Research Article

Comparative Performance of Diverse Advanced Wheat Genotypes in Response to Different Sowing Times

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Abstract | Wheat is one of the important staple crops of the world. Its grain yield is affected by various factors including genotype and planting time. An experiment was conducted to study the yield performance of 10 different wheat advanced genotypes (PR-133, PR-135, PR-136, PR-137, PR-138, PR-139, PR-140, Khaista-17, Gulzar-19 and Pirsabak-19) at different sowing times of 15-days interval. A pooled analysis across the same environment revealed a significant difference ($P \geq 0.01$) for all the parameters i.e., days to heading, days interval, plant height, flag leaf area, tillers m^{-2}, spike length, spikelet $spike^{-1}$, grain $spike^{-1}$, thousand grain weight, grain yield and biological yield across three planting dates i.e., early, normal, and late respectively. Differences between wheat genotypes and genotype-environment interaction were also highly significant ($P \geq 0.01$) for studied traits, indicating that genotypes performed differently in three sowing times. Under early, normal and late planting, genotypes PR-138, PR-140 and Gulzar-19 had the highest grain yield respectively. PR-138 performed outstandingly across three sowing times for seed yield. Hence, it is concluded from the present study that delayed sowing progressively decreases the yield performance of the studied genotypes and the most suitable sowing time is from 15th October to 15th November.

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Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereal crops and a staple food in cuisines all over the world. It is one of the primary sources of protein, carbohydrates, and essential minerals. The population is predicted to increase to almost 9 billion people by 2050, posing a serious threat to the massive global wheat production. However, wheat production is severely hampered by abiotic and biotic stressors (Kumar *et al*., 2014; Ali *et al*., 2018).

One of the limiting variables that lower yield, is the late planting of the wheat crop. Therefore, growing wheat crops at the right time is crucial to increase productivity and avoiding climate consequences brought on by changes. Through the use of novel, high-yielding, disease-resistant cultivars and by choosing the right planting date, several approaches can be used to increase wheat production. Wheat needs a specific temperature and amount of light to grow, thus winter is the best season to sow it. Plants will grow poorly if the temperature is over the ideal threshold early in the planting process (Anwar *et al*., 2015). When seeds are sown at the ideal temperature, plants grow more quickly and are more efficient at absorbing nutrients. On the other hand, delay sowing results in decreased crop growth and yield. Early sowing of wheat is to improve germination per unit area, plant height, spikelets/spike, grain/spike, and weight of 1000 grains compared to late sowing (Shah *et al*., 2006).

Wheat is a temperate crop that can be damaged by extreme heat. Its various growth stages require various temperatures and under high temperatures, biochemical, physiological performance and yield are significantly impacted. Heat stress occurs when temperatures rise above 24 °C and get close to 30 °C. Under crop's exposure to heat during the anthesis and grain filling stages, resulting in a variety of structural and physiological changes in the crop plant, such as a decrease in the plant's height, spike length, number of grains, and overall grain production (Dwivedi *et al*., 2017). New crop varieties developed by plant breeders/agronomists are usually tested for their yield performance and adaptability across environments to identify germplasm for target environments. Interaction due to genotype and environment refers to the differential ranking of the same set of genotypes across environments which complicates the selection process and recommendation of suitable genotypes for target environments. In the above circumstances, the present study was envisaged to evaluate the yield potential of different advanced wheat genotypes at various sowing timings and select the best genotypes for the late sowing season.

Materials and Methods

The field experiment was conducted on 6 sowing dates such as early: 15-30 Oct, normal: 1-20 Nov, and late: 21-10 Dec with 15 days of intervals. Ten advanced wheat genotypes were evaluated as independent in a randomized complete block design (RCBD) with three replicates. The experimental plot for every tested genotype was 2 meters long and comprised of four rows with row-row spacing of 30 cm and recommended doses of fertilizer of nitrogen phosphorus and potassium (NPK) was applied at the ratio of 120: 90: 60 Kg ha^{-1}. All the agronomic practices were carried out uniformly during the growing season. All the data were recorded at appropriate times and procedures on days to heading, flag leaf (cm^2), days to maturity, plant height (cm), fertile tillers per m^2, spike length (cm), spikelets $spike^{-1}$, grain $spike^{-1}$, thousands of grains weight (g), biological yield (Kg ha^{-1}), grain yield (Kg ha^{-1}) and Harvest Index (HI).

Statistical analysis

Data were recorded for all parameters on examined advanced wheat genotypes (8 PR lines and 2 checks), across three dates of sowing (Table 1), and were analyzed using SAS (Statistical Analysis System Software to get the effect of Genotype × Environment (G×E) interaction (Gomez and Gomez, 1984). Since G×E interaction was significant for important yield components, the data were independently analyzed for each sowing environment. The least significant test (LSD) was also estimated for the mean comparison of genotypes, environment and Genotype × Environment interaction.

