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RESEARCH ARTICLE

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Response of Dual-Purpose Barley (*Hordeum vulgare*) to Different Sowing Dates and Nutrient Management

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ABSTRACT

Background: Barley (*Hordeum vulgare* L.) is a vital crop for food and fodder production in semi-arid regions. Its grain potential is well documented in previous studies but its dual-purpose potential has not been evaluated completely. Growing of dual-purpose barley is an approach for producing forage as well as grain in marginal environments having low forages.
Objective: To optimize dual-purpose performance of barley, the objective of this study was to investigated the impact of sowing dates, NPK fertilizer levels and different cutting intervals on barley productivity in the semi-arid conditions of Multan, Pakistan.
Methodology: The experiment was conducted in 2021, with two sowing dates (1st November and 25th November) and two NPK fertilizer levels (recommended dose and 25% higher). Results showed that early sown barley without cuttings yielded the highest grain and biomass production at the recommended fertilizer dose. Delayed sowing and barley harvest at 60 days after sowing negatively impacted barley performance.
Results: These findings suggested that early sowing with recommended NPK fertilizer application can enhance dual-purpose barley productivity in semi-arid environments, contributing to food security and sustainable agriculture. The best sowing time for dual purpose barley crop starts from the mid of last week of October to first week of November for the semi-arid region of South Punjab and preferred time of cutting at vegetative stage for fodder is 45 days post-sowing.
Conclusion: Standard fertilization dose must be applied to ensure proper growth, development and nourishment of barley plants and also to enhance its productivity. Furthermore, early sowing and optimum fertilization ensures healthy plants having more resistance against pest and diseases than the late sowing

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the important winter cereals that has the advantage of growing successfully on marginal soils that are unfavorable for other cereal crops. Barley was cultivated on 39 thousand hectares and yielding 42 thousand tons during 2020–2021 (Government of Pakistan 2021). Its primary uses include cattle and poultry feed, human consumption and starch production due to its substantial health benefits and dietary fiber content (Newman and Newman 2006).

Cultivating cereals for both pasture and grain yields simultaneously is known as dual-purpose management. Plants are trimmed during vegetative stage and then given time to recover and yield grains (Bell *et al.* 2005). Dual-purpose crops including oats, barley, and wheat are often produced throughout the Mediterranean basin (Salama 2019). In contrast to other cereal crops, barley exhibits resistance to salt and generates more dry matter under these conditions (Moustafa *et al*. 2021a). Furthermore, it shows higher growth after grazing, which provides feed to animals (El-Shatnawi *et al*. 2011). Therefore, dual-purpose barley can provide fodder and then regrown for grain, is a notable alternative (Harrison *et al*. 2012). Successful dual-purpose barley cultivation in marginal locations necessitates the use of improved genotypes with effective agronomic management practices. The adverse impacts of climate change on barley production may be mitigated by adjusting planting schedules and using superior cultivars (Desoky *et al.* 2021). The planting date is a critical agricultural technique that influences barley output when cultivated as a dual-purpose crop. To get maximum grain and forage yields, it is crucial to regulate the planting dates for dual-purpose barley (Tahir *et al*. 2019).

In Pakistan's agricultural sector, livestock constitutes 62% and contributes around 14.04% to the GDP (Government of Pakistan 2021). The augmentation of livestock output significantly influences the national economy. The greater milk and meat output needs sufficient amount of fodder. Temperature variations diminish the quality of summer fodder production. Winter-grown fodders exhibit high quality due to their resilience to climatic variations; yet, their growth season coincides with that of wheat, Pakistan's primary crop. A 2.33 M ha area allocated for fodder has been declined (Government of Pakistan 2021). Consequently, farmers now have a substantial challenge in supplying enough feed for their cattle production.

The grain yield and its properties are significantly influenced by different NPK doses. The optimal nitrogen dosage for maximum grain output, while only using nitrogen fertilizer, is 100 kg N ha^{-1}. Increasing nitrogen levels from 60 to 90 kg ha^{-1} considerably enhanced the traits (Narolia and Yadav 2013). The date of sowing is a critical factor for enhancing yield output, as it determines the optimal period for planting the crop. Efficient use of growth nutrients enhances the yield of barley when sown at the optimal period. Given that dual-purpose barley plants may provide green fodder during periods of scarcity, it is crucial to plant at the optimal time to guarantee an extended availability of green fodder. The effects of varying planting dates on dual-purpose barley are quite significant. A common technique to get high-quality green fodder over an extended duration is staggered sowing. The optimal nutritional phase must be maintained for an extended duration to maximize the yield of superior quality green fodder. To optimize the prime sowing period, it is essential to use the appropriate sowing date (Singh *et al.* 2016).

