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RESEARCH PAPER

Effect of different sowing dates, planting methods and irrigation intervals on performance of wheat varieties under agro-climatic conditions of Bahawalpur region

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Key Message: The objective of this research is to highlight the significant effect of different characteristics such as planting time, planting method and irrigation intervals on optimization of cultivation practices in wheat crop. Additionally, the study also exposed that crop growth and production were also influenced by genotype selection, sowing time and planting method.

Abstract

Wheat is considered one of the most important staple foods of Pakistan that plays a substantial role to address the food security challenges. Due to increase in water scarcity in southern region of Pakistan, wheat production is highly affected during winter season. The research was conducted to investigate the response of wheat varieties under different moisture regimes, sowing dates and planting methods at Regional Agricultural Research Institute (RARI), Bahawalpur, Pakistan in 2021. Under experiment 1, five genotypes of wheat [V1 (18003), V2 (180059), V3 (BF-1019), V4 (195715), and V5 (Ghazi-19)] showed significant variations in plant height, spike length and plant density across different irrigation regimes. In experiment 2, the effect of sowing dates on eight wheat genotypes was evaluated. Growth parameters displayed diverse responses based on sowing time in this experiment. Experiment 3 investigated the effect of different planting methods on the growth and yield of wheat genotype Ghazi-2019. The results revealed significant variations in plant height, spike length and plant density by applying different planting methods. Planting of wheat variety Ghazi-2019 on ridges exposed best results with highest yield per square meter and per hectare. The outcomes of this research provide valuable insights that overall yield of wheat genotypes was enhanced under Bahawalpur agro-climatic conditions by optimizing cultivation practices and considering genotype-specific characteristics, sowing time and sowing methods. The findings proposed that genotype selection, sowing time and sowing method all can influence wheat growth and productivity and emphasize on the need for comprehensive strategies for maximum agricultural productivity under diverse environmental conditions.

Keywords: Genotypes, Growth parameters, Irrigation regimes, Planting methods, Sowing dates, Wheat varieties

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Introduction

Wheat is the most important staple crop in Pakistan, particularly in the irrigated zones of Punjab and Sindh during the winter season (Anser et al., 2018; Shafqat et al., 2019; Mehmood et al., 2020; Shehzad et al., 2022). Furthermore, about 8 M hectare is cultivated by wheat farmers in state, making up 37% of all cultivated land and 66% of the area dedicated to food grain. It makes up over 74% of the entire amount of food grains produced (Khan et al., 2016; Skorupka & Nosalewicz, 2021). Water is becoming an increasingly important and scarce resource in Pakistani agriculture, which is heavily reliant on rainfall, irrigation flow from the Indus basin, and water storage in dams. River flow is heavily impacted by the seasonal rainfall, which is significantly more erratic, specifically in the Rabi season (Swelam et al., 2022). Wheat is among the most crucial crops for human nutrition (*Triticum aestivum* L.). Hunger and unstable prices are a result of recent wheat production that has not kept up with consumer demand. With a project there will be 9 billion people on the world in 2050, 60% rise in the need for wheat (Tariq et al., 2020). Wheat crops produced the Previous studies have consistently demonstrated that applying irrigation at all discernible growth stages leads to the highest grain yield. However, the increase in yield per unit space is necessary for the effective use of inputs and irrigation water, is progressively declining. The importance of efficient water usage is inevitable due to the increasing demand for food and clean water. Research conducted earlier in Pakistan consistently revealed that irrigation significantly boosted wheat yield (Igrejas & Branlard, 2020). In Pakistan, wheat cultivation is classified as rainfed wheat production (Barani) and irrigated wheat production.