Results and Discussion

Statistical analysis revealed that genotypes were significantly affected across three sowing times for the studied attributes (Table 2). Similarly, genotypes and genotype-environment interactions were also highly significant ($P \geq 0.01$), indicating that genotypes performed differently on different sowing dates (Table 2). The mean values ranged from 101.6 to 111. 5 for days to heading, 183.5 to 190.6 for maturity, 109.0 to 112.7cm for plant height, 117.2 to 136.3 for tillers m^{-2}, 31.5 to 47.8 cm^2 for flag leaf area, 18.9 to 23.3 for spikelets $spike^{-1}$ (Table 3), 13.1 to 15.2 cm for spike length, 82.4 to 95.8 for grain $spike^{-1}$, 45.8 to 52.8 g for thousand-grain weight (Table 4), 21.58 to 26.6 Kg $hectare^{-1}$ for biological yield, 6827.54 to

Table 1: *List of 10 wheat genotypes evaluated at Cereal Crop Research Institute, Pirsabak, Nowshera, during 2020-2021.*

S.No	Genotype	Parentage
1	PR-133	C80.1/3*BATAVIA//2*WBLL1/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/ HUITES*2/6/TRCH/SRTU//KACHU
2	PR-135	CROC_1/AE.SQUARROSA(205)//BORL95/3/PRL/SARA//TSI/VEE#5/4/FRET2/5/TRCH/SRTU//KACHU
3	PR-136 (Late)	PREMIO//PARUS/PASTOR
4	PR-137	MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN/5/GK ARON/AG SECO 7846// 2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92
5	PR-138	UP2338*2/SHAMA/3/MILAN/KAUZ//CHIL/CHUM18/4/UP2338*2/SHAMA*2/5/PBW343*2/KUKUNA*2//FRTL/PIFED
6	PR-139	KACHU/SAUAL*2/5/SERI.1B//KAUZ/HEVO/3/AMAD*2/4/KIRITATI
7	PR-140 (Early)	KFA/2*KACHU*2//WAXBI
8	Khaista-17	KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/7/ CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71 /5/2*KAUZ/6/PASTOR
9	Gulzar-19	VORB/3/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR
10	Pirsabak-19	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU

Table 2: *Mean squares for days to headings, day's interval, plant height, flag leaf area, tillers m^2, spike length of ten wheat genotypes across six planting dates at CCRI, Nowshera.*

(SOV)	D F	DH	DM	PH	FLA	SL	TL (m^2)	SPS	GPS	TGW	GY	BY	HI
Envir	5	837.86**	11862.41**	1535.72**	4501.66*	93.76	53573.93	231.8	6592.2	51.8	177374379.9	1521279773.1	0.02
Reps. w/n Envir	12	11.85	3.70	69.17	6.86	0.59	1537.73	1.1	114.3	9.7	7520794.2	49379332.0	0.0005
Geno	9	66.40**	53.82**	18.33**	86.91**	2.81**	389.11**	24.1**	275.9**	145.7**	1625594.1**	12099348.8**	0.0018**
Geno×Envir	45	174.87**	1319.83**	159.23**	529.50**	10.95**	5772.81**	26.8**	770.6**	20.1**	19276243.9**	160584491.1**	0.0034**
Error	108	12.90	2.54	4.3	10.90	0.36	211.41	1.0	46.1	16.0	493565.7	3613211.1	0.0005
CV (%)	-	3.31	0.96	1.98	13.6	4.73	14.24	4.8	8.7	8.3	10.1	10.1	5.7

*SOV, Source of Variables; DF, degree of freedom; DH, days to heading; DM, days to maturity; PH, plant height; FLA, Flag leaf area; SL, Spike length; TL (m2) -number of tillers m-2; GPS, grains per spike; SPS, Spikelets, Grain per spike; TGW, thousand grain weight; GY, Grain yield; BY, biological yield; Harvest index-HI; SL, spike length; spike-1; *, **, Significant at 5 and 1% probability level, respectively.*

Table 3: *Means of days t0 heading and days to maturity and plant height of 10 wheat genotypes across six planting dates at CCRI Pirsabak.*

Genotype	Days to heading (no)			Genotype mean	Days to maturity (no)			Genotype mean	Plant height (cm)			Genotype Mean
	Early	Normal	Late		Early	Normal	Late		Early	Normal	Late	
PR-133	106.6	103.0	116.5	108.7	184.6	169.0	142.8	165.5	109.4	106.9	97.3	104.5
PR-135	111.5	102.6	115.0	109.7	186.8	170.5	142.5	166.6	112.1	102.6	98.5	104.4
PR-136	107.5	106.3	119.3	111.0	190.6	175.0	146.0	170.5	111.3	106.3	95.9	104.5
PR-137	106.0	98.3	112.1	105.5	185.1	168.1	144.0	165.7	110.6	98.3	97.0	101.9
PR-138	108.5	101.3	114.6	108.1	185.0	168.1	143.6	165.5	110.6	101.3	96.1	102.6
PR-139	105.0	101.8	111.6	106.1	186.8	169.6	144.0	166.8	110.8	101.8	98.4	103.6
PR-140	101.6	109.8	111.3	107.6	186.0	167.5	143.6	165.7	109.0	109.8	95.3	104.7
Khaista-17	112.6	101.3	114.5	109.5	188.1	171.1	144.5	167.9	112.7	101.3	97.5	103.8
Gulzar-19	110.6	110.3	111.6	110.8	183.5	167.6	143.1	164.7	109.0	110.3	94.3	104.5
Pirsabak-19	105.1	103.8	114.0	107.6	185.0	169.6	144.0	166.2	110.8	103.8	96.7	103.7
Envir Mean	107.4	103.8	114.3		186.1	169.6	144.0		110.5	107.7	96.7	
$LSD_{0.05\%}$	Envirement			1.83				0.81				1.06
	Genotype			2.37				1.05				1.37
	Envirement × Genotype			5.81				2.58				3.36

