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Research Paper

Effect of sowing time and cutting - management on growth, productivity and economics of barley (*Hordeum vulgare*)

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ABSTRACT

An experiment was carried out during the winter season of 2015–16 and 2016–17 at Ludhiana, Punjab, to study the performance of barley (*Hordeum vulgare* L.) as influenced by sowing time and different cutting-management practices. Crop sown on 15 October had the maximum plant height, dry-matter accumulation and tiller density throughout the life span of crop as compared to the other 2 sowing dates i.e. 30 October and 15 November. This date also resulted in significantly higher grain yield and fodder yield than the other 2 sowing dates. Fodder cutting at 50 days after sowing (DAS) provided at par grain yield with no-cutting treatment during both the years. Though fodder cutting at 60 DAS resulted in more green fodder (40.5 to 41.8%) than 50 DAS, significant reduction in grain yield (20.6–22.7%) was recorded in both the years. Economically, crop sown on 15 October produced significantly higher gross returns, net returns and benefit: cost (B: C) ratio than the other 2 sowing dates. However, fodder cut at 60 DAS + N_{15} gave significantly higher gross returns, net returns and benefit: cost ratio as compared to the other treatments.

Key words: Barley, Cutting management, Economics, Grain yield

In world, about 70% of barley is used for animal feed, 20% for malting and 5% for direct food use, whereas its straw is used for making hay and silage. This crop was grown on 589.4 thousand hectares and recorded a production of 1437.5 thousand tones, with an average yield of 24.39 q/ha in India, during 2015–16 (PAU, Ludhiana 2017). It is considered as an important coarse cereal crop of India, being grown on marginal and sub-marginal lands with low inputs. Sowing time affects crop performance by altering weather conditions prevailing during the crop growth, especially germination and maturity period, thus, causing variation in duration of various phenophases, and consequently crop duration. Early sowing always results in higher yield than late sowing. Variation in weather conditions among and within seasons is one of the most important constraints affecting yield potential (Murungu and Madanzi, 2010). In addition to agriculture, livestock plays an important role in strengthening rural economy of northern regions. Of late, it has been observed that in the drier parts of northern plains there is an acute shortage of green fodder in winter season. To improve the productivity of animals, availability of adequate quantity of nutritive fodder is pre-requisite. The productivity of milch animals in India is very low as compared to developed countries, primarily due to less availability of nutritive feed and fodder to animals (Patel *et al.,* 2011). The estimated requirement of green and dry fodder in the country is 1,400 and 950 million tonnes, respectively, against the corresponding availability of 250 and 440 million tonnes (Chotiya and Singh, 2005). To maintain good health and potential of animals in terms of milk, meat and wool, feeding of quality fodder is highly important (Bhilare and Joshi, 2007).

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). Therefore, it is reasonable to assume that one cutting for green forage at active growth stage will reduce the lodging chances in barley. It will also help in mitigating the fodder shortage. Under Punjab conditions, green fodder availability is only 28.4 kg/animal against a requirement of 40.0 kg/animal. 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

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irrigations along with satisfactory levels of grain yield from the regenerated crop, which can be utilized as feed for cattle or for human consumption.

MATERIALS AND METHODS

A field experiment was conducted at the Punjab Agricultural University, Ludhiana (30º54 N, and 75º48 E, 247 m altitude), during 2 consecutive growing seasons (2015–16 and 2016–17). The site is characterized by subtropical and semi-arid type of climate with average annual rainfall of 755 mm, 75–80% of which is received in July–September. The maximum temperature, minimum temperature and mean temperature during growing seasons of 2015–16 and 2016–17 were 26.3°C, 12.8°C and 19.6°C and 26.9°C, 12.7°C and 19.8°C, respectively. The soil at experimental site was a loamy sand (Typic Ustipsament), 7.3 *p*H, 0.36% organic C content, 186.0 kg/ha available N content, 29.9 kg/ha available P content, 147.5 kg/ha available K content, 2.77 mg/kg available Zn content, 9.39 mg/kg available Fe content, 8.2 mg/kg available Mn content and 0.46 mg/kg available Cu content. The bulk density was 1.6 Mg/m^3 in the 0–1 m soil profile.

The experiment was laid out in a split-plot design with 15 treatment combinations (3 × 5) and 3 replications. The main factor comprised 3 sowing dates (15, 30 October and 15 November) and the sub-factor 5 cutting management [un-cut, cut at 50 and 60 days after sowing (DAS), cut at 50 and 60 DAS + additional 15 kg N/ha after cut (N_{15})]. The size of the subplots was 3.6 m 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 at 5 cm depth with single-row cotton drill, spaced 22.5 cm apart by a uniform seed rate of 87.5 kg/ha on specified dates. 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 in the form of urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively.