Soil moisture deficiencies have an impact on both grain production and water efficiency. Water constraints during jointing (50-60% of field capacity), booting, and heading (65-70%) affected wheat yield, which increased by 25% during the late reproductive stage (50-60% of the field's potential). Irrigation with a 66 percent soil moisture difference was shown to be the most efficient for increasing wheat grain output (Zhang et al., 2022). The ultimate result of a multitude of supporting and interconnected factors, such as the quantity of grains per ear, the quantity of ears per unit area, and the average kernel weight, is how water deprivation affects plant development and grain output in wheat and other cereals. Relative to stressed plants, watered plants' tillers developed 94% more ears. Compared to watered plants, stressed plants' grain output decreased by 65% (Liu et al., 2020). Insufficient water during key growth stages, such as tillering and heading, leads to notable decreases in wheat yield and its various components. The extent of yield reduction becomes more substantial when water deficit takes place during these critical developmental stages (Kanwal et al., 2020). Irrigation may improve water consumption efficiency. The response of crops to water deficiency circumstances throughout various growth stages is essential for this aim. Less irrigation has three benefits: better water use efficiency, reduced irrigation, and lower water costs. To increase productivity, the extra area may be watered using water saved from deficit irrigation (Khan et al., 2021).

One of the best ways to achieve higher yield is to plant cereal crops at the right time, which enables the crops to reach their maximum production potential. Delayed wheat planting has been identified as the main obstacle to good output. Moreover, delaying in sowing can raise the probability of crop failure due to disease attack etc (Gul et al., 2012). Thus, delayed sowing impacts not only germination but also the number of grains per spike, the weight of 1000 grains and eventually the grain yield (Anwar et al., 2011; Coventry et al., 2011; Sattar et al., 2015). Each day delay in sowing from 20th November decreases grain yield at 39 kg ha^{-1} per day (Singh & Uttam, 1999). Growing degree day is a good estimator of wheat growth stages (Pal et al., 1996), and accumulation of degree days for each stage of growth is relatively stable and independent of planting date (Castillo & Santibanez, 1987). For that reason, It is essential to understand how climate change influences agricultural production and water productivity in order to become accustomed to crop systems, the changing climate and the growing population (at least until 2050). Additionally, there is a need to produce more agricultural harvests under unfavorable climatic conditions for a greater number of people (Rockstrom et al., 2009).

Conversely, poor crop management and seed rate might result in a lower output from an inappropriate sowing method. While drill and bed sowing are advised for consistent seed distribution. Broadcasting does not only need higher seed rate but also result in a lower plant density (Soomro et al., 2009). One of the true and tried agricultural techniques that reduced the weeds infestation and crop lodging while increasing fertilizer use efficiency and water distribution is bed planting. Additionally, it lessens the soil degradation, erosion and planting costs (Hobbs & Morris, 1996). Then, raised bed and sowing at proper time offer a way to better coordinate crop growth with water availability. This can be achieved by developing improved agronomic and water management practices with other approaches. One of the assessment methods to increase crop yield and water consumption per unit is agricultural water management (Molden et al., 2003). Food requirements of the growing population can be achieved either by increasing area under wheat or maximizing yield per unit area through input management. So, this study aimed to evaluate the irrigation regimes, planting dates and sowing methods on wheat growth and Production.

Materials and Methods

Experiment 1: Response of wheat varieties under different moisture regimes

This experiment was conducted at Regional Agricultural Research Institute (RARI), Bahawalpur, and Pakistan during the year 2021. The experiment employed a Randomized Complete Block Design (Split plot) with three replications. The main factors investigated were moisture regimes and wheat varieties. Separate plots of 1.8 m × 6 m were selected with enough space for growth and evaluation of wheat plants in different treatments. Three moisture regimes acted as irrigation treatments: Irrigation level at a depth of 4 inches was applied during each time of irrigation. In treatment T1, irrigation was done after 20 days of sowing, treatment T2 comprised irrigation after 40 days of sowing while in treatment T3 irrigation was done after 60 days of sowing. 5 different genotypes of wheat were selected for the experiment marked as: V1 (18003), V2 (180059), V3 (BF-1019), V4 (195715), and V5 (Ghazi-19). Before sowing, fertilizers were applied at the rate of 150-115-60kg/ha of NPK (Urea, DAP and SOP) on all plots uniformly. Application of fertilizers ensured the availability of nutrients for all treatments. Different growth parameters i.e., Plant height, spike length, and no. of plants/m^2 were assessed and response was recorded under varying moisture regimes.

