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Effect of different sowing dates on growth and development of wheat (*Triticum aestivum* L.) genotypes at different locations of Sindh province, Pakistan

Saquib Hussain Siddiqui[1], Wajid Ali Jatoi[2*], Shahnaz Memon[3], Tarique Ali Jatoi[4], Wazir Ali Maitlo[5], Muhammad Siddique Depar[6], Saima Siddiqui[7]

[1]*Department of Crop Physiology, Sindh Agriculture University, Tandojam, Pakistan*

[2]*Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam, Pakistan*

[3]*Cotton Research Institute, Tandojam, Sindh Pakistan*

[4]*Department of Soil Science, Sindh Agriculture University, Tandojam, Pakistan*

[5]*Shaheed Benazir Bhutto University, Benazirabad, Sindh Pakistan*

[6]*Arid Zone Research Center, Umar Kot, Sindh Pakistan*

[7]*Agriculturer Research Center, Tandojam, Sindh Pakistan*

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Abstract

Wheat production in Pakistan is low as it is severely affected by various biotic and abiotic stresses. Amongst the abiotic stress, heat stress (terminal high temperature) is one of the major causes of low wheat yield in Pakistan. This paper focuses on the evaluation and performance of newly evolved wheat genotypes under different sowings (temperature regimes) conditions and the selection of suitable promising lines. In this experiment, the twenty wheat genotypes (DH-1, DH-3, DH-4, DH-5, DH-6, DH-7, DH-8, DH-10, DH-11, DH-12, DH-13, DH-14, DH-15, DH-16, DH-18, DH-19, DH-20, DH-21, Lu26s and Kiran-95) were cultivated in three locations of the Sindh province i.e., Sakrand, Tandojam, and Mirpursakro under three different sowing dates viz., November 7, November 27 and December 17; November 5, November 25 and December 15 and November 6, November 26 and December 16, 2015-17 (two years), as S1 (optimum), S2 (heat stress) and S3 (high heat stress), respectively. All the bio-growth parameters *viz.*, productive tillers plant^{-1}, spikelets spike^{-1}, grain weight plant^{-1}(g) and 1000-grains weight (g) showed significant difference among genotypes and sowing dates in their interactions. A significantly decreasing trend was observed in all the bio-growth parameters at late sown crop over normal sown. Based on summarized results of three locations, the wheat genotypes DH-1, DH-6, DH-7, DH-11, DH-14, DH-18, DH-21 and Lu26s were classified as tolerant as these showed <40% reduction in quantum of 4 & 3 variables while DH16 and Kiran-95 were appeared sensitive as these displayed <40% reduction in <2 variables.

* **Corresponding Author:** Wajid Ali Jatoi ✉ jatoiwajid@yahoo.com

Introduction

Wheat cereal crop is the most important for the reason that it is the staple food of the people of Pakistan and thus occupies a vital role in agricultural forming policies and dominates all crops in acreage and production. Wheat contributes 9.1 percent to the value added in agriculture and 1.7 % to GDP of Pakistan. Wheat area cultivated 8734 thousand hectares witnessing a decrease of 2.6 percent compared over last year's area 8972 thousand hectares. Wheat production was estimated at 25.492 million tonnes during 2017-18, recorded to decline of 4.4 % over the last year's production of 26.674 million tonnes (GOP, 2018). Grain yield of any crop is affected by several factors. Among them, multifarious types of environmental conditions contribute to great yield losses as they cause change in metabolism thereby trigging the entire crop physiology (Arshad *et al.,* 2008; Li *et al.,* 2011). Production of wheat is the main factor that relates appearance of all yield components that prejudiced by various growth processes such as genetically affects and the prevailing circumstances. Therefore, associations of several morpho-physiological traits with yield factor were studied by many scientists, had testified different magnitude of relationships between the same pair of characters in wheat (Kashif and Khaliq , 2014). Wheat is sown in winter season and its own specific requirements for temperature and light for emergence, growth and flowering (Dabre *et al.,* 1993). Rahman (2009) evaluated thirty spring wheat cultivars in an experiment to determine interrelationships of various traits relating with yield. He found that spikes m^{-2}, 1000-grain weight, rate of grain filling and biomass exhibited statistically positive as well as significant correlation with yield of grains. Normal sown increase productive tillers, spikelets spike^{-1}, grains spike^{-1} and 1000-grain weight over late sown. High producing genotypes have been evolved and recommended for general cultivation in the past. These genotypes are losing their production due to changes in several of environmental conditions (Shafiq, 2004). Keeping this in view, the present study was therefore, designed to determine the effect of different sowing dates on growth and yield of wheat varieties in province Sindh.

Materials and methods

A field experiment to determine the effect of different sowing dates on growth and development of wheat (*Triticum aestivum* L.) genotypes was conducted in the three selected sites (Tandojam, Sakrand and Mirpursakro) Sindh province, Pakistan during rabi season for two years (2015-16 & 2016-17). The experiment comprised twenty wheat genotypes were collected eigteen were Double Haploid (DH line) and one check varity (Kiran-95) from Nucear Institute of Agriculture (NIA), Tandojam and another check varity (Lu-26s) from University of Agriculture, Faisalabad (DH-1, DH-3, DH-4, DH-5, DH-6, DH-7, DH-8, DH-10, DH-11, DH-12, DH-13, DH-14, DH-15, DH-16, DH-18, DH-19, DH-20, DH-21, Kiran-95, Lu-26s) having three sets of experiment optimum (normal sowing), heat stress (after 20 days gap from normal sowing) and high heat stress (after 40 days gap from normal sowing) and was laid out in RCBD with split plot arrangement having three-replications and plot size of 31.5 x 10 meter & sub plot size of 1.0 x 2.0 m. The nitrogen (120 kg ha^{-1}) and phosphorous (90 kg ha^{-1}) was used in the form of urea and DAP, respectively. Before conducted the experiment at three different locations the soil samples were taken from the experimental area for physio-chemical analysis of the soil (Table 1). At the time of sowing all the phosphorous and ½ of the nitrogen were applied. The crop was sown with hand drill on a good prepared seedbed using seed rate of 120 kg ha^{-1}. For all the treatments all other agronomic practices were kept normal and consistent. The parameters recorded included number of productive tillers plant^{-1}, number of spikelets spike^{-1}, grain weight plant^{-1} and 1000-grain weight. The data collected was analyzed statistically by Fisher's techniques and differences amid treatment were compared using least-significant difference test at 5% probability level (Steel *et al.,* 1997). The genotypes were also classified into various classes as tolerant, medium tolerant, medium sensitive and sensitive on the basis of less than 40% reduction in different agronomical variables (Khan, 2008).