Under cutting management, crop was harvested from specified net plots for fodder purpose, leaving the stumps of 5 cm for further regeneration. An additional dose of nitrogen (15 kg N/ha) and irrigation was applied immediately after each fodder cut only in cutting plots of barley. Plant height, dry- matter accumulation and tiller density were recorded at 30-day intervals after sowing. Green fodder was cut at height of 5 cm from the ground 50 and 60 days after sowing as per treatments. Green-fodder yield from net plot was weighed and converted into q/ha. One kilogram of green fodder was taken from bulk sample of each treatment in duplicate, dried first in the sun and then oven dried at 60ºC until the weight become constant. Dry fodder yield was calculated by multiplying dry-matter percentage with total green fodder yield of the particular plot and finally converted into q/ha.

Economics of barley was calculated by using prevailing prices for inputs and produce of the crop. Gross returns was calculated by multiplying the grain, fodder and straw yields of barley as per treatment with their respective selling prices. The cost of cultivation of crop was calculated by using the inputs and labour used. Net returns was the returns after deducting the cost of cultivation from gross returns. Benefit: cost ratio (B : C) was calculated by dividing the gross returns with the cost of cultivation.

RESULTS AND DISCUSSION

Growth attributes

The data on periodic plant height recorded at 30, 60, 90, 120 days after sowing (DAS) and at maturity are presented in Table 1. Plant height decreased consistently with delay sowing from 15 October to 15 November. The crop sown on 15 October was significantly higher in plant height than that sown on 30 October and 15 November sowing at 30, 60, 90, 120 DAS and at maturity. Plant height of 30 October and 15 November sown crop was statistically at par with one another at 30, 60 and 90 DAS. But, 30 October sown crop recorded significantly higher plant height than 15 November sown crop at 120 DAS and at maturity. Taller plant in early sowing, i.e. 15 October might be owing to longer day length and suitable temperature conditions that increase the photosynthetic efficiency which resulted more plant growth. Whereas significantly shorter plants under late sowing, i.e. 30 October and 15 November may be due to fact that this phase of crop growth coincided with the lowering of temperature and reduced day-length, which reduced the growth of plant by affecting its various metabolic processes like photosynthesis. Plant height at all the stages of plant growth except at 30 DAS differed significantly with cutting management. At 60 DAS, the plant height in un-cut, cut at 60 DAS and cut at 60 DAS + N_{15} was statistically at par, but significantly higher than cut at 50 DAS and cut at 50 DAS + N_{15} treatment. At 90 DAS, fodder cut at 60 DAS and cut at 60 DAS + N_{15} produced significantly shorter plants than the control, cut at 50 DAS and cut at 50 DAS + N_{15}.

Dry-matter accumulation is one of the most important parameters and has a marked influence on final yield realization of a crop. Data pertaining to dry-matter accumulation at 30, 60, 90 and 120 DAS are presented in Table 2. 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 throughout the growing season of crop. At 30, 60, 90 and 120 DAS, 15 October sowing resulted in the highest dry matter accumulation, being significantly higher than 30 October and 15 November sown crop. The crop sown on 15 October accumulated 23.7 and 24.9% higher dry-matter at 30 DAS, 15.9 and 18.2% at 60 DAS, 13.9 and 18.9% at 90 DAS and 9.7 and 21.5% at 120 DAS than 30 October and 15 November-sown crop, respectively. The crop sowin on 15 October recorded higher dry matter accumulation because of larger day length led to higher photosynthesis owing to which higher plant height (Table 1) and tiller density (Table 3), ultimately enhancing the dry-matter production under early sowing, i.e. 15 October. Among cutting management, at 60 DAS, the treatments un-cut, cut at 60 DAS and cut at 60 DAS + N_{15} were statistically at par with each other and accumulated significant higher dry matter accumulation than cut at 50 DAS and cut at 50 DAS + N_{15} treatment. There was significantly higher dry matter accumulation at 90 and 120 DAS in un-cut treatment than the other cutting treatments.

As no stress was imposed on the crop due to fodder harvest, it might be the reason for higher dry matter accumulation in the un-cut treatment. Among fodder cutting treatments, the maximum dry matter accumulation in treatments where fodder cut was taken at 50 days after sowing than fodder cut at 60 days after sowing might be due to longer duration of vegetative growth.