Experiment 2: Response of different wheat varieties in different sowing date

The primary effects of different sowing dates on different varieties were examined in this research. Individual plots with dimensions of 1.2 m × 6 m provided sufficient area for assessment of growth and development of wheat verities under different treatments. Eight sowing dates were considered as main treatments: T1 (21st October), T2 (1st November), T3 (11th November), T4 (21st November), T5 (1st December), T6 (11th December), T7 (21st December), and T8 (1st January). Additionally, eight wheat varieties were selected as sub-treatments: V1 (BF-1705), V2 (BF-1807), V3 (181601), V4 (BF-1902), V5 (BF-1910), V6 (17BF2190), V7 (Akbar-19), and V8 (Ghazi-19). For uniform availability of nutrients to the plants, NPK fertilizers were applied at the rate of 150-115-60kg /ha (Urea, DAP and MOP) before sowing. Various growth parameters including plant height at maturity stage, spike length and no. of plants/m^2 were assessed in order to evaluate the response of different wheat varieties to varying sowing dates.

Experiment 3: Response of different wheat varieties in different planting methods

A Randomized Complete Block Design (RCBD) was applied with three applications to conduct the experiment. The study compared 5 different sowing/planting methods: in treatment T1, 4 rows of plants were planted on beds, treatment T2 with 3 rows of plants, treatment T3 with line sowing (conventional), treatment T4 with broadcast method, and treatment T5 with ridge sowing method. To assess and evaluate the wheat plants, a plot of 3.6 m × 7 m measurement was prepared. A seed rate of 50 Kg/ha was used for the experiment. Weeds were controlled by hand weeding with khurpa. Wheat variety Ghazi-2019 used in this study due to its adaptability in local conditions and late sowing. NPK fertilizers were applied at the rate of 150-115-60 kg/ha before sowing uniformly. On December 10, 2020, all treatments were applied to stimulate late sowing conditions. Data collection involved measurement of plant height (cm), spike length (cm) and no. of plants/m^2 to evaluate the effect of plant methods.

Data analysis

Tukey's HSD (Honestly Significant Difference) and Analysis of Variance (ANOVA) were employed to identify significant differences among various treatment means and for comparison.

Results

Effect of moisture regimes on wheat genotypes

The effects of different irrigation regimes on the growth parameters of wheat genotypes were evaluated in Table 1.
Three irrigation regimes, corresponding to 20, 40, and 60 days after sowing, were investigated across five wheat genotypes: 18003 (V1), 180059 (V2), BF-1910 (V3), 195715 (V4), and Ghazi-19 (V5). Under each regime, the no. of plants per square meter, plant height and spike length were measured. The maximum plant height ranged from 90.6 cm to 106.2 cm was observed in V5 under 60-day regime. V3 exhibited longest spike length varied from 8.23 cm to 9.90 cm under 60-day regime. Genotype V1 showed the highest density at 420.33 plants/m^2 under 40-day regime as compared to other genotypes. These findings highlight the substantial influence of moisture regimes on the growth characteristics of wheat genotypes and suggest potential strategies for optimizing wheat cultivation practices.

Table 1 Effect of different irrigation regimes on plant height, spike length and no. of plants/m^2 in different genotypes of wheat

Irrigation regimes (Days after sowing)	Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
20	18003	92.9	8.30	410.6
20	180059	90.6	8.23	287.6
20	BF-1910	93.0	8.80	285.3
20	195715	94.3	8.56	286
20	Ghazi-19	93.1	9.23	309.6
40	18003	101.0	8.53	420.33
40	180059	97.0	8.93	329.67
40	BF-1910	98.0	9.16	328
40	195715	100.9	8.53	315
40	Ghazi-19	98.8	9.43	340.67
60	18003	99.2	8.87	393.3
60	180059	96.4	9.50	367.6
60	BF-1910	99.4	9.90	397.6
60	195715	102.7	8.73	386
60	Ghazi-19	106.2	9.37	374