Barley is usually grown for grain purpose, and its forage potential has not been explored yet completely. Moreover, fodder cultivation area has shrunk by 2.33 million hectares in recent years which cause fodder shortage in winter. Different sowing times can minimize the effects of climate change on barley crop which is damaging Pakistan's crop productivity. There is little or no research conducted on combined effect of sowing time and NPK on dual-purpose barley under this climatic condition. Therefore, this one-year study was planned to mitigate those challenges. It was hypothesized that early sowing and proper fertilizers application may serve as a sustainable approach to mitigate dual-purpose barley low production under semi-arid conditions of Multan district. It was further hypothesized that barley harvesting at 45 days after sowing (DAS) or 60 DAS can overcome the fodder shortage particularly during the winter season.

MATERIALS AND METHODS

Experimental site and location

This field trial was conducted on November 1st and November 25th, 2021, at Agronomic Research Farm (30.2° N, 71.4° E), Institute of Agronomy, Bahauddin Zakariya University, Multan, Pakistan to evaluate the dual-purpose potential of barley cultivated under various NPK levels. Data regarding soil analysis before sowing and after harvesting is given below in Table 1. Weather conditions (relative humidity, daily temperature, sunshine hours, wind speed and total rainfall) during trial period are presented in Fig. 1.

Treatments and experimental details

This research trial was consisted of three factors i.e., sowing dates, fertilizer dozes and cutting intervals. Barley was sown on November 01 and 25 by using recommended levels (60:30:20 kg/ha) of NPK and 25% extra than recommended dose. Barley was harvested after 45 and 60 days of sowing and then left for sprouting to get grain yield while the no-cut was maintained as control. A randomized complete block design (RCBD) with split-plot layouts was used, consisting of three replications. There were total thirty-six (36) experimental units in this trial and the net plot size was 1.35 m × 4.00 m = 5.4 m^2.

Crop husbandry

In order to create conditions suitable for seedbed preparation, 10 cm of pre-soaking irrigation was applied. Once the ideal moisture level was attained, fine seedbeds were prepared. The sowing was done on two separate dates: 1st and 25th November and the seed rate was kept at 100 kg ha^{-1}. Fertilizers were applied as per treatments and seed rate was 100 kg/ha. All phosphatic and potash fertilizers, together with half of the nitrogen, were administered as a baseline dosage, while the remaining half of nitrogen was applied

Table 1: Soil chemical and physical analysis

Determination	Prior to sowing	After harvest
Soil physical analysis		
Clay (%)	21.8	21.8
Silt (%)	50.7	50.6
Sand (%)	27.3	27.4
Soil texture	Loam	Loam
Soil chemical analysis		
EC (mS cm^{-1})	2.25	2.57
pH	8.3	8.2
Saturation (%)	39	39
Organic matter (%)	0.48	0.46
Available phosphorus (mg kg^{-1})	6.44	8.05
Total nitrogen (%)	0.05	0.07
Available potassium (mg kg^{-1})	118	133

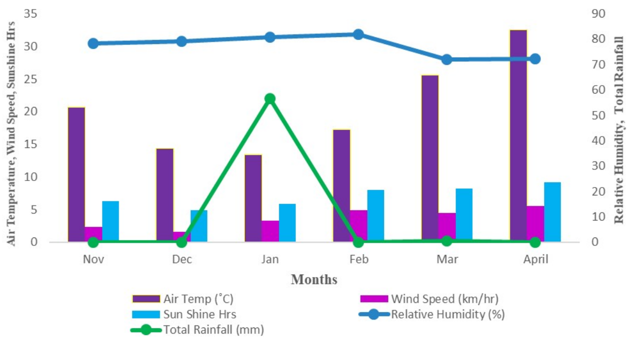

Fig. 1: Meteorological data of the experimental location for the years 2021 and 2022
Source: Pakistan central cotton committee (PCCC), Multan, Pakistan

during the first irrigation. To alleviate the detrimental impacts of water stress on the crop, it was watered four times throughout the growth season. All other agronomic requirements were maintained to guarantee the crop was free from insects and diseases. The barley crop was harvested on 15 April 2022, at reaching maturity. Barley was harvested for fodder at 45 and 60 days after seeding.

