Indian Journal of Agronomy **67** (4): 374–379 (December 2022)

Research Paper

Growth indices, photosynthetic parameters and productivity of barley (*Hordeum vulgare*) as influenced by sowing dates and cutting management

BALWINDER SINGH DHILLON[1] AND HARI RAM[2]

Punjab Agricultural University, Ludhiana, Punjab 141 004

Received: February 2022; Revised accepted: October 2022

ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2015–16 and 2016–17 at the Punjab Agricultural University, Ludhiana, to study the effect of staggered sowing on growth indices, photosynthetic parameters and productivity of barley (*Hordeum vulgare* L.) in relation to different cutting management. The experiment was laid out in a split-plot design with 3 sowing dates, viz. 15 October, 30 October and 15 November in main plots and 5 cutting management, viz. un-cut (control), cut at 50 days after sowing (DAS), cut at 60 DAS, cut at 50 DAS + additional 15 kg N/ha after cut (N_{15}) and cut at 60 DAS + additional 15 kg N/ha after cut (N_{15})] in subplots, replicated 4 times. The results indicated that, the crop sown on 15 October registered the highest values of absolute growth rate (AGR) and crop growth rate (CGR) up to 120 days of crop-growth. Thereafter, crop sown on 15 November showed higher AGR and CGR values than that sown on 15 October and 30 October. Relative growth rate (RGR) was the highest in the crop sown on 15 October up to 30 days; 30 October up to 120 days and 15 November thereafter. Fodder cut at 50 DAS and cut at 50 DAS + N_{15} treatments resulted in the negative values of AGR, CGR and RGR during 30–60 DAS. Transpiration rate and stomatal conductance decreased significantly and progressively with each delay in sowing. Uncut crop recorded the highest transpiration rate (0.53 m mol/m^2/sec), whereas the crop cut at 60 DAS resulted in the lowest transpiration rate (0.26 m mol/m^2/sec). Crop sown on 15 October resulted in 11.9 and 47.9% more grain yield and 18.3 and 25.2% more fodder yield than that sown on 30 October and 15 November, respectively. Control and cutting for fodder at 50 DAS gave similar grain yields, but were significantly higher than the other cutting-management treatments.

Key words: Grain yield, Growth indices, Stomatal conductance, Transpiration rate

Barley (*Hordeum vulgare* L.) is a photo- and thermo-sensitive long-day plant. It is an important coarse cereal crop of India, being grown in northern plains as well as in northern hills, mostly under rainfed or limited irrigation condition on poor to marginal soils. Sowing date is one of the most important factors which influences the yield potential of any crop under given set of conditions. It affects crop performance by altering weather conditions prevailing during crop growth, especially germination and maturity period, consequently, affecting crop duration (Dhillon and Ram, 2020).

Barley can be utilized as a source of green fodder during an acute shortage of green fodder (November to January). The crop can be given 1 cut at definite time after sowing for green fodder and regenerated crop may be utilized for grain purpose. It will help in mitigating the fodder shortage. Barley possesses high total biomass, thus the small and marginal farmers of our country used green barley fodder as feed for milch animals (Singh *et al.,* 2012). Indian dairy industry is facing a lot of shortage of green forage during winter and summer seasons, especially in terms of cereal forage. Information on growth indices, photosynthetic parameters (transpiration rate and stomatal conductance) and productivity under variable environmental conditions is essential for identification and overcoming the yield constraints to amplify the crop potential. However, so far little information is available on such aspects of barley under Punjab conditions. Hence, an experiment was conducted to study the growth indices (absolute growth rate, crop-growth rate and relative growth rate), photosynthetic parameters (transpiration rate and stomatal conductance) and productivity of staggered sown barley in relation to different cutting-management practices.

