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THERMAL TIME REQUIREMENT AND FODDER YIELD OF DUAL PURPOSE BARLEY (*HORDIUM VULGARE* L.) AS INFLUENCED BY SOWING DATES AND CUTTING MANAGEMENT IN A SEMI-ARID ENVIRONMENT

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SUMMARY

Field experiments were conducted during 2015-16 and 2016-17 at the Punjab Agricultural University, Ludhiana, to study the effect of different sowing dates and fodder cutting stages along with nitrogen application on the phenological stages of barley. The experiment was laid out in split-plot design with three sowing dates (October 15, October 30 and November 15) in main plots and five cutting management [un-cut (control), cut at 50 days after sowing (DAS), cut at 60 DAS, cut at 50 DAS + additional 15 kg N/ha after the cut (N_{15}) and cut at 60 DAS + additional 15 kg N/ha after the cut (N_{15})] in subplots, replicated four times. Results revealed that the late sown crop (*i.e.* November 15) sowing recorded a significantly higher number of days to emergence, tillering, jointing and regeneration. October 15 sowing took significantly higher days to booting, heading and physiological maturity. Fodder cut at 50 DAS regenerated significantly faster than cut at 60 DAS. The booting, heading and physiological maturity was delayed significantly by a delay in fodder harvest. Application of an additional dose of nitrogen (15 kg N/ha) after fodder cut (50 and 60 DAS) took significantly more days to maturity as compared to without N application. One fodder cut of barley taken at 50 DAS without any significantly grain yield reduction and it can be delayed up to 60 DAS to get more production of green fodder (40.5 to 41.8%) than that at 50 DAS.

Key words : Barley, cutting management, phenology, regeneration, sowing date

Barley (*Hordeum vulgare* L.) is a *rabi* cereal crop that is cultivated mainly for grain production. It can also be grown as a dual-purpose crop for providing good quality fodder as well as grains. Temperature plays the most important role in almost all biological processes of crop plants and hence the growth and development of living biota (Kaur *et al.*, 2019). Under changing climatic conditions, various management options viz. date of sowing, cutting for fodder etc. are important production components that can be manipulated to counter the adverse effects of environmental stresses. Matching the phenology of the crop to the duration of favourable environmental conditions to avoid periods of stress is crucial for maximum yield and resource use efficiency under changing climate.

Sowing date is one of the most important factors which influence the yield potential of any crop under a 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 Uppal, 2019). In India, barley is grown from November to March, as it requires cool and moist weather during the vegetative phase, and warm and dry weather during the reproductive phase. Cardinal (minimum, maximum and optimum) temperature is one of the most critical parameters that decide the fate of crop productivity in barley. However, barley sowing after the rice is delayed because of late harvesting of rice, large turn around time and poor soil tilth of seedbed which forces delaying of wheat sowing to varying degrees. Barley yield under such circumstances is mainly affected by terminal heat and water stress. The reproductive phase is the ultimate determinant of yield, if faces high-temperature stress shows a significant impact on yield (Mitra and Bhatia, 2008).

Different barley cultivars take different times from germination to maturity under varied agro-climatic conditions. Therefore, crop development phases alone cannot be considered as a good predictor for measuring abiotic stress. In view of this, the present investigation was made to evaluate the effect of different management options *viz.* sowing time and fodder cutting stages along with nitrogen application etc on various phonological stages of barley in Indo-Gangetic Plains of India so that suitable adaptation measures can be explored to improve its productivity because of changing climatic conditions.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season 2015-16 and 2016-17 at Research Farm, Department of Agronomy, the Punjab Agricultural University, Ludhiana (30°56' N latitude, 75°52' E longitude and an elevation of 247 metres above the mean sea level). The soil of location was a loamy sand (Typic Ustipsamment) in texture, low in available N and soil organic carbon (SOC) status. However, high in available–P, available–Zn, available–Fe, available–Cu and available–Mn and medium in available–K. The soil pH and electrical conductivity were within the normal range. The bulk density was 1.6 Mg m^{-3} in the 0-1m soil profile. The site was under sunhemp-wheat (*Triticum aestivum* L.) cropping system for three years before the establishment of the experiment. The field experiments was laid out in split-plot design with 15 treatment combinations consisting of three sowing dates (October 15, October 30 and November 15) in main plots and five cutting management [un-cut, cut at 50 DAS, cut at 60 DAS, cut at 50 DAS + additional 15 kg N/ha after the cut (N_{15}) and cut at 60 DAS + additional 15 kg N/ha after the cut (N_{15})] in subplots. Each treatment was replicated four times. The size of the subplots was 3.6 by 6.0 m. Before sowing, the seed was treated with Raxil @ 1.5 g/kg to control covered smut, loose smut and stripe disease. Barley variety PL 807 was sown at a row to row and plant to plant spacing of 30 × 22.5 cm with a single row cotton drill. A uniform basal dose of nitrogen (62.5 kg N/ha), phosphorous (30 kg P_2O_5/ha) and potassium (15 kg K_2O/ha) were applied at the time of sowing in the form of 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 the crop. Instead of this irrigation, the other post sowing irrigations were applied as per need. The crop was harvested at 15–18% grain moisture. The crop was irrigated as per requirement. One hand hoeing was given with the help of a wheel hoe at 35 DAS. Undercutting management, crop was harvested from specified net plots for fodder purposes leaving the stumps of 5 cm for further regeneration.

