

Agroclimatic indices and yield of barley (*Hordium vulgare*) under different cutting management and sowing dates

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ABSTRACT

A field study was conducted to know the effect of cutting management on different agroclimatic indices and yield of barley (*Hordium vulgare* L.) in relation to sowing time during the winter (*rabi*) season of 2015–16 and 2016–17 at Ludhiana, Punjab. Results revealed that delay in sowing caused significant reduction in fodder, biological and grain yields of barley probably due to significant reduction in accumulated growing degree-days (GDD), heliothermal units (HTU) and photothermal units (PTU). The crop sown on 15 November resulted in 33.8 and 15.2% higher phenothermal index (PTI) at heading and 16.9 and 8.72% at physiological maturity, as compared to the crop sown on 15 October and 30 October, respectively. Among cutting management, the highest GDD, HTU, PTU, PTI for attainment of booting, heading and physiological maturity was recorded in fodder cut at 60 DAS (both with and without N application) than cut at 50 DAS and un-cut. Application of additional dose of 15 kg N/ha fodder cut at 50 and 60 DAS resulted the higher GDD, HTU, PTU, PTI than fodder cut at 50 and at 60 DAS without N application for attainment of heading and physiological maturity. The crop without fodder cutting and that cut at 50 DAS gave similar grain and biological yields and significantly higher than the other cutting treatments. Fodder cut at 60 DAS gave higher yield but at the cost of 9.43–18.3% reduction in grain yield than the crop cut at 50 DAS.

Key words : Barley, Growing degree-days, Phenothermal index, Physiological maturity

Barley is a cereal crop which is grown throughout the temperate, tropical and subtropical regions of the world. It is a valuable crop because it is used for food, processed food and feed for livestock. Traditionally, barley is considered as a poor man's crop and in India it is favoured because of its low-input requirement and better adaptability to harsh environments like drought, salinity/alkalinity and marginal lands. Whole barley grain contains important vitamins and high levels of minerals like calcium, magnesium, phosphorus, potassium, vitamin A, vitamin E and niacin. Each 100 g of barley grain comprises 10.6 g protein, 2.1 g fat, 64 g carbohydrate, 50 mg calcium, 6 mg iron, 0.31 mg vitamin B₂ and 50 µg folate (Vaughan *et al.*, 2006). Various environmental factors influencing growth are interception of photosynthetically active radiation (PAR), air and leaf temperature, relative humidity, prevailing wind speed, CO₂ concentration and soil moisture availability. Temperature and light play a key role in influencing

crop production. Sowing time influences the crop by subjecting it to variable temperature during growth period by affecting various physiological processes. Sowing time is an important non-monetary input that can be manipulated to avail the congenial environment for best yield accrual (Dhillon *et al.*, 2017).

Barley possesses high total biomass, thus the small and marginal farmers of our country used green barley fodder as feed for milch animals. So, barley can serve as an alternative for augmenting the green-forage demand in the arid and semi-arid areas of northern plains under limited irrigations along with satisfactory levels of grain yield from the regenerated crop, which can be utilized as feed for cattle or for human consumption.

In the present study, an attempt was made to evaluate the influence of different cutting practices on agroclimatic indices such as growing degree-days (GDD), heliothermal units (HTU), photothermal units (PTU) and phenothermal index (PTI) and productivity of barley sown on different dates.

MATERIALS AND METHODS

The field studies were conducted in the winter (*rabi*) seasons of 2015–16 and 2016–17 at Research Farm, De-

