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IMPACT OF SOWING DATES ON GROWTH ATTRIBUTES, YIELD COMPONENTS AND QUALITY TRAITS OF BARLEY CULTIVARS (*Hordeum vulgare* L.)

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ABSTRACT

Barley (*Hordeum vulgare* L.), the fourth most widely cultivated cereal crop globally, was evaluated for its growth characteristics and yield response to different sowing dates and genotypes during 2023-2024 growing season at Khalsa College, Amritsar, Punjab. The study investigated growth parameters such as plant height, leaf area index (LAI), dry matter accumulation (DM) along with yield-contributing traits including the number of effective tillers, spike length, grain number spike^{-1}, test weight, biological yield, straw yield, and harvest index. Four sowing dates (October 30th, November 5th, November 10th, and November 15th) and three barley genotypes (DWRUB 52, DWRB 123, and PL-426) were assessed. Results revealed that early sowing (October 30) significantly enhanced plant height compared to delayed sowing (November 15), which resulted in reduced performance in growth and yield parameters. Among the genotypes, DWRB 123 showed superior performance in most growth and yield parameters, while PL 426 exhibited the best LAI and test weight. DWRB 123 produced the 23.74% highest grain yield followed by DWRUB 52, which produced a 16.47% higher grain yield than PL 426. Straw yield also decreased with delayed sowing, but early sowing produced the highest straw yield. The biological yield was higher with early sowing, and the harvest index was better in early sowing, particularly with PL 426. Grain protein content and nitrogen content were highest with early sowing, while kernel plumpness increased with delayed sowing. Malt yield and recovery were highest with delayed sowing, although grain quality and overall yield were compromised. Early sowing also led to improved biological and straw yields, higher protein and nitrogen content, and a better harvest index. Although delayed sowing marginally increased kernel plumpness and malt recovery, it negatively impacted grain yield and quality. Overall, the study suggests that early sowing (30th October) combined with appropriate high-performing genotype like DWRB 123 maximized barley productivity and grain quality under the agroclimatic conditions of Punjab.

(Key words : Barley, dry matter, leaf area index, sowing dates, yield)

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the fourth most widely cultivated cereal crop worldwide, following maize, rice, and wheat in terms of production volume. It accounts for approximately 7% of global cereal production and contributes around 15% to total coarse grain consumption (Li *et al*., 2022; Lukinac and Jukie, 2022). Barley is commonly referred to as the poor man's crop due to its ability to thrive under marginal and suboptimal agroecological conditions. Global production of barley reached approximately 151.62 million metric tons in the 2022-2023 crop year, increasing from around 145.37 million metric tons in 2021-2022 (Shahbandeh, 2024). During the financial year 2023, India produced approximately 1.91 million metric tons of barley, reflecting an increased from about 1.37 million metric tons in the previous year. Rajasthan continued to be the leading barley-producing state, followed by UttarPradesh, Haryana, and Punjab. In Punjab, barley cultivation covered 6.8 thousand hectares, with an average productivity of 37.77 q ha^{-1} during 2020-21 (Anonymous, 2022). Barley serves multiple purposes, being utilized as livestock feed, food and in the production of other malt-based food products (Al-Tawaha *et al*., 2020). It is traditionally used to prepare homemade recipes and drinks such as Dabo, kolo, genfo, kinche, 'beso', 'tela', 'borde', and other foods (Bekele *et al.,* 2020 a, b). Nutritionally, it is rich in carbohydrates (55.8%), crude protein (11%), fat (3.4%) and mineral elements such as iron, potassium and magnesium (Kumari *et al.*, 2019). In developing countries like India, it remains an important dietary staple (Saisho and Purugganan,2007).