Effect of sowing on 21st October on wheat genotypes

Table 2 presents the effect of a sowing date on the growth parameters of wheat genotypes. Specifically, the effects of sowing on 21st October were examined across eight wheat genotypes: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910 (V5), 17BF2190 (V6), Akbar-19 (Check) (V7), and Ghazi-2019 (V8) (Check). The tallest plant height ranged from 84.63 cm to 107.07 cm was achieved in V6. V2 exhibited the longest spikes varied from 8.37 cm to 10.59 cm. V6 again demonstrated the highest density of plants ranging from 285.3 to 420.3. These findings emphasize the significant variability in growth characteristics among wheat varieties in different sowing dates and proposed a roadmap for optimizing wheat cultivation practices based on variety selection and sowing time.

Table 2 Effect of 21st October sowing date on plant height, spike length and no. of plants/m^2 in various genotypes of wheat

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	100.57	8.83	410.6
BF-1807	98.53	10.59	287.6
181601	84.63	8.37	285.3
BF-1902	97.53	10.13	286.0
BF-1910	95.73	9.60	309.6
17BF2190	107.07	10.40	420.3
Akbar-19	98.80	10.26	329.7
Ghazi-2019	99.00	9.27	328.0

Effect of 1st November sowing on wheat genotypes

The effect of sowing date 1st November on growth characteristics of wheat varieties elucidates in Table 3. The study encompassed eight genotypes: BF-1705 (V1), BF-1807 (V2), 181601(V3), BF-1902 (V4), BF-1910(V5), 17BF2190 (V6), Akbar-19 (check) (V7) and Ghazi-19 (Check) (V8). V6 displayed the tallest plants ranged from 89.26 cm to 105.10 cm. V2 exhibited longest spike length varied from 8.83 cm to 10.30 cm. The highest density of plants observed in V1 was 329.67-443.30. These results highlight the varied responses of sowing dates on wheat genotypes and provide valuable insights for optimizing cultivation practices by considering both genotypes selection and sowing time.

Table 3 Effect of 1st November sowing date on plant height, spike length and no. of plants/m^2 in various genotypes of wheat

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	94.67	9.53	443.30
BF-1807	95.20	10.30	329.67
181601	89.26	8.83	395.30
BF-1902	93.80	9.63	422.00
BF-1910	96.93	9.20	397.00
17BF2190	105.10	9.50	418.67
Akbar-19	95.53	9.97	403.67
Ghazi-2019	100.06	9.43	409.00

Effect of 11th November sowing on wheat genotype

Table 4 illuminates the effect of sowing on November 11 on the growth parameters of various wheat genotypes. The study incorporated eight genotypes: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910 (V5), 17BF2190 (V6), Akbar-19 (Check) (V7), and Ghazi-19 (Check) (V8). Maximum plant height was observed in V6 ranged from 86.67 cm to 110.07 cm and also longest spike length was achieved that varied from 9.03cm to 9.77 cm. The highest density of plants per square meter ranged from 314.3 to 398.3 attained in V7. The findings of this trial underscore the diverse response of wheat genotypes with different sowing dates and paved the way to optimize the management practices of wheat cultivation and production.

Effect of sowing on 21st November on wheat genotypes

Table 5 explains the effect of sowing on 21st November on the growth characteristics of different wheat genotypes. The investigation included eight genotypes: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910(V5), 17BF2190 (V6), Akbar-19 (Check) (V7) and Ghazi-19 (Check) (V8). V5 exhibited the tallest plants varied from 90.21 cm and 100.47 cm while highest spike length ranged from 9.74 cm to 11.17 cm was achieved by V6. The number of plants per square meter varied from 238.3 to 312.0 showing higher density attained by V5. These results emphasize on the necessity of practicable management strategies to optimize wheat cultivation and enhance the overall yield by comparing the results of different sowing dates on various wheat genotypes.

