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AGRONOMIC ASSESSMENT OF DUAL-PURPOSE WHEAT (*TRITICUM AESTIVUM* L.) VARIETIES AND SEED RATES UNDER SEMIARID CONDITIONS OF FAISALABAD

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Abstract

Fodder demand for livestock, particularly in lean periods is a common issue and it poses a significant effect on livestock production. Therefore, this study was set up on wheat as dual-purpose crop with respect to fodder and grain production especially under limited land of agricultural community. The experiment comprised of four wheat varieties (Fakhr-e-bahkhar-19, Anaj-17, C-228 and Gulzar-19), two cutting times (No cut & cut at 60 days after sowing) and three seed rates (123, 148 and 173 kg ha^{-1}). The experiment was laid out using randomized complete block design (RCBD) with a factorial arrangement. Concluding the results of this study, wheat variety C-228 had the leading fresh fodder yield using 173 kg ha^{-1} seed. However, Fakhr-e-bahkhar-19 and Anaj-17 exhibited the highest grain yield under no cut treatment using seed rate of 123 kg ha^{-1} and 173 kg ha^{-1}, respectively. As per economic concern, the highest benefit-cost ratio was observed in variety Anaj-17 when fodder was harvested after 60 DAS using 123 kg ha^{-1} seed rate followed by Fakhr-e-bahkhar-19 where the fodder was cut at prescribed cutting interval using 173 kg ha^{-1} seed rate. Hence, findings of this study recommend the specific wheat varieties as dual-purpose cultivation, with optimized cutting time and seed rates to enhance yield and economic returns. It is offering a planned way for farmers to overcome fodder scarcity in the winter lean period and maximize land productivity in changing climate challenges.

Keywords: Wheat, Dual-Purpose, Varieties, Seed Rate, Climate Change, Cutting Time, Grain Yield, Economic Returns.

1. INTRODUCTION

Wheat is the most valuable cereal in the world, serving as a staple food for almost 2.5 billion people and accounting for 30% of worldwide grain production (Zhao *et al.,* 2018). Wheat contributes USD 39.6 billion to the world economy by cultivating over 220 million hectares and yielding a production of 770.4 million tonnes. Notably, wheat plays a pivotal role in Pakistan’s economy, contributing 9.8% to agricultural value addition and 1.8% to the national GDP. In Pakistan, fodder is cultivated over an area of 2.45 million hectares, yielding 55.47 million metric tons during 2019-20. Punjab is the leading province in this

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respect where 41.98 million tonnes of fodder was produced during aforementioned fiscal year (FAOSTAT, 2021).

The animal population is increasing by 4.2% annually while the fodder area has declined by 2% per decade. Currently, Pakistan's fodder shortfall is 15-30% (Govt. of Pakistan, 2021). Pakistan is located in one of the leading populations globally and ranks 5th with birth rate of 2.1% per annum. Feeding such a gigantic mass is a crucial concern, and agrarians are among top-notch scenarios.

Increasing area for fodder production is again out of possibilities because of high tilt of agronomics towards cash crops including cereals, sugar crops and vegetables as well as fiber crops. Fodders are counted among neglected and less privileged crops at the individual farmers end who spends nill on nutritional and protection aspects of the crop, resulting in subsistent yields and production (Vijay *et al*., 2018).

Different cultivars correspond differently to compensate for low or high seed rates in a variety of ways, including changing the number of spikes m^{-2}, number of tillers m^{-2}, weight of the grains in each spike and the number of grains per spike, i.e., a genotype to maintain dry biomass yield despite a low seeding rate by enhancing tiller production under encouraging environmental conditions (Šarauskis *et al*., 2022). Dual-purpose wheat varieties are specifically cultivated for both grain production and cattle grazing. When selecting dual-purpose varieties, it is important to consider their forage production potential, date of first hollow stem (which determines how long cattle can graze in the spring), and their recovery potential from grazing stress (West, 2022).

Higher seeding rates promote the development of more plants, which can compensate for the removal of biomass during grazing or cutting, ultimately leading to improved grain yield potential. Moreover, studies have shown that adjusting seeding rates based on environmental conditions and management goals can further enhance the performance of dual-purpose wheat by maximizing both forage quality and grain yield. By carefully considering seeding rates as a key management factor, farmers can effectively harness the dual-purpose potential of wheat to achieve sustainable and profitable agricultural outcomes (Naveed *et al.,* 2014). Differences in the relative significance of plants competition for nutrients, light and water at different stages of crop growth, the seeding rate significantly impacts the number of environmental resources (Ma *et al*., 2018). Higher seeding rates or a greater number of plants compensate for the loss of tillers caused by cutting in dual-purpose wheat when compared to low seeding rates. When it comes to the regulation of wheat production seed rate is among the most key parameter (Geleta *et al*., 2002).

Cutting enhanced yield from the same land with agronomic manipulation encourages single means and ways in the prevailing panorama. Cereals, particularly members of Poaceae family have the tendency to resprout and develop new tillers in response to injury to the top new leaves either because of frost or specific mechanical/animal or anthropogenic factors (Arber, 2010). Manipulating the potential of wheat to comprehend

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growth even in response to frost-based burning of foliage and multiplication of newly emerged tillers make it important to using it as fodder by cutting its foliage at an early stage before anthesis and the initiation of hollow stem stage (Wu *et al*., 2014).

Seeding rates have a significant impact on dual-purpose wheat production. Planting at lower seeding rates may result in similar forage yield but lower grain yield compared to higher seeding rates. Additionally, it is recommended that dual-purpose wheat management requires seeding rates 1.5 to 2.0 times greater than those used for only grain production. This strategy helps to optimize production risks and provides a balance between forage and grain yields in dual-purpose wheat systems (Munsif *et al.,* 2021).

Furthermore, optimization of SR in such aspects will help develop sustainable interventions to assess the food security of masses, both humans and livestock. Taking into consideration the above discussion wheat can be a dual-purpose crop as a persistent grain yield can be obtained even after cutting it for fodder use. Such practices can help sustain symbiotic productivity on the problem soils and environment and hilly areas where humans simultaneously depend on crops and livestock for livelihood.

2. MATERIALS AND METHODS

2.1 Experimental soil characteristics

Soil samples of the experimental site were collected through soil auger at depth of 0-25 cm before sowing of the crop. Samples were dried and aggregates were crushed into smaller ones and sieved with 2 mm of sieve size and forwarded to Soil and Water Testing Laboratory, Ayub Agricultural Research Institute, Faisalabad (Table 3.1).

Table 1: Soil physico-chemical analysis of experimental site

Parameters	Unit	Values	Status
Sampling depth	cm	0-25	-
pH	-	7.5±0.16	Slightly Alkaline
EC	dS m^{-1}	0.9±0.18	Normal
saturation %	%	42±0.8	-
Organic Matter	%	0.87±0.03	Medium
Texture	-	-	Loam soil
Sand	%	34.5±4	-
Silt	%	36.5±3	-
Clay	%	29±2.2	-
Nitrogen	%	0.51±0.02	Medium
Extractable Phosphorus	mg kg^{-1}	19.04±0.07	Medium
Extractable Potassium	mg kg^{-1}	187±8	High

Source: Soil and Water Testing Laboratory, Ayub Agricultural Research Institute, Faisalabad.