The days took to attain different phenological stages namely emergence, tillering, jointing, booting, heading and physiological maturity were recorded through visual observations. Data on booting was taken, when 80 per cent tillers showed the swollen base of flag leaf but before the emergence of awns out of flag leaf whorl, was taken as days to boot leaf stage. When grains were hard but still have more moisture about 30-50%, crushed between the finger with some force and crop started giving yellow look from outside of the plot was taken as days to physiological maturity stage. Daily maximum and minimum temperature and sunshine hours during the crop growing period were recorded from the agrometeorological observatory.

Green fodder was cut at height of 5 cm from the ground after 50 and 60 days after sowing as per treatments. Green fodder yield from net plot was weighed and converted into q/ha.

Grain equivalent yield (GEY)

Yield of individual crop was converted into equivalent yield (q ha^{-1}) on the basis of prevailing market price of the crop (Anjaneyulu *et al.,* 1982). It was calculated by the following formula:

$$\text{GEY} = \text{Grain yield of barley} + \frac{\text{Fodder yield of barley} \times \text{Fodder price}}{\text{Grain Price}}$$

The price (₹ q^{-1}) of barley green fodder was 200 and grains for calculation of GEY was 1225 and 1325 during 2015-16 and 2016-17, respectively.

RESULTS AND DISCUSSION

Weather parameters

The maximum, minimum and mean temperature and rainfall were measured at agro-meteorological observatory of PAU, Ludhiana. The 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

TABLE 1
Mean monthly meteorological data during *rabi* 2015-16 and 2016-17

Months	Max Temp (°C)		Min Temp (°C)		Mean Temp (°C)		Rainfall (mm)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
October	31.3	32.7	19.0	19.0	25.1	25.9	16.4	0
November	26.9	27.7	12.6	12.0	19.8	19.9	0	2.0
December	21.3	22.2	7.3	8.6	14.3	15.4	1.7	0
January	17.2	18.2	7.4	7.6	12.3	12.9	19.4	46.1
February	23.0	23.1	9.0	9.3	16.0	16.2	8.8	5.2
March	28.0	27.2	14.6	12.5	21.3	19.9	41.1	40.8
April	36.6	36.9	19.6	20.0	28.1	28.5	3.0	14.8

Where, Max Temp: Maximum temperature, Min Temp: Minimum temperature.

and 2016-17, respectively (Table 1). 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 irrigations was given during the first year than the second year.

Phenology of barley

Days taken to emergence: Seedling emergence constitutes the basis of optimum plant population, which ultimately contributes to the crop yield. Days taken to emergence were strongly influence by weather conditions. The germination of crop is mainly depends on soil temperature (Nelson, 1963). The maximum cardinal temperature for germination of barley is 38 to 40°C, whereas, minimum is 3.5 to 5°C and the optimum is 20°C (Malik, 1980).

Sowing dates had a significant effect on days taken to emergence because of changed weather conditions especially temperature (Table 2). If we look at the mean temperature of days taken to the emergence in case of October 15, October 30 and November 15 sown crop it was 25.4, 21.1 and 20.3°C, respectively, during 1st year and 25.3, 21.9 and 19.3°C, respectively, during 2nd year of study. Due to favourable temperature conditions prevalent in the third week of October, the October 15 sown crop (4.0 and 4.3) took a minimum number of days to emergence, which was significantly lower than October 30 (5.0 and 4.8) and November 15 (6.3 and 6.8) sown crop during 1st and 2nd year, respectively. November 15 sown crop took the maximum number of days to emergence. The emergence delayed in November 15 sown crop due to lowering of temperature (Table 1).