Statistical analysis

Data regarding all the traits measured at crop maturity stage were analyzed using analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) by MSTATC computer package (Anonymous, 1991)

Results and discussion

Productive tillers plant⁻¹

The data regarding productive tillers $plant^{-1}$ significant difference among genotypes and sowings conditions under three different locations (Sakrand, Tandojam and Mirpursakro) is given in Table 2.

Table 1. Physio-chemical analysis of the soil and irrigated water before sowing at three (Tandojam, Sakrand and Mirpursakro), experimental farms.

Soil character	Tandojam	Sakrand	Mirpursakro
Sand (%)	21	22	23
Clay (%)	24	20	25
Silt (%)	55	58	52
Organic matter (%)	0.44	0.67	0.59
Textural class	Silty Loam	Silty Loam	Silty Loam
pH (1:2)	8.40	8.10	8.00
N (%)	0.022	0.033	0.029
P (ppm)	2.3	1.9	0.9
K (ppm)	221	179	214
Water parameters	Tandojam	Sakrand	Mirpursakro
ECw	0.58	0.43	0.59
pH	7.3	7.6	7.2
T.S.S (ppm)	371	362	382
Cl (mg L^{-1})	350	338	368
Ca (mg L^{-1})	4.9	4.3	5.4
Mg (mg L^{-1})	9	8.7	9.8

The maximum productive tillers under optimum condition in Sakrand, Tandojam and Mirpursakro were 6.33, 6.56, and 5.94 per plant in genotype Lu-26s, DH-6 and DH-4, whereas the minimum productive tillers were recorded 4.00, 4.33 and 4.00 per plant in DH-21 in all three locations and differed significantly from all other genotypes. Under heat stress condition, the genotype DH-12 again showed maximum productive tiller per plant in three different location Sakrand, Tandojam and Mirpursakro (6.00 per plant) and significantly different from all other genotypes while minimum productive tiller was recorded 3.50, 4.00 and 3.44 per plant on DH-21 in Sakrand, Tandojam and Mirpursakro (Table 2). Under high stress condition in Sakrand the genotype DH-12 again showed maximum productive tiller per plant i.e. 5.17 while the minimum 2.67 per plant were found in DH-16 and was at par statistically with those of found in DH-21 and Kiran-95 with 3.0 and 2.83 per plant, respectively. In both Tandojam and Mirpursakro, under high stress condition the genotype DH-14 showed maximum productive tillers i.e. 4.67 and 4.33 per plant respectively, while the minimum productive tillers were recorded to be 3.50 and 2.33 per plant in DH-16 and Kiran-95. Furthermore in Sakrand, Tandojam and Mirpursakro the maximum reduction in productive tillers was 23.60, 33.33 and 22.86 % found in DH-13, DH-20 and DH-6 was appeared as sensitive under heat stress condition over optimum condition while minimum reduction i.e. 4.38, 4.25 and 6.28 % was found in DH-12 and DH-8 appeared as tolerant. Similarly in Sakrand and Mirpursakro the genotype DH-16 showed maximum reduction in productive tillers (44.86 and 12.97 %) under high heat stress over optimum condition.

On an average of genotypes in various locations, the maximum productive tillers were recorded to be 5.63 per plant in Tandojam under optimum conditions and followed by 5.41 and 5.12 per plant in Sakrand and Mirpursakro, respectively.

Table 2. Interactional effect among sowing periods on the productive tillers plant^{-1} in various genotypes of wheat at different localities of Sindh province, Pakistan.