Tillering is one of the most important determinants of

Table 1. Periodic plant height of barley as affected by sowing date and cutting management (pooled data of 2015–2016 and 2016–2017)

Treatment	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Date of sowing					
15 October	31.7	39.3	62.0	90.8	93.9
30 October	28.8	36.8	52.5	85.4	90.8
15 November	28.1	35.0	50.8	78.9	85.5
SEm±	0.8	0.9	0.8	1.1	0.8
CD (P=0.05)	2.4	2.8	2.4	3.3	2.4
Cutting management					
Un-cut	29.7	46.7	75.9	93.2	95.5
Cut at 50 DAS	29.2	21.4	55.7	86.0	90.9
Cut at 60 DAS	29.6	47.4	41.3	76.9	83.2
Cut at 50 DAS + N_{15}	29.4	23.2	58.0	88.7	93.4
Cut at 60 DAS + N_{15}	29.8	47.9	44.0	80.4	87.3
SEm±	0.2	0.9	0.7	0.6	0.8
CD (P=0.05)	NS	2.8	2.3	2.0	2.3

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

Table 2. Periodic dry matter accumulation of barley as affected by sowing date and cutting management (pooled data of 2015–2016 and 2016–2017)

Treatment	Dry-matter accumulation (t/ha)			
	30 DAS	60 DAS	90 DAS	120 DAS
Date of sowing				
15 October	1.51	2.74	3.54	10.81
30 October	1.16	2.31	3.05	9.76
15 November	1.14	2.25	2.68	8.48
SEm±	0.08	0.09	0.08	0.18
CD (P=0.05)	0.28	0.33	0.27	0.55
Cutting management				
Un-cut	1.36	3.32	5.64	11.00
Cut at 50 DAS	1.18	1.10	3.29	10.29
Cut at 60 DAS	1.30	3.30	1.48	8.53
Cut at 50 DAS + N_{15}	1.24	1.14	3.50	9.67
Cut at 60 DAS + N_{15}	1.27	3.31	1.55	8.90
SEm±	0.03	0.08	0.12	0.12
CD (P=0.05)	NS	0.26	0.39	0.49

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

fodder and grain yields in barley. Better tillering leads to production of more number of ears or spikes/unit area, resulting in higher grain yield. Barley crop sown on 15 October recorded significantly higher number of tillers than 30 October and 15 November-sown crop at 120 DAS. Tiller density of 30 October-sown crop was significantly higher than 15 November-sown crop at 120 DAS. The 15 October-sown crop produced 2.2 and 6.6% higher tillers than 30 October and 15 November sowing, respectively (Table 3). Higher tiller density of 15 October-sown crop was attributed sowing to earlier sown crop has higher day length due to which harvested more sunlight which increased photosynthesis that led to increases in photosynthates, which ultimately resulted in higher tiller count. The poor growth parameters of later sown crop at late stages may be attributed to prevalence of lower temperature at the corresponding stages. Similar results were reported by Nizamuddin *et al.* (2014). Higher tiller density was recorded in un-cut crop which was statistically at par with fodder cut at 50 DAS + N_{15} treatment, but significantly higher than the fodder cut stage at 50 DAS, cut at 60 DAS and cut at 60 DAS + N_{15}.

Nutrient uptake

Total nitrogen uptake among sowing dates was found to be significant. Significantly higher values of total nitrogen, phosphorus and potassium uptake were recorded in crop sown on October 15 as compared to crop sown on 30 October and 15 November. Sowing on 15 October resulted in 6.07% higher total nitrogen uptake as compared to 30 October and 23.2% as compared to 15 November. The sowing on 15 October resulted in 21.7% higher total phosphorus uptake as compared to 30 October, whereas 35.4% as compared to 15 November sowing. The 15 October sowing resulted in 9.48% higher total potassium uptake as compared to 30 October, whereas 15.1% as compared to 15 November. Among the cutting management, treatments, higher values of total nitrogen uptake were recorded in uncut, being statistically at par with the cut at 50 DAS, but significantly higher than cut at 60 DAS, cut at 50 DAS + N_{15} and cut at 60 DAS + N_{15}. The lowest value of total nitrogen uptake was recorded in fodder cut at 60 DAS crop. It might be due to lower biomass production under cut at 60 DAS treatment. Fodder cut at 50 DAS recorded significantly higher total nitrogen uptake than cut at 60 DAS, might be due to higher grain yield and straw yield in cut at 50 DAS. The higher total phosphorus uptake was recorded in un-cut crop recorded which was statistically at par with fodder cut at 50 DAS, but significantly higher than cut at 60 DAS, cut at 50 DAS + N_{15} and cut at 60 DAS + N_{15}. Un-cut and cut at 50 DAS treatments for total potassium uptake was statistically at par with each other and significantly better than cut at 60 DAS, cut at 50 DAS + N_{15} and cut at 60 DAS + N_{15}.