Days taken to tillering: November 15 sown crop (28.0 and 28.8) took a maximum number of days to tillering, which was significantly higher than October 15 (each 26.8) and October 30 sown crop (27.0 and 28.8) during 1st and 2nd year, respectively (Table 2). October 15 sown crop took a minimum number of days to tillering. More days taken for commencement of tillering under late sowing conditions might be due to low-temperature conditions prevailing during that period of the later sown crop. Rooney *et al.* (1989) reported that low temperature during the early stages of growth promotes tiller production, whereas, high temperature during the same phase inhibited tillering or increased tiller mortality. Due to low-temperature conditions, it took more days to accumulate the required heat units. As fodder cut was taken later in the season so cutting management practices did not affect the days taken to tillering. Similar results were observed by Rickman *et al.* (1985).

Days taken to jointing: At the jointing stage plant develops its vegetative parts like stem, nodes start multiplying and internodal distance becomes longer. Crop sown on November 15 (48.8) took significantly more number of days for the attainment of jointing than October 15 (47.0) and October 30 (47.5) during 1st year, but during 2nd year, November 15 (48.0) and October 30 (47.8) were statistically at par with one another (Table 2). October 15 sown crop took the least number of days to jointing during both the years of study. As fodder cut was taken later in the season so cutting management did not affect the days taken to jointing.

Days taken to regeneration: The crop sown on November 15 (6.6 and 7.3) took significantly more number of days for regeneration than the October 15 (5.6 and 5.9) and October 30 (6.0 and 6.5) sown crop during 1st and 2nd year, respectively (Table 2).

TABLE 2
Effect of sowing date and cutting management on phenological stages of barley

Treatment	Days taken to													
	Emergence		Tillering		Jointing		Regeneration		Booting		Heading		Physiological maturity	
	15-16	16-17	15-16	16-17	15-16	16-17	15-16	16-17	15-16	16-17	15-16	16-17	15-16	16-17
Sowing date														
October 15	4.0	4.3	26.8	26.8	47.0	47.0	5.6	5.9	99.3	100.9	110.2	111.8	166.8	168.1
October 30	5.0	4.8	27.0	28.0	47.5	47.8	6.0	6.5	96.8	98.4	108.0	109.6	154.5	155.9
November 15	6.3	6.8	28.0	28.8	48.8	48.0	6.6	7.3	92.5	94.9	104.7	108.1	139.9	141.8
LSD (P=0.05)	0.5	0.4	0.5	0.5	0.6	0.5	0.2	0.4	0.2	0.1	0.2	0.2	0.2	0.2
Cutting management														
Un-cut	5.1	5.3	27.3	27.8	47.8	47.6	-	-	83.9	85.7	96.1	98.4	149.3	150.6
Cut at 50 DAS	5.1	5.3	27.3	27.8	47.8	47.6	4.3	4.8	94.0	95.6	105.6	107.5	152.3	153.9
Cut at 60 DAS	5.1	5.3	27.3	27.8	47.8	47.6	7.9	8.3	104.3	106.4	114.8	117.3	156.3	158.2
Cut at 50 DAS + N_{15}	5.1	5.3	27.3	27.8	47.8	47.6	4.3	4.8	94.3	95.8	106.0	107.8	153.2	154.4
Cut at 60 DAS + N_{15}	5.1	5.3	27.3	27.8	47.8	47.6	7.9	8.3	104.5	106.7	115.5	117.8	157.2	159.0
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	0.2	0.1	0.4	0.3	0.3	0.2	0.3	0.3

N_{15}= 25% additional nitrogen after cut (15 kg N/ha).

October 15 sown crop took significantly less number of days for regeneration as compared to other two sowing dates.

Fodder cut at 50 DAS (4.3 and 4.8) regenerated significantly faster than fodder cut at 60 DAS (7.9 and 8.3) during 1st and 2nd respectively. It might be due to early growth and initiation of active tillering period and favourable environment like congenial temperature for regeneration. The fodder cut at 60 DAS took more days for regeneration because crop at this stage was in late tillering stage and stem elongation had started.

Days taken to booting: The booting is one of the most important growth stage of barley crop. Days taken to booting are strongly influenced by the prevailing environmental conditions and varieties grown. Significantly higher number of days was taken by October 15 (99.3 and 100.9) sown crop to booting than October 30 (96.8 and 98.4) and November 15 (92.5 and 94.9) sowing during 1st and 2nd year, respectively (Table 2). October 15 sown crop took 2.5 and 6.8 days more than October 30 and November 15 sown crop, respectively during 1st year and 2.5 and 6.0 days more than October 30 and November 15 sown crop, respectively during 2nd year of study. The minimum number of days for attaining booting were recorded in November 15 sown crop. Similar results were reported earlier by Mumtaz *et al.* (2015).