Genotypes	Sakrand (Lsd at 5%= 0.3758)					Tandojam (Lsd at 5%= 0.3314)					Mirpursakro (Lsd at 5%= 0.4488)				
	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction		1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction		1st sowing (Opt.)	2nd sowing (HS)	3rd Sowing (HHS)	Percent Reduction	
				HS over Opt.	HHS over Opt.				HS over Opt.	HHS over Opt.				HS over Opt.	HHS over Opt.
DH-1	5.28 CD	5.00 DEF	4.33 HIJ	5.21	17.85	5.22 GH	4.83 HIJ	4.00 NOPQ	7.45	23.40	5.00 CDFEG	4.50 GHIJKL	3.89 MNOPQ	10.00	22.23
DH-3	5.83 B	5.00 DEF	4.00 J	14.29	31.43	6.17 BCD	4.83 HIJ	3.60 QES	21.62	41.62	5.45 ABCD	4.89 EFG	4.17 JKLMNOP	10.20	23.52
DH-4	5.72 B	5.00 DEF	4.00 J	12.66	30.10	6.33 ABC	5.00 HI	4.17 MNOP	21.05	34.24	5.94 A	4.61 GHIJK	4.00 LMNOP	22.45	32.71
DH-5	5.00 DEF	4.72 EFGH	4.33 HIJ	5.57	13.33	5.00 HI	4.73 IJK	4.17 MNOP	5.50	16.70	5.00 CDEFG	4.50 GHIJKL	4.19 IJKLMNOP	10.00	16.12
DH-6	6.00 AB	5.00 DEF	3.33 KL	16.67	44.50	6.56 H	4.67 IJKL	4.10 MNOP	28.81	37.46	5.83 AB	4.50 GHIJKL	3.67 PQR	22.86	37.17
DH-7	6.00 AB	5.17 DE	4.83 DEFG	13.89	19.44	6.33 ABC	5.67 EF	5.00 HI	10.53	21.05	5.50 ABC	4.28 IJKLMNO	4.00 LMNOP	22.21	27.27
DH-8	5.28 D	5.00 DEF	4.00 J	5.21	24.17	5.22 GH	5.00 HI	4.00 NOPQ	4.25	23.40	5.28 CDEF	4.95 DEF	4.17 JKLMNOP	6.28	21.06
DH-10	4.83 DEFG	4.39 GHIJ	4.00 J	9.24	17.24	4.83 HIJ	4.28 MNO	4.00 NOPQ	11.53	17.22	4.72 GHI	4.22 IJKLMNOP	4.11KLMNOP	10.65	12.97
DH-11	5.00 DEF	4.39 GHIJ	4.00 J	12.27	20.00	5.67 EF	4.00 NOPQ	3.83 PQR	29.41	32.37	4.89 EFG	4.33 HIJKLM	3.78 OPQR	11.35	22.73
DH-12	6.28 A	6.00 AB	5.17 DE	4.38	17.66	6.28 ABC	6.00 CDE	3.97 OPQ	4.40	36.71	5.83 AB	5.39 BCDE	3.45 QRS	7.66	40.86
DH-13	5.67 BC	4.33 HIJ	4.00 J	23.60	29.42	5.00 HI	4.28 MNO	4.00 NOPQ	14.50	20.00	5.00 CDEFG	4.11 JKLMNOP	3.78 OPQR	17.77	24.40
DH-14	5.83 B	5.00 DEF	4.00 J	14.29	31.43	5.83 DE	5.17 GH	4.67 IJKL	11.43	20.03	5.50 ABC	4.83 FGH	4.33 HIJKLMN	12.12	21.21
DH-15	5.83 B	5.00 DEF	4.00 J	14.29	31.43	6.00 CDE	4.83 HIJ	4.00 NOPQ	19.44	33.33	5.33 BCDEF	4.83 FGH	4.00 LMNOP	9.38	25.00
DH-16	4.83 DEFG	4.17 IJ	2.67 N	13.79	44.86	5.00 HI	4.44 JKLM	2.50 U	11.17	50.10	4.83 FGH	4.33 HIJKLMN	2.50 T	10.34	48.28
DH-18	4.55 FGHI	4.17 IJ	3.50 K	8.49	23.13	4.67 IJKL	4.28 LMNO	3.67 QRS	8.39	21.43	4.50 GHIJKL	4.00 LMNOP	3.33 RS	11.11	26.00
DH-19	5.83 B	5.00 DEF	4.55 FGHI	14.29	21.94	6.22 ABC	5.00 HI	4.39 S	19.61	29.47	5.00 CDEFG	4.50 GHIJKL	3.78 NOPQR	10.00	24.47
DH-20	4.83 DEFG	4.00 J	3.17 KLM	17.24	34.48	6.50 AB	4.33 LMNO	3.58 RS	33.33	44.90	5.00 CDEFG	4.17 JKLMNOP	3.00 S	16.67	40.00
DH-21	4.00 J	3.50 K	3.00 LMN	12.50	25.00	4.33 LMNO	4.00 NOPQ	3.44 S	7.62	20.52	4.00 LMNOP	3.44 QRS	3.00 S	13.92	25.00
Lu26s	6.33 A	5.11 DE	4.50 GHI	19.32	28.95	5.42 FG	5.00 HI	4.00 NOPQ	7.67	26.14	5.36 BCDEF	4.67 GHIJ	3.89 MNOPQ	12.95	27.47
Kiran-95	5.17 DE	4.61 FGH	2.83 MN	10.71	45.23	6.08 CD	4.67 IJKL	3.00 T	23.29	50.68	4.50 GHIJKL	4.00 LMNOP	2.33 T	11.11	48.22
Mean (Lsd at 5% = 0.088	5.41 B	4.73 D	3.91 F			5.63 A	4.75 D	3.90 F			5.12 C	4.44 E	3.67 G		

*Means sharing similar letters in column and rows did not differ significantly.

The minimum productive tillers were found to be 3.67 per plant under high heat stress condition in Mirpursakro and differed significantly from those of all other condition and districts. In brief, it is clear from the results that a decreasing trend was found in all the locations under heat stress conditions over optimum condition.

The present judgments are in agreement with Ehdaie *et al.* (1988) who also reported that heat stress condition showed negative correlation with productive tillers plant^{-1}, grain spike^{-1} and grain weight. These results are close with those reported by Haider (2004) that under normal sowing resulted in enhanced development of the productive tillers plant^{-1} and grains weight due to late sowing stage.

Number of spikelets spike^{-1}

The data pertaining significantly affected to spikelets per spike in different genotypes of wheat at various sowings (temperature) conditions in Sakrand, Tandojam and Mirpursakro of Sindh province are given in Table 3. It is evident from the results that the genotypes DH-10, DH-20 and DH13 showed maximum spikelets i.e. 23.14, 23.97 and 20.61 per spike under optimum condition in Sakrand, Tandojam and Mirpursakro. The minimum number of spikelets per spike was noted to be 15.17, 13.87 and 14.58 in genotype DH-1, DH-6 and DH-1 at differed significantly from those of found in all other genotypes.

At heat stress condition, in Sakrand, Tandojam and Mirpursakro side the genotype DH-13, possessed maximum number of spikelets i.e. 21.79 per spike and showed significant variation with the other genotypes. The minimum number of spikelets was observed to be 14.17, 13.87 and 9.69 per spike in DH-1, DH-6 and Kiran-95 and also showed significant difference with the other genotypes. At high heat stress condition, in Sakrand, Tandojam and Mirpursakro side the genotype DH-13, DH-21 and DH-12 showed maximum number of spikelets i.e. 18.95, 17.75 and 11.55 per spike, respectively.

