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Influence of cutting management on photosynthetic parameters, heat use efficiency and productivity of barley (*Hordium vulgare* L.) under variable sowing dates

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ABSTRACT

Field experiments were conducted during 2015–16 and 2016–17 at Punjab Agricultural University, Ludhiana, to study the effect of staggered sowing on photosynthetic parameters, heat use efficiency and the productivity of barley (*Hordium vulgare* L.) in relation to different cutting management. 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^{-1} after cut (N_{15}) and cut at 60 DAS + additional 15 kg N ha^{-1} after cut (N_{15})] in sub plots,replicated four times. The results indicated that photosynthetic parameters (PAR interception, chlorophyll index and normalized difference vegetation index) decreased significantly and progressively with each delay in sowing. Heat use efficiency and helio thermal use efficiency of October 15 and October 30 sown crops were statistically similar. Delay in sowing caused significant reduction in fodder, grain and biological yield of barley probably due to significant reduction in photosynthetic parameters.Nitrogen application after fodder cut improved the chlorophyll index, whereas, cutting did not influence the normalized difference vegetative index (NDVI).Un-cut crop recorded higher PAR interception.Significantly higher heat use efficiency and helio thermal use efficiency were recorded in un-cut crop. Un-cut and fodder cut at 50 DAS produced similar grain and biological yield and significantly higher than other cutting treatments. Cut at 60 DAS gave higher fodder yield but at the cost of 9.43-18.3 per cent reduction in grain yield than cut at 50 DAS.Correlation studies indicated significant positive correlation of grain yield with photosynthetic parameters, emphasizing the importance of higher growth and photosynthetic rate during reproductive period for best yield accrual from barley.

Keywords : Barley, chlorophyll, cutting management,grain yield andheat use efficiency

Barley (*Hordeum vulgare* L.) is a hardy crop which is grown throughout the temperate and tropical regions of the world. In production, it ranks fourth after rice, maize and wheat and is usually used as food for human beings and feed for animals and poultry.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 factor which influence 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.

Barley possesses regeneration capacity like other cereals after taking it as fodder before jointing stage. The regeneration ability of barley can be put to use by taking one cutting during the active vegetative growth stage and then leaving the regenerated crop for grain production (Mishra and Kumar, 2002). 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. Looking to its high total biomass and salt tolerance nature, there has been an increasing interest in exploiting barley as a dual purpose cereal, which can permit forage production in early season in addition to the grain yield later on (Singh *et al.,* 2012). Since berseem and oats are not available due to water shortage, in such areas, barley being a fast growing crop with high biomass in early stages can be utilized as green fodder with very limited water supply or less rainfall in these areas. In drier parts of northern plains (Rajasthan, Madhya Pradesh, Southern Haryana, South West Punjab and Western Uttar Pradesh) during *rabi* season, farmers can grow dual purpose barley over other forage crops because of its dual utilization and less water requirement (Verma *et al.,* 2007). In these regions, animal husbandry occupies an important role and there is a big gap between demand and supply of forage. Under Punjab conditions, green fodder availability is only 28.4 kg per animal against a requirement of 40.0 kg per animal. So, barley can serve as 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. Efficiency of conversion of heat in to dry matter depends upon sowing time and crop type. The concept of thermal use efficiency has been used by several scientists to compare the performance of different crops sown on several sowing dates (Mrudula *et al.*, 2012).Information on photosynthetic parameters, thermal use efficiency and productivity under variable environmental conditions is essential for identification and overcoming theyield constraints to amplify the crop potential. However, sofar little information is available on such aspects of barley under Punjab conditions. Hence, experiment wasconducted to study the photosynthesis, thermal use efficiency and productivity of staggered sown barley in relation to different cutting management practices.