Significantly early booting was found in un-cut crop (83.9 and 85.7) than the fodder cut at 50 DAS (94.0 and 95.6) and cut at 60 DAS (94.3 and 95.8) during 1st and 2nd year of study, respectively. Booting was delayed significantly by a delay in fodder harvest. There was a delay of 10.2 and 10.9 days in booting by 10 days delay in fodder harvest during 1st and 2nd year, respectively. Application of additional dose of nitrogen (15 kg N ha^{-1}) after fodder cut 50 DAS (94.3 and 95.8 during 1st and 2nd year, respectively) took a maximum number of days to booting than fodder cut at 50 DAS. Similarly, the application of an additional dose of nitrogen (15 kg N ha^{-1}) after fodder cut at 60 DAS (104.5 and 106.7 during 1st and 2nd year, respectively) also took a maximum number of days to heading than fodder cut at 60 DAS.

Days taken to heading: Environment conditions prevailing at the heading significantly influence the grain yield and yield attributes of barley. October 15 (110.2 and 111.8) sown crop took maximum calendar days to heading which was significantly higher than October 30 (108.0 and 109.6) and November 15 (104.7 and 108.1) sowing during 1st and 2nd year, respectively (Table 2). October 15 sown crop took 2.2 and 5.5 more days than October 30 and November 15 sowing, respectively during the 1st year and 2.2 and 3.7 more days than October 30 and November 15 sowing, respectively during the 2nd year of study. November 15 sown crop took least number of days to heading under high temperature. Similar results were observed earlier by Ram *et al.* (2012).

TABLE 3
Interaction effect of sowing date and cutting management with respect to green fodder yield (q/ha) of barley during 2015-16

Sowing date	Cutting management			
	Cut at 50 DAS	Cut at 60 DAS	Cut at 50 DAS + N_{15}	Cut at 60 DAS + N_{15}
October 15	135.7	211.3	137.9	210.8
October 30	125.8	162.2	123.9	159.4
November 15	115.6	157.0	111.1	159.7
LSD (P=0.05): 6.8				

N_{15}= 25% additional nitrogen after cut (15 kg N/ha).

TABLE 4
Interaction effect of sowing date and cutting management with respect to green fodder yield (q/ha) of barley during 2016-17.

Sowing date	Cutting management			
	Cut at 50 DAS	Cut at 60 DAS	Cut at 50 DAS + N_{15}	Cut at 60 DAS + N_{15}
October 15	135.7	226.6	138.7	225.0
October 30	139.0	175.2	138.3	178.4
November 15	121.3	176.8	120.1	174.0
LSD (P=0.05): 7.7				

N_{15}= 25% additional nitrogen after cut (15 kg N/ha).

Among cutting treatments, fodder cut at 50 DAS (105.6 and 107.5) attained heading significantly earlier than fodder cut at 60 DAS (114.8 and 117.3) during the 1st and 2nd year, respectively. There was a further delay of 9.5 and 10.0 days in attaining heading stage with the delay of 10 days for fodder harvest during 1st and 2nd year of study, respectively. Application of additional dose of nitrogen (15 kg N/ha) after fodder cut at 50 DAS (106.0 and 107.8 during 1st and 2nd year, respectively) took a maximum number of days to heading, which was significantly higher than cut at 50 DAS. Similarly, the application of an additional dose of nitrogen (15 kg N/ha) after fodder at 60 DAS (115.5 and 117.8 during 1st and 2nd year, respectively) also took a maximum number of days to heading, which was significantly higher than cut at 60 DAS. Dolan *et al.* (2006) showed that higher nutrient availability and favourable soil conditions due to N fertilizer could be a possible reason for delayed phonological stages in N-treated plots.

Days taken to physiological maturity: October 15 (166.8 and 168.1) sowing took a maximum number of days to physiological maturity, which was significantly higher than October 30 (154.5 and 155.9) and November 15 (139.9 and 141.8) sowing during 1st and 2nd year, respectively (Table 2). Crop sown on October 15 took 7.4 and 16.1 per cent during 1st year and 7.3 and 15.6 per cent during 2nd year of study, higher days to physiological maturity as compared to October 30 and November 15 sowing, respectively. The lower number of days to physiological maturity in October 30 and November 15 sown crop was due to a sudden rise in temperature late in the season. Often, flowering in many crops is not induced, until substantial vegetative growth has been accomplished. At that stage, certain external stimuli such as temperature and photo-period trigger floral induction (Copeland and Mcdonald, 1995). Accumulation of required heat units and biomass are some of the pre-requisite for commencement of a particular pheno-phase. Due to low-temperature conditions, early sown crop took more days to accumulate the required heat units and the required dry matter accumulation. Therefore, the crop took more days for attaining various phenological stages in early sown conditions. Similarly, very high-temperature conditions and comparatively low humidity (Table 1)

TABLE 5
Interaction effect of sowing date and cutting management with respect to grain equivalent yield (q/ha) of barley during 2015-16.