Table 3. Interactional effect among sowing periods on the spikelets spike^{-1} in various genotypes of wheat at different localities of Sindh province, Pakistan.

Genotypes	Sakrand (Lsd at 5%=0.358)					Tandojam (Lsd at 5%=0.6306)					Mirpursakro (Lsd at 5%=1.8306)				
	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction		1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction		1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction	
				HS over Opt.	HHS over Opt.				HS over Opt.	HHS over Opt.				HS over Opt.	HHS over Opt.
DH-1	15.17 X	14.17 Z	13.25 [	6.59	12.63	16.94PQRS	14.60 UV	12.94 [	13.77	23.61	14.58 JKLMNOP	13.35 NOPQRS	11.04 UVWX	8.46	24.27
DH-3	20.58 GHI	19.17 L	17.60 RS	6.88	14.49	21.10 E	16.94 PQRS	11.64]	19.70	44.84	15.86 EFGHIJKL	14.93 GHIJKLMNO	13.25 OPQRST	5.81	16.41
DH-4	19.81 J	18.96 LMN	17.43 ST	4.31	11.99	19.44 HI	16.58 RST	11.12]	14.71	42.80	16.39 DEFGHIJ	15.82 EFGHIJKL	13.80 LMNOPQ	3.43	15.77
DH-5	21.08 EF	20.38 I	18.26 PQ	3.33	13.37	21.94 CD	18.24 JKLM	14.08 XYZ	16.88	35.82	17.67 BCDEF	16.39 DEFGHIJ	13.99 KLMNOPQ	7.25	20.84
DH-6	16.43 V	15.58 W	13.89 Z	5.14	15.43	17.62 MNOP	13.87 YZ	12.47 [	21.30	29.25	16.71 DEFGHIJ	13.05 OPQRSTU	10.77 VWX	21.92	35.58
DH-7	18.22 PQ	17.59 RS	15.07 XY	3.46	17.30	18.80 IJK	15.95 TU	13.64 Z	15.16	27.48	15.58 FGHIJKLMN	13.71 LMNOPQR	11.29 STUVWX	12.01	27.52
DH-8	18.76 MNO	16.61 V	10.93 ʌ	11.44	41.72	18.13 KLMN	17.24 OPQR	15.44 UV	4.90	14.86	15.83 EFGHIJKL	13.98 KLMNOPQ	11.55 RSTUVWX	11.69	27.04
DH-10	23.14 A	21.47 CD	13.88 Z	7.22	40.04	23.56 AB	18.94 IJ	13.85 YZ	19.59	41.21	17.17 CDEFG	16.20 DEFGHIJK	10.27 WX	5.64	40.17
DH-11	18.23 PQ	17.11 TU	14.72 Y	6.15	19.26	18.30 JKLM	16.46 ST	14.73 WX	10.01	19.49	18.35 BCD	15.04 GHIJKLMNO	12.63 PQRSTUV	18.07	31.17
DH-12	18.23 PQ	17.01 U	10.75 _	6.67	41.03	18.94 IJ	16.58 RST	10.48 ʌ	12.46	44.71	17.72 BCDEF	16.52 DEFGHIJ	10.56 VWX	6.80	40.43
DH-13	23.12 AB	21.79 C	18.95 LMN	5.72	18.04	23.23 B	18.77 IJK	17.26 OPQR	19.18	25.68	20.61 A	17.04 CDEFGH	11.96 QRSTUVW	17.35	41.97
DH-14	19.92 J	19.55 JK	16.29 V	1.87	18.20	20.39 FG	20.00 GH	14.45 XY	1.94	29.16	16.54 DEFGHIJ	15.70 EFGHIJKL	13.63 LMNOPQR	5.04	17.59
DH-15	20.44 HI	19.11 LM	11.60]	6.52	43.24	19.78 GH	18.46 JKL	12.34 [\	6.69	37.63	16.97 CDEFGHI	14.85 HIJKLMNOP	12.64 PQRSTUV	12.51	25.55
DH-16	21.52 CD	20.89 EFG	12.52 \	2.95	41.84	22.58 C	18.94 IJ	13.70 Z	16.09	40.42	19.40 AB	15.70 EFGHIJKL	11.00 UVWX	19.05	43.30
DH-18	22.74 B	19.61 JK	17.96 QR	13.76	21.01	19.79 GH	19.27 IJ	15.45 UV	2.63	21.92	17.00 CDEFGH	14.70 IJKLMNOP	12.32 QRSTUVW	13.50	27.52
DH-19	17.64 RS	16.61 V	15.30 WX	5.83	13.25	16.08 TU	15.22 VW	11.75 \]	5.36	26.94	19.07 ABC	15.04 GHIJKLMNO	11.13 TUVWX	21.10	41.63
DH-20	22.95 AB	20.81 FGH	18.76 MNO	9.33	18.27	23.97 A	20.96 EF	16.86 QRS	12.56	29.66	17.91 BCDE	16.54 DEFGHIJ	12.25 QRSTUVW	7.65	31.63
DH-21	21.24 DE	20.61 GHI	18.60 NOP	2.96	12.42	22.10 CD	21.58 DE	17.75 LMNO	2.38	19.69	17.83 BCDEF	17.02 CDEFGH	14.80 HIJKLMNOP	4.58	16.99
Lu26s	18.41 OP	17.06 TU	15.19 X	7.34	17.48	17.44 NOPQ	15.93 TU	14.61 WX	8.66	16.22	15.58 FGHIJKLM	14.66 JKLMNOP	12.24 QRSTUV	5.96	21.45
Kiran-95	19.26 KL	17.79 RS	11.23 ʌ	7.61	41.71	17.78 LMNO	17.11 OPQRS	10.28 ʌ	3.74	42.15	16.31 DEFGHIJ	13.37 MNOPQRS	9.69 X	18.01	40.55
Mean (Lsd at 5%=0.298)	19.84 A	18.59 B	15.11 E			19.90 A	17.58 C	13.74 F			17.15 D	15.18 E	12.04 G		

*Means sharing similar letters in column and rows did not differ significantly.