Table 4: *Means of flag leaf area cm², tillers m² and spike length of ten wheat genotypes across six planting dates at CCRI Pirsabak.*

Genotype	Flag leaf area (cm²)			Genotype mean	Tillers m² (no)			Genotype mean	Spike length (cm)			Genotype Mean
	Early	Normal	Late		Early	Normal	Late		Early	Normal	Late	
PR-133	41.3	25.1	13.8	26.7	127.7	130.9	56.0	104.9	14.7	12.6	10.4	12.6
PR-135	35.2	21.2	12.6	23.0	117.2	120.5	45.9	94.5	15.2	13.1	10.9	13.1
PR-136	32.1	23.2	13.2	22.8	135.9	130.6	52.2	106.2	13.7	12.8	10.7	12.4
PR-137	32.2	22.4	13.5	22.7	123.9	124.6	49.2	99.2	14.1	13.9	10.9	13.0
PR-138	47.8	24.8	12.8	28.4	127.8	124.1	49.1	100.3	15.2	13.8	11.0	13.4
PR-139	33.7	23.1	16.1	24.3	118.6	126.2	42.5	95.8	14.2	13.5	10.6	12.8
PR-140	32.5	21.3	14.2	22.7	127.6	132.3	50.3	103.4	13.8	13.5	10.9	12.7
Khaista-17	31.5	20.9	13.3	21.9	130.0	141.1	55.4	108.8	14.4	13.5	11.0	13.0
Gulzar-19	36.6	24.4	14.3	25.1	121.1	138.3	47.4	102.3	13.1	12.3	10.3	11.9
Pirsabak-19	35.7	22.9	13.8	24.1	136.3	129.8	49.8	105.3	14.1	3.2	110.7	12.7
Envir Mean	35.9	22.9	13.8		126.6	129.8	49.8		14.3	13.2	10.7	
$LSD_{0.05\%}$	Envir			1.68				3.7				1.06
	Geno			2.18				4.8				1.37
	Envir× Geno			5.34				11.8				3.36

Table 5: *Means of spikelets per spike, grain/spike and thousand grain weight 0f 10 wheat gen0types across six planting dates at CCRI Pirsabak.*

Genotype	Spikelets per spike (no)			Genotype mean	Grain per spike (no)			Genotype mean	Thousand grain weight (g)			Genotype mean
	Early	Normal	Late		Early	Normal	Late		Early	Normal	Late	
PR-133	21.2	22.1	17.5	20.3	82.8	76.3	58.5	72.5	48.5	49.2	43.3	47.0
PR-135	23.3	24.1	18.7	22.0	94.8	90.1	60.5	81.8	48.3	46.5	46.7	47.2
PR-136	21.2	22.9	16.6	20.3	88.2	85.2	56.5	76.7	46.8	43.7	44.5	45.0
PR-137	21.7	23.7	18.0	21.1	84.0	79.9	53.6	72.5	52.8	55.5	57.9	55.4
PR-138	22.3	23.9	18.7	21.6	88.5	83.1	59.6	77.1	46.8	48.6	43.3	46.2
PR-139	23.1	24.0	19.3	22.1	93.6	85.0	63.2	80.6	46.6	49.7	47.2	47.8
PR-140	20.8	23.7	18.8	22.1	82.4	81.5	62.1	75.4	47.9	47.2	45.2	46.8
Khaista-17	23.2	24.4	18.2	21.9	95.8	88.9	59.8	81.5	47.2	49.5	45.9	47.5
Gulzar-19	18.9	19.7	16.5	18.3	90.8	85.2	62.5	79.5	45.8	45.9	47.8	46.5
Pirsabak-19	21.1	23.2	18.0	20.8	89.5	83.9	59.6	77.7	47.5	48.4	46.9	47.6
Envir Mean	21.7	23.2	18.0		89.1	83.9	59.6		47.8	48.4	46.9	
$LSD_{0.05\%}$	Envir			7.4				3.47				2.0
	Geno			9.6				4.48				2.6
	Envir× Geno			23.5				10.9				6.4

10027.5 Kg hectare^{-1} for grain yield and 0.3 for harvest index (Table 5). The studied genotype PR-138 recorded the highest values for flag leaf area, spikelets spike^{-1}, spike length, biological yield and grain yield. Similarly, genotypes PR-140, Gulzar-19, PR-133, PR-135, PR-137 and Pirsabak-19 showed the best performance for various important traits under early planting. Averaged over 10 genotypes, the harvest index was the same (0.3) under early, normal and late planting. Wheat heads were generally earlier under normal planting conditions than early and late planting conditions.