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Barley is extensively cultivated across the globe due to its remarkable adaptability to diverse agroecological conditions and its multifunctional uses (Kim *et al*.,2022). It grows across a wide range of soil and climatic conditions. However, it is a cool-season crop adapted to high-altitude regions and is best adapted to fertile, well-drained silty to clay loam soils and warm, dry climatic conditions (Bayeh and Berhane, 2011). It gives good yield in moderately heavy loam to sandy soils with neutral to slightly saline pH and moderate fertility levels. In the context of climate change and increasing input constraints, breeding for genetic resistance to biotic and abiotic stresses, along with the advancement of sustainable crop management practices, has become a major focus. Climate change has also been demonstrated to impact the nutritional value of grains, leading to a decline in grain quality and nutritional content. Environmental stressors, particularly drought and heat, have been reported to increase grain protein concentration (GPC), whereas elevated atmospheric CO, levels tend to reduce GPC and overall nutritional quality (Kim *et al.,* 2022). Therefore, enhancing the resilience and input-use efficiency of barley is essential to sustain productivity and grain quality under shifting climatic regimes. Furthermore, the development and cultivation of barley genotype with broad adaptability and high input responsiveness have significantly contributed to maximizing yield potential (Amarjeet *et al.*, 2020). Late sowing adversely affects grain development due to reduced grain filling duration, increased temperature exposure, and extended photo-periods during the reproductive phase. These conditions often lead to reduced grain weight and the formation of shrivel-led kernels (Mani *et al.,* 2006).

Therefore, optimizing the sowing time is critical for achieving successful barley cultivation in central Punjab. Aligning the crop's phenological development with prevailing weather conditions is a key strategy to maximize yield potential. Early sowing may subject the crop to elevated temperatures during the tillering stage, negatively affecting growth, whereas delayed sowing can lead to reduced biomass accumulation and impaired grain development due to exposure to high temperatures during the maturity phase (Ram *et al.,* 2010; Nass *et al.,* 1975). Barley is a thermosensitive long-day plant and requires appropriate temperature and light conditions for optimal spike emergence and maturation (Bavei *et al.,* 2011). Moreover, both genotype selection and seeding rates are crucial for the optimum yield of the crop. In the same way, recognizing high-yielding, responsive genotypeis critical for enhancing production efficiency (Elis and Yildiri, 2023). However, genetic variability observed among agronomical attributes is generally moderate to low (30 to 60%), representing a significant influence of environmental factors on crop performance (Sravani *et al*.,2018).

In the current epoch, climate variability and water resource management present major constraints to barley productivity. About 40% of barley cultivation relies on rainfall, making it highly susceptible to environmental fluctuations. Agronomic parameters, such as the optimal sowing date, are crucial for successful germination and crop establishment (Bussmann *et al.,* 2016; Yawson *et al.,* 2020). Thus, the present study aimed to evaluate the impact of sowing dates on barley cultivation with a focus on growth attributes, yield components and quality traits.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted during the year 2023-2024 cropping season at Khalsa College, Amritsar (Punjab), located at of 31° 40' 12'' N latitude, 74° 50' 24 E longitude, and an altitude of 327 m above mean sea level (Arabian Sea). The crop growth period extended from October to April. The climate of Amritsar, Punjab, India, is classified as subtropical, characterized by hot, humid summers influenced by the southwest monsoon (July to mid-September), and relatively dry, mild winters. However, winter nights can be quite cold, with minimum temperatures occasionally dropping below freezing (0 to –2°C), sometimes sometimes accompanied by frost. During peak summer, maximum temperatures may exceed 40°C.

Layout and treatment details

The most popular barley crop cultivars *viz.,* DWRUB 52, PL 426 and DWRUB 123 were sown in the split-plot design with three replications. The experimental treatments included four sowing dates *viz*., 30th October, 5th November, 10th week of November and 15th week of November. The sowing date constituted the main plot treatment and cultivars as a sub-plot treatment. All other agronomic practices were based on the package and practices recommended by the Punjab Agricultural University, Ludhiana, and details of which are available elsewhere.

Plant attributes, yield and yield-related traits

Seven plant traits were evaluated across the different treatments. Plant height was measured at harvest from a sample of five randomly selected plants within each plot. The leaf area index (LAI) was calculated based on equation 1.

$$LAI = Lnet_i \times PDI_i / 10^4$$

Where LAI is the leaf area index (m^2/m^2), L net_i is the net leaf area (cm^2 $plant^{-1}$) on the ith day (observation day *i.e.*25, 50, 75 days after sowing (DAS) and at harvest stage)

PDI_i is the population density (plant/m^2) on the ith day and 10^4 is a conversion factor from cm^2 to m^2.