Sowing date	Cutting management				
	Un-cut	Cut at 50 DAS	Cut at 60 DAS	Cut at 50 DAS + N_{15}	Cut at 60 DAS + N_{15}
October 15	45.6	69.3	73.0	62.5	76.0
October 30	42.2	61.3	58.8	55.3	63.0
November 15	33.0	48.8	51.3	42.2	53.1
LSD (P=0.05): 3.8					

N_{15}= 25% additional nitrogen after cut (15 kg N/ha).

TABLE 6
Interaction effect of sowing date and cutting management concerning grain equivalent yield (q/ha) of barley during 2016-17.

Sowing date	Cutting management				
	Un-cut	Cut at 50 DAS	Cut at 60 DAS	Cut at 50 DAS + N_{15}	Cut at 60 DAS + N_{15}
October 15	40.9	63.9	67.2	58.8	72.5
October 30	39.5	59.0	57.0	53.0	62.5
November 15	34.4	47.3	51.5	38.9	52.2
LSD (p=0.05): 4.1					

N_{15}= 25% additional nitrogen after cut (15 kg N/ha).

during the grain filling stage of the later sown crop (November 15), led the crop to forced maturity. Similar results were also reported earlier by Basu *et al.* (2014) and Sattar *et al.* (2015).

Significantly less number of days was taken by un-cut treatment for maturity (149.3 and 150.6 days during 1st and 2nd year of study, respectively) than fodder cut treatments. The fodder cut at 60 DAS took significantly more days to maturity than the fodder cut at 50 DAS. Application of an additional dose of nitrogen (15 kg N/ha) after each fodder cut (50 and 60 DAS) took significantly more days to maturity as compared to without N application after each fodder cut during both the years of study. It might be due to the fact of maintenance of crop nutrition for building up photosynthetic apparatus of plant for a longer period.

Fodder yield

Total green fodder production per unit area is the most important aspect of fodder crops and is one of the criteria to assess the efficiency of various treatments. The data on green fodder yield have been presented in Table 3 & 4.

During 1st year, a progressive decrease in green fodder yield with delay in sowing was observed. October 15 sown crop produced the highest green fodder yield when cut was taken at 50 DAS and it was significantly better than October 30 and November 15 during 1st year of study. But during 2nd year, green fodder yield was statistically similar by cutting fodder at 50 DAS under October 15 and October 30 sowing which was significantly better than November 15. However, in case cutting 60 DAS, October 15 sown crop gave significantly more green fodder yield than October 30 and November 15 during both the years of study. October 30 and November 15 sown crops produced statistically similar green fodder yield under cutting management 60 DAS during both the years of study.

Grain equivalent yield

Interaction effect of sowing date and cutting management concerning grain equivalent yield was found to be significant during both the years of study. Data on the interaction between sowing date and cutting management have been presented in Tables 5 and 6. Fodder cut at 60 DAS + N_{15} recorded the highest grain equivalent yield of crop sown on October 15 which was statistically similar with the cut at 60 DAS during 1st year, but significantly higher than all other treatments during both the years of study. Grain equivalent yield of un-cut crop was significantly lower in all three sowing dates viz., October 15, October 30 and November 15 than cut at 50 DAS, cut at 60 DAS, cut at 50 DAS + N_{15} and cut at 60 DAS + N_{15}. Application of an additional dose of 15 kg N ha^{-1} after fodder cut at 60 DAS increased the grain equivalent yield in all three sowing dates. But grain equivalent yield in all three sowing dates *viz.,* October 15, October 30 and November 15 decreased with the application of an additional dose of 15 kg N ha^{-1} after fodder cut at 50 DAS might be due to more lodging under this treatment in each sowing date i.e. October 15, October 30 and November 15.

CONCLUSIONS

The results of the study indicated that October 15 sowing took significantly higher days to booting, heading and physiological maturity. Fodder cut at 50 DAS regenerated significantly faster than cut at 60 DAS. Booting, heading and physiological maturity were delayed significantly by delay in fodder harvest. Application of an additional dose of nitrogen (15 kg N/ha) after each fodder cut (50 and 60 DAS) took significantly more days to maturity. One fodder cut of barley may be taken at 50 DAS without any significantly yield reduction and it can be delayed up to 60 DAS to get more production of green fodder (40.5 to 41.8%) than that at 50 DAS but at the cost of 20.6-22.7% reduction in grain yield.

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