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partment of Agronomy, Punjab Agricultural University, Ludhiana (30°56' N, 75°52' E, 247 m above mean sea-level). The soil of the experimental site was loamy sand (Typic Ustipsamment) in texture with 0.36% organic carbon, 186.0 kg/ha available nitrogen, 29.9 kg/ha available phosphorous and 147.5 kg/ha available potassium. The soil pH and electrical conductivity were within the normal range. The bulk density was 1.6 Mg/m³ in the 0-1m soil profile. The site was a under sunnhemp (*Crotalaria juncea* L.)–wheat (*Triticum aestivum* L.) cropping system for 3 years before the establishment of the experiment. The field experiments was laid out in 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 (N₁₅) and cut at 60 DAS + additional 15 kg N/ha after cut (N₁₅)] in sub-plots. Each treatment was replicated 4 times. The size of the subplots was 3.6 by 6.0 m. Before sowing, seed was treated with Raxil (tebuconazole) @ 1.5 g/kg to control covered smut, loose smut and stripe disease. Barley variety 'PL 807' was sown with single-row cotton drill. The crop was raised with a row-to-row spacing of 30 cm and plant-to-plant spacing of 22.5 cm. The full recommended doses of nitrogen (62.5 kg N/ha), phosphorus (30 kg P₂O₅/ha) and potassium (15 kg K₂O/ha) were applied basal through urea, single superphosphate (SSP) and muriate of potash (MoP), respectively. An additional dose of nitrogen@15 kg/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. The crop was harvested at 15–18% grain moisture. Crop was irrigated as per requirement. 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 agroclimatic indices, namely growing degree-days (GDD), heliothermal units (HTU), photothermal units (PYU), phenothermal index (PTI) were worked out. Growing degree-days (GDD) were determined as per Nuttonson (1955).

$$\text{GDD} = \frac{T_{\max} + T_{\min}}{2} - T_{\text{base}}$$

where, T_{max}, daily maximum temperature (°C); T_{min}, daily minimum temperature (°C); T_{base}, base temperature for barley was taken as 4.4 °C as suggested by Nuttonson (1956).

Heliothermal units (HTU), the product of GDD and corresponding actual sunshine hours for that day were

computed on daily basis as:

$$\text{HTU} = \text{GDD} \times \text{Actual sunshine hours}$$

Photothermal units (PTU), the product of GDD and corresponding day-length for that day were computed on daily basis as follows:

$$\text{PTU} = \text{GDD} \times \text{Day-length}$$

where day-length refers to maximum possible sunshine hours.

Growing degree-days, heliothermal units and photothermal units were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to give accumulated indices.

Phenothermal index (PTI), the ratio of degree-days to the number of days between two phenological stages was calculated as:

$$\text{PTI} = \frac{\text{Degree-days consumed between 2 phenological stages}}{\text{Number of days between 2 phenological stages}}$$

Green fodder was cut at height of 5 cm from the ground after 50 and 60 days after sowing as per treatments. The biological and 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. Data were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS 9.4) to evaluate differences between treatments.

RESULTS AND DISCUSSION

Weather parameters

Daily rainfall and maximum, minimum and mean temperatures during barley-growing seasons (2015–16 and 2016–17) and long-term averages of the last 30 years (normal) were measured at the PAU Meteorological Station, located approximately 200 m away from the experimental site. Seasonal weather data including maximum temperature, minimum temperature, mean temperature and cumulative monthly rainfall recorded during 2015–16 and 2016–17 are shown in Figs. 1 and 2. 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. Total rainfall of 90.4 and 108.9 mm was received during respective crop seasons 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. Consequently, to meet the water requirement of crop more number of irrigations was given during the first year than the second year.

Agrometeorological indices

Growing degree-days: Crop sown on 15 October re-

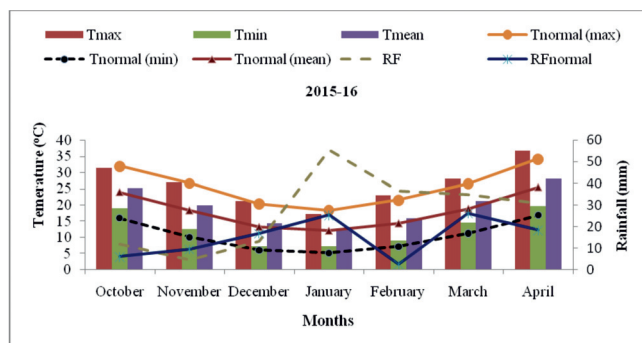


Fig. 1. Monthly and long-term average (normal) maximum temperature, minimum temperature, mean temperature and rainfall during 2015–16.