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) seasons of 2015–16 and 2016–17 at the research

[1]**Corresponding author's Email:** dhillonbalwinder@pau.edu

[1]Agronomist, Regional Research Station, Punjab Agricultural University, Ballowal Saunkhri, SBS Nagar, Punjab 144 521; [2]Wheat Agronomist, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab 141 004

farm, Punjab Agricultural University, Ludhiana (30°56' N, 75°52' E and 247 m above the mean sea-level). Maximum air temperature varied from 17.2 to 36.6°C and 18.2 to 36.9°C, minimum from 7.3 to 19.6°C and 7.6 to 20.0°C, with mean temperature variation from 14.3 to 28.1°C and 12.9 to 28.5°C during 2015–16 and 2016–17, respectively (Fig. 1).

Total rainfall of 90.4 and 108.9 mm was received during respective crop season of 2015–16 and 2016–17. Overall, both the seasons were normal but rainfall during the crop season 2016–17 was reasonably distributed and 18.5 mm higher than during 2015–16. The experimental soil had *p*H 7.4 and 7.3, containing 0.37 and 0.39% organic carbon, 179.2 and 192.8 kg/ha available N, 28.5 and 31.3 kg/ha available P and 143.9 and 137.1 kg/ha available K during growing season of 2015–16 and 2016–17 respectively. The site was under sunhemp (*Crotalaria juncea* L.)–wheat (*Triticum aestivum* L.) cropping system for 3 years before the establishment of the experiment.

The field experiment was laid out in a split-plot design with 15 treatment combinations, consisting of 3 sowing dates (15 October, 30 October and 15 November) in main plots and 5 cutting management [un-cut, cut at 50 days after sowing (DAS), cut at 60 DAS, cut at 50 DAS + additional 15 kg N/ha after cut (N_{15}) and cut at 60 DAS + additional 15 kg N/ha after cut (N_{15})] in subplots.

Each treatment was replicated 4 times. The size of the subplots was 3.6 m × 6.0 m. Before sowing, seed was

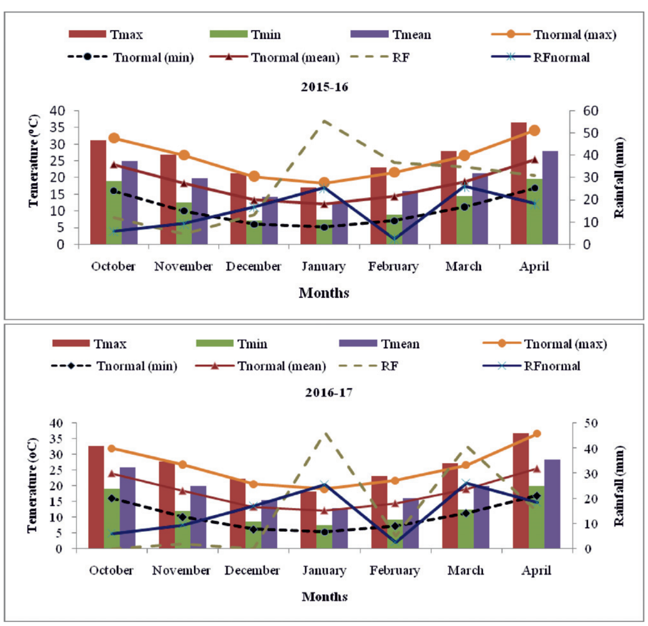

Fig. 1. Monthly and long–term average (normal) maximum temperature, minimum temperature, mean temperature and rainfall during 2015–16 and 2016–17 (Tmax, Maximum temperature; Tmin, Minimum temperature; Tmean, Mean temperature; RF, Rainfall; Normal means: 30 years average)

treated with Tebuconazole in the name of chemical; we must avoid trade name 'Raxil' @ 1.5 g/kg to control covered smut, loose smut and stripe disease. Barley variety 'PL 807' was sown at row-to-row and plant-to-plant spacing of 30 cm × 22.5 cm with single-row cotton drill. A uniform basal dose of nitrogen (62.5 kg N/ha), phosphorus (30 kg P_2O_5/ha) and potassium (15 kg K_2O/ha) was applied at the time of sowing through urea (46% N), single superphosphate (16% P_2O_5), and muriate of potash (60% K_2O), respectively. An additional dose of nitrogen @ 15 kg N/ha through urea was applied after taking fodder cutting. One irrigation was applied immediately after each cut only in cutting plots of crop. Instead of this irrigation, the other post-sowing irrigations were applied as per need. One hand-hoeing was given with the help of wheel hoe at 35 DAS. Under cutting management, crop was harvested from specified net plots for fodder purpose leaving the stumps of 5 cm for further regeneration. The crop was harvested at 15–18% grain moisture.

