and 125% RDN is best interpreted as a response specific to the present site and season rather than as a universally optimal combination.

3.2 Dry Matter Accumulation (g plant⁻¹)

Dry matter accumulation was highest under 20 November sowing (65.38 g plant⁻¹), followed by 5 November sowing (63.31 g plant⁻¹), whereas the lowest value (61.57 g plant⁻¹) was recorded with 5 December sowing. Among nitrogen levels, 125% RDN recorded the highest dry matter accumulation (66.82 g plant⁻¹), followed by 100% RDN (65.89 g plant⁻¹), while the minimum (57.55 g plant⁻¹) was recorded with 75% RDN. The interaction between sowing date and nitrogen level was non-significant.

The greater dry matter accumulation under 20 November sowing may be attributed to more favourable growing conditions that enhanced leaf development and photosynthetic activity. Increasing nitrogen supply promoted greater biomass production by improving vegetative growth and nitrogen accumulation. Similar enhancements in dry matter accumulation with improved nitrogen management in barley has been reported by Singh *et al.* (2013), Alghabari and Al-Solaimani (2015) and Dordas (2012).

Comparable field evidence indicates that increasing nitrogen availability can increase barley biomass and nitrogen uptake, while the realised response is moderated by soil water supply and the timing and placement of fertiliser nitrogen (Plaza-Bonilla *et al.*, 2021; Sainju *et al.*, 2013; Sieling & Kage, 2022). The present dry matter response therefore accords with the broader physiological role of nitrogen in supporting canopy development and assimilatory capacity, while remaining dependent on local growing conditions.

3.3 Number of Tillers

The maximum number of tillers (208 m⁻²) was recorded with 20 November sowing, followed by 5 November sowing (193 m⁻²), whereas the minimum (191 m⁻²) was recorded with 5 December sowing. Among nitrogen levels, 125% RDN produced the maximum number of tillers (202 m⁻²), followed by 100% RDN (200 m⁻²), while the minimum (189 m⁻²) was recorded with 75% RDN. The interaction between sowing date and nitrogen level was significant.

The higher tiller production under 20 November sowing may be due to favourable environmental conditions during the tillering phase. Increased nitrogen availability probably enhanced vegetative growth and tiller initiation, resulting in greater tiller density. Similar improvements in effective tiller numbers with suitable sowing time and increasing nitrogen levels has been reported by Singh *et al.* (2013) and Sandhu *et al.* (2017).

Tillering in barley is particularly responsive to nitrogen availability and crop establishment conditions. Experimental evidence shows that early nitrogen supply can stimulate tiller production, but the contribution of those tillers to final yield depends on their subsequent survival and conversion to fertile spikes (Baethgen *et al.*, 1995; Sieling & Kage, 2022; Siller *et al.*, 2021). This provides a plausible agronomic context for the significant sowing date × nitrogen interaction detected for tiller density in the present experiment.

3.4 Grains per Ear Head

Sowing date significantly influenced the number of grains per ear head. The maximum number of grains per ear head (37.56) was recorded with 20 November sowing, followed by 5 November sowing (35.33), whereas the minimum (33.11) was recorded with 5 December sowing. Nitrogen application also significantly increased the number of grains per ear head, with the highest value (40.56) recorded under 125% RDN, followed by 100% RDN (39.00), while 75% RDN recorded the minimum (31.44). The interaction between sowing date and nitrogen level was non-significant.

The higher number of grains per ear head under 20 November sowing may be associated with favourable conditions during ear development and grain setting. The increase with nitrogen application may be attributed to improved crop growth, photosynthetic activity and assimilate availability for reproductive development. Similar increases in the number of grains per ear with appropriate sowing time and nitrogen application have been reported by Sandhu *et al.* (2017), Kaur and Kaur (2017) and Singh *et al.* (2013).

Grain-number responses to nitrogen are consistent with evidence that adequate nitrogen supply can increase the number of reproductive sinks in barley, whereas sowing date modifies the environmental conditions experienced during spike development and grain set (Baethgen *et al.*, 1995; Moustafa *et al.*, 2021; Sieling & Kage, 2022). Accordingly, the higher number of grains per ear head under 20 November sowing and greater RDN levels may reflect improved crop resource status during reproductive development under the conditions of this study.