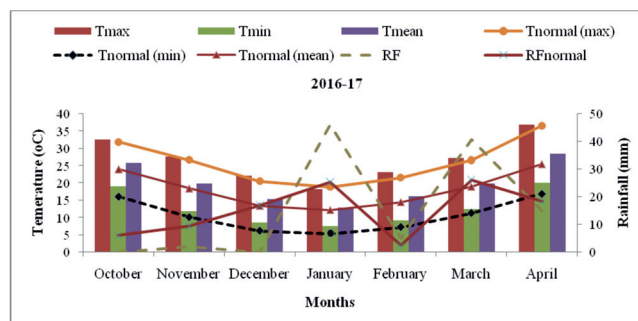


Fig. 2. Monthly and long-term average (normal) maximum temperature, minimum temperature, mean temperature and rainfall during 2016–17.

corded significantly higher growing degree-days (GDD) than the crop sown on 30 October and 15 November at jointing, booting, heading and physiological maturity (Table 1). Higher GDD accumulation by 15 October sowing was attributed to higher number of days taken by 15 October-sown crop to booting, heading and physiological maturity due to lower temperature. The crop sown on 15 November recorded significantly lower GDD at jointing, booting, heading and physiological maturity than the other 2 sowing dates. Early sowing resulted in more accumulation of growing degree-days to crop (Sattar *et al.*, 2015). Cutting for fodder at different stages significantly increased the GDD at booting, heading and physiological maturity of barley. The highest GDD for attainment of booting, heading and physiological maturity was recorded in fodder cut at 60 DAS (both with and without N application) recorded than cut at 50 DAS and un-cut. Application of additional dose of 15 kg N/ha after fodder cut at 50 and 60 DAS re-

sulted in the higher GDD than fodder cut at 50 and 60 DAS, respectively for attainment of booting, heading and physiological maturity. Because nitrogen was available for longer period with additional nitrogen application increase in number of days taken to booting, heading and physiological maturity by the crop led to higher GDD.

Heliothermal units: Significantly higher heliothermal units (HTU) were noticed at jointing, booting, heading and physiological maturity in crop that sown on 15 October than 30 October and 15 November-sown crop (Table 1). The crop sown on 15 October recorded 31.9 and 30.2% higher HTU at jointing, 21.6 and 20.8% at booting, 14.9 and 8.70% at heading and 11.2 and 16.3% at physiological maturity, than the crop sown on 30 October and 15 November, respectively. This might be due to duration of sunshine hours were more in 15 October-sown crop as compared to 30 October and 15 November-sown crop. The decrease in number of HTU with delay in sowing for at-

Table 1. Accumulated growing degree-days (GDD, °C days) and heliothermal units (HTU, °C days hr) during different phenological stages of barley affected by cutting management and sowing (pooled analysis over 2 seasons)

Treatment	Jointing		Booting		Heading		Physiological maturity	
	GDD	HTU	GDD	HTU	GDD	HTU	GDD	HTU
<i>Sowing date</i>								
15 October	808	4,499	1,308	6,641	1,401	7,151	2,207	13,696
30 October	688	3,066	1,122	5,204	1,244	6,079	1,968	12,159
15 November	579	3,141	990	5,258	1,153	6,529	1,739	11,469
SEM±	2	21	3	49	2	33	1	36
CD (P=0.05)	8	67	10	159	8	110	4	131
<i>Cutting management</i>								
Un-cut	692	3,568	1,025	5,062	1,140	5,687	1,873	11,685
Cut at 50 DAS	692	3,568	1,112	5,488	1,238	6,328	1,945	12,294
Cut at 60 DAS	692	3,568	1,223	6,213	1,352	7,239	2,034	12,867
Cut at 50 DAS + N ₁₅	692	3,568	1,115	5,507	1,242	6,375	1,957	12,401
Cut at 60 DAS + N ₁₅	692	3,568	1,226	6,236	1,360	7,302	2,052	12,959
SEM±	–	–	1	15	1	11	2	20
CD (P=0.05)	NS	NS	5	48	5	38	6	67