From these results it is concluded that heat stress condition had adverse effect on the spikelets per spike in all the genotypes of wheat over optimum temperature condition under all three locations. As regard to percent reduction in spikelets, it is clear that genotype DH-6 showed maximum reduction in Tandojam and Mirpursakro i.e. 21.30 and 21.92 % and in Sakrand the genotype DH-18 showed maximum reduction i.e. 13.76 % and was appeared as a sensitive genotype. Furthermore, under high heat stress condition the genotype DH-15, DH-3 and DH-16 showed maximum reduction i.e. 43.24, 44.84 and 43.30 % in Sakrand, Tandojam and Mirpursakro whereas, it was minimum i.e. 11.99, 14.86 and 4.58 % in DH-4, DH-8 and DH-21 and these genotypes appeared as sensitive and tolerant, respectively. The results are given in last row of Table 2. The maximum number of spikelets was recorded to be 19.90 per spike under optimum condition in Tandojam and did not show significant variation with those of recorded in Sakrand under the same temperature condition. The minimum number of spikelets was found to be

12.04 per spike in high heat stress condition of Mirpursakro and differed significantly from those of observed in all other locations and sowings conditions. High temperature burden is main limitation in bread wheat production as stated by Sing *et al.* (2011) who studied the ten diverse genotypes under normal and late sowing condition. The results showed that heat stress intensity evidently directed that number of spikelets spike^{-1}, grain yield spike^{-1} and 1000-grain weight were affected during very late sown environmental conditions. These results accordingly with those of (Khaliq, 2004; Shah *et al.,* 2006; Khan, 2010) suggested that number of spikelets spike^{-1}, grains spike^{-1} and l000-grain weight were related to yield through their direct effected through late sowing.

Table 4. Interactional effect among sowing periods on the grains weight plant^{-1} (g) in various genotypes of wheat at different localities of Sindh province, Pakistan.

Genotypes	Sakrand (Lsd at 5%=0.402)					Tandojam (Lsd at 5%=0.402)					Mirpursakro (Lsd at 5%=0.440)				
	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction HS over Opt.	Percent Reduction HHS over Opt.	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction HS over Opt.	Percent Reduction HHS over Opt.	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction HS over Opt.	Percent Reduction HHS over Opt.
DH-1	9.90 JKL	8.82 PQ	4.93 Z[	10.92	50.21	9.24 NO	8.64 PQ	5.40 VW	6.46	41.57	5.72 [	2.95 _	1.40 a	48.42	75.55
DH-3	8.67 PQ	6.98 W	4.59 [\	19.45	47.03	12.63 G	10.22 KL	4.16 Y	19.07	67.05	11.58 IJ	8.99 TU	6.09 Z[	22.39	47.43
DH-4	9.80 KLM	7.46 UV	6.03 X	23.90	38.41	13.77 EF	9.61 MN	8.25 Q	30.22	40.08	13.62 F	10.86 LM	9.05 TU	20.28	33.61
DH-5	11.98 DE	9.84 KL	5.11 Z	17.89	57.34	13.72 EF	10.18 KL	5.68 V	25.76	58.59	11.41 JK	8.72 UV	5.81 [	23.54	49.09
DH-6	8.49 QR	7.77 STU	5.56 Y	8.53	34.52	12.80 G	6.88 T	4.30 Y	46.23	66.43	9.85 PQR	7.18 X	4.27]	27.12	56.66
DH-7	14.08 B	10.42 HI	8.80 PQ	26.00	37.52	18.09 A	14.77 C	11.03 I	18.34	39.00	17.10 B	14.40 E	10.66 MN	15.78	37.62
DH-8	13.03 C	9.36 MNO	7.91 ST	28.21	39.32	15.29 B	13.56 F	10.40 K	11.33	31.97	14.98 D	11.06 KLM	9.42 RST	26.15	37.08
DH-10	9.73 KLM	8.66 PQ	3.96]	11.04	59.32	15.03 BC	9.16 O	6.95 T	39.09	53.79	12.20 H	9.45 QRST	6.58 Y	22.55	46.05
DH-11	10.70 H	9.44 LMN	7.22 VW	11.77	32.52	10.89 IJ	10.22 KL	7.98 RS	6.14	26.67	9.93 OPQ	8.20 W	6.45 YZ	17.40	35.01
DH-12	11.66 EF	8.39 QR	6.91 W	28.02	40.76	10.48 JK	9.87 LM	3.95 Y	5.74	62.26	7.64 X	4.85 \	1.99 `	36.50	73.94
DH-13	12.00 DE	6.97 W	4.86 Z[	41.92	59.55	9.27 NO	7.59 S	5.11 WX	18.20	44.95	6.46 YZ	3.68 ^	1.80 `a	43.10	72.11
DH-14	12.33 D	9.90 JKL	4.42 \	19.76	64.20	14.78 C	12.52 G	6.09 U	15.32	58.78	12.85 G	10.17 OP	7.30 X	20.88	43.19
DH-15	10.44 HI	8.96 OP	3.73]^	14.18	64.25	14.31 D	10.88 IJ	4.20 Y	23.97	70.67	11.50 IJK	8.78 UV	5.83 [	23.62	49.30
DH-16	11.32 FG	10.31 HIJ	3.47 ^	8.93	69.35	14.31 D	9.09 O	6.16 U	36.49	56.92	17.65 A	15.48 C	9.36 ST	12.31	46.97
DH-18	10.17 IJK	7.49 TUV	5.89 XY	26.43	42.15	9.04 OP	8.49 Q	4.20 Y	6.11	53.58	6.19 YZ[	3.45 ^	1.54 `a	44.32	75.11
DH-19	11.88 E	7.36 UVW	7.19 X	38.05	39.52	12.06 H	9.65 MN	7.79 RS	19.97	35.39	11.15 JKL	9.65 QRS	8.40 VW	13.47	24.64
DH-20	11.76 E	7.74 TU	5.08 Z	34.17	56.83	14.11 DE	9.89 LM	4.71 X	29.89	66.62	15.37 CD	12.98 G	9.20 STU	15.55	40.16
DH-21	8.20 RS	7.20 VW	3.74]^	12.21	54.37	13.54 F	10.18 KL	8.05 R	24.82	40.55	11.73 I	8.94 TU	6.08 Z[	23.77	48.16
Lu26s	14.66 A	11.15 G	9.05 NOP	23.96	38.23	13.35 F	9.91 LM	8.64 PQ	25.77	35.27	11.90 HI	10.37 NO	7.40 X	12.79	37.80
Kiran-95	12.07 DE	8.21 RS	5.06 Z	32.02	58.08	11.76 H	9.76 LM	6.82 T	17.06	42.06	8.71 UV	5.88 [	4.24]	32.49	51.38
Mean (Lsd at 5%=0.929)	11.14 C	8.62 F	5.63 I			12.92 A	10.05 D	6.50 G			11.38 B	8.80 E	6.14 H		