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2.2. Trial execution

Field experiment was conducted on 7th November 2022 to evaluate four wheat varieties for their dual-purpose wheat production and seed rate (SR) optimization. Seedbed was formed by ploughing the field twice with a cultivator followed by a rotavator. Research trials was conducted at Agronomy Research Farm, Department of Agronomy, University of Agriculture, Faisalabad (N° = 31° 26', E° = 73° 06' and Altitude = 184.4). Sowing of crop was done using hand drill by maintaining 22 cm row to row distance. The experiment was comprised of three factors i.e. three seed rates (123, 148 and & 173 kg ha^{-1}), two cuttings (no cut & cut at 60 DAS) and four varieties (Fakhr-e-bahkhasr-19, Anaj-17 & C-228). Nitrogen (N), phosphorus (P) and potassium (K) were applied as source of urea, diammonium phosphate (DAP) and Sulphate of potash (SOP) @133, 84, and 62 kg ha^{-1}, respectively. Phosphorus and potassium were incorporated during field preparation, while N was applied in three splits. The initial dose of N @60% was used at sowing time, while subsequently 2nd and 3rd splits @20% was applied at first irrigation and after 5 days of fodder cutting respectively. A total of four irrigations were applied using canal water as source. Moreover, 1st, 2nd, 3rd and 4th irrigation were managed 25, 45, 65 and 125 DAS (grain filling), respectively. Moreover, weeds control was done using Atlantis super 6% WP @ 247 g ha^{-1}, along with Biopower (Adjuvant) @ 395 ml ha^{-1}. For rust control, Teboconazole and Rectara Thiamethoxam were used as fungicide (50% W/W) and Pesticide (25% WG) with dose of 160 g ha^{-1} and 60 g ha^{-1}, respectively. The trial was laid out using randomized complete block design under factorial arrangement with three replicates. Weather data of experimental location was collected from Metrological Cell (Davis Vantage Pro2 Weather Station) of University of Agriculture, Faisalabad (Figure 1).

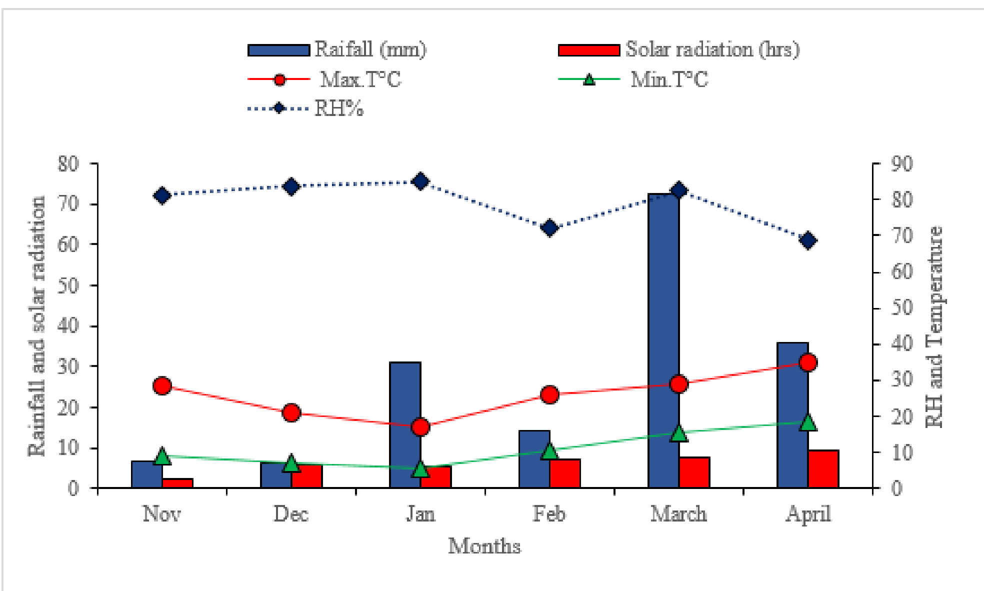

Figure 1: Monthly minimum and maximum temperature, rainfall, relative humidity and solar radiation during growing seasons of 2022-23

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2.3. Procedures for observation recording

The measurement of plant height and spike length was carried out at physiological maturity. A total of five plants were selected from each plot and measurement was made using a meter rod. However, grains per spike were counted of prescribed plants of each experimental unit. Number of tillers were collected from each plot in one-meter length and converted into square meter. Similarly, 1000-grain weight of experimental plot was weighed through using electric weighing balance.

Fresh fodder yield was assessed by harvesting two central rows after 60 days of sowing and weight was obtained of corresponding treatments and converted into kg ha^{-1} using the following formula.:

$$FFY\ (kg\ ha^{-1}) = \frac{Fresh\ fodder\ yield\ in\ 2\ central\ rows\ (kg)}{R\text{-}R\ distance\ (m)\ x\ No.\ of\ rows\ x\ row\ length\ (m)}\ x\ 10000m^2$$

Similarly, biological yield was obtained by harvesting two central rows from each plot and allowing them to dry under sun and transformed into kg ha^{-1} using the following formula:

$$Biological\ yield\ (kg\ ha^{-1}) = \frac{Biological\ yield\ in\ 2\ central\ rows\ (kg)}{R\text{-}R\ distance\ (m)\ x\ No.\ of\ rows\ x\ row\ length\ (m)}\ x\ 10000m^2$$

However, grain yield was obtained by employing the biological yield procedure and transformed into kg ha^{-1} using the following equation:

$$Grain\ yield\ (kg\ ha^{-1}) = \frac{Grain\ yield\ in\ 2\ central\ rows\ (kg)}{R\text{-}R\ distacne\ (m)\ x\ Row\ length\ (m)\ x\ No.\ of\ rows}\ x\ 10000\ m^2$$

Harvest index (HI) was calculated by grain yield over biological yield (Hay, 1995).

Economic analysis was done to evaluate the benefit and cost ratio associated with wheat production during the whole cropping cycle. Total expenditures related to the procurement of seeds, fertilizers, pesticides, personnel, machinery, irrigation and other pertinent operations. Fixed expenses weren’t incorporated into the analysis.

The gross returns (GR) were calculated by multiplying the grain yield (kg ha^{-1}) of each crop for that year with local market price. The valuation of the fodder and straw were determined by looking at the prices at local market. After deducting the cultivation cost (CC) from the gross returns (GR) and net return (NR) was determined using the formula NR = GR – CC. The determination of the benefit-to-cost ratio (B:C ratio) involves dividing the gross returns by the cost of cultivation (B:C ratio = GR/CC).

For BCR calculation the following method was approached (Adler and Posner, 2001).

$$Benefit\ cost\ ratio = \frac{Total\ income\ (Rs.)}{Total\ expenses\ (Rs.)}$$

Moreover, leaf area index, crop growth rate, leaf area duration and net assimilation rate were measured by Hunt’s method (Hunt, 1978).