MATERIALS AND METHODS

The field experiment was conducted during two consecutive barley growing seasons (2015–16 and 2016–17) at Research Farm, Department of Agronomy, 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 selected for conducting experiment 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 a under sunhemp-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 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^{-1} after cut (N_{15}) and cut at 60 DAS + additional 15 kg N ha^{-1} after cut (N_{15})]in sub plots.Each treatment was replicated four times.The size of the subplotswas 3.6 by 6.0 m.Before sowing, seed was treated with Raxil @ 1.5 g kg^{-1} 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 x 22.5 cm with single row cotton drill. A uniform basal dose of nitrogen (62.5 kg N ha^{-1}), phosphorous (30 kg P_2O_5 ha^{-1}) and potassium (15 kg K_2O ha^{-1}) were applied at the time of sowing in the form of urea (46% N), single super phosphate (16% P_2O_5), and muriate of potash (60% K_2O), respectively. An additional dose of nitrogen @ 15 kg N ha^{-1} 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 per cent 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.

Observations on photosynthetically active radiations at 90 DAS and 120 DAS were recorded at between 12:30 to 1:30 pm, on clear sunny day using line quantum facing sensor. The incoming, transmitted and reflected PAR were measured by keeping the sensor upward on the top of canopy, bottom of the canopy and by sensor facing invertedat about 10 cm above the soil surface, respectively. The intercepted PAR (%) was calculated by using following formula:

$$PARI(\%) = \frac{PAR(I) - PAR(T) - PAR(R)}{PAR(I)} \times 100$$

where,

PAR (I), PAR (T) and PAR (R) are the incident, transmitted and reflected photo-synthetically active radiations, respectively.

Chlorophyll index (CI) was measured periodically at 90 and 120 DAS from fully expanded apical leaves, using a portable SPAD Chlorophyll Meter (Model-CCM-200, Opti-Sciences, Inc.). Normalized difference vegetative index (NDVI) was measured at 90 and 120 DAS using green seeker. Green seeker was revolved over the crop canopy in each plot and mean value given by instrument at the end was recorded for final presentation. The NDVI was calculated from reflectance measurements in the red and near infrared (NIR) portion of the spectrum:

$$NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}}$$

Where, R_{NIR} is the reflectance of near infrared radiation and

R_{Red} is the reflectance of visible red radiation.Heat use efficiency was calculated by using the grain yield, biomass yield and growing degree days consumed to produce that grain yield and biomass yield, respectively. The heat use efficiency was calculated using the following formula:

Heat use efficiency = Grain or biological yield / AGDD

Where,

AGDD=Accumulated growing degree days (°C day)

Base temperature for barley was taken as 4.4°C as suggested by Nuttonson (1956).The helio thermal use efficiency was calculated using the following formula:

Helio thermal use efficiency = Grain yield / HTU

Where,

HTU= Helio thermal units (°C day hour)

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^{-1}. 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

Maximum, minimum and mean temperatures and rainfall were measured at agro–meteorological observatory of PAU, Ludhiana. 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 (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 number of irrigations was given during the first year than the second year.

Photosynthetic parameters

Data in Table 2 reveals that PAR interception, chlorophyll index and normalized difference vegetation index (NDVI)decreased significantly and progressively with each delay in sowing. Crop sown on October 15 recorded higher chlorophyll index, which was significantly higher than October 30 and November 15 at 90 and 120 DAS (days after sowing). Higher chlorophyll index of October 15 sown crop was attributed due to earlier sowing crop has higher day length due to which harvested more sunlight which increased photosynthesis, which ultimately increased the chlorophyll of leaves. Whereas, the chlorophyll index of later sown crop may be attributed to prevalence of lower temperature and less leaf are index at the corresponding stages. At 120 DAS, chlorophyll index was reduced due to translocation of photo assimilates to the developing grains. Similar results were reported by Ahmed *et al.* (2015).Fodder cut at 50 DAS + N_{15} results the higher chlorophyll index at 90 DAS, which was statistically at par with cut at 60 DAS + N_{15} treatment but it was significantly higher than other treatments which might be due to application of additional dose of 15 kg N ha^{-1} after fodder cut significantly increased the chlorophyll index of barley in cut at 50 DAS + N_{15} treatment. At 120 DAS, fodder cut at 60 DAS + N_{15} recorded significantly higher chlorophyll index than other treatments. Reduction in chlorophyll index of cut at 50 DAS + N_{15} treatment at 120 DAS was attributed to higher lodging of the crop. The increase in chlorophyll index due to additional dose of nitrogen may be ascribed to the role of N in chlorophyll synthesis: a pigment responsible for photosynthesis. Similar results were reported by Zubriski and Zimmerman (1974) and Robinson (1978).