Under normal sowing conditions, the mean values ranged from 98.3 to 110.3 for days to heading, 98.3 to 110.3 for maturity, 98.3 to 110.3 cm for plant height (Table 2), 120.5 to 141.1 for tillers m^{-2}, 20.9 to 25.1 cm² for flag leaf area, 19.7 to 24.4 for spikelets spike^{-1}

(Table 3) 12.3 cm to 13.9 cm for spike length, 76.3 to 90.1 for grain spike^{-1}, 45.9 g to 55.5 g for thousand-grain weight (Table 4), 18.4 to 20.6 Kg ha^{-1}for biological yield and 7413.0 to 8410.1 Kg hectare^{-1} for grain yield (Table 5). The studied genotype PR-140 recorded minimum days to maturity and the highest grain yield, Gulzar-19 recorded maximum tillers, PR-135 had maximum grain spike^{-1}, PR-137 had maximum thousand-grain weight and Khaista-17 exhibited the highest biological yield under normal planting.

For late sowing, different genotype's mean values ranged from 101.6 to 111. 5 for days to heading, 142.8 to 146.0 for maturity, 94.3cm to 98.5 cm for plant height (Table 2), 42.5 to 56.0 for tillers m^{-2}, 42.5 to 56.0 cm^2 for flag leaf area, 16.5 to 19.3 for spikelets spike^{-1} (Table 3), 49.5 to 57.9 cm for spike length, 53.6 to 63.2 for grain spike^{-1}, 43.3 g to 57.9 g for the thousand-grain weight (Table 4), 9.2 to 11.3 Kg ha^{-1} for biological yield and 3727.5 to 4424.6 Kg hectare^{-1} for grain yield (Table 5). Among studied wheat genotypes, Gulzar-19 had the highest grain yield and minimum days to maturity, heading in late sowing. Khaista-17 exhibited the highest biological yield followed by PR-138 and Khaista-17. PR-137 showed a maximum thousand-grain weight under late sowing. PR-133 had maximum tillers m^{-2}.

A pooled analysis across environments found a significant difference (P≥ 0.01) for all parameters across three planting dates (early, normal, and late). Differences between wheat genotypes and genotype-environment interaction were also highly significant (P≥ 0.01) for studied traits, indicating that genotypes performed differently in three dissimilar environments of sowing, while a 1.3% decline in grain yield been reported by delaying sowing per day (Gomez-Macpherson and Richards, 1995). It has been reported that late-sowing wheat utilized N efficiently compared to early and mid-sowing (Yin *et al*., 2018). For days to heading, averaged over 10 genotypes were 107.6, 103.8 and 114.3 intervals under early, normal and late planting, respectively. Because the genotypes were sown in December and did not receive favorable conditions, the projected improvement in heading initiation in late planting will be greater than in early and normal sowing. Under early, normal, and late planting, the average intervals to maturity were 186.1, 169.6, and 144.0, respectively, based on ten genotypes. These results indicated that projected improvement in maturity intervals with late planting will be lower than under early and standard planting. Plant height was 110.5 cm, 107.7 cm, and 96.7 cm on average across 10 genotypes under early, normal, and late planting, indicating a loss of 2.7 cm between early and normal planting and 13.7 cm between early and late planting due to late planting. The average over 10 genotypes, tillers m^{-2} was 129.8, 126.6 and 49.8 under, normal, early and late planting. There is a net drop due to late planting, with a reduction of roughly 3.2 between normal and early planting and 80 between normal and late planting as a 38% decline has been reported by late sowing on December 30 (Baloch *et al*., 2012).

Table 6: *Means of grain yield and biological yield Of ten wheat genotypes across six planting dates at CCRI Pirsabak.*

Genotype	Grain yield (kg/ ha)			Genotype mean	Biological yield (kg/ ha)			Genotype Mean	Harvest index (HI)			Genotype mean
	Early	Normal	Late		Early	Normal	Late		Early	Normal	Late	
PR-133	8182.6	8043.4	4143.4	6789.8	25289.8	20000.0	10434.8	18574.8	0.3	0.4	0.4	0.3
PR-135	9350.7	8267.3	4000.0	7206.0	26159.4	20797.1	10507.2	19154.6	0.3	0.3	0.3	0.3
PR-136	9311.5	7413.0	3781.1	6835.2	26884.0	19420.3	9855.1	18719.8	0.3	0.3	0.3	0.3
PR-137	8266.6	8230.4	4191.3	6896.1	24275.3	21231.8	11449.3	18985.5	0.3	0.3	0.3	0.3
PR-138	10027.5	8311.5	3908.7	7415.9	27898.5	20869.6	10000.0	19589.4	0.3	0.4	0.3	0.3
PR-139	8976.8	7713.0	3727.5	6805.8	24347.8	19275.4	9710.1	17777.8	0.3	0.4	0.3	0.3
PR-140	6827.5	8410.1	4327.5	6521.7	22608.7	20362.3	11087.0	18019.3	0.3	0.4	0.3	0.3
Khaista-17	9566.6	8007.2	4313.0	7295.6	27463.7	21666.7	11884.1	20338.2	0.3	0.3	0.3	0.3
Gulzar-19	8817.3	7746.3	4424.6	6996.1	24202.9	19275.4	10507.3	17995.2	0.3	0.4	0.4	0.4
Pirsabak-19	7855.7	8015.8	4090.8	6654.1	24017.7	20322.1	10603.9	18314.5	0.3	0.3	0.3	0.3
Envir Mean	8669.6	8018.3	4095.6		25314.8	20322.1	10603.9		0.3	0.3	0.3	
$LSD_{0.05\%}$	Environment			1.83				0.81				1.06
	Genotype			2.37				1.05				1.37
	Environment × Genotype			5.81				2.58				3.36