N₁₅, 25% additional nitrogen after cut (15 kg N/ha); DAS, days after sowing

taining a particular stage may be due to the prevailing of low temperature conditions during the growth period of later-sown crop. Cutting management had no effect on HTU at jointing. However, the highest HTU for attainment of booting, heading and physiological maturity was recorded in fodder cut at 60 DAS (both with and without N application) than the other treatments. Application of additional dose of 15 kg N/ha after fodder cut at 50 DAS and cut at 60 DAS resulted in the accumulation of higher HTU for attainment of booting, heading and physiological maturity than fodder cut at 50 and 60 DAS respectively. Accumulation of higher HTU with additional nitrogen application attributed due to increase in number of days taken to booting, heading and physiological maturity by the crop. The crop sown on 15 October accumulated significantly higher photothermal units (PTU) than 30 October and 15 November-sown crops (Table 2). The crop sown on 15 October recorded 12.2 and 18.1% higher PTU at heading and 10.8 and 20.7% at physiological maturity, than 30 October and 15 November-sown crops, respectively. Higher PTU accumulation at booting, heading and physiological maturity in 15 October sowing was attributed to higher number of days taken to attain these growth stages. Similar observations recorded by Pal *et al.* (2013). Cutting management had no effect on PTU at jointing. However, delay in the fodder cut significantly increased the PTU at booting, heading and physiological maturity of crop. Application of additional dose of 15 kg N/ha after fodder cut at 50 DAS and cut at 60 DAS resulted in the accumulation of more PTU for attainment of booting, heading and physiological maturity, than without N application after fodder cut at 50 and 60 DAS, respectively.

Significantly higher pheno-thermal index (PTI) at jointing and booting was recorded in 15 October than 30 October and 15 November sowing (Table 2). However, at heading and physiological maturity, PTI accumulated in 15 November sowing was significantly higher than 15 October and 30 October sowing. Sowing on 15 November resulted in 33.8 and 15.2% higher PTI at heading and 16.9 and 8.72% at physiological maturity as compared to 15 October and 30 October sowing, respectively. Cutting management did not differ from each other with respect to PTI at jointing. However, at booting, heading and physiological maturity, PTI accumulation of fodder cut at 60 DAS and cut at 60 DAS + N₁₅ treatments was statistically at par with each other, but were significantly higher than the other treatments. Un-cut crop recorded significantly lower PTI at heading and physiological maturity than the other cutting treatments.

Productivity

Fodder yield:

The crop sown on 15 October gave 18.3 and 25.2% higher green-fodder yield than the crops sown on 30 October and 15 November respectively (Table 3). Higher green-fodder yield under 15 October sowing was attributed to higher growth attributes, *i.e.* plant height, tiller density *etc.* The higher green-fodder yield of early sowing date was due to higher day-length led to higher photo-thermal units (Table 2), high temperature conditions led to more accumulated growing degree-days (Table 1) owing to which higher plant height, tiller density and leaf-area index, ultimately enhancing the green-fodder yield under early sowing. Fodder cut at 60 DAS resulted in significantly higher green-

Table 2. Accumulated photothermal units (PTU °C day hr) and PTI, photothermal index °C days/day) during different phenological stages of barley as affected by sowing dates and cutting management (pooled analysis over 2 seasons)

Treatment	Jointing		Booting		Heading		Physiological maturity	
	PTU	PTI	PTU	PTI	PTU	PTI	PTU	PTI
<i>Sowing date</i>								
15 October	8704	14.8	13891	9.46	14903	8.6	24325	14.3
30 October	7240	12.0	11743	8.65	13082	11.0	21708	15.7
15 November	5956	9.3	10332	8.97	12201	13.0	19297	17.2
SEm±	33	0.1	34	0.02	20	0.2	17	0.03
CD (P=0.05)	114	0.5	116	0.08	81	0.7	57	0.1
<i>Cutting management</i>								
Un-cut	7300	12.0	10751	8.92	11981	9.0	20533	14.1
Cut at 50 DAS	7300	12.0	11679	8.90	13056	10.5	21433	15.3
Cut at 60 DAS	7300	12.0	12894	9.21	14374	12.0	22558	16.8
Cut at 50 DAS + N ₁₅	7300	12.0	11705	8.89	13110	10.6	21582	15.4
Cut at 60 DAS + N ₁₅	7300	12.0	12914	9.21	14456	12.1	22778	17.0
SEm±	-	-	15	0.01	17	0.1	23	0.03
CD (P=0.05)	NS	NS	54	0.05	56	0.6	73	0.1

N₁₅, 25% additional nitrogen after cut (15 kg N/ha); DAS, days after sowing

Table 3. Effect of sowing dates and different cutting management on fodder, biological and grain yields of barley (pooled analysis over 2 seasons)

Treatment	Fodder yield (kg/ha)	Biological yield (kg/ha)	Grain yield (kg/ha)
<i>Sowing date</i>			
15 October	17,772	12,298	4,064
30 October	15,026	11,289	3,631
15 November	14,194	10,127	2,746
SEm±	199	112	39
CD (P=0.05)	605	342	137
<i>Cutting management</i>			
Un-cut	–	11,976	3,928
Cut at 50 DAS	12,983	11,730	3,787
Cut at 60 DAS	18,452	10,434	3,080
Cut at 50 DAS + N ₁₅	12,733	11,110	3,177
Cut at 60 DAS + N ₁₅	18,489	10,940	3,430
SEm±	112	123	47
CD (P=0.05)	339	402	150