PAR interception at 90 and 120 DAS of October 15 sowing was significantly higher than other sowing dates. Higher PAR interception of October 15 sown crop was attributed because of higher leaf area index recorded under this sowing date. Un-cut crop recorded significantly higher PAR interception at 90 DAS than other cutting treatments, whereas, at 120 DAS, PAR interception of un-cut crop was statistically at par with fodder cut at 50 DAS and cut at 50 DAS + N_{15}. The maximum PAR interception recorded in un-cut crop might be due to the retention of forage led to higher LAI in un-cut crop.

Normalized difference vegetation index (NDVI) of October 15 sowing was 6.7 and 9.6 per cent at 90 DAS and 7.0 and 13.9 per cent at 120 DAS, higher than October 30 and November 15 sowing, respectively. Raun *et al.* (2005) reported that higher NDVI values were recorded in timely sown maize than late sown. However, cutting treatments did not exerted significant effect on NDVI. All interactions were found to be non-significant.

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

Table 2: Photosynthetic parameters of barley as influenced by sowing dates and different cutting management (Mean of two years±S.D.)

Treatment	Chlorophyll index		PAR interception (%)		NDVI	
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS
Sowing date						
October 15	37.1±7.46	25.1±4.81	72.9±13.8	87.0±5.25	0.80±0.05	0.76±0.05
October 30	28.6±8.31	21.5±4.92	66.2±12.4	78.5±5.42	0.75±0.06	0.71±0.06
November 15	41.7±5.29	30.5±6.05	61.7±12.8	72.6±3.99	0.73±0.07	0.67±0.06
LSD (P=0.05)	1.9	2.5	2.4	1.7	0.02	0.03
Cutting management						
Un-cut	35.7±7.57	24.9±5.63	88.0±6.36	82.6±6.56	0.74±0.06	0.70±0.07
Cut at 50 DAS	33.3±8.31	24.3±4.92	67.6±6.79	81.5±7.32	0.79±0.07	0.74±0.07
Cut at 60 DAS	31.2±8.48	22.0±6.82	54.1±5.68	74.3±6.56	0.74±0.06	0.69±0.07
Cut at 50 DAS + N_{15}	40.8±7.04	28.0±6.31	68.9±6.69	81.6±7.91	0.78±0.06	0.72±0.07
Cut at 60 DAS + N_{15}	38.2±6.95	29.2±5.01	55.9±6.87	76.8±7.14	0.75±0.06	0.72±0.06
LSD (P=0.05)	2.5	1.6	2.3	1.9	NS	NS

N_{15}= 25% additional nitrogen after cut (15 kg N ha^{-1})

Heat use efficiency

The heat use efficiency (HUE) for grain yield under the October 15 and October 30 was statistically at par but significantly higher than November 15 sowing crop (Table 3). Sowing date had non-significant effect on HUE for biomass.Significantly higher HUE for grain and biomass recorded in un-cut crop than other cutting treatments. HUE for grain and biomass was significantly decreased with delay in fodder harvest. Application of additional dose of 15 kg N ha^{-1} after fodder cut at 50 DAS significantly decreased the HUE for grain and biomass of barley might be due to more lodging which led to less grain yield under this treatment (Table 4).Whereas, application of additional dose of 15 kg N ha^{-1} after cut at 60 DAS significantly increased the HUE for grain and biomass of barley might be due to more grain and biomass in this treatment than without N application treatment.