Spike length was 14.3, 13.2, and 10.7 cm on average across 10 genotypes under early, normal, and late planting, demonstrating a loss of 1.1 cm between normal and early planting and 2.5 cm between normal and late planting due to late planting. As a result, predicted spike length improvements were larger with early planting than with standard or late planting. Thousand-grain weight was 48.4, 47.8, and 46.9 g on average across 10 genotypes under normal, early, and late planting, demonstrating a loss of 0.6 g between early and normal planting and 1.5 g between normal and late planting due to late planting. Similarly, the biological yield was 24.1, 19.4, and 10.1 Kg ha^{-1} under early, normal, and late planting, respectively, demonstrating a 4.7 Kg ha^{-1} loss in biological yield between early and normal planting and a 9.3 Kg ha^{-1} reduction in biological yield between normal and late planting due to late planting. As a result, biological yield improvements were projected to be bigger under, early planting than under normal or late planting. Grain yields under early, normal, and late planting were 8669.6, 8018.3, and 4095.6 kg ha^{-1}, respectively, demonstrating a loss of 651.3 Kg ha^{-1} between early and normal planting and 3922.7 Kg ha^{-1} between normal and late planting due to late planting. As a result, the predicted increase in grain yield was larger for early planting than for normal or late planting. Averaged over 10 genotypes, the harvest index was the same (0.3) under early, normal and late planting. Earlier, Raza *et al*. (2018) conducted an experiment under rainfed conditions and reported non-significant differences for days to heading. The projected improvement in maturity intervals with late planting will be lowered than early and standard planting as reported (Tsegaye *et al*., 2012). The predicted increase in plant height with early planting will be larger than regular and late planting. Plant height was significant among cultivars × sowing date interaction as has been previously reported (Khosravi *et al*., 2010). Said *et al*. (2007) in their experiment reported that genotype performance was significant for flag leaf area while non-significant results were obtained by Akmal *et al*. (2000). Similarly, for spike length significant differences were observed across two seasons (Bhutto *et al*., 2021). In another experiment, it has been reported that spikelets spike^{-1} varied significantly across sowing dates but the genotype difference was non-significant (Hussain *et al*., 2021). The date × genotype interaction was significant for thousand seed weight (Inamullah *et al*., 2007). In the same way, significant differences were found among the planting dates for biological yield (Said *et al*., 2012). Grain yield was also considerably variable amongst wheat genotypes and genotype-environment interactions. In our results, the predicted increase in spikelets spike^{-1} thousand-grain weight, grain yield and biological yield were larger for early planting than for normal or late planting. Marasini *et al*. (2016) in their research concluded that the grain yield was significantly higher on the 14th of November whereas the higher straw yield on the 29th of November sowing.

Conclusions and Recommendations

From the current study, it was concluded that the most suitable time for sowing in those late sowing areas is from 15th October to 15th November and genotype PR-140 was the best in grain yield in early (October) sowing. This study suggests that the PR-140 line can be used in the future for obtaining high yields in the late-sowing areas.

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Novelty Statement

The analysis of ten advanced wheat genotypes for yield at different sowing timing (early, normal and late) revealed the best yield performance by genotypes PR-138, PR-140 and Gulzar-19, while PR-138 performed exceptionally well across three sowing times for seed yield.

Author's Contribution

This M. Phil research project was designed by Dr. Abdur Rauf and Dr. Khilwat Afridi, and was executed by M. Jawad Khan. Abdur Rauf, Ikramullah Khan, Farooq Jan, Muhammad Qayash, Muhammad Yasin and Samrin Gul helped with the manuscript writing and formatting, while Tanweer Kumar, Wajid Khan, Farhanda, Muhammad Aarif and Wisal Khan helped in statistical analysis.

Conflict of interest

The authors have declared no conflict of interest.

References

Abinasa, M., A. Ayana and G. Bultosa. 2011. Genetic variability, heritability and trait associations in durum wheat (*Triticum turgidum* L. var. *durum*) genotypes. Afr. J. Agric. Res., 6(17): 3972-3979.