For estimation of dry matter above-ground plant samples from 50-cm-row length were taken periodically at 30, 60, 90 and 120 DAS. The samples were first sun-dried and thereafter, they were kept in an oven at a temperature of 60ºC to achieve constant weight. The dry weight thus obtained was recorded. Absolute growth rate (AGR), crop-growth rate (CGR) and relative growth rate (RGR) were calculated by using the formulae as suggested by Radford (1967).

Photosynthetic parameters, viz. transpiration rate and stomatal conductance, were measured at 90 DAS from fully-expanded apical leaves, using portable LCi photosynthesis system (ADC Bio-Scientific Limited). Green fodder was cut at height of 5 cm from the ground 50 and 60 days after sowing as per treatments. The grain yield was recorded as total weight and weight of threshed grains obtained from net plot area of each experimental unit, respectively, and expressed as kg/ha.

Analysis of variance was performed using Proc GLM procedure of SAS version 9.4 (SAS, 2017) and significant mean differences were tested using Fisher's protected least significant difference (LSD) test. For pooled analysis, the year was taken as a main factor to increase its precision.

RESULTS AND DISCUSSION

Growth indices

Dry-matter accumulation: The dry-matter accumulation increased continuously with the age of crop. Dry-matter accumulation decreased consistently, as the sowing was delayed from 15 October to 15 November through 30 October throughout the growing season of crop (Fig. 2). Dry-matter accumulation in 30 October sown crop was significantly higher than 15 November sown crop at 90 and

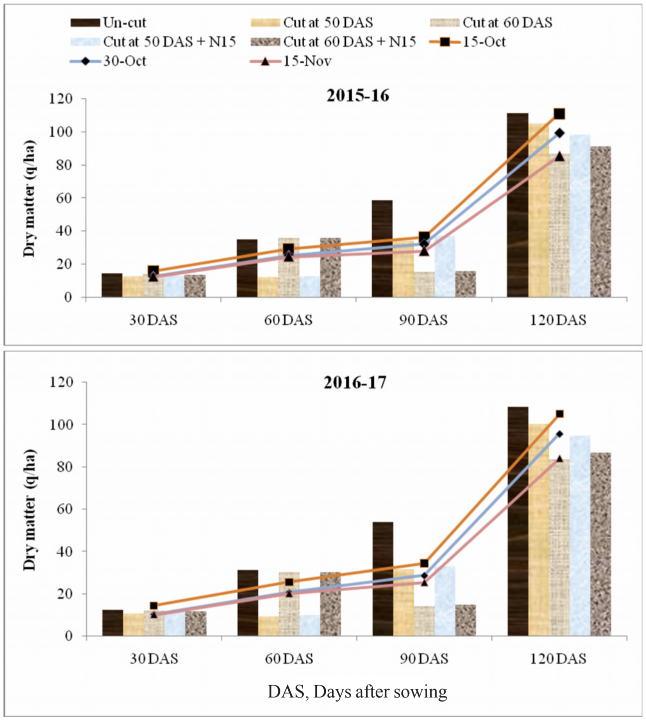

Fig. 2. Periodic dry-matter accumulation of barley under different sowing date and cutting management

120 DAS, whereas at 30 and 60 DAS, the dry-matter accumulation in 30 October and 15 November sown crop was statistically at par. The crop sown on 15 October accumulated 2.9 and 3.2 q/ha at 30, 3.7 and 4.5 q/ha at 60, 4.0 and 8.2 q/ha at 90 and 11.9 and 25.8 q/ha at 120 DAS during 1st year of study and 4.2 and 4.3 q/ha at 30, 4.9 and 5.4 q/ha at 60, 5.8 and 9.1 q/ha at 90, 9.1 and 20.8 q/ha at 120 DAS during 2nd year, being higher than 30 October and 15 November-sown crop respectively.