Dry weight was calculated by using the equation given below and expressed in kg.

$$\text{Dry weight} = \frac{\text{fresh weight - dry weight}}{\text{fresh weight}}$$

The number of tillers (per m²) was estimated by counting both the main stem and tillers in 50 cm segment (west to east) from the second or third inner row of each plot and calculated by using the equation given below

$$\text{Number of tillers (per m}^2) = \frac{\text{Number of tillers 50 cm}^{-1}\text{ row}}{0.075} \times 1$$

Spike length was measured using a calibrated ruler from five selected plants at maturity and expressed as centimeter. For the number of grains spike^{-1}, five spikes were randomly collected from each plot before harvesting. These spikes were threshed and grains were cleaned, counted and weighed to compute 1000-grain weight.

Grain yield (q ha^{-1}) was determined by using equation given below

$$\text{Grain yield (MT ha}^{-1}) = \frac{\text{Adjusted grain yield to standard 14\% grain moisture content}}{0.9} \times 10$$

For straw yield (q ha^{-1}), straw from each plot was dried, weighed and recorded; the data were expressed in kg and converted to kg ha^{-1}.

Biological yield was calculated as the grain-plus-straw dry weight and harvest index was calculated as grain dry weight/biological yield by using the equation given below

$$\text{Biological yield (q ha}^{-1}) = \frac{\text{dry weight of grain}}{\text{grain yield}}$$

The harvest index serves as an indicator of the effectiveness of each crop in converting absorbed nutrients into grains. This index was calculated by the equation given below

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Quality traits

Grain nitrogen content was determined by Kjeldahl's method. The percentage of crude protein in grain was calculated using the following equation

Grain protein content (%) = N content in grain (%) x 6.25 (Anonymous, 2005).

Kernel plumpness was estimated as an indicator of grain quality and calculated by using the following formula:

$$\text{Kernel plumpness (\%)} = \frac{\text{Weight of grains restained on sieve}}{\text{Weight of grains before sieving}} \times 100$$

Malting of barley grains was performed to assess malt yield.A 250 g sample of properly cleaned barley grains was steeped in water at 15°C in an incubator for 60 hours. Following steeping, the grains were transferred into a muslin cloth and placed in a wooden box with a wire mesh bottom to facilitate germination, maintained at 15°C and a relative humidity exceeding 90%. Germination was allowed to proceed for five days. Subsequently, the resulting green malt was cleaned in an oven, initially at 45°C for 20 hours, followed by 85°C for 4 hours. After cleaning, the rootlets were manually removed from the malt. The final weights of both the malt and the removed rootlets were recorded separately to calculate the malt recovery percentage.

Malt yield and malt recovery were calculated by using the given equation (Briggs, 1998).

$$\text{Malt recovery (\%)} = \frac{\text{Malt weight}}{\text{Sample weight}} \times 100$$

Statistical analysis

The means were used for the estimation of analysis of variance (ANOVA) to estimate the differences among the treatments. The data was statistically analysed by using statistical procedures and comparisons among treatments were made at 5% level of significance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Effect of date of sowing and genotype on growth characteristics of barley

In this study, variations in sowing dates and barley cultivars significantly influenced plant growth characteristics, yield components and quality traits of barley. Among growth traits, plant height serves as a critical indicator of plant vigour, structural robustness, and adaptive capacity to environmental conditions. It was recorded at four different stages *viz*., 25, 50, 75 days after sowing (DAS) and at the harvest stage. A statistically significant difference ($p < 0.05$) was observed in plant height across different sowing dates—30th October (D1), 5th November (D2), 10th November (D3), and 15th November (D4). The fold increase of plant height at the harvesting stage of D_1 was 1.30-fold and 1.25-fold and 1.20-fold over D_2 and D_3, respectively. However, the minimum plant height was recorded with D_4. This trend is likely attributed to environmental factors, including temperature and photoperiod, which modulate the growth of the vegetative part of the plant. On the other hand, delayed sowing reduced plant height, which is a result of shorter growing periods and unfavourable conditions. Our results are in agreement with Amarjeet *et al.* (2020), who reported that early sowing of barley (last week of October to first week of November) increased plant height as compared to delayed sowing (second to third week of November). This might be due to reduction in duration of the vegetative growth phase caused by photoperiod-induced changes, which accelerated the crop's transition toward the reproductive stage (Shaikh *et al.*, 2009; Jiotode *et al.,* 2015). Genotype variation also played a significant role in plant height. Among the tested barley genotype, DWRUB 52 consistently exhibited taller plants as compared to DWRB 123 and PL-426 at all growth stages, *viz*., 25 DAS, 50 DAS, 75 DAS and harvesting stage. The superior performance of DWRUB 52 can be attributed to its better adaptability to prevailing agro-environmental conditions, including soil fertility, moisture availability, and ambient temperature conditions (Table 1).