*Means sharing similar letters in column and rows did not differ significantly.

Grain weight plant^{-1} (g)

Significant difference was found to exist among genotypes and various sowings (temperature) conditions regarding grain weight plant^{-1} at Sakrand, Tandojam and Mirpursakro (Table 4). The genotype Lu-26s possessed maximum grain weight i.e. 14.66, 11.15 and 9.05 gram per plant under optimum, heat stress and high heat stress conditions, respectively whereas minimum grain weight was recorded to be 8.20 gram per plant in DH-21 and found at par statistically with those of observed in DH-6 showing 8.49 gram per plant under optimum temperature condition in Sakrand. In Tandojam, the genotype DH-7 showed maximum grain weight i.e. 17.09, 14.77, 11.03 gram per plant under optimum, heat stress and high heat stress conditions, respectively and differed significantly. The minimum grain weight was recorded to be 9.04, 7.59 and 3.95 gram per plant in genotype DH-18, DH-13 and DH-12 under optimum, heat stress and high heat stress condition, respectively. In Mirpursakro, the significantly maximum grain weight was recorded to be 17.65 and 15.48 gram per plant in genotype DH-16 under both optimum and heat stress condition, respectively, whereas it was significantly maximum i.e. 10.66 gram per plant in genotype DH-17 under high heat stress condition and the minimum grain weight was found to be 5.72, 2.95 and 1.40 gram per plant under optimum, heat stress and high heat stress conditions in Mirpursakro, respectively. As regard to percent reduction in grain weight, it is evident that the genotype DH-6 and DH-20 had maximum reduction i.e. 46.23 and 66.62 % whereas it was minimum in DH-18 and DH-11 with 6.11, 26.67 percent grains weight per plant, under heat stress and high heat stress conditions in Tandojam, respectively.

Table 5. Interactional effect among sowing periods on the 1000-grains weight (g) in various genotypes of wheat at different localities of Sindh province, Pakistan.