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The determination of dry matter% was conducted in accordance with the standard protocol as described in the AOAC (2006) guidelines.

$$Dry\ matter\ (\%) = \frac{Weight\ of\ dry\ matter}{Weight\ of\ sample} \times 100$$

The moisture content (%) of the feed sample was determined by following the formula as described by AOAC (2006).

$$Moisture\ content\ (\%) = \frac{Loss\ of\ weight}{Weight\ of\ sample} \times 100$$

Kjeldahl method, as outlined by AOAC (2006), was used to calculate the N percentage.

$$N\ \% = \frac{Volume\ of \frac{N}{10}\ H_2SO_4 \times 0.0014 \times vol.of\ sample\ dilution}{Wt.of\ sample \times volume\ of\ solution\ used\ (10mL)} \times 100$$

Crude Protein (%) = N% × 6.25

To determine the Ether extract percentage recommended procedure by (AOAC, 2006) was followed.

$$Ether\ Extract\ (\%) = \frac{(Weight\ of\ Petri\ dish + resiude) - wt\ of\ petri\ dish}{Weight\ of\ sample} \times 100$$

Crude fiber was calculated using the method as described by (AOAC, 2006).

$$Crude\ Fibre\ (\%) = \frac{(Sample\ wt + Crucibe\ wt) - Wt.of\ crucible}{Weight\ of\ sample} \times 100$$

Total ash content was calculated using following method of AOAC, 2006

$$Ash\ content\ \% = \frac{(Wt.of\ ash + Wt.of\ Crucible)\ - Wt.of\ empty\ crucuble}{Weight\ of\ sample} \times 100$$

2.4. Statistical Analysis

The collected data were analyzed by employing Fisher analysis of variance technique (ANOVA) and the treatment means were compared by using Tukeys' Honestly Significance difference (HSD) at P ≤ 0.05 (Steel *et al.,* 1997). Moreover, Statistix-10 and OriginPro-2024 software's were used for data analyses. However, Pearson correlation analysis was performed using two- tailed test (df-2) through R studio version 4.3.1.

3. RESULTS

Reference to data of this study which was evident from the Table 2 and Table 3 showing that the F-value of studied traits had significant variation for wheat varieties, cutting intervals and seed rates under semiarid conditions of Faisalabad Pakistan.

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Table 2: F-value of studied traits as affected by seed rates, cutting intervals and wheat varieties under Faisalabad conditions

Traits	F-value of studied traits						
	SR	Cutting	Varieties	SR x Cutting	SR x Varieties	Cutting x Varieties	SR x Cutting x Varieties
Days to 50% heading	5.52**	34.67**	15.13**	2.03NS	0.72NS	2.13NS	1.50NS
Days to physiological maturity	1.69NS	16.78**	4.62**	0.08NS	1.02NS	1.61NS	0.58NS
Plant height	83.23**	121.61**	58.54**	0.77NS	14.09**	1.91NS	7.35**
Tillers per plant	2.89NS	0.72NS	1.20NS	4.52*	2.47*	4.82**	3.01*
Spike length	1.59NS	5.05*	4.72**	3.79*	1.96NS	0.20NS	1.60NS
Grains per spike	84.58**	33.61**	7.51**	5.70**	48.77**	15.93**	16.31**
1000-grain weight	2.77NS	14.80**	51.96**	0.49NS	2.61*	0.45NS	2.15NS
Biological yield	18.29**	17.20**	2.22NS	5.01*	1.36NS	0.25NS	0.68NS
Grain yield	0.29NS	94.98**	9.45**	3.12NS	2.78*	1.20NS	6.77**
Harvest index	9.32**	21.54**	4.91**	7.66**	1.70NS	1.12NS	4.27**
Leaf area index	3.61*	4.24*	6.97**	6.67**	0.70NS	1.30NS	0.96NS
Leaf area duration	37.00**	2119.85**	22.12**	10.67**	4.07**	13.12**	6.64**
Total dry matter	57.21**	1703.93**	1.37NS	5.44**	4.27**	0.80NS	4.19**
Crop growth rate	2.62NS	198.33**	0.42NS	0.08NS	0.87NS	1.18NS	0.85NS
Net assimilation rate	13.75**	243.69**	17.33**	8.99**	5.01**	5.93**	4.87**

Here, SR = seed rate, * = P≤0.05, ** = P≤0.01

Table 3: F-value of studied traits as affected by seed rates, cutting interval and wheat varieties under Faisalabad conditions

Traits	F-value of studied traits		
	SR	Varieties	SR x Varieties
Fresh fodder yield	8.86**	65.40**	8.27**
Crude protein (%)	12.96**	0.87NS	0.28NS
Fiber content (%)	5.92**	6.34**	4.78**
Fat (%)	18.98**	4.82**	11.30**
Ash (%)	2.53NS	3.45*	1.88NS

Here, SR = seed rate, * = P≤0.05, ** = P≤0.01

C.22. **Days to 50% heading (days)**

Significant effects were observed for seed rate (SR), cutting intervals, and varieties however, no significant interactions were noted of subject trait (Table 2). For days to 50% heading (DH 50%) the highest value (115.12) was observed at a seed rate of 123 kg ha^{-1}, while the lowest (113.46) duration recorded at 173 kg ha^{-1} (Table 4). Cutting at 60 DAS had increased DH 50% (115.53) as compared to no cutting. Among the varieties, C-228 exhibited the highest DH 50% (116.22), whereas Anaj-17 showed the lowest (112.33).

3.2. Days to physiological maturity

Significant effects were observed for cutting intervals and varieties, although no significant interactions were noted (Table 2). For day to physiological maturity (DPM), the highest value (160.33) was recorded at a seed rate of 123 kg ha^{-1}, while the lowest

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(159.38) was recorded at a seed rate of 148 kg ha^{-1} (Table 4). Cutting at 60 DAS increased the DPM (160.69) as compared to no cutting (158.72). Among the varieties, C-228 exhibited the highest DPM (160), whereas Anaj-17 showed the lowest DPM (158).

3.3. Crop growth rate (g m^{-2} day^{-1})

Cutting intervals as sole factor had a significant effect on crop growth rate (CGR), although no significant interactions were observed (Table 2). The maximum CGR value (13.58) was recorded at a seed rate of 148 kg ha^{-1}, while the minimum (13.22) was observed at 123 kg ha^{-1} (Table 4).

No cutting resulted in the highest CGR (14.41), whereas cutting at 60 DAS decreased it to 12.26. Among the varieties, Anaj-17 had the highest CGR (13.42), while Gulzar-19 had the lowest (13.19) CGR.

Table 4: Mean comparison of studied attributes i.e. days to 50% heading (DH 50%), days to physiological maturity (DPM) and crop growth rate (CGR). Identical lowercase alphabets indicate insignificant differences among experimental treatments

Seed rate	DH 50%	DPM	CGR
123 kg ha^{-1}	115.12^{a}	160.33	13.22
148 kg ha^{-1}	114.38^{ab}	159.38	13.58
173 kg ha^{-1}	113.46^{b}	159.42	13.21
HSD	1.22	NS	NS
Cutting time			
No cut	113.11^{b}	158.72^{b}	14.41^{a}
Cut at 60 DAS	115.53^{a}	160.69^{a}	12.26^{b}
HSD	**0.83**	**0.97**	**0.31**
Varieties			
Fakhr-e-bahkhar-19	114.56^{b}	160.11^{a}	13.35
Anaj-17	112.33^{c}	158.17^{b}	13.42
C-228	116.22^{a}	160.39^{a}	13.37
Gulzar-19	114.17^{b}	160.17^{a}	13.19
HSD	1.55	1.82	NS

3.4. Plant height (cm)

Seed rate, cutting intervals, and varieties significantly affected the plant height (PH), however, interactive effect of SR x cutting x varieties also observed significant (Table 2).

The highest plant height (113.33) was measured in Fakhr-e-bahkhar-19 variety with no cut treatment using 123 kg ha^{-1} seed rate (Fig. 2.A). Conversely, the shortest plants length (86) recorded in C-228 variety with Cut at 60 DAS treatment by employing 173 kg ha^{-1} seed rate.