Leaf area Index is a crucial growth coefficient, which reflects a plant's ability to capture sunlight for photosynthesis and serves as one of the principal determinants of crop growth and productivity. Concerning the LAI, the maximum increase was observed until the harvesting stage, after which it decreased as the crop approached maturity due to senescence. In the present study, a noticeable reduction in LAI was observed with delayed sowing, from D1 (30th October) to D4 (15th November). Since LAI is influenced by both plant height and the number of tillers plant^{-1}, early sowing resulted in taller plants with more tillers, thereby contributing to a higher LAI. This decline may be attributed to reduced photosynthetic efficiency and sub-optimal leaf development under later sowing conditions (Gupta *et al.,* 2017; Jiotode *et al.,* 2017; Potbhare *et al.,* 2020). Tripathi *et al*. (2006) also reported that a timely sown crop has a higher LAI in comparison to a late sown crop. The leaf area index was found to decrease due to the senescence of leaves 75 days after sowing. Among the genotype evaluated, PL 426 exhibited the highest LAI (3.92), followed by DWRB 123 (3.78), whereas the lowest LAI was recorded in DWRUB 52 (3.32) (Table 2). The amount of dry matter that accumulates is a critical physiological trait influencing crop yield, as this process entails the distribution of assimilates to the growing sinks. The results of the present study indicated that dry matter accumulation was significantly influenced by the date of sowing. As the sowing was delayed from D_1 (October 30) to D_4 (November 15), there was a significant increase in dry matter accumulation on 75 DAS and at the harvest stage. The maximum dry matter accumulation was recorded on 30th October (45.00 q ha^{-1}), whereas the lowest was recorded on 15th November (31.99 q ha^{-1}). Increase in dry matter accumulation with delayed sowing might be due to more plant height and the greater number of tillers plant^{-1}. A delay in sowing led to more dry matter accumulation at 60 and 90 DAS because of higher plant height and more tillers (Gupta *et al.,* 2017; Ram and Kaur, 2018). Among barley genotypes, DWRB 123 recorded the highest dry matter accumulation (43.37q ha^{-1}) followed by DWRUB 52 (39.62q ha^{-1}) and PL-126 (37.5337q ha^{-1}), suggesting genotypic variation in biomass production and resource use efficiency (Table 3).

Yield and yield-related traits

The density of tillers plant^{-1} is another parameter that directly influences the grain yield of barley. In the current study, the number of effective tillers plant^{-1} was found to be higher in the early sowing, that is, on 30th October (125.71 m^2); which declined as sowing was delayed from 30th October (D_1) to 15th November (D_4) (74.28 m^2). Gopale *et al*. (2022) reported that 30th October sowing with genotype ACN-250 proved to be best among the interactions for all morpho-physiological parameters (plant height, number of branches, dry matter, leaf area, RGR and NAR) yield and harvest index. Correlation was found highly significant and positive for all morphophysiological characters and harvest index with yield. Early sowing provides a window for utilizing warmer temperature conditions, accommodating the crop to produce more tillers (Chintale, 2015; Khattak *et al.,* 2016). A comparison between genotypes revealed that DWBR 123 possessed the highest number of effective tillers (107.56 m^2$_)$, while DWBR 52 possessed the second highest with 100.2 m^2 followed by PL 426 (92.48 m^2), indicating differences in cultivars in their tillering potential (Table 4). Spike length, another important yield component, was also significantly influenced by sowing date. The longest spikes were observed under early sowing (D1), which can be attributed to optimal partitioning of assimilates toward reproductive organs during the early growth stages (Sundari, 2003). In contrast, the shortest spikes were recorded under delayed sowing (D4), with a per cent reduction of 29.85% over D1, which was statistically at par with D3. Sowing dates D1 and D2 (5th November) showed statistically similar spike lengths, suggesting a critical sowing window for maximizing spike development. These findings align with Amarjeet *et al*. (2020), who reported that early-sown barley produced significantly longer spikes due to better environmental conditions and assimilate supply during panicle initiation. Among cultivars, PL 426 produced the longest spikes (9.45 cm), followed by DWRB 123 (8.05 cm), whereas DWRUB 52 had the shortest spike length (6.86 cm), indicating that genotypicvariation plays a significant role in determining spike architecture (Table 4).