Fodder yield

Green-fodder yield: Total green-fodder production/unit area is the most important aspect of fodder crops and is one of the criteria to assess the efficiency of various treatments. The crop sown on 15 October gave the highest green-fodder yield when cut was taken at 50 DAS and it was significantly better than that sown on 30 October and 15 November (Table 4). However, in case of cutting at 60 DAS, 15 October-sown crop gave significantly more green fodder

Table 3. Tiller density and nutrient uptake in barley as affected by sowing date and cutting management (pooled data of 2015–2016 and 2016–2017)

Treatment	Tiller density at 120 DAS (/m^2)	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)
Date of sowing				
15 October	275.5	117.0	25.2	94.7
30 October	261.4	110.3	20.7	86.5
15 November	253.3	94.9	18.6	82.3
SEm±	2.7	1.4	0.4	1.6
CD (P=0.05)	12.0	5.5	1.6	5.2
Cutting management				
Un-cut	265.3	117.0	23.4	96.3
Cut at 50 DAS	262.2	111.8	22.4	90.9
Cut at 60 DAS	263.5	91.0	19.1	80.6
Cut at 50 DAS + N_{15}	263.8	108.5	21.5	84.8
Cut at 60 DAS + N_{15}	262.1	109.2	21.2	83.5
SEm±	0.6	2.1	0.4	1.9
CD (P=0.05)	NS	6.3	1.5	6.4

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

yield than the crop sown on 30 October and 15 November. Green fodder yield in 30 October and 15 November-sown crops was statistically at par under cutting at 60 DAS. Green fodder yield of cut at 50 DAS and cut at 50 DAS + N_{15} under all 3 sowing dates statistically at par with each other and cut at 60 DAS and cut at 60 DAS + N_{15} under all 3 sowing dates were statistically at par.

Dry fodder yield: Dry-matter yield of barley fodder depends on its moisture content at harvesting and green fodder yield. In general, more sacculency and early cutting produce less dry fodder. Crop sown on 15 November (2.13 t/ha) gave significantly lowest dry fodder yield than 15 October (3.12 t/ha) and 30 October sowing (3.09 t/ha), but 15 October and 30 October sown crops were at par with each other. The higher dry fodder yield of early sowing was owing to higher day length led to higher photothermal units, high-temperature conditions led to more accumulated growing degree-days due to which higher plant height (Table 1) and tiller density (Table 3), ultimately enhanced the dry fodder yield under early sowing. Fodder cut at 60 DAS (3.27 t/ha) and cut at 60 DAS + N_{15} (3.27 t/ha) resulted in significantly higher dry-fodder yield than the fodder cut at 50 DAS (2.28 t/ha) and cut at 50 DAS + N_{15} (2.30 t/ha). The fodder cut at 60 DAS resulted in 43.4% higher dry fodder yield than the fodder cut at 50 DAS. The higher dry fodder yield might be owing to 10 days longer period of vegetative growth which led to more photosynthesis and their translocation to growth parameters such as plant height, dry matter, number of tillers, which ultimate led to more production of dry fodder yield. The higher dry fodder yield might be owing to more green fodder yield and more dry matter accumulation.

Grain yield

Grain yield is the principle criterion for evaluating efficiency of various growth factors as ultimate effects of various experimental variables are reflected in the crop yield. Significant reduction was observed in grain yield due to delayed sowing (Table 4). Crop sown on 15 October (4.06 t/ha) recorded significantly higher grain yield than 30 October (3.64 t/ha) and 15 November sowing (2.75 t/ha). Sowing on 15 October sowing recorded 11.5 and 48.1% higher grain yield than 30 October and 15 November sowing, respectively. Significantly higher grain yield was obtained 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 photothermal units, high temperature conditions led to more accumulated growing degree-days in this sowing date. Therefore, early sowing of crop (i.e. October 15) resulted in higher plant height (Table 1) and dry matter production (Table 2) due to which more supply of photosynthates to grains.