3.5. Number of tillers $plant^{-1}$

Data regarding the subject parameter, no individual factors showed significant variation. However, significant interaction of SR x cutting x varieties was found (Table 2). The

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maximum number of tillers plant^{-1} (TPP) (6.67) observed in C-228 variety with no cut treatment using 148 kg ha^{-1} seed rate (Fig. 2.B). Conversely, the lowest TPP (4.67) were recorded in Anaj-17 and Fakhr-e-bahkhar-19 variety with no cut treatment using 123 kg ha^{-1} seed.

3.6. Number of grains spike^{-1}

Seed rate, cutting intervals, and varieties significantly influenced grains spike^{-1} (GPS). However, all interactions effects also found significant (Table 2). The highest GPS (73.56) observed in Anaj-17 variety with no cut treatment by using seed rate of 173 kg ha^{-1} and the lowest number of GPS (41.11) recorded in same variety with no cut treatment by employing 123 kg ha^{-1} seed rate (Fig. 2.C).

3.7. Grain yield (kg ha^{-1})

Garin yield (GY) was significantly influenced by varying seed rates, varieties and cutting intervals (Table 2). The highest GY (5142.13) was observed in the Fakhr-e-bahkhar-19 variety with the no cut treatment at a seed rate of 123 kg ha^{-1} (Fig. 2.D). Conversely, the lowest GY (3456.67) was recorded in C-228 variety with cutting at 60 DAS treatment and a seed rate of 148 kg ha^{-1}.

3.8. Spike length (cm)

Cutting intervals and varieties had a significant effect on spike length (SL), while interactive response of SR x cutting, and SR x Varieties also recorded significant (Table 2). Describing results of SR x varieties interaction (Fig. 3.A), the highest (13.5) SL was observed in Fakhr-e-bahkhar-19 variety using 148 kg ha^{-1} seed rate.

In contrast, the minimum SL (11.5) noted in the Gulzar-19 variety at 123 kg ha^{-1} seed rate. Moreover, seed rate x cutting resulted that the highest SL (12.83) was recorded in cut treatment by using 148 kg ha^{-1} seed rate while the least SL (11.75) was measured under no cut treatment and 173 kg ha^{-1} seed rate (Fig. 3.C).

3.9. 1000-grain weight (g)

Cutting intervals and varieties significantly affected the 1000-grain weight (Table 2). The maximum 1000-grain weight (44.8) was observed in Fakhr-e-bahkhar-19 variety at 148 and 173 kg ha^{-1} seed rates. While the minimum 1000-grain weight (35.8) recorded in Anaj-17 variety at 148 kg ha^{-1} seed rate (Fig. 3.B).

3.10. Biological yield (kg ha^{-1})

Interactive response of seed rate and cutting intervals showed significant effect on biological yield (Table 2). The maximum BY (13016.8) was collected using 148 kg ha^{-1} seed rate along with no cut treatment. In contrast, the minimum biomass (10861.4) obtained by employing 123 kg ha^{-1} seed rate with cut at 60 DAS treatment (Fig. 3.D).

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3.11. Harvest index (%)

Seed rate, cutting intervals, and varieties showed significant response on harvest index (HI) and interactive response of SR x cutting also found significant (Table 2). The highest HI (43.86) was calculated in Anaj-17 variety with no cut treatment and 173 kg ha^{-1} seed rate. Conversely, the lowest HI (27.1) reflected in C-228 variety with cut at 60 DAS treatment and 148 kg ha^{-1} seed rate (Fig. 6.D).

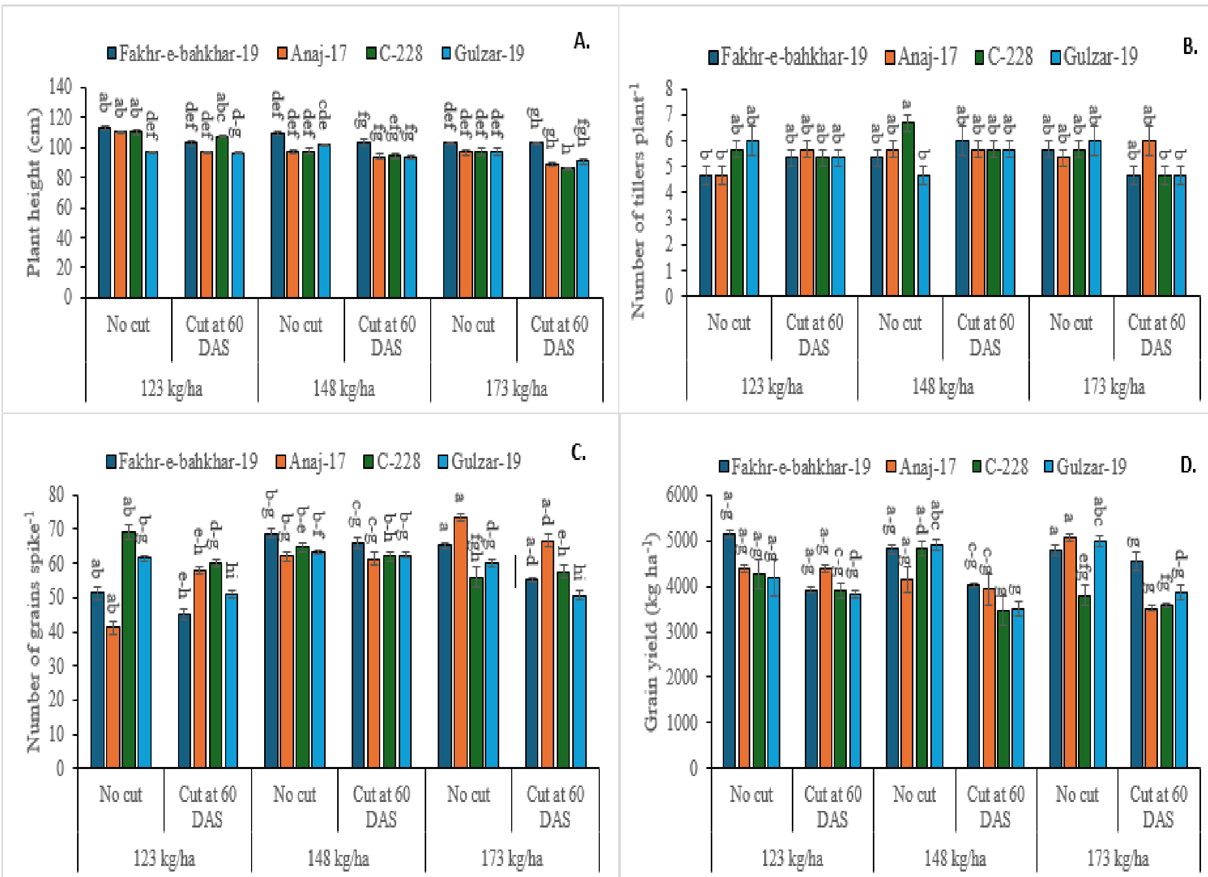

Figure 2: Mean comparison of studied attributes i.e. plant height (A), number of tillers per plant (B), number of grains per spike (C) and grain yield (D). Identical lowercase alphabets indicate insignificant differences among experimental treatments. Error bars showing the variation among the experimental units which have been treated alike