The number of grains spike^{-1} is a critical yield component that was also influenced by the sowing date. The number of grains spike^{-1} declined with delayed sowing from D_1 (30 October) to D_4 (15 November). The percentage reduction in grain spike^{-1} over D1 was recorded as 22.90% in D2, 34.40% in D3, and 44.11% in D4. These results indicate that early sowing provides more favourable conditions during spike development, contributing to higher grain set spike^{-1}(Singh *et al*., 2013). Similar observations were made by (Amarjeet *et al*., 2020), who reported reduced spike numbers and lower spike fertility under delayed sowing conditions in November. Among the cultivars, PL 426 produced the maximum number of grains spike^{-1} (39.64), followed by DWRB 123 (33.73) and DWRUB 52 (29.95), highlighting the role of genetic makeup in influencing this trait (Table 4). Another essential parameter reflecting both yield and grain quality is the test weight. Delayed sowing negatively impacted test weight, with a significant decline of 8.39% in D2 (November 5), 16.64% in D3 (November 10), and 32.41% in D4 (November 15) as compared to D1 (October 30). The effect of date of sowing on seed yield, seed germination and vigour were also reported in peas and flex (Siddique and Wright, 2004). The higher test weight recorded under D1 could be attributed to the cumulative effects of increased photosynthetic activity and efficient assimilate partitioning during the grain filling period (Choudhary *et al.,* 2017). Variation in cultivars also played a key role in determining test weight. Genotype PL 426 exhibited the highest test weight (45.22 g), followed by DWRB 123 (41.39 g), while DWRUB 52 had the lowest (34.92 g), suggesting that PL 426 possesses superior grain density and filling capacity under favourable conditions (Table 4).

The primary focus of agronomic research is optimizing crop yield, which is a cumulative result of robust plant growth and development. In this study, the highest grain yield was recorded under timely sowing conditions. Thereafter, yield progressively declined as the sowing was delayed from D_1 (30 October) to D_4 (15 November). The per cent decrease in D_4 (15 November) sowing was 36.76 %, D_3 (10 November) sowing was 17.67 % and D2 (5 November) sowing was 9.26 % over D_1(30 October). Previous research by Sehgal *et al*. (2018) reported that early sowing enhances the availability of photosynthates and nutrients to developing reproductive structures, thereby improving the yield-attributing characters and overall productivity. Furthermore, late-sown crops were observed to have a shorter growth period than the normally sown crops. Among the genotypes evaluated, DWRB 123 gave the highest yield among all the treatments (44.40 q ha^{-1}), followed by DWRUB 52 (41. 22 q ha^{-1}), while PL 426 recorded the minimum grain yield (35.88 q ha^{-1}) (Table 5). Gopale *et al*. (2022) reported that sowing of mustard genotype ACN-250 on 30th October proved to be best in enhancing the number of siliquae plant^{-1}, number of seeds siliqua^{-1}, test weight and seed yield ha^{-1}.

Straw yield exhibited a strong association with sowing dates (Table 5). The highest straw yield was recorded under D_1 (30 October) (64.63 q ha^{-1}) followed by D_2 (5 November) (60.15 q ha^{-1}) and D_4 (10 November) (55.64 q ha^{-1}). However, D_4 (15 November) recorded the lowest straw yield (52.14 q ha $^{-1}$). The highest straw yield during D1 (30 October) might be due to more vegetative growth in barley, possibly due to relatively higher prevailing temperature and longer day lengths during the early sowing period. Among the cultivars, DWRB 123 resulted in the highest straw yield (63.52 q ha^{-1}), while DWRUB 52 and PL426 recorded lower straw yields of 59.18 q ha^{-1} and 51.72 q ha^{-1}, respectively (Table 5). Organic biomass, being the total net biological yield, was highest recorded under D_1 (30 October) (113.04 q ha^{-1}) followed by D_2 (5 November) (104.07 q ha^{-1}) and D_3 (10 November) (95.49 q ha^{-1}). However, D_4 (15 November) recorded the lowest biological yield (82.75 q ha^{-1}). A comparison among the genotype revealed that DWRB 123 resulted in the highest biological yield (107.92 q ha^{-1}), closely followed by DWRUB 52 (100.98 q ha^{-1}) and PL426 (82.75 q ha^{-1}) (Table 5). Our results revealed a decline in harvest index (%) with a delay in sowing from D_1 (30 October) to D_4 (15 November). D_1 (30 October) resulted in the highest harvest index (42.81 %), closely followed by D_2 (42.20 %) and D_3 (41.73 %). Whereas the lowest harvest index was recorded with D_4 (37.01 %). (Table 5). Among the cultivars, PL 426 had the highest harvest index (43.35%), followed by DWRB 123 (41.14%). (Table 5). These findings are consistent with Dudi *et al*. (2019), who reported that DWRUB 52 exhibited a significantly higher harvest index compared to other barley genotypes. The lowest harvest index in their study was reported for RD 2552.