Acharya, R., S. Marahatta and L.P. Amgain. 2017. Response of wheat cultivars in different agricultural practices differed by sowing date. Int. J. Appl. Sci. Biotechnol., 5(2): 250-255. https://doi.org/10.3126/ijasbt.v5i2.17629

Agcaoili, M. and M.W. Rosegrant. 1995. Global and regional food supply, demand, and trade prospects to 2010. In Population and food in the early twenty-first century: Meeting future food demand of an increasing population.

Akmal, M., S.M. Shah and M. Asim. 2000. Yield performance in three commercial wheat varieties due to flag leaf area. Pak. J. Biol. Sci., 3(12): 2072-2074. https://doi.org/10.3923/pjbs.2000.2072.2074

Akram, Z., S.U. Ajmal and M. Munir. 2008. Estimation of correlation coefficient among some yield parameters of wheat under rainfed conditions. Pak. J. Bot., 40(4):1777-1781.

Ali, K., S.I. Haq, H.U.K. Bushra, P. Iqbal, S. Ali, A. Nawaz and H. Noor. 2018. Evaluation of wheat and weed growth under different mulching and organic amendments. Pak. J. Weed Sci. Res., 24(4): 377-385. https://doi.org/10.28941/24-4(2018)-7

Ali, M.A., M. Ali and Q.M. Din. 2004. Determination of grain yield of different wheat varieties as influenced by planting dates in agro-ecological conditions of Vehari. Pak. J. Life Soc. Sci., 2(1): 5-8.

Ali, Y., B.M. Atta, J. Akhter, P. Monneveux and Z. Lateef. 2008. Genetic variability, association and diversity studies in wheat (*Triticum aestivum* L.) germplasm. Pak. J. Bot., 40(5): 2087-2097.

Anwar, S., W.A. Khattak, Inamullah, M. Islam, S. Bashir, M. Shafi and J. Bakht. 2015. Effect of sowing dates and seed rates on the agro-physiological traits of wheat. J. Environ. Earth Sci., 5: 135-141.

Anwar, T., Y. Jamal, M. Ibrahim, H. Ullah, A. Mukhtar, M.A. Adnan, H. Muhammad, K. Mehran and M. Anwar. 2008. Comparative performance of wheat cultivars under semi-arid climatic conditions of Khyber Pakhtunkhwa, Pakistan. Biyolojik Çeşitlilik ve Koruma, 9(2), pp.44-47.

Aslani, F and M.R. Mehrvar. 2012. Responses of wheat genotypes as affected by different sowing dates. Asian J. Agri. Sci., 4(1): 72-74.

Aycicek, M. and T. Yildirim. 2006. Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L.) genotypes. Pak. J. Bot., 38(2): 417.

Baloch, M.S., M.A. Nadim, M. Zubair, I.U. Awan, E.A. Khan and S.A. Ali. 2012. Evaluation of wheat under normal and late sowing conditions. Pak. J. Bot., 44(5): 1727-1732.

Bhutto, T.A., M. Buriro, N.A. Wahocho, S.A. Wahocho, M.I. Jakhro, Z.A. Abbasi, R. Vistro, F. Abbasi, S. Kumbhar, F.M. Shawani and N.H. Khokhar. 2021. Evaluation of wheat cultivars for growth and yield traits under agro-ecological condition of Tandojam. Pak. J. Agric. Sci., 34(1): 136. https://doi.org/10.17582/journal.pjar/2021/34.1.136.143

Braun, H.J., G. Atlin and T. Payne. 2010. Multi-location testing as a tool to identify plant response to global climate change. Clim. Change Crop Prod., 1: 115-138. https://doi.org/10.1079/9781845936334.0115

Dwivedi, R., S. Prasad, B. Jaiswal, A. Kumar, A. Tiwari, S. Patel, G. Pandey and G. Pandey. 2017. Evaluation of wheat genotypes (*Triticum aestivum* L.) at grain filling stage for heat tolerance. Int. J. Pure Appl. Biosci., 5(2): 971-975. https://doi.org/10.18782/2320-7051.2614

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. John Wiley and Sons.

Gomez-Macpherson, H. and R.A. Richards. 1995. Effect of sowing time on yield and agronomic characteristics of wheat in South-Eastern Australia. Aust. J. Agric. Res., 46(7): 1381-1399. https://doi.org/10.1071/AR9951381

Hameed, E., W.A. Shah, A.A. Shad, J. Bakht and T. Muhammad. 2003. Effect of different planting dates, seed rate and nitrogen levels on wheat. Asian J. Plant Sci., https://doi.org/10.3923/ajps.2003.467.474

Hussain, J., T. Khaliq, A. Ullah, I. Ahmed, A.K. Srivastava, T. Gaiser and A. Ahmad. 2021. Effect of temperature on sowing dates of wheat under arid and semi-arid climatic regions and impact quantification of climate change through mechanistic modeling with evidence from field. Atmosphere, 12(7): 927. https://doi.

org/10.3390/atmos12070927

Hussain, M., G. Hussain, L.H. Akhtar, A.H. Tariq, M. Rafiq, M.Z. Aslam, M. Aslam, M. Arshad, S. Ahmad and S.T. Sahi. 2010. New wheat variety "Fareed-06" for irrigated areas of Punjab, Pakistan. Pak. J. Bot., 42(5): 3285-3297.