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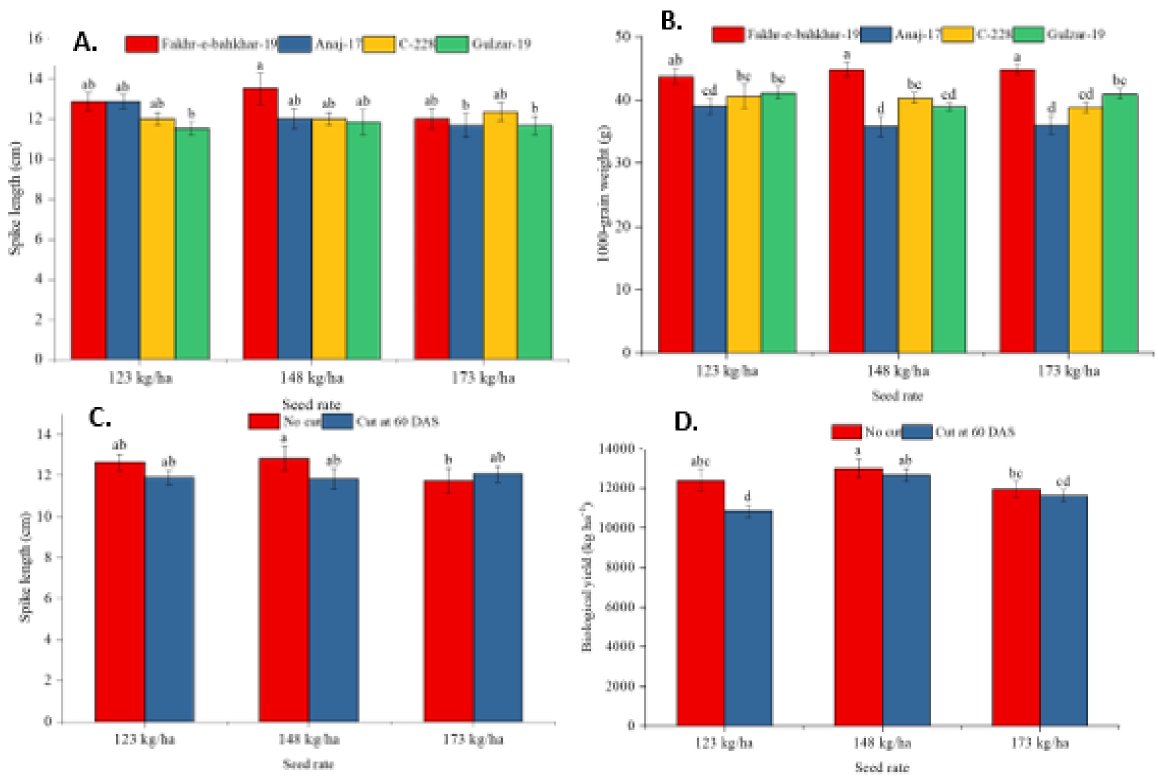

Figure 3: Mean comparison of studied attributes i.e. spike length (A.), 1000 grain weight (B), spike length (C) and biological yield (D). Identical lowercase alphabets indicate insignificant differences among experimental treatments. Error bars showing the variation among the experimental units which have been treated alike

3.12. Fresh fodder yield (kg ha^{-1})

The study found that seed rates and varieties had significant effect on fresh fodder yield (FFY) as well as interaction effect also found significant (Table 3). Interactive effect of SR x varieties resulted that the maximum FFY (32323.23) was collected from C-228 variety using 173 kg ha^{-1} seed rate. In contrast, the minimum FFY (19696.97) was obtained from Gulzar-19 variety along with 123 and 173 kg ha^{-1} seed rates (Fig. 4.A).

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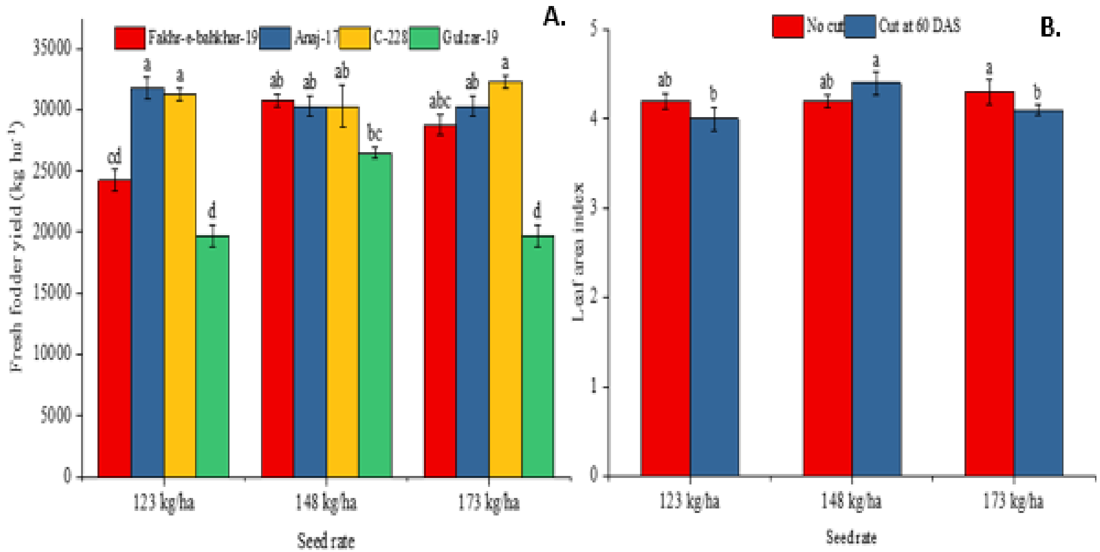

Figure 4: Mean comparison of studied attributes i.e. Fresh fodder yield (A) and leaf area index (B). Identical lowercase alphabets indicate insignificant differences among experimental treatments. Error bars showing the variation among the experimental units which have been treated alike.

3.13. Crude protein (%)

Seed rates had significant effect on crude protein content (CP%), but interactive effect was not found significant (Table 3). The highest CP% (12.65) was determined using 148 kg ha^{-1} seed rate while the lowest CP% (10.44) was recorded at 173 kg ha^{-1} (Table 5). Among the varieties, Anaj-17 had the highest (12.10) CP%, whereas both Fakhr-e-bahkhar-19 and C-228 showed the lowest protein content.

3.14. Ash content (%)

Varieties showed a significant effect on ash content, whereas seed rates and interaction effect were found insignificant (Table 3). Among the varieties, Fakhr-e-bahkhar-19 exhibited the highest ash content (10.67), while the lowest ash content (9.06) was observed in C-228 (Table 5).

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Table 5: Mean comparison of crude protein (CP) and ash content as affected by seed rates, cutting interval and wheat varieties under Faisalabad conditions. Identical lowercase alphabets indicate insignificant differences among experimental treatments

Seed rate	Crude protein %	Ash %
123 kg ha^{-1}	12.04^{a}	10.46
148 kg ha^{-1}	12.65^{a}	9.47
173 kg ha^{-1}	10.44^{b}	9.45
HSD	1.13	NS
Varieties		
Fakhr-e-bahkhar-19	11.42	10.67^{a}
Anaj-17	12.10	9.22^{b}
C-228	11.42	9.06^{b}
Gulzar-19	11.89	10.22^{ab}
HSD	NS	1.65

3.15. Fiber content (%)

Both seed rates and varieties significantly affected fiber content (FC) as well as interactive effect was also recorded significant (Table 3). Moreover, the maximum FC (25) was determined in C-228 variety at 148 kg ha^{-1} seed rate. In contrast, the minimum FC (18) recorded in Gulzar-19 variety at 123 kg ha^{-1} seed rate (Fig. 5.A).

3.16. Fat content (%)

Seed rates and wheat varieties had significant effect on fat content and the interactive effect also found significant (Table 3). The maximum fat content (3.4) was observed in Fakhr-e-bahkhar-19 variety at 148 kg ha^{-1} seed rate. In contrast, the minimum fat content (2) recorded in C-228 variety at 173 kg ha^{-1} seed rate (Fig. 5.B).