Table 1. Effect of sowing date and nitrogen levels on growth and yield attributes of barley

Treatment	Plant height(cm) atharvest	Dry matter accumulation at harvest	Tillers m-2	Grains per ear head	Test Weight (g)
Factor(A) Date of sowing					
5 Nov	101.80	63.31	193	35.33	37.90
20 Nov	104.56	65.38	208	37.56	37.98
5 Dec	99.89	61.57	191	33.11	37.05
S.Em±	0.51	0.46	0.59	0.64	0.19
CDat 5%	1.54	1.37	1.78	1.91	NS
CV	7.71	6.62	6.36	6.42	6.23
Factor(B) Level of Nitrogen					
75%	79.31	57.55	189	31.44	37.36
100%	106.39	65.89	200	39.00	37.70
125%	107.54	66.82	202	40.56	38.88
S.Em±	0.47	0.46	0.59	0.64	0.19
CDat 5%	1.39	1.37	1.78	1.91	NS
CV	7.71	6.62	6.36	6.42	6.23
Interaction (Factor A and Factor B)					
S.Em±	0.47	0.681	0.886	1.05	0.310
CDat 5%	NS	NS	2.602	NS	NS
CV	7.71	6.62	6.36	6.42	6.23

3.5 Test Weight (g)

Test weight varied from 37.05 to 37.98 g among sowing dates, with the highest value under 20 November sowing (37.98 g) and the lowest under 5 December sowing (37.05 g). However, the effect of sowing date was non-significant. Among nitrogen levels, the highest test weight (38.88 g) was recorded with 125% RDN, followed by 100% RDN (37.70 g) and 75% RDN (37.36 g). The effects of nitrogen level and the interaction between sowing date and nitrogen level were non-significant.

The comparatively higher test weight under 20 November sowing and 125% RDN may be associated with better crop growth and assimilate availability during grain filling. However, the non-significant differences indicate that test weight was relatively less responsive to the imposed sowing dates and nitrogen levels under the present experimental conditions. Similar observations regarding the relatively smaller response of kernel weight to nitrogen application in barley have been reported by McKenzie *et al.* (2005) and Dabhi *et al.* (2017), while Singh *et al.* (2013) also reported variation in yield attributes under different sowing and nitrogen regimes.

The weak treatment response for test weight is also biologically plausible because kernel weight and test weight may be less responsive than grain number or biomass to additional nitrogen once other resources are adequate. In field studies, nitrogen effects on test weight have ranged from negligible to negative depending on water regime, cropping system and grain-quality requirements (Rogers *et al.*, 2022; Sainju *et al.*, 2013; Siller *et al.*, 2021). The non-significant effects observed here should therefore be interpreted within the specific environmental and management conditions of the experiment.

4. Conclusion

The study demonstrated that sowing date and nitrogen level influenced several growth and yield attributes of barley under the experimental conditions of Sri Ganganagar, Rajasthan. Sowing on 20 November resulted in greater plant height, dry matter accumulation, tiller density and grains per ear head than the other evaluated sowing dates. Similarly, 125% of the recommended nitrogen dose produced the highest numerical values for most measured traits. The interaction between sowing date and nitrogen level was significant only for tiller density, whereas interactions for plant height, dry matter accumulation, grains per ear head and test weight were non-significant. These findings indicate that timely sowing and nitrogen availability are important determinants of barley growth and reproductive development. The results should be interpreted specifically for the genotype, season, location and management conditions evaluated in this experiment.

5. Limitations

The experiment was conducted at a single location during one growing season and examined one barley cultivar, three sowing dates and three nitrogen levels. Consequently, the responses may not represent those under other climatic conditions, soil types or management regimes. Only the reported growth and yield attributes were evaluated. The absence of multi-season and multi-location evidence limits the generalisability of the observed treatment effects.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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