Determination of agronomic or yield related parameters

To measure plant height, within each treatment 10 plants were selected at random, and their height was measured using a measuring rod in centimetres. Spike length of the same ten plants was also measured and average data were recorded. The number of spikelets per spike and the number of grains per spike were measured by manually counting 10 plants that were selected at random from the experimental units. In a similar manner, ten distinct plant samples were used to determine the weight of 1000 grains from each plot by physically counting the seeds, followed by weighing 1000 grains using an analytical balance, after which their average was computed. The total number of tillers in wheat plants were recorded from a 1 m² area for each treatment. Upon completion of the count, spike-bearing tillers were classified as fertile, whilst the other tillers were classified as non-fertile. After harvesting of plots, plants were kept in field for 04 days to dry to note biological yield (tons ha^{-1}). The grains were threshed manually and weighed using a digital scale to determine the grain yield. Straw yield was calculated by deducting grain yield from biological yield. The harvest index for barley was determined as the percentage ratio of grain yield to biological yield.

Statistical analysis

A three-way analysis of variance (ANOVA) was used to assess the significance of the results. The data were assessed for normality before ANOVA, revealing a normal distribution. Consequently, analyses were performed on the original data. The Duncan post-hoc test was used to compare treatment means at a 5% probability level, after significant differences indicated by ANOVA (Steel *et al.* 1997). Graphical presentation of weather data was prepared using MS-Excel 2016 version.

RESULTS

Yield related traits

Investigated data disclosed that first treatment sowing dates (S) had highly significant effect on quantity of fertile tillers, straw yield, biological yield and grain yield, while significant effect on one thousand grain weight and total number of tillers, however number of grains $spike^{-1}$, number of spikelets $spike^{-1}$ and harvest index remains non-significant. Second treatment, cutting intervals (C) had the highly significant effect on one thousand grain weight, number of spikelets $spike^{-1}$, number of fertile tillers, total number of tillers, grain yield, biological yield and straw yield while number of grains $spike^{-1}$ and harvest index. Third treatment, fertilizer dozes (F) remained non-significant throughout all the yield parameters except number of sipkelets $spike^{-1}$ and grain yield. The cumulative effects of all three treatments (S×C×F) were not significant, with the exception of the number of grains $spike^{-1}$.

Maximum grain yield was recorded at early sowing with no cutting at recommended fertilizer doze, while utmost biological and straw yield was observed in early sown, no cut and 25% higher doze of fertilizers treatments. Latterly late sown, cut at 45 DAS and recommended fertilizer doze shown the highest harvest index.

Growth and development

Data demonstrated that sowing dates (S) and cutting intervals (C) had a significant effect on plant height and spike length of barley while fertilizer levels (F) and its interaction with S and C (S×F×C) had the non-significant effect on the plant height and spike length of barley.

Barley expressed maximum plant height and spike length at early sowing with no cutting as compared to late sowing and cutting at 45 days after sowing (DAS) and 60 DAS, while in case of fertilizer doses, 25% extra fertilizer

Table 2: Effect of individual treatments and their interactions on different agronomic parameters of barley

Treatments	Total No. of tillers (m^{-2})	No. of fertile tillers (m^{-2})	Plant height (cm)	Spike length (cm)	No. of spikelets spike^{-1}	No. of grains spike^{-1}	Grain yield (tons ha^{-1})	Biological yield (tons ha^{-1})	Straw yield (tons ha^{-1})	1000 grain weight (g)	Harvest Index (%)
Sowing Dates (S)	5.38*	7.23**	4.47*	14.1**	0.43	0.97	32.6**	31.5**	17.5**	4.35*	0.39
Fertilizer Doses (F)	0.03	0.03	0.00	2.25	10.7**	0.05	5.21*	1.38	0.16	0.72	0.85
Cutting Intervals (C)	11.19**	7.94**	5.65**	21.1**	18.04**	0.81	48.9**	31.9**	13.5**	7.36**	0.42
S×F	0.05	0.18	0.12	0.03	3.85	0.00	0.07	0.19	0.16	0.02	0.01
S×C	0.12	0.54	0.43	0.24	2.90	0.28	2.32	3.6*	2.63	0.06	0.6
F×C	0.00	0.03	0.00	0.01	4.43**	0.02	0.33	0.18	0.14	0.00	0.08
S×F×C	0.27	0.23	0.17	0.21	2.52	0.03	0.09	0.68	0.88	0.05	0.68