N₁₅, 25% additional nitrogen after cut (15 kg N/ha); DAS, days after sowing

fodder yield might be owing to 10 days longer period of vegetative growth than cut at 50 DAS, which led to more photosynthesis and photosynthates and their translocation to growth parameters such as plant height, dry matter, number of tillers, leaf area *etc.*, which ultimate led to more production of green-fodder yield. Similar results were also reported by Krishna *et al.* (1998).

Grain and biological yields: Progressive reduction was observed in biological and grain yields due to delayed sowing during both the years. The crop sown on 15 October recorded maximum biological and grain yields which were significantly higher than other sowing dates. Significantly higher biological and grain yields were obtained under 15 October sowing, which might be owing to fact that favourable environmental conditions at all phenological stages such as longer day-length led to higher photo-thermal units (Table 2), high temperature conditions led to more accumulated growing degree-days (Table 1) in this sowing date. Therefore, early sown crop (*i.e.* 15 October), obtained higher growth parameters owing to which more supply of photosynthates to grains. Similar results were reported by Rashid *et al.* (2010). The crop without fodder cutting recorded the highest grain and biological yields, which was statistically at par with fodder cut at 50 DAS, but significantly higher than the other treatments. Higher biological and grain yields of early-cutting (*i.e.* at 50 DAS)

treatment might be owing to better growth with longer period than cutting at 60 DAS. Further delay in cutting from cut at 50 DAS to 60 DAS resulted reduction in grain and biological yields, might be due to reduced period for vegetative and reproductive growth. After Delayed forage harvesting, significantly reduced the leaf area of crop which causes reduction in the photosynthesis efficiency and restriction on supply of photosynthates from source (leaves) to sink (grains) that ultimately reduced the grain yield for the crop cut for fodder at 60 DAS. Shortening of grain-filling period might have led to forced maturity, thereby more production of shriveled grains.

The early-sown barley crop performed better in terms of accumulation and utilization of heat units, because of very close relation between temperature and plant development. The highest GDD, HTU, PTU, PTI for attainment of booting, heading and physiological maturity was recorded in fodder cut at 60 DAS. The crop without fodder cutting and that cut at 50 DAS gave similar grain and biological yields and significantly higher than the other cutting treatments.

REFERENCES

- Dhillon, B.S., Sharma, P.K. and Kingra, P. K. 2017. Agronomic measures to improve thermal energy utilization by spring sunflower. *Journal of Agrometeorology* **19**: 34–38.
- Krishna, A., Raikhakar, and Reddy, A.S. 1998. Effect of planting pattern and nitrogen on fodder maize (*Zea mays*) intercropped with cowpea (*Vigna unguiculata*). *Indian Journal of Agronomy* **43**(2): 237–240.
- Nuttonson, M.Y. 1955. *Wheat Climate relationships and Use of Phenology in Ascertaining the Thermal and Photothermal Requirement of Wheat*, 338 pp. American Institute of Crop Ecology, Washington DC, USA.
- Nuttonson, M.Y. 1956. *A comparative study of lower and upper limits of temperature in measuring variability of day-degree summation of wheat, barley and rye*. American Institute of Crop Ecology, Washington DC, USA.
- Pal, R.K., Rao, M.N.N. and Murty, N.S. 2013. Agro-meteorological indices to predict plant stages and yield of wheat for foothills of western Himalayas. *The International Journal of Agriculture Food Science and Technology* **9**: 909–14.
- 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 Agriculture and Soil Science* **6**: 480–485.
- Sattar, A., Iqbal, M.M., Areeb, A., Ahmed, Z., Irfan, M., Shabbir, R.N., Aisha, G. and Hussian, S. 2015. Variety variation in wheat for phenology and accumulative heat unit under different sowing times. *Journal of Environmental and Agricultural Sciences* **2**: 1–8.
- Vaughan, J.G., Judd, P.A. and Bellamy, D. 2006. “The Oxford Book of Health Foods”. <http://books.google.co.in/books>. pp: 37.