Genotypes	Sakrand (Lsd at 5%=0.907)					Tandojam (Lsd at 5%=3.683)					Mirpursakro (Lsd at 5%=1.352)				
	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction HS over Opt.	Percent Reduction HHS over Opt.	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction HS over Opt.	Percent Reduction HHS over Opt.	1st sowing (Opt.)	2nd sowing (HS)	3rd sowing (HHS)	Percent Reduction HS over Opt.	Percent Reduction HHS over Opt.
DH-1	44.42 GH	43.72 H	33.25 T	1.58	25.15	40.14 NOPQRS	39.38 NOPQRST	37.03 QRSTUVW	1.89	7.74	35.61 OPQ	31.41 VW	23.16 [\	11.79	34.96
DH-3	36.53 QR	35.83 R	31.55 UV	1.90	13.63	42.81KLMN	41.90 LMNO	38.16 OPQRSTU	2.11	10.86	38.48LM	34.54 QRS	26.07 Z	10.25	32.25
DH-4	41.11 JKLM	40.48 LM	32.80 T	1.55	20.23	47.42 DEFGHIJ	46.65 GHIJK	39.52 NOPQRST	1.61	16.65	42.39 I	38.31 LM	29.94 X	9.63	29.37
DH-5	44.40 GH	41.82 IJK	30.32 W	5.80	31.72	54.31AB	47.96 DEFGH	32.31 XYZ	11.69	40.52	53.65 A	49.78 C	40.50 JK	7.22	24.52
DH-6	42.23 I	39.25 N	34.16 S	7.06	19.10	43.13 IJKLMN	41.48 LMNOPQ	37.37 PQRSTUV	3.84	13.35	38.53 LM	34.67 QR	26.15 Z	10.01	32.12
DH-7	44.07 H	38.38 NO	31.56 V	12.90	28.38	47.14 EFGHIJK	41.13 LMNOPQR	35.19 TUVWX	12.75	25.36	42.62 HI	38.69 LM	30.42 WX	9.22	28.62
DH-8	42.13 IJ	40. 21 M	37.88 O	4.55	10.08	49.15 CDEFG	43.83 HIJKLMN	34.35 UVWX	10.84	30.11	44.52 G	40.65 JK	32.03 UV	8.69	28.04
DH-10	46.59 E	40.63 LM	23.12 [	12.80	50.38	48.30 CDEFG	39.50 NOPQRST	32.28 XYZ	18.22	33.16	43.98 GH	39.85 JKL	31.52 VW	9.40	28.34
DH-11	41.14 JKLM	34. 25 S	34.55 S	16.76	16.04	45.25 GHIJKLM	43.28 IJKLMN	37.46 OPQRSTUV	4.34	17.22	40.83 J	36.45 STU	28.42 Y	10.72	30.39
DH-12	42.32 I	35.85 R	31.69 UV	15.29	25.12	42.81 KLMN	35.84 STUVWX	24.06 \	16.28	43.80	38.60 LM	34.58 QRS	25.98 Z	10.41	32.68
DH-13	45.34 FG	36.87 PQ	28.09 X	18.67	38.04	41.30 LMNOPQR	40.75 NOPQR	29.75 YZ	1.34	27.97	36.79 NO	32.84 TUV	23.94 [	10.74	34.94
DH-14	55.36 A	46.06 EF	38.25 O	16.81	30.91	54.58 AB	52.44 ABC	36.87 RSTUVW	3.91	32.45	50.26 BC	46.01EF	37.77 MN	8.46	24.87
DH-15	48.33 D	41.52 IJKL	35.92 QR	14.09	25.66	55.95 A	51.53 BCDE	40.19 NOPQRS	7.90	28.17	51.35 B	47.50 D	38.85 LM	7.50	24.34
DH-16	51.00 C	44.06 H	24.87 Z	13.60	51.24	57.52 DEFGHI	47.37 DEFGHIJ	30.02 YZ	17.65	47.82	53.17 A	48.95 C	29.06 XY	7.93	45.36
DH-18	51.44 C	42.29 I	32.55 TU	17.80	36.73	45.46 GHIJKL	40.75 NOPQR	32.84 WXYZ	10.35	27.76	36.30 OP	32.20 UV	23.53 [	11.29	35.18
DH-19	45.19 FG	41.50 IJKL	37.63 OP	8.16	16.72	43.55 IJKLMN	41.58 LMNOP	35.80 STUVWX	4.51	17.79	39.19 KLM	35.23 PQR	26.74 Z	10.11	31.77
DH-20	47.60 D	42.28 I	28.17 X	11.19	40.83	49.15 CDEFG	40.18 NOPQRS	28.89 Z[	18.26	41.22	44.72 FG	40.71 J	24.50 [	8.96	45.21
DH-21	52.46 B	46.02 EF	32.43 TU	12.28	38.18	51.77 BCD	48.70 CDEFG	43.06 JKLMN	5.93	16.83	47.38 DE	43.48 GHI	33.93 RST	8.23	28.39
Lu26s	40.80 KLM	34.37 S	26.40 Y	15.77	35.29	51.15 BCDEF	49.42 CDEFG	33.33 VWXY	3.38	34.85	46.64 DE	42.62 HI	34.19 QRST	8.62	26.70
Kiran-95	40.8S KLM	33.06 T	23.56 [	19.07	42.32	46.75 FGHIJK	40.84 MNOPQR	25.55 [\	12.65	45.35	42.30 I	38.26LM	22.09 \	9.54	47.77
Mean (Lsd at 5%= 0.516)	45.17 B	39.92 D	31.44 G			47.38 A	43.73 C	34.20 F			43.37 C	39.17 E	29.44 H		

*Means sharing similar letters in column and rows did not differ significantly.

In Sakrand the genotype DH-13 possessed maximum reduction i.e. 41.92 percent under heat stress condition over optimum condition whereas the maximum reduction i.e. 69.35 percent was recorded in DH-16 under high heat stress condition over optimum condition. In Mirpursakro, the genotype DH-1 showed maximum reduction i.e. 48.42 and 75.55 percent under heat stress and high heat stress conditions over optimum condition, respectively, whereas, it was minimum i.e. 12.79 and 24.64 percent in LU-26s and DH-19 under heat stress and high heat stress condition, respectively and found comparatively tolerant.

On an average of genotypes in various locations, the maximum grain weight was recorded to be 12.92 under optimum condition in Tandojam and differed significantly from those of found in all other locations. The minimum grain weight was recorded to be 5.63 gram per plant in Sakrand under high heat stress condition. In general heat stress condition adversely affected the grain weight over optimum condition in all the districts. The present research are in close conformity with Khajam *et al.* (2011), Akbar and Jaime (2012) and Lack *et al.* (2013) who reported that heat stress conditions exerted adverse effects on the biological growth and grain yield in wheat. Similarly, according to Laghari *et al.* (2012) that grain yield and its associated traits in wheat were decreased significantly when the crop was sown late on December 27 (heat stress condition). These results are link with those of (Shahzad, 2002) variation in number of grains plant^{-1} among genotypes might be ascribed to their genetic variability.

Table 6. Wheat genotypes categorized on the bases of < 40% reduction on high heat stress (3rd sowing).