Ijaz, F., M.T. Shahzad, A. Sattar and H.S. Gul. 2014. Estimating of heritability for some agronomic traits in wheat (*Triticum aestivum* L.). Int. J. Modern Agric., 3(2): 25-30.

Ikhtiar, K. and Z. Alam. 2007. Nutritional composition of Pakistani wheat varieties. J. Zhejiang Univ. Sci. B, 8(8): 555-559. https://doi.org/10.1631/jzus.2007.B0555

Inamullah, N.H., Z.H. Shah and K. Fu. 2007. An analysis of the planting dates effect on yield and yield attributes of spring wheat. Sarhad J. Agric., 23(2): 269-275.

Iqbal, J., A. Zohaib, M. Hussain, I. Ahmad, A. Bashir, W. Muzaffer, N. Faisal, M.T. Latif and S. Ullah. 2020. Grain yield and critical yield determining component of bread wheat varieties in response to sowing dates. Pak. J. Agric. Sci., 33(3): 550-560. https://doi.org/10.17582/journal.pjar/2020/33.3.550.560

Kalwar, Z.A., A. Tunio, M.Y. Shaikh, I. Khan and J.Q. Jogi. 2018. Impact of sowing dates on the growth and yield of wheat variety benazir-2013, Sindh Province, Pakistan. Int. J. Agron. Agric. Res., 12(5): 65-71.

Khan, A., M.T. Jan, M. Arif, K.B. Marwat and A. Jan. 2008. Phenology and crop stand of wheat as affected by nitrogen sources and tillage systems. Pak. J. Bot., 40(3): 1103-1112.

Khan, A.J., F. Azam and A. Ali. 2010. Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions. Pak. J. Bot., 42(1): 259-267.

Khan, F., M.I. Khan, S. Khan, M.A.U. Zaman, H. Rasheed and A.R. Khan. 2018. Evaluation of agronomic traits for yield and yield components in wheat genotypes with respect to planting dates. Malays. J. Sustain. Agric., 2(1): 7-11. https://doi.org/10.26480/mjsa.01.2018.07.11

Khan, N. and F.N. Naqvi. 2012. Correlation and path coefficient analysis in wheat genotypes under irrigated and non-irrigated conditions. Asian J. Agric. Sci., 4(5): 346-351.

Khosravi, V., G. Khajoie-Nejad, G. Mohammadi-Nejad and K. Yousefi. 2010. The effect of different sowing dates on yield and yield components of wheat (*Triticum aestivum* L.) cultivars. Int. J. Agron. Plant Prod., 1(3): 77-82.

Kumar, T., I.A. Khan, N. Ali, M.A. Zia, T. Hameed, S. Roomi, A. Bahadur and H. Ahmad. 2014. Estimation of genetic diversity in genetic stocks of hexaploid wheat using seed storage proteins. Curr. Res. J. Biol. Sci., 6(4): 150-153. https://doi.org/10.19026/crjbs.6.5514

Mannion, A.M., 1995. Agriculture and environmental change: Temporal and spatial dimensions. John Wiley and Sons.

Marasini, D., S. Marahatta, S.M. Dhungana and R. Acharya. 2016. Effect of date of sowing on yield and yield attributes of different wheat varieties under conventional tillage in sub-humid condition of Chitwan District of Nepal. Int. J. Appl. Sci. Biotechnol., 4(1): 27-31. https://doi.org/10.3126/ijasbt.v4i1.14335

Meleha, A.M., A.F. Hassan, M.A. El-Bialy and M.A. El-Mansoury. 2020. Effect of planting dates and planting methods on water relations of wheat. Int. J. Agron., 2020. https://doi.org/10.1155/2020/8864143

Miralles, D.J., B.C. Ferro and G.A. Slafer. 2001. Developmental responses to sowing date in wheat, barley and rapeseed. Field Crops Res., 71(3): 211-223. https://doi.org/10.1016/S0378-4290(01)00161-7

Mumtaz, M.Z., M. Aslam, H.M. Nasrullah, M. Akhtar and B. Ali. 2015. Effect of various sowing dates on growth, yield and yield components of different wheat genotypes. Am. Eurasian J. Agric. Environ. Sci., 15(11): 2230-2234.

Murungu, F.S. and T. Madanzi. 2010. Seed priming, genotype and sowing date effects on emergence, growth and yield of wheat in a tropical low altitude area of Zimbabwe. Afr. J. Agric. Res., 5(17): 2341-2349.

Petersen, G., O. Seberg, M. Yde and K. Berthelsen. 2006. Phylogenetic relationships of Triticum and Aegilops and evidence for the origin of the A, B, and D genomes of common wheat (*Triticum aestivum*). Mol. Phylogenet. Evol., 39(1): 70-82. https://doi.org/10.1016/j.ympev.2006.01.023

Rajput, R.S., and V.S. Kandalkar. 2018. Combining ability and heterosis for grain yield and its attributing traits in bread wheat (*Triticum aestivum* L.). J. Pharmacogn. Phytochem., 7(2): 113-119.