Cutting management greatly influenced the grain yield of barley during both the years. The un-cut crop recorded the highest grain yield (3.93 t/ha), which was statistically at par with fodder cut at 50 DAS (3.79 t/ha), but significantly higher than fodder cut at 60 DAS (3.08 t/ha), cut at 50 DAS + N_{15} (3.18 t/ha) and cut at 60 DAS + N_{15} (3.43 t/ha). There was an increase of 23.1% in grain yield when fodder cut was taken at 50 DAS than cut was taken at 60 DAS. Higher grain yield 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 in grain yield reduction, might be due to reduced period for vegetative and repro-

Table 4. Effect of sowing date and cutting management on green fodder, dry fodder and grain yields of barley (pooled data of 2015–2016 and 2016–2017)

Treatment	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Grain yield (t/ha)
Date of sowing			
15 October	17.8	3.12	4.06
30 October	15.0	3.09	3.64
15 November	14.2	2.13	2.75
SEm±	0.2	0.04	0.03
CD (P=0.05)	0.7	0.14	0.12
Cutting management			
Un-cut	–	–	3.93
Cut at 50 DAS	12.9	2.28	3.79
Cut at 60 DAS	18.5	3.27	3.08
Cut at 50 DAS + N_{15}	12.8	2.30	3.18
Cut at 60 DAS + N_{15}	18.5	3.27	3.43
SEm±	0.1	0.04	0.05
CD (P=0.05)	0.4	0.13	0.21

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

ductive growth. After delayed forage harvest, due to which there was significant reduction in the leaf-area of crop which decreased in the photosynthesis efficiency and restricted the supply of photosynthates from source (leaves) to sink (grains) was which ultimately reduced the 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.

Application of additional dose of 15 kg N/ha after fodder cut at 60 DAS recorded 9.37% higher grain yield than the fodder cut at 60 DAS without application of additional dose of 15 kg N/ha after fodder cut. Whereas the fodder cut at 50 DAS recorded 16.2% higher grain yield as compared to fodder cut at 50 DAS with application of additional dose of 15 kg N/ha after cut.

Economics

Gross returns are total returns from the crop including from grain and straw. The crop sown on 15 October recorded 11.4 and 24.9% higher gross returns than 30 October and 15 November-sown crops, respectively (Table 5). The highest gross returns was obtained in case of cut at 60 DAS + N_{15} which were significantly higher than the other cutting treatments. The un-cut crop gave the lowest gross returns during both the years. Application of additional 15 kg N/ha resulted in significantly increased gross returns of fodder cut at 60 DAS. Sowing on 15 October resulted in significantly higher gross returns, net returns and benefit: cost (B: C) ratio. Fodder cut at 60 DAS + N_{15} gave the highest net returns and was significantly higher than un-cut at 50 DAS, cut at 60 DAS and cut at 50 DAS + N_{15}. Significantly lowest net returns was recorded in un-cut crop. Application of additional 15 kg N/ha resulted in significantly increased the net returns of fodder cut at 60 DAS treatment, whereas the net returns of fodder cut at 50 DAS treatment was significantly decreased by the additional application of 15 kg N/ha which might be due to lower grain yield. Fodder cut at 60 DAS + N_{15} treatment recorded the highest benefit: cost ratio (3.36) which was significantly higher than un-cut (2.99), cut at 50 DAS (3.19), cut at 60 DAS (3.22) and cut at 50 DAS + N_{15} (2.88). The significantly lowest value of benefit: cost ratio was recorded in cut at 50 DAS + N_{15} treatment which was statistically at par with un-cut treatment.

Table 5. Economics of barley as influenced by sowing date and cutting management (pooled data of 2015–2016 and 2016–2017)

Treatment	Gross returns ($\times 10^3$₹/ha)	Net returns ($\times 10^3$₹/ha)	Benefit: cost ratio
Date of sowing			
15 October	97.4	70.0	3.55
30 October	86.4	59.0	3.16
15 November	73.2	45.9	2.68
SEm±	0.1	0.1	0.04
CD (P=0.05)	3.2	3.2	0.13
Cutting management			
Un-cut	66.9	44.5	2.99
Cut at 50 DAS	90.9	62.4	3.19
Cut at 60 DAS	91.6	63.1	3.22
Cut at 50 DAS + N_{15}	82.6	53.9	2.88
Cut at 60 DAS + N_{15}	96.4	67.7	3.36
SEm±	0.1	0.1	0.04
CD (P=0.05)	3.3	3.3	0.12

N_{15}, 25% additional nitrogen after cut (15 kg N/ha). The price (₹/q) of barley green fodder was 200 and grains was 1,225 and 1,325 during 2015–16 and 2016–17, respectively, and straw was 200; DAS, days after sowing

Thus, the crop sown on 15 October gave significantly higher grain yield and fodder yield than the other 2 sowing dates. One fodder cut of barley (variety 'PL 807') taken at 50 DAS without any significant reduction in yield and it can be delayed up to 60 DAS to get more production of green fodder than that at 50 DAS but at the cost of 21.7% reduction in grain yield. The crop sown on 15 October with fodder cut at 60 DAS + N_{15} gave significantly higher gross returns, net returns and benefit: cost ratio.

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