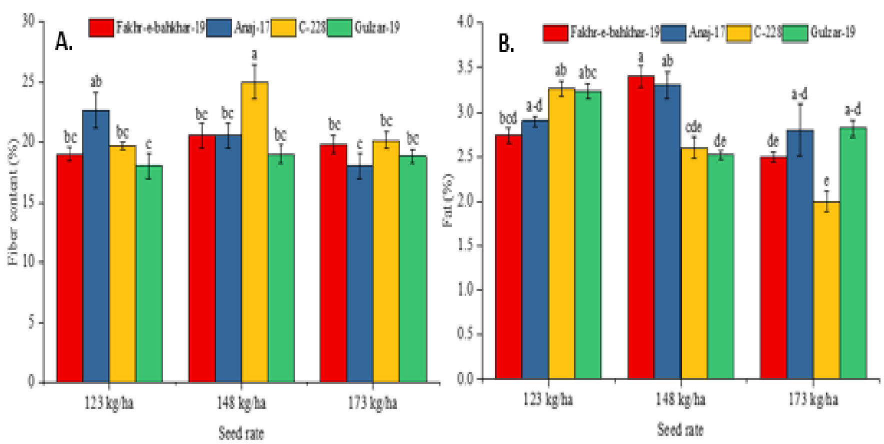

Figure 5: Mean comparison of studied attributes i.e. fiber content (A) and fat content (B). Identical lowercase alphabets indicate insignificant differences among experimental treatments. Error bars showing the variation among the experimental units which have been treated alike

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3.17. Leaf area index (%)

The main effects of seed rate, cutting intervals, and varieties were significant (Table 2). Additionally, the interaction between seed rate and cutting was also significant. The maximum leaf area index (4.4) was observed at seed rate of 148 kg ha^{-1} when cut at 60 DAS treatment. In contrast, the minimum leaf area index (4) was recorded at a seed rate of 123 kg ha^{-1} with cut at 60 DAS treatment (Fig. 6.A).

3.18. Leaf area duration (days)

Seed rate, cutting intervals, and varieties significantly affected leaf area duration (LAD). Significant interactions were noted for seed rate x cutting, seed rate x varieties, and cutting x varieties (Table 2). The highest LD (179.58) was found in C-28 variety with no-cut treatment at a seed rate of 173 kg ha^{-1}. Conversely, the lowest LAD (117.23) was observed in Anja-17 variety when cut at 60 DAS using 123 kg ha^{-1} seed rate (Fig. 6.A).

3.19. Total dry matter (g m^{-2})

Seed rate and cutting intervals significantly influenced total dry matter (TDM) as well as interactive effect of three factors also found significant (Table 2). The highest TDM (1275.03) was achieved from variety Fakhr-e-bahkhar using 173 kg ha^{-1} seed rate by employing not cut treatment, while the lowest value was obtained by employing all seed rates and wheat varieties when cut at 60 DAS (Fig. 6.C).

3.20. Net assimilation rate (g m^{-2} day^{-1})

Seed rate, cutting intervals, and varieties significantly influenced net assimilation rate and interactive effect of three factors also found significant (Table 2). Results indicated that the highest NAR (8.85) was calculated from C-228 variety when crop was cut at 60 DAS and with seed rate of 123 kg ha^{-1}. In contrast, the minimum NAR (6.96) was recorded in Gulzar-19 variety with no-cut treatment at seed rate of 173 kg ha^{-1} (Fig. 6.B).

3.21. Description of Pearson correlation analysis

Pearson correlation analysis was performed to address the relationship among agronomic traits of seed rates, wheat verities and cutting intervals (Fig. 7). It highlighted strong positive correlations of grain yield (GY) with thousand grain weight (TGW) and plant height (PH).

The analysis also showed that TGW strongly positively correlated with PH and spike length (SL). Similarly, the correlation coefficients also indicated a positive relationship between SL and PH. Conversely, PH had a negative correlation with number of tillers $plant^{-1}$ (TPP) as well grains $spike^{-1}$ suggesting that taller plants might not always lead to a greater TPP.

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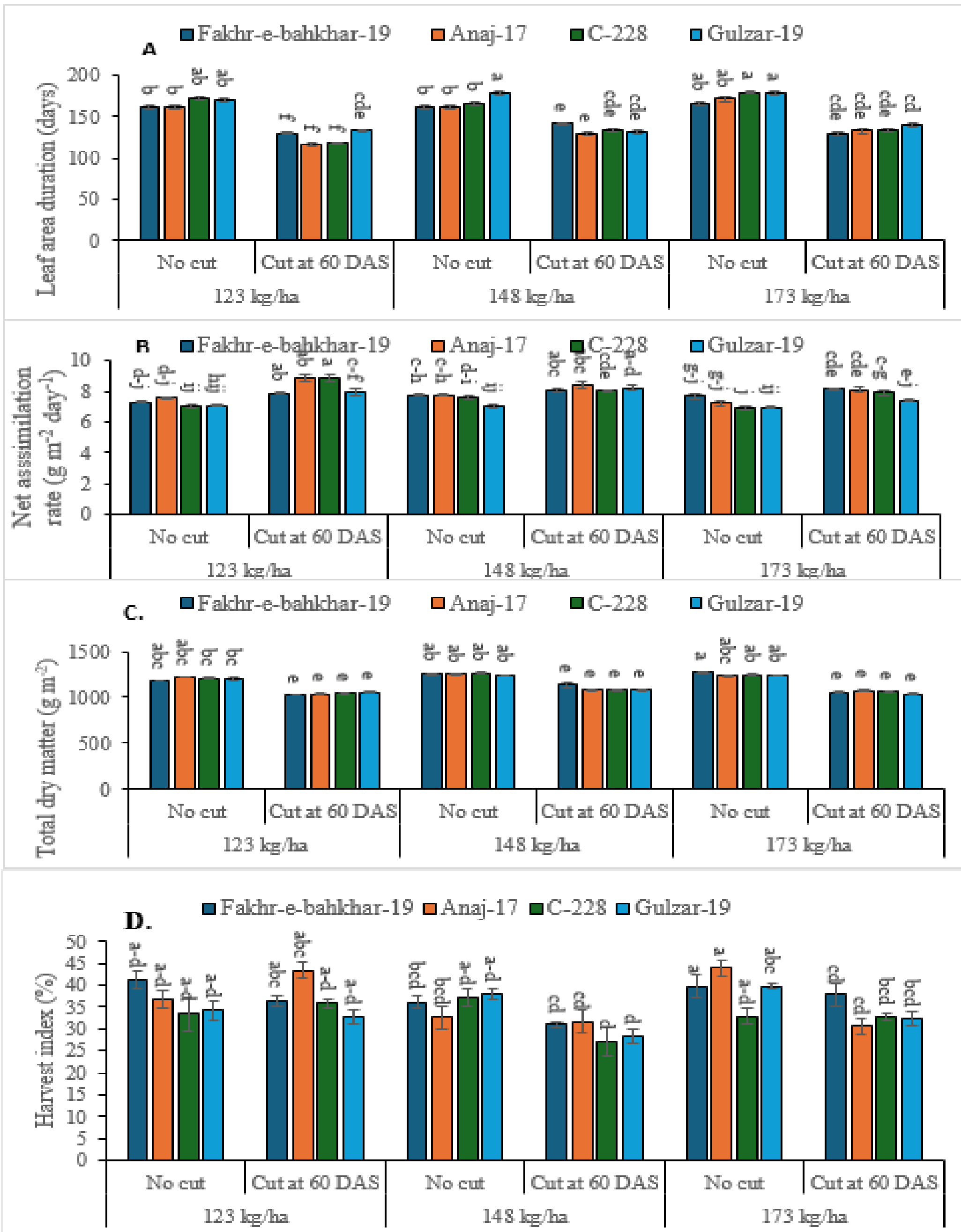