Cutting management significantly affected the periodic dry-matter accumulation at 60, 90 and 120 DAS during both the years. But at 30 DAS, cutting treatments did not differ significantly for dry-matter accumulation. At 60 DAS, un-cut, cut at 60 DAS and cut at 60 DAS + N_{15} treatments were found statistically at par with each other, accumulated significant higher dry-matter accumulation than cut at 50 DAS and cut at 50 DAS + N_{15} treatments during 1st and 2nd year respectively. There was significantly higher dry-matter at 90 and 120 DAS in un-cut treatment than the other cutting treatments. Cut at 60 DAS + N_{15} treatment resulted 4.5 and 3.0 q/ha higher dry matter at 120 DAS than cut at 60 DAS during 1st and 2nd year, respectively, which might be owing to application of additional dose of 15 kg N/ha after fodder cut that increased dry matter in this treatment (cut at 60 DAS + N_{15}). However, cut at 50 DAS + N_{15} treatment resulted 6.8 and 5.6 q/ha lower dry matter at 120 DAS than cut at 50 DAS during 1st and 2nd year, respectively, which might due to higher lodging of crop under this treatment (cut at 50 DAS + N_{15}). As reported by Acreche and Slafer (2011) in an experiment conducted in Spain and Berry and Spink (2012) in Ireland that higher lodging, highly reduced the dry matter production of wheat due to reduction in grain yield.

Absolute growth rate (g/m row length/day): Absolute growth rate (AGR) was higher during 90–120 DAS than during 0–30, 30–60 and 60–90 DAS and subsequent 120 DAS to maturity stages of the crop under all the treatments during both the years (Table 1). Crop sown on 15 October registered the highest values of AGR followed by 30 October and 15 November sown crop up to 120 days of crop growth during both the years. Thereafter, 15 November-sown crop recorded higher AGR than 15 October and 30 October sowing.

The quite narrow differences were observed for AGR among cutting management during 30–60 DAS during both the years. Fodder cut at 50 DAS and cut at 50 DAS + N_{15} treatments obtained the negative values of AGR during 30–60 DAS due to removing vegetation by fodder cutting

Table 1. Effect of sowing date and cutting management on absolute growth rate (AGR) of barley

Treatment	Absolute growth rate (g/m row length/day)									
	0–30 DAS		30–60 DAS		60–90 DAS		90–120 DAS		120 DAS-maturity	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Sowing date										
15 October	1.18	1.09	1.01	0.83	0.53	0.67	5.62	5.29	0.75	0.66
30 October	0.96	0.77	0.95	0.78	0.51	0.60	5.03	5.04	1.02	0.93
15 November	0.94	0.77	0.92	0.75	0.26	0.39	4.30	4.41	1.92	1.65
Cutting management										
Un-cut	1.10	0.95	1.55	1.40	1.76	1.72	3.97	4.08	0.79	0.68
Cut at 50 DAS	0.96	0.81	-0.02	-0.11	1.61	1.68	5.35	5.16	1.06	0.90
Cut at 60 DAS	1.05	0.90	1.64	1.36	-1.53	-1.20	5.35	5.23	1.22	1.09
Cut at 50 DAS + N_{15}	1.01	0.86	-0.04	-0.11	1.82	1.73	4.61	4.65	1.01	0.91
Cut at 60 DAS + N_{15}	1.03	0.88	1.67	1.40	-1.49	-1.16	5.64	5.40	1.24	1.17

N_{15}, 25% additional nitrogen after cut (15 kg N/ha); DAS, Days after sowing

reduced the dry matter of crop (Fig. 2). The higher values of AGR between 60 and 90 DAS were obtained under fodder cut at 50 DAS and cut at 50 DAS + N_{15} treatments as compared to fodder cut 60 DAS and cut at 60 DAS + N_{15} during 1st and 2nd year (Table 1). Between 60 and 90 DAS, fodder cut at 60 DAS and cut at 60 DAS + N_{15} recorded the lower values of AGR because of harvesting the crop for fodder at 60 DAS reduced the dry matter of crop under these treatments (Fig. 2). Application of additional dose of 15 kg N/ha after fodder cut resulted in progressive increase in AGR between 90 and 120 DAS and 120 DAS to maturity in cut at 60 DAS + N_{15} treatment, but reverse trend was observed in cut at 50 DAS + N_{15} treatment due to higher lodging of crop led to lower dry matter production at 120 DAS under later treatment (Fig. 2).