The helio thermal use efficiency (HTUE) under the October 15 and October 30 was statistically at par but significantly higher than November 15 sowing crop. Un-cut crop recorded significantly higher HTUE as compared to other treatments. HTUE was significantly decreased with delay in fodder harvest. Application of additional dose of 15 kg N ha^{-1} after fodder cut at 50 DAS significantly decreased the HTUE might be due to less grain yield. Whereas, application of additional dose of 15 kg N ha^{-1} after fodder cut at 60 DAS significantly increased the HTUE might be due to more grain yield under this treatment.

Table 3: Heat use efficiency (HUE) and heliothermal use efficiency (HTUE) of barley as influenced by sowing dates and different cutting management (Mean of two years±S.D.)

Treatment	HUE (kg ha^{-1}°C day^{-1})		HTUE (kg ha^{-1} °C day^{-1}hr^{-1})
	Grain	Biomass	
Sowing date			
October 15	1.85±0.26	5.59±0.53	0.23±0.06
October 30	1.85±0.26	5.75±0.59	0.23±0.06
November 15	1.59±0.30	5.84±0.80	0.18±0.05
LSD (P=0.05)	0.07	NS	0.01
Cutting management			
Un-cut	2.10±0.15	6.44±0.62	0.26±0.06
Cut at 50 DAS	1.93±0.24	6.01±0.45	0.23±0.06
Cut at 60 DAS	1.50±0.16	5.12±0.35	0.18±0.04
Cut at 50 DAS + N_{15}	1.61±0.27	5.70±0.43	0.19±0.05
Cut at 60 DAS + N_{15}	1.67±0.19	5.37±0.43	0.20±0.05
LSD (P=0.05)	0.07	0.21	0.01

N_{15}= 25% additional nitrogen after cut (15 kg N ha^{-1})

Table 4: Effect of sowing dates and different cutting management on fodder, grain yield and biological yield of barley (Mean of two years±S.D.)

Treatment	Fodder yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Sowing date			
October 15	17772±4200	4064±471	12298±917
October 30	15026±2156	3631±431	11289±930
November 15	14194±2716	2746±447	10127±1138
LSD (P=0.05)	605	137	342
Cutting management			
Un-cut	-	3928±491	11976±819
Cut at 50 DAS	12983±946	3787±753	11730±1411
Cut at 60 DAS	18452±2687	3080±525	10434±1001
Cut at 50 DAS + N_{15}	12733±1357	3177±740	11110±1469
Cut at 60 DAS + N_{15}	18489±2623	3430±629	10940±1280
LSD (P=0.05)	339	150	402

N_{15}= 25% additional nitrogen after cut (15 kg N ha^{-1})

Fodder, grain and biological yields

October 15 sowing crop recorded 18.3 and 25.2 per cent higher green fodder yield than October 30 and November 15 sowing crop, respectively (Table 4). Higher green fodder yield under October 15 sowing was attributed to higher growth attributes.Fodder cut at 60 DAS produced significantly higher green fodder yield than the fodder cut at 50 DAS. It might be due to more dry matter production and more plant height. Time of cutting for fodder has great influence on the total green forage yield.

Progressive reduction was observed in grain and biological yields due to delayed sowing during both the years of study. Crop sown on October 15 recorded the highest grain and biological yields which were significantly higher than other sowing dates. Significantly higher grain and biological yields were obtained under October 15 sowing might be due to fact that favourable environmental

Table 5: Correlation (Pearson correlation coefficients) between photosynthetic parameters (Chlorophyll Index, PAR interception and NDVI), HUE,HTUE and yield of barley

Parameters	Chlorophyll index		PAR interception		NDVI		HUE	HUE	HTUE
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	(Grain)	(Biomass)	
Grain yield	0.34** (0.0001)	0.38** (<0.0001)	0.58** (<0.0001)	0.75** (<0.0001)	0.43** (<0.0001)	0.57** (<0.0001)	0.86** (<0.0001)	0.38** (<0.0001)	0.42** (<0.0001)
Biological yield	0.27** (0.0007)	0.30** (0.0026)	0.55** (<0.0001)	0.70** (<0.0001)	0.44** (<0.0001)	0.56** (<0.0001)	0.82** (<0.0001)	0.56** (<0.0001)	0.34** (0.0002)