* = Significant, ** = Highly Significant

Table 3: Effect of different treatments on growth and yield parameters of barley crop

Treatments	Plant height (cm)	Spike length (cm)	Number of spikelets spike^{-1}	Number of grains spike^{-1}	1000-grain weight (g)
			Sowing Dates		
1st November	73.6 A	21.2 A	17.7^{NS}	42.7^{NS}	44.9 A
25th November	70.0 B	19.4 B	17.4	41.8	42.7 B
			Fertilizer Dozes		
RD	71.9^{NS}	20.7^{NS}	18.2 A	42.4^{NS}	44.2^{NS}
HD	71.8	19.9	16.9 B	42.2	43.4
			Cutting Intervals		
No harvest	74.9 A	21.8 A	18.8 A	43.1^{NS}	45.6 A
Harvest at 45 DAS	72.5 A	20.9 A	18.1 A	42.2	44.7 A
Harvest at 60 DAS	68.1 B	18.1 B	15.8 B	41.5	41.0 B

Means of individual effects following different letters differ significantly from each other at 5% probability level
Here, RD= Recommended dose of fertilizer; HD= 25% higher dose than RD; DAS= Days after sowing; NS= Non-significant

Table 4: Effect of sowing dates and NPK levels on yield-related traits of dual-purpose barley

Treatments	Number of tillers (m^{-2})	Number of fertile tillers (m^{-2})	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
			Sowing Dates			
1st November	233.8 A	203.6 A	3.69 A	8.87 A	5.18 A	41.7^{NS}
25th November	221.2 B	191.1 B	3.34 B	7.95 B	4.60 B	42.1
Fertilizer Dozes						
RD	228.0^{NS}	196.9^{NS}	3.59 A	8.51^{NS}	4.92^{NS}	42.2^{NS}
HD	227.1	197.8	3.45 B	8.31	4.16	41.6
			Cutting Intervals			
No harvest	239.3 A	207.2 A	3.82 A	9.08 A	5.26 A	42.1^{NS}
Harvest at 45 DAS	233.5 A	200.1 A	3.62 B	8.63 B	5.00 A	42.1
Harvest at 60 DAS	209.8 B	184.8 B	3.11 C	7.52 C	4.41 B	41.4

Means of individual effects following different letters, differ significantly from each other at 5% probability level
Here, RD= Recommended dose of fertilizer; HD= 25% higher dose than RD; DAS= Days after sowing; NS= Non-significant

doze shown maximum plant height however maximum spike length was recorded at recommended fertilizer dose.

DISCUSSION

Barley performance altered under various treatments viz. S, F and C. Barley enhanced its ability to tiller when sown early and applied with optimum nutrition, this leads to enhanced solar absorption and an elevated photosynthetic rate. The highest number of tillers per square meter were seen with early seeding, significantly decreasing with late sowing (Devi *et al.* 2018). Increased tillers had positive impact on grain yield and biological yield. Similarly increased length of barley spikes enhanced seeds count and quality (Table 2).

The findings of the field experiment indicated that early seeding enhances barley growth metrics (plant height and spike length). In comparison to early seeding, the sowing on 25th November exhibited significantly reduced growth, resulting in a truncated vegetative phase (Table 3). In their study on barley, Moustafa *et al.* (2021a) indicated that plant height decreased with late sowing. The findings indicate that early seeding considerably enhanced grain production, biological yield, and straw yield of barley (Table 4). Moustafa *et al.* (2021b) further found that, late sowing diminished development phases, thereby reducing plant efficiency to capture more sunlight and assimilates. Furthermore, delayed sowing may decrease yield due to heat stress at critical growth phase, consequently impacting yield-related characteristics and overall biological yield. Shahzad *et al.* (2007) showed that earlier sowing, due to the extended growing season, resulted in enhanced grain development. He experienced a reduced grain yield due to a shorter growth and development period associated with a later sowing date. The plants grown on the median date yielded the greatest average straw weight (Chaudhary *et al.* 2017). Biological yield variations were noted concerning sowing date. Moustafa *et al.* (2021b) demonstrated that early planting resulted in higher biological output (8345 kg ha^{-1}) as compared to late sowing (7033 kg ha^{-1}). By seeding early on October 25^{th}, the maximum spikelets and grains $spike^{-1}$ were produced (Table 3). Moustafa *et al*. (2021a) indicated that, except from that, late sowing on December 4th resulted in the lowest spikes. The dual-purpose produced 5% more spikes (238.8) compared to the single purpose crop, which contradict with our findings.