Crop growth rate (g/m²/day): Crop growth rate (CGR) increased up to 120 DAS under all sowing dates and decreased thereafter during both the years (Table 2). Crop sown on 15 October recorded the higher CGR than the late-sown crops (30 October and 15 November) up to 120 days of crop growth. Thereafter, the CGR of late-sown crop (15 November) surpassed the 15 October and 30 October-sown crop and maintained its superiority till maturity during both the years.

The quite narrow differences for CGR were observed among cutting management during growth period of 30–60 DAS. Fodder cut at 50 DAS and cut at 50 DAS + N_{15} treatments recorded lower and negative values of CGR between 30 and 60 DAS during 1st and 2nd year, respectively, which might be due to removing vegetation by cutting reduced the dry matter of crop. Thereafter, fodder cut at 50 DAS and cut at 50 DAS + N_{15} treatments recorded the higher values of CGR during 60–90 DAS than fodder cut 60 DAS and cut at 60 DAS + N_{15} during 1st and 2nd year respectively (Table 2). However, fodder cut at 60 DAS and cut at 60 DAS + N_{15} treatments recorded the lower values of CGR during 60–90 DAS which might be due to harvesting the crop for fodder at 60 DAS reduced the dry matter of crop (Fig. 2) under these treatments. Application of additional dose of 15 kg N/ha after fodder cut increased the crop growth which led to higher CGR during 90–120 DAS and 120 DAS to maturity under fodder cut at 60 DAS + N_{15} treatments. But in case of fodder cut at 50 DAS + N_{15} treatment, the CGR value not increased by application of additional 15 kg N/ha after fodder cut due to higher lodging of crop led to lower dry-matter production at 120 DAS (Fig. 2) under this treatment.

Relative growth rate (g/g/day): Crop sown on 15 October recorded the highest relative growth rate (RGR) during 0–30 DAS in both years (Table 3). However, during 30–60, 60–90 and 90–120 DAS, 30 October-sown crop recorded the higher RGR during 1st and 2nd year. The crop sown on 15 November recorded higher RGR between 120 DAS and maturity during 1st and 2nd year.

The quite narrow differences for RGR were observed among cutting management during growth period of 30–60 DAS. Fodder cut at 50 DAS, cut at 50 DAS + N_{15} during 30–60 DAS and cut at 60 DAS and cut at 60 DAS + N_{15} during 60–90 DAS showed negative values of RGR during 1st and 2nd year, because harvesting the crop for fodder at corresponding stages reduced the dry matter of crop (Fig. 2). Thereafter, fodder cut at 60 and cut at 60 DAS + N_{15} recorded the higher RGR during 90–120 DAS and 120 DAS to maturity.

Photosynthetic parameters

The transpiration rate and stomatal conductance decreased significantly and progressively with each delay in sowing (Table 4). But stomatal conductance did not differ due to cutting treatments. Uncut crop recorded the highest transpiration rate among the cutting treatments. Fodder cut at 50 DAS was statistically at par with cut at 60 DAS

Table 2. Effect of sowing date and cutting management on crop-growth rate (CGR) of barley

Treatment	Crop-growth rate (g/m²/day)									
	0–30 DAS		30–60 DAS		60–90 DAS		90–120 DAS		120 DAS-maturity	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Sowing date										
15 October	5.23	4.83	4.50	3.70	2.37	2.97	25.0	23.5	3.33	2.95
30 October	4.27	3.43	4.23	3.47	2.27	2.67	22.3	22.4	4.55	4.15
15 November	4.17	3.40	4.07	3.33	1.13	1.73	19.1	19.6	8.54	7.34
Cutting management										
Un-cut	4.87	4.20	6.87	6.20	7.80	7.63	17.6	18.1	3.52	3.01
Cut at 50 DAS	4.27	3.60	–0.10	–0.47	7.17	7.47	23.8	22.9	4.71	4.01
Cut at 60 DAS	4.67	4.00	7.27	6.03	–6.80	–5.33	23.8	23.2	5.43	4.84
Cut at 50 DAS + N_{15}	4.47	3.80	–0.17	–0.50	8.07	7.67	20.5	20.7	4.49	4.04
Cut at 60 DAS + N_{15}	4.57	3.90	7.40	6.20	–6.60	–5.13	25.0	24.0	5.51	5.21