Quality traits

Grain protein content is an important determinant of nutritional quality in barley, influencing its suitability for food and feed purposes. The highest protein content was recorded at timely sowing (D1, 30 October) at 11.55% with a progressive decline under delayed sowing *viz.,* D2 (5 November) by 8.92%, D3 (10 November) by 23.64%, and D4 (15 November) by 54.55%. This reduction may be attributed to a shorter vegetative growth period under delayed sowing, which limits nutrient assimilation (Singh *et al.,* 2013; Kumar *et al.,* 2014). Among the cultivars, DWRB 123 exhibited the highest protein content (11.03%), followed by DWRUB 52 (9.18%), while PL 426 had the lowest (6.89%) (Table 6). Similarly, grain nitrogen content plays a vital role in influencing grain quality and malting potential. The highest nitrogen content was observed in D1 (1.82%) and declined with delayed sowing; D2 by 8.79%, D3 by 15.93%, and D4 by 23.63%. This trend might be due to reduced vegetative growth under late sowing conditions (Batwal *et al*., 2004; Choudhary *et al.,* 2017). Among the cultivars, DWRB 123 showed the highest nitrogen content (1.71%), followed by DWRUB 52 (1.57%), and the lowest was observed in PL 426 (1.52%) (Table 6). Kernel plumpness is a key parameter in determining grain weight and malt quality. The highest kernel plumpness was recorded in D4 (82.89%) and the lowest in D1 (80.03%). This pattern may be explained possibly by increased vegetative growth under early sowing. Among the cultivars, PL 426 demonstrated the highest kernel plumpness (82.27%), followed by DWRUB 52 (81.89%), while DWRB 123 had the lowest (78.45%) (Table 6). Malt yield is a crucial trait for the brewing industry, affecting overall production efficiency. The highest malt yield was recorded in D4 (20.56%), followed by D3 (18.89%), D2 (16.02%), and D1 (13.14%), with a previous study reporting maximum malt content in December sowing due to lower grain protein content (Chaudhary *et al.,* 2017). Among genotypes, PL 426 had the highest malt yield (19.14%), followed by DWRUB 52 (16.98%), while DWRB 123 recorded the lowest (15.34%). Malt recovery determines the efficiency of converting barley into malt, which impacts brewing profitability. The highest malt recovery was observed in cultivar PL 426 (83.65%), followed by DWRUB 52 (82.54%) and the lowest in DWRB 123 (80.66%). Delayed sowing showed higher malt recovery under cultivar D4 (85.72%) followed D3 (83.02%) and D2 (81.51%) and noted lowest in D1 (78.89%) (Table 6).

The experiment revealed that both sowing dates and cultivars significantly influenced growth attributes and yield traits in barley. Early sowing (30th October) resulted in better growth characteristics, including taller plants, higher leaf area index and greater dry matter accumulation. Among the tested cultivars, DWRB 123 exhibited superior performance in most growth traits and yield, whereas PL 426 performed well in terms of grain yield and test weight. Delayed sowing led to reduced plant growth, lower yield, and quality traits, emphasizing the importance of timely sowing for optimal barley production. Barley cultivars also showed variations in effective tillers, spike length, grain number and grain quality, with DWRB 123 being superior for yield and straw production. Although malt yield and recovery were relatively higher under delayed sowing, overall grain quality and yield were compromised. Overall, the results suggest that sowing of cultivar DWRB 123 at 30th October can maximize barley productivity with better agronomic and quality outcomes.