The optimum fertilizer (NPK) application had a positive influence on number of spikelets per spike and grain yield of barley. Maximum number of spikelets $spike^{-1}$ and grain yield per plant were produced by applying recommended dose (18.2) and (3.59 t ha^{-1}) compared to 25% extra dosage (16.9) and (3.45 t ha^{-1}) respectively (Tables 3-4). Islamzade *et al.* (2024) also showed same information; indicating that the maximum grain production was achieved at higher nitrogen rates and appropriate crop densities. The results highlight the importance of optimal fertilizer applications in improving grain and straw yields in research region. Previous research has shown that increasing fertilizer application rates enhances plant biomass and crop productivity (Nogalska *et al.* 2011; Agegnehu *et al.* 2016). The observed trends are closely associated with N availability in different growth stages, particularly in the 140-N60P45K45 treatment, indicating that enhanced nitrogen availability promotes both grain development and increased vegetative biomass (Islamzade *et al.* 2024). The grain count per spike manifested a notable trend, with the 120-N45P45K45 treatment showing the largest quantity. This indicated that this treatment ideally facilitates grain development (Islamzade *et al.* 2024). The results provide actionable insights for enhancing agricultural operations in semi-arid regions.

Harvesting intervals had a highly significant impact on the grain yield and other yield related parameters like one of the vital yield components, is the number of $tillers^{-2}$, increased after cutting at 45 days as compared to 60 days cut however, no cut (control) has exhibited maximum tillers (Table 3). Similar findings were reported by Zeleke (2019), cutting at the earliest results in higher number of effective tillers/metre row length. Obtained results have shown that no cut (control) gains maximum grain yield, biological yield and straw yield (Table 4). Pal and Kumar (2009) observed highest grain yield in no cut crop. Beji (2016) also reported the gain in grain yield after a cutting during vegetative stage of barley, which could be associated with decrease of lodging. He further documented that the practice of cutting helps to get the nutritious forage, but may reduce the production (grain and straw), particularly when cut was scheduled at later stage. Tian *et al.* (2012) revealed that forage harvested before growth stage 30 i.e. before stem elongation could provide a valuable feed without reducing the grain yield significantly. Results showed that barley expressed maximum plant height (74.9 cm) and number of grains per spike (43.1) at no harvest (control) (Table 3). As reported previously (Neelam *et al*. 2024), maximum plant height of 108.46 cm was recorded in no fodder cut treatment which was found at par with fodder cut at 50–60 DAS above 10 and 5 cm height and significantly higher from fodder cutting at 60–70 DAS at both the heights. This might be owing to better regenerative capacity of dual-purpose barley when cut was taken above 10 cm height from the base as compared to cutting above 5 cm. The irrigation and nitrogen were applied after green fodder cutting in dual cut system, which enhanced the growth, and tillering started about 15–20 days after cutting. Effective tillers/m^2 and number of grains per ear-head were maximum in fodder cut at 50–60 DAS above 10 cm height.

CONCLUSIONS

The best sowing time for dual purpose barley crop starts from the mid of last week of October to first week of November for the semi-arid region of South Punjab and preferred time of cutting at vegetative stage for fodder is 45 days post-sowing. Standard fertilization dose must be applied to ensure proper growth, development and nourishment of barley plants and also to enhance its productivity. Furthermore, early sowing and optimum fertilization ensures healthy plants having more resistance against pest and diseases than the late sowing.

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AUTHOR CONTRIBUTIONS

Conceptualization, Mubshar Hussain; Formal analysis, Muhammad Bahram Khan; Investigation, Mujahid Ali, Nusrat Javed; Methodology, Muhammad Bahram Khan, Abdul Majeed, and Mujahid Ali; Project administration, Mubshar Hussain; Supervision, Mubshar Hussain; Validation, Mubshar Hussain; Writing – review & editing, Mubshar Hussain, Nusrat Javed and Muhammad Bahram Khan. All authors have read and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The writers affirm that they possess no conflicts of interest.

DATA AVAILABILITY

Not applicable to this paper.

ETHICS APPROVAL

This paper is not relevant.

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