N_{15}, 25% additional nitrogen after cut (15 kg N/ha); DAS, Days after sowing

Table 3. Effect of sowing date and cutting management on relative growth rate of barley

Treatment	Relative growth rate (g/g/day)									
	0–30 DAS		30–60 DAS		60–90 DAS		90–120 DAS		120 DAS-maturity	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Sowing date										
15 October	0.0732	0.0720	0.0090	0.0082	0.0032	0.0043	0.0162	0.0161	0.0012	0.0011
30 October	0.0702	0.0671	0.0100	0.0101	0.0034	0.0047	0.0163	0.0174	0.0018	0.0017
15 November	0.0699	0.0670	0.0099	0.0099	0.0019	0.0033	0.0161	0.0173	0.0040	0.0035
Cutting management										
Un-cut	0.0721	0.0700	0.0127	0.0131	0.0074	0.0080	0.0093	0.0101	0.0013	0.0012
Cut at 50 DAS	0.0702	0.0678	–0.0003	–0.0020	0.0145	0.0176	0.0164	0.0167	0.0018	0.0016
Cut at 60 DAS	0.0715	0.0693	0.0136	0.0133	–0.0122	–0.0110	0.0250	0.0258	0.0024	0.0023
Cut at 50 DAS + N_{15}	0.0709	0.0686	–0.0006	–0.0020	0.0153	0.0174	0.0141	0.0153	0.0018	0.0017
Cut at 60 DAS + N_{15}	0.0712	0.0689	0.0139	0.0138	–0.0116	–0.0103	0.0251	0.0255	0.0024	0.0023

N_{15}, 25% additional nitrogen after cut (15 kg N/ha); DAS, Days after sowing

+ N_{15}, whereas cut at 60 DAS resulted in the lowest transpiration rate. Similar results were also reported by Mani *et al.,* (2009) and Dhillon *et al.,* (2018).

Productivity

Early-sown crop, i.e. 15 October resulted in 18.3 and 25.2% higher green fodder yield than later-sown crops, i.e. 30 October and 15 November, respectively (Table 4). Higher green fodder yield under 15 October sowing was might be owing to higher growth attributes of barley. Fodder cut at 60 DAS gave significantly higher green fodder yield than the fodder cut at 50 DAS. It might be owing to more dry-matter production (Fig. 2). Time of cutting for fodder has great influence on the total green forage yield. Progressive reduction was recorded in grain yield due to delayed sowing during both the years. Crop sown on 15 October resulted in the highest grain yield which was significantly higher than the other sowing dates. Significantly higher grain yield was recorded under 15 October sowing, might be owing to fact that favourable environmental conditions at all phenological stages such as longer day-length led to higher photo-thermal units, high temperature conditions led to more accumulated growing degree-days under this sowing date. Therefore, early-sown crop (i.e. October 15) obtained higher growth parameters owing to which more supply of photosynthates to grains. Bhilare and Joshi (2007) and Rashid *et al*., (2010) also reported similar results. Un-cut crop gave the highest grain yield, which was statistically at par with fodder cut at 50 DAS, but significantly higher than the other treatments. Higher productivity under early cutting (i.e. at 50 DAS) treatment might be because of better growth with longer period than cutting at

Table 4. Effect of sowing dates and different cutting management on transpiration rate, stomatal conductance, fodder and grain yields of barley (mean of 2 years ± SD)