Table 1. Effect of different dates of sowing and varieties on periodic plant height of barley cultivars

Treatments	Plant height (cm)			
Main plot	**25 DAS**	**50 DAS**	**75 DAS**	**Harvesting stage**
30th October	22.23	43.15	67.91	82.88
5th November	20.75	43.38	65.06	79.93
10th November	17.31	39.95	61.81	74.28
15th November	15.71	37.48	57.35	63.82
SE(m)±	0.65	1.23	1.72	2.04
CD (5%)	1.95	3.69	5.16	6.12
Sub plot				
DWRUB 52	19.38	43.08	65.17	75.97
DWRB 123	21.85	45.3	68.85	81.43
PL 426	15.76	34.59	55.07	65.27
SE(m)±	0.34	0.62	0.86	0.95
CD 5%	1.02	2.58	2.58	2.87
Interactions				
Factor (A) SE(m)±	0.97	1.81	2.54	3.00
CD (5%)	-	-	-	-
Factor (B) SE(m)±	0.80	1.46	2.03	2.32
CD 5%	-	-	-	-

Table 2. Effect of different dates of sowing on leaf area index (LAI) of barley cultivars

Treatments	Leaf area Index			
Main plot	**25 DAS**	**50 DAS**	**75 DAS**	**Harvesting stage**
30th October	1.86	2.51	3.42	4.28
5th November	1.64	2.29	3.11	3.83
10th November	1.49	2.15	2.80	3.30
15th November	1.38	2.09	2.78	2.90
SE(m)±	0.01	0.04	0.07	0.07
CD (5%)	0.03	0.12	0.21	0.21
Sub Plot				
DWRUB 52	1.19	1.77	2.48	3.32
DWRB 123	1.6	2.24	3.03	3.78
PL 426	1.99	2.77	3.56	3.92
SE(m)±	0.01	0.04	0.04	0.05
CD 5%	0.03	0.12	0.12	0.15
Interactions				
Factor (A) SE(m)±	0.02	0.07	0.10	0.13
CD (5%)	-	-	-	-
Factor (B) SE(m)±	0.03	0.08	0.10	0.11
CD 5%	-	-	-	-

Table 3. Effect of different dates of sowing on dry matter accumulation ($q\ ha^{-1}$) of barley cultivars

Treatments	Dry matter ($q\ ha^{-1}$)			
Main Plot	**25 DAS**	**50 DAS**	**75 DAS**	**Harvesting stage**
30th October	2.95	15.52	33.11	45.00
5th November	2.72	14.84	32.15	44.05
10th November	2.59	13.87	30.10	39.65
15th November	2.24	13.78	24.27	31.99
SE(m)±	0.06	0.36	1.29	1.78
CD (5%)	0.18	1.08	3.87	5.33
Sub Plot				
DWRUB 52	2.63	14.79	28.21	39.62
DWRB 123	3.14	16.74	34.72	43.37
PL 426	2.11	11.97	26.8	37.53
SE(m)±	0.03	0.25	0.80	0.83
CD 5%	0.09	0.75	2.40	2.49
Interactions				
Factor (A) SE(m)±	0.09	0.53	1.90	2.61
CD (5%)	-	-	-	-
Factor (B) SE(m)±	0.08	0.52	1.70	2.02
CD 5%	-	-	-	-

Table 4. Effect of different dates of sowing on yield attributes and grain yield of different barley cultivars

Treatments	No effective tillers(m^2)	Spike length(cm)	No. of grainsspike^{-1}	Test weight(g)
Main plot treatments				
30th October	125.71	9.48	46.11	47.30
5th November	108.38	8.68	35.55	43.33
10th November	91.93	7.68	30.32	39.43
15th November	74.28	6.65	25.77	31.97
SE(m)±	1.36	0.45	0.94	0.80
CD (5%)	4.07	1.35	2.82	2.40
Sub plot				
DWRUB 52	100.2	6.86	29.95	34.92
DWRB 123	107.56	8.05	33.73	41.39
PL 426	92.48	9.45	39.64	45.22
SE(m)±	0.46	0.20	0.36	0.32
CD 5%	1.38	0.60	1.08	0.96
Interactions				
Factor (A) SE(m)±	2.00	0.68	1.40	1.19
CD (5%)	-	-	-	-
Factor (B) SE(m)±	1.39	0.51	1.00	0.87
CD 5%	-	-	-	-

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