Raza, A., K. Khan, M.M. Anjum, N. Ali, U.

Sultan and S.Z. Samiullah. 2018. Evaluation of wheat lines for yield and yield components under rain-fed conditions. Adv. Plants Agric. Res., 8(6): 400-404. https://doi.org/10.15406/apar.2018.08.00358

Rehman, A.U., S. Iqbal and M. Mohibullah. 2017. Assessment of genetic diversity in wheat (*Triticum aestivum* L.) under elevated yellow rust pressure. Int. J. Hortic., 7.

Rosegrant, M.W. and M. Agcaoili. 2010. Global food demand, supply and prospectus to 2010. IFPRI, Washington, D.C, U.S.A.

Sabit, Z., B. Yadav and P.K. Rai. 2017. Genetic variability, correlation and path analysis for yield and its components in f5 generation of bread wheat (*Triticum aestivum* L.). J. Pharmacogn. Phytochem., 6(4): 680-687.

Said, A., H. Gul, B. Saeed, B. Haleema, N.L. Badshah and L. Parveen. 2012. Response of wheat to different planting dates and seeding rates for yield and yield components. ARPN J. Agric. Biol. Sci., 7(2): 138-140.

Said, A., I. Ahmad and T. Hussain. 2007. Performance of different wheat genotypes under environmental conditions of Peshawar Valley. Sarhad J. Agric., 23(3): 545.

Sattar, A., M.M. Iqbal, A. Areeb, Z. Ahmed, M. Irfan, R.N. Shabbir, G. Aishia and S. Hussain. 2015. Genotypic variations in wheat for phenology and accumulative heat unit under different sowing times. J. Environ. Agric. Sci., 2(8): 1-8.

Shah, W.A., J. Bakht, T. Ullah, A.W. Khan, M. Zubair and A.A. Khakwani. 2006. Effect of sowing dates on the yield and yield components of different wheat varieties. J. Agron.,

Shazma, A., W.A. Khattak, I. Muhammad, B. Saqib, S. Muhammad and B. Jehan. 2015. Effect of sowing dates and seed rates on the agro-physiological traits of wheat. J. Environ. Earth Sci., 5(1): 135-141.

Sheedy, J.G., 2004. Resistance to root-lesion nematode (*Pratylenchus thornei*) in wild relatives of bread wheat (*Triticum aestivum*) and Iranian landrace wheats (Doctoral dissertation, University of Queensland).

Sial, M.A., M.A. Arain, S. Khanzada, M.H. Naqvi, M.U Dahot and N.A. Nizamani. 2005. Yield and quality parameters of wheat genotypes as affected by sowing dates and high temperature stress. Pak. J. Bot., 37(3): 575.

Suryavanshi, S. and P.B. Gurmeet. 2016. Mitigating terminal heat stress in wheat. Int. J. Bio-Resour. Stress Manag., 7(1): 142-150. https://doi.org/10.23910/IJBSM/2016.7.1.1333f

Tahir, M., A. Ali, M.A. Nadeem, A. Hussain and F. Khalid. 2009. Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum* L.) varieties in district Jhang, Pakistan. Pak. J. Life Soc. Sci., 7(1): 66-69.

Tsegaye, D., T. Dessalegn, Y. Dessalegn and G. Share. 2012. Genetic variability, correlation and path analysis in durum wheat germplasm (*Triticum durum* Desf). Agric. Res. Rev., 1(4): 107-112.

Virk, D.S. and S.S. Anand. 1970. Studies on correlations and their implication of selection in wheat. Madras I. Agrie, 57: 713-717.

Wajid, A., A. Hussain, A. Ahmad, A.R. Goheer, M. Ibrahim and M. Mussaddique. 2004. Effect of sowing date and plant population on biomass, grain yield and yield components of wheat. Int. J. Agric. Biol., 6(6): 1003-1005.

Yajam, S. and H. Madani. 2013. Delay sowing date and its effect on Iranian winter wheat cultivars yield and yield components. Ann. Bio. Res., 4: 270-275.

Yang, Q., I. Ahmad, S. Bushra, J. Zhang, G. Huang and G. Du. 2018. Current agricultural mechanization practices and attractive attributes towards its modernization for food security in belt and road countries: Pakistan as a case study. Int. J. Multidiscip. Res. Dev., 5(10): 97-105.

Yin, L., X. Dai and M. He. 2018. Delayed sowing improves nitrogen utilization efficiency in winter wheat without impacting yield. Field Crops Res., 221: 90-97. https://doi.org/10.1016/j.fcr.2018.02.015

Zeeshan, M., W. Arshad and S. Ali 2013. Genetic diversity and trait association among some yield parameters of wheat elite lines genotypes under rainfed conditions. J. Renewable Agric., 1(2): 23-26. https://doi.org/10.12966/jra.05.03.2013