Treatment	Transpiration rate (m mol/m²/sec)	Stomatal conductance (mol/m²/sec)	Fodder yield (kg/ha)	Grain yield (kg/ha)
Sowing date				
15 October	0.20±0.03	0.11±0.01	17,772±4,200	4,064±471
30 October	0.39±0.05	0.13±0.01	15,026±2,156	3,631±431
15 November	0.52±0.06	0.16±0.03	14,194±2,716	2,746±447
SEm±	0.02	0.03	199	39
CD (P=0.05)	0.08	0.01	605	137
Cutting management				
Un-cut	0.53±0.03	0.10±0.01	-	3,928±491
Cut at 50 DAS	0.35±0.05	0.13±0.02	12,983±946	3,787±753
Cut at 60 DAS	0.26±0.06	0.15±0.03	18,452±2,687	3,080±525
Cut at 50 DAS + N_{15}	0.41±0.05	0.13±0.02	12,733±1,357	3,177±740
Cut at 60 DAS + N_{15}	0.32±0.06	0.16±0.04	18,489±2,623	3,430±629
SEm±	0.02	-	112	47
CD (P=0.05)	0.05	NS	339	150

N_{15}, 25% additional nitrogen after cut (15 kg N/ha); DAS, Days after sowing

60 DAS. Further delay in cutting from cut at 50 DAS to 60 DAS reduced the grain yield, might be due to reduced period for vegetative and reproductive growth. Delayed forage harvesting significantly reduced the leaf area of crop which caused reduction in the photosynthetic efficiency, and supply of photosynthates from source (leaves) to sink (grains) was restricted, which ultimately decreased the grain yield in cutting crop for fodder at 60 DAS. When crop was cut for fodder at 60 DAS also was under stress and took more number of days for regeneration due to less temperature conditions. Shortening of grain-filling period might have led to forced maturity, thereby more production of shriveled grains.

Thus, the crop sown on 15 October registered the highest values of absolute growth rate (AGR) and crop-growth rate (CGR). Fodder cut at 50 DAS and cut at 50 DAS + N_{15} treatments obtained the negative values of AGR, CGR and relative growth rate (RGR) between 30 and 60 DAS. Transpiration rate and stomatal conductance decreased significantly and progressively with each delay in sowing. Delayed sowing of barley resulted in a substantial reduction in fodder and grain yields. Un-cut and fodder cut at 50 DAS resulted in similar grain yield and significantly higher than the other cutting treatments. Cut at 60 DAS gave higher fodder yield but at the cost of 9.43–18.3% reduction in grain yield than cut at 50 DAS.

REFERENCES

Acreche, M.M. and Slafer, G.A. 2011. Lodging yield penalties as affected by breeding in mediterranean wheats. *Field Crops Research* **122**: 40–48.

Berry, P.M. and Spink, J. 2012. Predicting yield losses caused by lodging in wheat. *Field Crops Research* **137**: 19–23.

Bhilare, R.L. and Joshi, Y.P. 2007. Productivity and quality of oats (*Avena sativa* L.) in relation to cutting management and nitrogen level. *Indian Journal of Agronomy* **22**: 247–250.

Dhillon, B.S., Sharma, P.K. and Sardana, V. 2018. Influence of foliar application of boron and TIBA on photosynthetic parameters *vis-a-vis* productivity of sunflower (*Helianthus annuus* L.) under variable sowing dates. *Journal of Agrometeorology* **20**(1): 16–21.

Dhillon, B.S. and Ram, H. 2020. Agroclimatic indices and yield of barley (*Hordeum vulgare*) under different cutting management and sowing dates. *Indian Journal of Agronomy* **65**(2): 25–29.

Radford, P.J. 1967. Growth analysis formulae–their use and abuse. *Crop Science* **7**: 171–175.

Rashid, A., Khan, R.U., Marwal, S.K. and Ali, Z. 2010. Response of barley to sowing date and fertilizer application under rainfed condition. *World Journal of Agricultural Sciences* **6**: 480–485.

Singh, D., Singh, D.R., Nepalia, V. and Kumari, A. 2012. Performance of dual purpose barley (*Hordeum vulgare* L.) varieties for green fodder and subsequent productivity under varying seed rate and fertility management. *Forage Research* **38**: 133–137.