Figure 6: Mean comparison of studied attributes i.e. leaf area duration (A), net assimilation rate (B), total dry matter (C) and harvest index (D). Identical lowercase alphabets indicate insignificant differences among experimental treatments. Error bars showing the variation among the experimental units which have been treated alike

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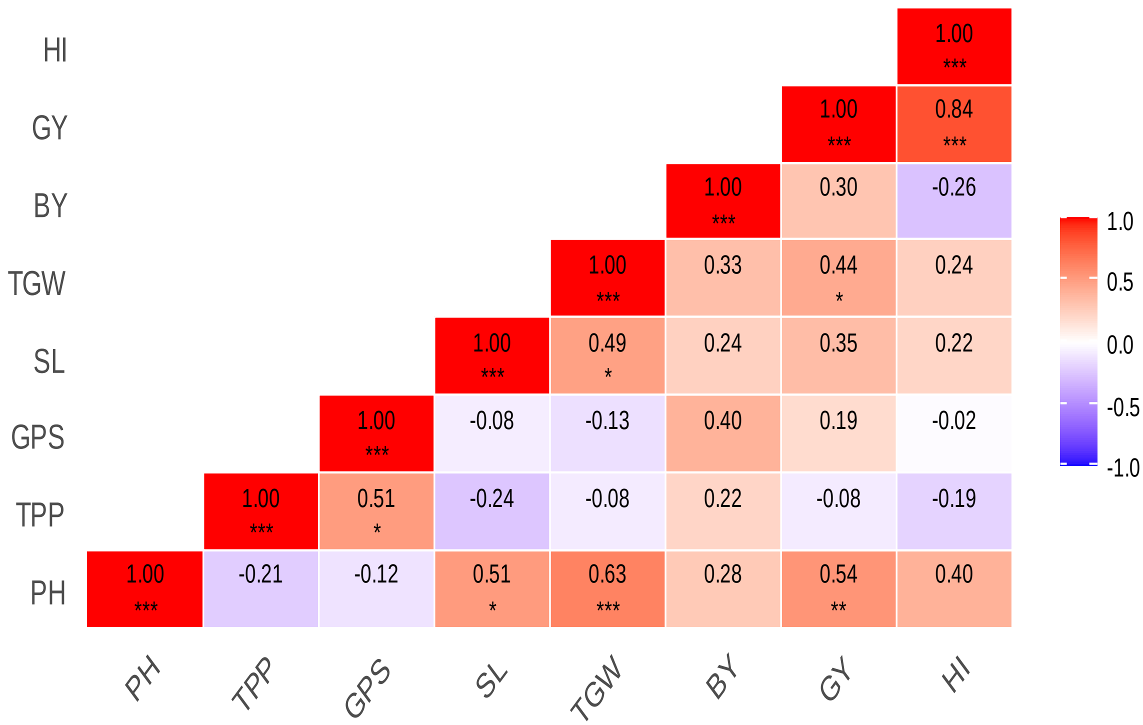

Figure 7: Pearson correlation matrix for wheat varieties under different seed rates i.e., Number of grains spike^{-1} (GPS), Spike length (SL), 1000-grain weight (TGW), Grain yield (GY), Biological yield (BY), Harvest index (HI), Number of tillers plant^{-1} (TPP), Plant height (PH).

* = p ≤ 0.05, ** = p ≤ 0.01, and *** = p ≤ 0.001

3.22. Economic analysis

Data regarding economic analysis is reported in Table 6. Analysis of the data revealed that cut plots produced higher net income as compared to no cut plots. Economic analysis showed the highest benefit-cost ratio in wheat variety Anaj-17 (1:3.05), where the fodder was harvested after 60 days of sowing, and a SR of 123 kg ha^{-1} was utilized which was followed by Fakhr-e-bahkhar-19 (1:3) where the fodder was also cut at 60 DAS and a SR of 173 kg ha^{-1} was employed. Conversely, the lowest benefit-cost ratio was recorded in no cut plots of C-228 variety (1:1.24) by using 173 kg ha^{-1} seed followed by Anaj-17 (1:1.46) in no cut plots with usage of 146 kg ha^{-1} seed. This indicated that Fakhr-e-bahkhar-19 generated the maximum revenue while C-228 produced minimum revenue as compared to the other varieties.

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Table 6: Economic analysis of Agronomic assessment of dual purpose wheat under different seed rates

Variety	Treatment	Cutting	Fodder Income (Rs)	Straw Income (Rs)	Grain Income (Rs)	Gross Income (Rs)	Total expenditure (Rs)	Net Income (Rs)	BCR
Fakhr-e-bahkhar-19	$C_0SR_1V_1$	No cut	0	73406	514213	587619	200795	386824	1:1.93
Anaj-17	$C_0SR_1V_2$	No cut	0	76092	437133	513225	200795	312430	1:1.56
C-228	$C_0SR_1V_3$	No cut	0	86750	427000	513750	200795	312955	1:1.56
Gulzar-19	$C_0SR_1V_4$	No cut	0	79958	419167	499125	200795	298330	1:1.49
Fakhr-e-bahkhar-19	$C_1SR_1V_1$	Cut at 60 DAS	242424	68421	391833	702678	200795	501883	1:2.50
Anaj-17	$C_1SR_1V_2$	Cut at 60 DAS	318182	57346	437333	812861	200795	612066	1:3.05
C-228	$C_1SR_1V_3$	Cut at 60 DAS	313131	69768	389733	772633	200795	571838	1:2.85
Gulzar-19	$C_1SR_1V_4$	Cut at 60 DAS	196970	78687	383433	659090	200795	458295	1:2.28
Fakhr-e-bahkhar-19	$C_0SR_2V_1$	No cut	0	85577	482300	567877	202595	365282	1:1.80
Anaj-17	$C_0SR_2V_2$	No cut	0	85906	413333	499239	202595	296644	1:1.46
C-228	$C_0SR_2V_3$	No cut	0	82458	482700	565158	202595	362563	1:1.79
Gulzar-19	$C_0SR_2V_4$	No cut	0	79794	491040	570834	202595	368239	1:1.82
Fakhr-e-bahkhar-19	$C_1SR_2V_1$	Cut at 60 DAS	308081	90052	402833	800966	202595	598371	1:2.95
Anaj-17	$C_1SR_2V_2$	Cut at 60 DAS	303030	84588	393000	780618	202595	578023	1:2.85
C-228	$C_1SR_2V_3$	Cut at 60 DAS	303030	94097	345667	742794	202595	540199	1:2.67
Gulzar-19	$C_1SR_2V_4$	Cut at 60 DAS	264918	89047	349880	703845	202595	501250	1:2.47
Fakhr-e-bahkhar-19	$C_0SR_3V_1$	No cut	0	73313	480532	553845	204395	349450	1:1.71
Anaj-17	$C_0SR_3V_2$	No cut	0	65380	507167	572546	204395	368151	1:1.80
C-228	$C_0SR_3V_3$	No cut	0	77455	380000	457455	204395	253060	1:1.24
Gulzar-19	$C_0SR_3V_4$	No cut	0	75453	499168	574621	204395	370226	1:1.81
Fakhr-e-bahkhar-19	$C_1SR_3V_1$	Cut at 60 DAS	287879	74857	453833	816569	204395	612174	1:3.00
Anaj-17	$C_1SR_3V_2$	Cut at 60 DAS	303030	80537	351967	735534	204395	531139	1:2.60
C-228	$C_1SR_3V_3$	Cut at 60 DAS	323232	73621	357833	754686	204395	550291	1:2.69
Gulzar-19	$C_1SR_3V_4$	Cut at 60 DAS	196970	80853	385833	663656	204395	459261	1:2.25