Table 4 Effect of 11th November sowing date on plant height, spike length and number of plants/m^2 in various genotypes of wheat

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	99.80	9.30	387.0
BF-1807	96.67	9.70	314.3
181601	86.67	9.63	353.3
BF-1902	94.47	9.73	329.3
BF-1910	97.33	9.03	314.5
17BF2190	110.07	9.77	360.7
Akbar-19	93.93	9.10	398.3
Ghazi-2019	95.87	9.73	323.0

Effect of sowing on 1st December on wheat genotypes

Table 6 highlights the effects of 11 December sowing date on growth parameters of different wheat genotypes. Eight genotypes were examined: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910 (V5), 17BF2190 (V6), Akbar-19 (Check) (V7), and Ghazi-19 (Check) (V8). V6 attained the maximum plant height ranged from 87.73 cm to 102.33 cm with tallest plants. The longest spike varied from 9.07 cm to 11.06 cm and maximum number of plants per square meter ranged from 194.0 to 236.0 was also observed in V6. These findings depict the varied response of wheat genotypes by sowing the seeds on different dates and impotence of selection of appropriate wheat genotypes to optimize cultivation practices and maximum yield.

Table 5 Effect of sowing date 21st November on plant height, spike length and number of plants/m^2 in various wheat genotypes

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	92.67	10.87	295.0
BF-1807	96.93	10.67	262.3
181601	90.21	10.83	267.0
BF-1902	96.53	10.33	238.3
BF-1910	100.47	11.06	312.0
17BF2190	100.06	11.17	307.3
Akbar-19	92.83	9.74	297.7
Ghazi-2019	94.85	10.73	260.0

Table 6 Effect of sowing done on 1st December on plant height, spike length and number of plants/m^2 in various genotypes of wheat

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	94.67	9.72	203.7
BF-1807	89.22	9.34	194.0
181601	87.73	9.07	211.0
BF-1902	87.93	9.33	211.3
BF-1910	94.53	9.13	229.3
17BF2190	102.33	11.06	236.0
Akbar-19	92.64	9.19	230.0
Ghazi-2019	90.00	10.03	220.0

Effect of sowing on 11th December on wheat genotypes

The effect of sowing date on 11th December is seen in table 7 regarding growth characteristics of various genotypes of wheat. The study encompassed eight genotypes: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910 (V5), 17BF2190 (V6), Akbar-19 (Check) (V7), and Ghazi-19 (Check) (V8). It was observed that V6 displayed the maximum height of plants ranged from 83.00 cm to 101.67 cm. on the other hand V8 exhibited longest spike length varied from 9.3 cm to 10.9 cm. Highest density of plants was detected in V6 with the range of 165.3 to 224.0. These results show the diverse effect of wheat varieties towards sowing dates and highlight the importance of genotype-specific cultural practices the importance of genotype-specific management practices to improve wheat farming and overall wheat production.

Effect of sowing on 21st December on wheat genotypes

Table 8 demonstrates the influence of sowing on 21st December on growth parameters of different wheat genotypes. Eight genotypes were evaluated: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910 (V5), 17BF2190 (V6), Akbar-19 (Check) (V7), and Ghazi-19 (Check) (V8). In this experiment, V6 exhibited tallest plants with the range of 77.25 cm to 92.93 cm. V8 presented the maximum spike length ranging from 8.62 cm to 9.93 cm with longest spikes. In comparison, V6 showed the highest density of plants varied from 155.67 to 177.00 per square meter. These findings accentuate the varied response of wheat genotypes to different sowing dates and suggest the improved cultivation practices for overall growth of wheat genotype and crop productivity.