** = Significant at 1 and 5% level of significance Parenthesis value indicates $P \leq 0.05$ and $P \leq 0.01$

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 in this sowing date. Therefore, early sowing crop (i.e. October 15) obtained higher growth parameters due to which more supply of photosynthates to grains. Similar results were reported earlier by Rashid *et al*. (2010). Un-cut crop recorded the highest grain and biological yields, which was statistically at par with fodder cut at 50 DAS, but significantly higher than other treatments. Higher grain and biological yields of early cutting (i.e. at 50 DAS) treatment might be due to better growth with longer period than cutting at 60 DAS. Further delay in cutting from cut at 50 DAS to 60 DAS, grain and biological yields reduction might be due to reduced period for vegetative and reproductive growth. After delayed forage harvest, due to which significantly reduced the leafarea of crop due to which reduction in the photosynthesis efficiency and supply of photosynthates from source (leaves) to sink (grains) was restricted, which ultimately reduction of grain yield in cutting crop for fodder at 60 DAS. When crop was cut for fodder at 60 DAS also under impose to 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.

Correlation study

Simple Pearsons correlation between grain and biological yield (Table 5) with various photosynthetic parameters and heat use efficiency of barley reveal positive correlation of grain and biological yield with chlorophyll index, PARI, NDVI, heat use efficiency (grain and biomass), helio thermal use efficiency.

CONCLUSION

From this study it may concluded that delay in sowing from October 15 to November 15 caused significant reduction in photosynthetic parameters as well as the fodder, grain and biological yield of barley probably due to significant reduction in photosynthetic parameters. Delayed sowing of barley resulted in a substantial reduction in fodder, grain and biological yields due to shorter the vegetative and reproductive phase under late sown crop. Significantly higher heat use efficiency and helio thermal use efficiency were recorded in un-cut crop. Un-cut and fodder cut at 50 DAS produced similar grain and biological yield and significantly higher than other cutting treatments. Cut at 60 DAS gave higher fodder yield but at the cost of 9.43-18.3 per cent reduction in grain yield than cut at 50 DAS.

REFERENCES

Ahmed, B., Sultana, M., Zaman, J., Paul, S.K., Rahman, M., Islam, R. and Majumdar, I. (2015). Effect of sowing dates on the yield of sunflower. *Bangladesh Agron. J.,* 18:1-5.

Mishra, B.N. and Kumar, S.(2002)."Barley: Text book of Field Crop Production". In: Rajendra Prashad (Tech. ed.) Directorate of Information and Publication of Agricultural, Indian Council of Agricultural Research, New Delhi. pp: 228.

Mrudala, G., Ashok, R.Y. and Rao, S. B. S. N. (2012). Quantification of heat units for chickpea under coastal environment of Andhra Pradesh. *J. Agrometeorol.,* 14 (1): 82-84.

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. *Am. Inst. Crop Ecol, Washington D.C.*

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 J. Agric. Sci.,* 6: 480-85.

Raun, W.R., Solie, J.B., Martin, K.L., Freeman, K.W., Stone, M.L., Johnson, G.V. and Mullen, R.W. (2005). Growth stage, development and spatial variability in corn evaluated using optical sensor readings. *J. Plant Nutr.,*28: 173-82.

Robinson, R.G. (1978). "Production and Culture". In: Carter J.F. (eds.): Sunflower Sci & Tech Madison. WI, ASA. *Agron.,* 19: 89-143.

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 Res.,* 38: 133-37.

Verma, R. P. S., Khrub, A. S., Sharma, R. K., Singh, R. and Mishra, B.(2007). "Jau Anusandhan– Paramparik se Vayasayik Upyog ki Aur".Directorate of Wheat Research, Karnal. Res. Bull.23, 36.

Zubriski, J.C. and Zimmerman, D.C. (1974). Effects of nitrogen, phosphorus and plant density on sunflower. *Agron. J.,*66: 798-801.

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