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4. DISCUSSION

The present study encompassed different wheat varieties, cutting intervals and seed rates were selected to assess the performance of different wheat varieties as dual purpose. Data regarding plant height (PH) and tillers plant^{-1} (TPP) manifested the maximum value at 123 kg ha^{-1} and 148 kg ha-^{1} seed rates respectively, while total dry matter (TDM) revealed the maximum value at 173 kg ha^{-1} seed rate while, LAI and CGR were higher at 148 kg ha^{-1} rate. Whereas the leading NAR was calculated where 123 kg ha^{-1} seed was used. Whilst the maximum leaf area duration (LAD) value was recorded for 173 kg ha^{-1} seed rate as compared to other seed rates. The soil water and nutrient consumption showed an increased tendency with increasing SR (Naseri *et al*., 2012; Zhang *et al*., 2023), so the maximum PH and TPP at 173 kg ha^{-1} might be linked with a higher light interception, lower nutrient, and water competition among wheat seedlings. While the reason for maximum total dry matter, leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) at 173 kg ha^{-1} might be associated with a higher seed rate led to an increased number of plants and an increased number of leaves and CGR, which led to maximum light interception and increased NAR. These results were supported by Hussain *et al*. (2010), Rajesh *et al*. (2018) and Singh *et al*. (2023). These results suggested that a higher plant population lowered the plant spacing and reduced the ground area per plant thus causing more LAI (Ishfaq *et al*., 2009).

The current study is corroborated by the findings of Sewhag *et al*. (2023) who also noted higher wheat growth with no cutting treatment. The cutting treatment reduced the LAI and CGR which could be due to cutting stress that resulted the curtailment of leaf area and hence lower crop growth (Naveed *et al*., 2015). However, the maximum PH, SL, LAI and TDM were observed in Fakhr-e-bahkhar-19, while TPP and CGR were measured higher in C-228 than in other varieties irrespective of SR and cutting treatments (Fig. 2.A, Fig. 3.A & C, Fig. 4.B and Fig. 6.C), these variations indicate that the morphological and growth traits are largely governed by genetic factors as compared to environmental factors (Chen *et al*., 2014; White *et al*., 2012).

The higher SL and HI, at 148 kg ha^{-1} seed rate whereas, DH 50% had the highest at 123 kg ha^{-1} might be due to the higher crop growth rate maintained due to no nutrient and water competition and maximum light penetration through plant canopy (Hussain *et al*., 2001). The extended maturity time at the highest seed rate may be linked with the retention of soil water under denser canopy cover due to higher population density (Melash *et al*., 2019). However, Jemal *et al*. (2015) noted the non-significant effect of the seed rate on the physiological maturity time of wheat. In contrast, high plant population per unit area resulted in higher biomass production as observed by Khalid *et al*. (2014) and Jemal *et al*. (2015), but the reduction of grain quality traits at increased SR might be due to its effect on individual grain weight because of plant competition for available resources. However, these traits were not only affected by SR but also varied with genetic factors (Melash *et al*., 2019).

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The present findings are also confirmed by Khalid *et al*., (2014), who noted that cutting of wheat at 60 DAS perturbed the wheat grain yield, number of grains per spikes, thousand grain weight and biological yield. The yield reduction at 60 DAS cutting may be due to the stress induced by cutting and detachment of foliage leaves for fodder, which play a pivotal role in photosynthesis, carbon dioxide fixation, light interception and reduced portioning of assimilates towards the sink. Moreover, initially accumulated nutrients in fresh forage were removed from the cut plants which resulted in reduced crop growth and economic yield penalty (Khalil *et al*., 2011; Islam *et al*., 2016). Light grain weight and reduced spike length in cut plots might be due to lower leaf area index at 60 DAS (Naveed *et al*., 2015; Islam *et al*., 2016). While higher DPM and DH 50% with increasing seed rate may be due to the activation of stress responsive genes. It is reportedly confirmed that during stress conditions plant onset grains. These studies were confirmed by Poudel *et al*. (2020), who noted that under stress conditions plants mature earliest as compared to control conditions.

However, higher SR resulted in maximum fresh fodder yield which may be associated with a denser plant population m^{-2}, and higher LAI, the number of leaves that resulted in higher biomass production, dry matter and higher fodder yield. These studies are also confirmed by Naveed *et al*., (2014) and Dagar *et al*., (2023). Additionally, ash % and fat content were higher at 123 kg ha^{-1} and 148 kg ha^{-1} rates respectively. The reason for the higher content of these attributes may be related to higher nutrient and water availability at the lowest seed rate as compared with increasing seed rate. Furthermore, higher CP and FC were ascertained under 148 kg ha^{-1} in varieties Anaj-17 and C-228 respectively. The higher CP and FC under increasing SR may be associated with population density stress caused by competition among plants for nutrient and water resources. According to Gebruers *et al*., (2010) and Rakszegi *et al.,* (2019), stress conditions have a synergetic effect on CP and FC content in wheat. In contrast, Dagar *et al.,* (2023) noted higher CP at the lowest SR. However, all the varieties have inherited the ability to retain different quality and quantity measures of fodder under varying SR conditions.

Economic analysis revealed that C_1 (cutting after 60 days of sowing) reduced the grain yield, but additional benefits were achieved in terms of fresh fodder yield that exceeded the loss of grain yield. This study is confirmed by Islam *et al*. (2016). So, cutting treatment after 60 DAS of sowing at 123 kg ha^{-1} and 173 kg ha^{-1} is recommended for Anaj-17 and Fakhr-e-bahkhar-19, respectively for the dual-purpose of wheat production. Moreover, 123 kg ha^{-1} seed rate was more beneficial for increasing the grain yield, while fodder yield was higher under 173 kg ha^{-1}. So, a slight change in seed rate and ignorance of cutting treatment can result in an economic crisis and a rise in inexplicable expenditures.

5. CONCLUSION

The optimal seed rate depends on the specific variety and environmental conditions. However, higher seed rates exposed substantial impact regarding denser stand establishment and potentially higher forage yields. Generally, optimization of seed rates

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for dual-purpose wheat prevailing Faisalabad climatic conditions exerted significant influence on phenology, fodder and grain production. Wheat variety C-228 gathered the leading fresh fodder yield using 173 kg ha^{-1} seed. However, Fakhr-e-bahkhar-19 and Anaj-17 exhibited the highest grain yield under no cut treatment using 123 kg ha^{-1} and 173 kg ha^{-1} seed rates respectively. Fodder crude protein was the maximum where 148 kg ha^{-1} seed was applied. As per economic concern the highest benefit-cost ratio was observed in wheat variety Anaj-17 where the fodder was harvested after 60 days of sowing, and seed rate of 123 kg ha^{-1} was employed which was followed by Fakhr-e-bahkhar-19 where the fodder was also cut after 60 days, using 173 kg ha^{-1} seed rate.

Conflict of Interest:

The Authors have no Conflict of Interest

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