Table 7 Effect of 11th December sowing date on plant height, spike length and number of plants/m^2 in various wheat genotypes

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	93.07	9.3	211.3
BF-1807	84.26	10.67	165.3
181601	89.73	9.567	216.7
BF-1902	83.00	9.967	185.7
BF-1910	88.93	9.5	186.0
17BF2190	101.67	9.967	224.0
Akbar-19	89.00	10.53	204.0
Ghazi-2019	92.26	10.9	193.0

Table 8 Effect of 21st December sowing date on plant height, spike length and number of plants/m^2 in various genotypes of wheat

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	85.67	8.93	160.67
BF-1807	79.63	9.83	155.67
181601	77.25	9.03	168.00
BF-1902	77.53	8.62	159.67
BF-1910	78.81	9.20	176.00
17BF2190	92.93	9.43	177.00
Akbar-19	77.27	9.13	167.00
Ghazi-2019	85.47	9.93	157.00

V_1 = BF-1705; V_2 = BF-1807; V_3 = 181601; V_4 = BF-1902; V_5 = BF-1910; V_6 = 17BF2190; V_7 = Akbar-19 (Check); V_8 = Ghazi-19 (Check)

Effect of sowing on 1st January on wheat genotype

The effects of seed sowing on 1st January on growth parameters of various wheat genotypes are explained in Table 9. The study encompassed eight genotypes: BF-1705 (V1), BF-1807 (V2), 181601 (V3), BF-1902 (V4), BF-1910 (V5), 17BF2190 (V6), Akbar (Check) (V7), and Ghazi-19 (Check) (V8). V6 displayed the tallest plant with plant height ranged from 74.00 cm to 85.82 cm. Whereas V7 exhibited spike length varied from 8.67 cm to 9.73 cm. V4 presented highest density with plant range from 155.67 to 212.00. These findings emphasize the importance of sowing time and genotype-specific characteristics to optimize wheat cultivation practices and maximize yield by considering the diverse response.

Effect of different sowing methods on growth parameters of wheat variety Ghazi-2019

Table 10 elucidates the effect of various planting methods on the growth characteristics of wheat variety Ghazi-19. In this experiment five treatments were examined: T1 (Bed sowing 4 lines), T2 (Bed sowing 4 lines), T3 (Broadcasting), T4 (Line sowing), and T5 (Ridge sowing). T2 exhibited the tallest plant height with a range from 83.67 cm to 104.33 cm. T1 displayed the longest spike length varied from 8.6 cm to 11.06 cm. The highest number of plants with more density was observed in T3 ranged from 186.67 to 261.33. These results demonstrate the significant effect of planting method on the growth and development of wheat and suggest that broadcast planting may offer advantages in term of plant density, while bed sowing with four lines could promote taller plants with longer spikes.

Table 9 Effect of 1st January sowing date on plant height, spike length and number of plants/m^2 in various genotypes of wheat

Genotypes	Plant height (cm)	Spike length (cm)	Number of plants/m^2
BF-1705	82.33	8.93	186.00
BF-1807	74.00	8.84	155.67
181601	74.82	9.23	207.33
BF-1902	77.45	8.67	212.00
BF-1910	78.86	9.43	190.00
17BF2190	85.82	9.26	197.67
Akbar-19	79.53	9.73	187.33
Ghazi-2019	80.68	9.03	177.67

Table 10 Effect of different plant methods on plant height, spike length and number of plants/m^2 of wheat variety Ghazi-19

Treatments	Plant height (cm)	Spike length (cm)	Number of plants/m^2
T1 (Bed sowing 4 lines)	83.67	11.06	222.33
T2 (Bed sowing 4 lines)	104.33	8.6	251.33
T3 (Broadcast)	94.67	10.76	261.33
T4 (Line sowing)	95.53	10.76	186.67
T5 (Ridge sowing)	90.13	9.13	191.67

Effect of different planting methods on yield of wheat

The effect of different planting methods on the yield of wheat variety Ghazi-2019 illustrate in Table 11 which was grown under agro-climatic conditions of Bahawalpur. Five treatments were assessed: T1 (Bed sowing 4 lines), T2 (Bed sowing 4 lines), T3 (Broadcasting), T4 (Line sowing), and T5 (Ridge sowing). T5 attained maximum yield per square meter varied from 0.35 kg to 0.48 kg and yield per hectare ranged from 3500 kg to 4833 kg was again produced in T5. These results propose that ridge sowing may be an effective planting method for optimizing wheat yield under Bahawalpur agro-climatic conditions and potentially offer the advantages over other methods such as bed sowing or line sowing.

Table 11 Effect of different planting methods on yield of wheat variety Ghazi-2019 under Bahawalpur agro-climatic conditions

Treatments	Yield/m^2 (kg)	Yield/ha (kg)
T1 (Bed sowing 4 lines)	0.45	4500
T2 (Bed sowing 4 lines)	0.43	4300
T3 (Broadcast)	0.35	3500
T4 (Line sowing)	0.36	3666
T5 (Ridge sowing)	0.48	4833

Discussion

Effect of different irrigation intervals on the growth and performance of wheat

Plant height is influenced by various factors like heredity, competition for sunlight, plants population, spacing, sowing methods and weed density which indicate plant vigor and health. The experimental variants among various wheat genotypes related to plant height by applying different irrigation intervals show the sensitivity of wheat crop to water availability. A 60-day irrigation regime produced the tallest plants that suggest to sustained moisture level throughout growth period to promote vertical growth. Zhou et al. (2020) found that implementation of optimized irrigation schedule can reduce the water requirements for winter wheat by 40-50mm without compromising crop production. In conditions of water scarcity, precise irrigation scheduling techniques and accurate crop water requirements measurement are essential for quantifying evapotranspiration and optimizing water use efficiency. When soil moisture level was kept up to 50 % of the available soil water level throughout the whole growth season, the highest level of water use efficiency is seen (Mahamed et al., 2011).

The potential of wheat yield is greatly influenced by spike length because longer spikes generally contain more grains. The variance in spike length observed in this study due to different irrigation regimes and genotypes suggests that water availability has a major effect on wheat production. Notably, genotype V3 showed the longest spike length during 60-day irrigation schedule suggesting that it could produce high yielding crop in the presence of ideal moisture level. Rajput et al. (1994); Saleem et al. (2007) studied that with the increase in the level of irrigation spike length also increased. Also found a trend towards irrigation. The key factor for wheat yield is spike length. Higher spike length results in more grain production which ultimately increases overall crop yield.

The number of plants per square meter indicates the crop establishment and population density which are crucial in determining the final yield. The notable difference in plant density under different irrigation regimes and genotypes shows the complex interaction among water availability, seed germination and early growth of seedlings. Genotype V1 showed the highest plant density across 40-day irrigation regime and indicating the suitability of environments with moderate water availability. It is researched that maximum resource utilization and yield potential can be enhanced through proper irrigation and optimization of plant density. Soleymani and Shahrajabian (2011) found that appropriate irrigation intervals increase the heading and stem elongation. Our results demonstrate the importance of irrigation strategies in optimizing wheat production practices. Farmers can implement precise irrigation techniques to alleviate water stress and wheat productivity by understanding how different genotypes respond to different moisture conditions. In addition, breeders can use this knowledge to develop new wheat varieties which are more water resistance, ensuring food security in water stressed areas.

Effect of different sowing dates on the growth and development of wheat

The study reveals the complex interaction between environmental factors and genetic traits in determining wheat performance by examining plant height, spike length and plant density across various sowing dates and wheat genotypes. Significant variation in plant height among wheat genotypes were recorded on the different sowing dates. Genotype V6, for instance, consistently showed the tallest plants on a number of sowing dates indicating its inherent genetic inclination towards rapid vertical growth. On the basis of our findings, there is considerable diversity in the spike length among the genotypes examined on different sowing dates. Under various sowing dates, genotype V2 consistently showed the longest spikes, indicating the potential for maximizing grain yield per spike. This variability is the reflection of genotype-specific response to planting dates and highlights the importance of selecting genotypes that have desirable productive traits. The study shows a considerable variation among wheat genotypes in term of plant density at different sowing dates. Genotype V6 demonstrated a consistency of high density of plants in the various sowing dates, reflecting its superior ability to produce a dense plant stand during unfavorable climatic conditions. In order to optimize plant population management strategies to maximize yield potential and resource utilization efficiency, it is essential to understand genotype specific responses to sowing dates.

Our results are in line with Maleha et al. (2020) who reported a decrease of 40% in wheat yield due to delaying in the sowing date. This may be due to the shortening of period of vegetative growth, along with insufficient plant growth, absence of spike and withering of grains because of the elimination of late spikes. This is compensated for by the intense heat during grain filling, making the crop more susceptible to insects and diseases. Our findings also corroborate those of Fischer & Maurer (1976); Lobell & Ortiz-Monasterio (2007) who found that lower grain yield of irrigated wheat crop under field conditions have been linked to rising mean temperatures during the growing season. These authors also attributed this to shorter growing seasons, less amount of light interference and fewer kernels per unit area. These findings align with the research conducted by Wieg & Cuellar (1981), which indicated a 3.1-day reduction in the grain filling period for every 1 °C rise in the average daily air temperature above the optimal temperature (15 °C) during grain filling. The shortened grain filling period was linked to a decrease in both yield and grain size. Furthermore, Refay (2011) noted that there were significant losses in term of grain yield projected 7.98% when sowing was delayed as compared to the early planting. According to Baloch et al. (2010), sowing of wheat on October 25th and November 10th yielded the tallest plant, highest number of branches, grain yield and weight of 1000 grains; these values declined with the succeeding sowing dates. Delaying the sowing of wheat causes high temperature during the stage of anthesis and grain filling which reduces the yield at maturity (Wieg & Cuellar, 1981; Dias & Lidon, 2009; Baloch et al., 2010; Modarresi et al., 2010; Refay, 2011). Also, Joshi et al. (2007) reported heat stress as major abiotic stress due to delayed sowing that affects wheat cultivation.

Influence of planting methods on growth of wheat

The present investigation regarding wheat sowing with improved methods for enhancing performance under different irrigation regimes suggests that improved sowing methods may enhance yield and yield traits of wheat as well as water use efficiency under water deficit at the anthesis stage. Based on the findings of the research, it can be inferred that the broad casting sowing method attained the highest plant density per square meter. The improved vertical distribution of photosynthetic radiations within wheat canopies grown elevated beds may have contributed to the increased wheat production (Li et al., 2008). The germination of weeds is less on dry bed surfaces compared to traditional flat layouts (Ram et al., 2005). The decrease in mean values under drilling at 15cm apart in the research may be due to the small distance between plants in the unit area, leading to a greater reliance on light for the growth of spike stages (Baktash & Hassan, 2015; Baktash & Naes, 2016; Khalaf & Shahaz, 2016). However, our findings match with results reported by Abbas et al. (2009) who also concluded that planting methods affect plant height. Similarly, Jakhar et al. (2005); Singh et al. (2005) also reported that there was maximum plant height under raised bed sowing in comparison to other methods of sowing. Exploiting the full height potential in wheat is associated with proper planting geometry. The number of tillers per unit area depends upon the availability of irrigation water for wheat. Under normal irrigation conditions more than 400 tillers m^{-2} was recorded by Sharif (1999); Musaddique et al. (2000). McDonald et al. (1984) also found a correlation between increased watering frequency and production of more wheat tillers. The numbers of wheat tillers per square meter was greatly affected by the method of sowing (Khatri et al., 2019).

Conclusion

Significant differences in plant height, spike length and plant density across different irrigation regimes were revealed in this study. The 40-day irrigation period produced the highest yield per square meter and per hectare, indicating that timely irrigation has a great effect on wheat productivity. Variations in growth factors were noted according to the sowing dates. Early sowing dates like 21st October typically produced taller plants with longer spikes. Whereas later sowing dates, like January 1st produced a shorter number of spikes and plants. These findings show that the time of planting has a key role in maximizing wheat yield, with potential benefits to plant growth and development at earlier stages. The study also showed the significant difference among different planting methods regarding plant height, spike length and plant density. The most favorable method was ridge sowing which results in the highest density of plants and promoting taller crops with a longer spike. These results revealed that by carefully selecting the planting method, wheat growth and yield can have a significant effect on crop development and productivity, while ridge sowing could provide an important benefit in terms of total productivity.

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