		Sakrand					Tandojam					Mirpursakro				
S. No.	Genotypes	PTP	No. SS	GWP	1000 GW	No. of variables	PTP	No. SS	GWP	1000 GW	No. of variables	PTP	No. SS	GWP	1000 GW	No. of variables
1	DH-1	+	+	-	+	3	+	+	-	+	3	+	+	-	+	3
2	DH-3	+	+	-	+	3	-	-	-	+	1	+	+	-	+	3
3	DH-4	+	+	+	+	4	+	-	-	+	2	+	+	+	+	4
4	DH-5	+	+	-	+	3	+	+	-	-	2	+	+	-	+	3
5	DH-6	-	+	+	+	3	+	+	-	+	3	+	+	-	+	3
6	DH-7	+	+	+	+	4	+	+	+	+	4	+	+	+	+	4
7	DH-8	+	-	+	+	3	+	+	+	+	4	+	+	+	+	4
8	DH-10	+	-	-	-	1	+	-	-	+	2	+	-	-	+	2
9	DH-11	+	+	+	+	4	+	+	+	+	4	+	+	+	+	4
10	DH-12	+	-	-	+	2	+	-	-	-	1	-	-	-	+	1
11	DH-13	+	+	-	+	3	+	+	-	+	3	+	-	-	+	2
12	DH-14	+	+	-	+	3	+	+	-	+	3	+	+	-	+	3
13	DH-15	+	-	-	+	2	+	+	-	+	3	+	+	-	+	3
14	DH-16	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
15	DH-18	+	+	-	+	3	+	+	-	+	3	+	+	-	+	3
16	DH-19	+	+	+	+	4	+	+	+	+	4	+	-	+	+	3
17	DH-20	+	+	-	-	2	-	+	-	-	1	-	+	-	-	1
18	DH-21	+	+	-	+	3	+	+	-	+	3	+	+	-	+	3
19	Lu26s	+	+	+	+	4	+	+	+	+	4	+	+	+	+	4
20	Kiran-95	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

*PTP= Productive tillers plant-1, No.SS= No. of spikelets spike^{-1}, GWP= Growth weight plant^{-1}, 100 GW= 1000 Grains weight.

1000-grain weight (g)

The data regarding 1000-grain weight in various genotypes of wheat under different sowings (temperature) condition at Sakrand, Tandojam and Mirpursakro revealed significant difference in their interaction (Table 5). In Sakrand the genotype DH-14 showed maximum 1000-grain weight i.e. 57.36, 46.06 and 38.25 gram under optimum, heat stress and high heat stress condition, respectively. The genotype DH-3 possessed minimum 1000-grain weight i.e. 36.53 gram and differed significantly from those of found in all other genotype under optimum temperature condition. The genotype Lu-26s had minimum 1000-grain weight i.e. 34.37 gram under heat stress condition whereas, under high heat stress condition, DH-10 possessed minimum 1000-grain weight i.e. 23.12 gram and was at par statistically with those of recorded in Kiran-95 with 23.56 gram 1000-grain weight. In Tandojam and Mirpursakro, the genotype DH-14 and DH-5 showed maximum 1000-grain weight 55.95 and 53.65 gram, respectively and also was found to be minimum in genotype DH-1, DH-21 i.e. 40.14 and 35.61 grams under optimum temperature condition. In Tandojam and Mirpursakro, under heat stress condition the maximum 1000-grain weight was recorded to be 52.44 and 49.78 gram in DH-14 and DH-5 and differed significantly from those of recorded in all other genotypes. Furthermore, under high heat stress condition, the maximum 1000-grain weight i.e. 43.06 and 40.50 gram was recorded in genotype DH-21 and DH-5 and differ significantly from those of found in all other genotype in Tandojam and Mirpursakro. The minimum 1000-grain i.e. 24.06 and 22.09 gram was observed in genotype DH-12 and Kiran-95 under high heat stress condition in Tandojam and Mirpursakro, respectively. Regarding percent reduction in 1000-grain weight in genotype revealed that Kiran-95, DH-20 and DH-5 showed maximum reduction i.e. 19.07, and 18.26 % under heat stress condition over optimum condition in Sakrand and Tandojam whereas minimum reduction of 1.55, 1.33 and 22.09 % in DH-4 and DH-13 (Table 3). Similarly under high heat stress condition over optimum condition the maximum reduction was recorded to be 57.24, 47.82 and 40.50 % in DH-16, DH-16 and DH-5 whereas it was minimum i.e. 10.08, 7.74 and 22.09 in DH-8, DH-1 and Kiran-95 in Sakrand, Tandojam and Mirpursakro, respectively.

Based on average the last row of (Table 4). Optimum condition in Tandojam showed maximum 1000-grain weight (47.38 g) and differed significantly from those of observed in all other locations.

Table 7. Categorization of wheat genotypes on the basis of tolerance level at three different field locations.

Categories	Bases on	Sakrand (Genotypes)	Tandojam (Genotypes)	Mirpursakro (Genotypes)	Wheat genotypes common in two locations	Wheat genotypes common in three locations
Tolerant	< 40 % reduction in 04 variables	DH-4, DH-7, DH-11, DH-19, LU-26s	DH-7, DH-8, DH-11, DH-19, LU-26s	DH-4, DH-7, DH-8, DH-11, LU-26s	DH-4, DH-7, DH-8, DH-11, DH19, LU-26s	DH-7, DH-11, LU-26s
Medium Tolerant	< 40 % reduction in 03 variables	DH-1, DH-3, DH-5, DH-6, DH-8, DH-13, DH-14, DH-18, DH-21	DH-1, DH-6, DH-13, DH-14, DH-15, DH-18, DH-21	DH-1, DH-3, DH-5, DH-6, DH-14, DH-15, DH-18, DH-19, DH-21	DH-1, DH-3, DH-5, DH-6, DH-13, DH-14, DH18, DH-21	DH-1, DH-6, DH-14, DH-18, DH-21
Medium Sensitive	< 40 % reduction in 02 variables	DH-12, DH15, DH-20	DH-4, DH-5, DH-10	DH-10, DH-13	DH-10	
Sensitive	< 40 % reduction in <02 variables	DH-10, DH-16, Kiran-95	DH-12, DH-16, DH-20, Kiran-95	DH-12, DH-16, DH-20, Kiran-95	DH-12, DH-16, DH-20, Kiran-95	DH-16, Kiran-95

The minimum 1000-grain weight was recorded to be 31.44 gram in Sakrand at high heat stress condition. Furthermore (Table 5) heat stress conditions exerted adverse effects on 1000-grain weight over optimum conditions. These findings are highly supported by those of (Spink *et al.*, 2000) also reported that under late sowing period the decreased grain weight per plant and 1000-grain weight. These results are according to Refay (2011) that maximum yield in wheat can be obtained by early sowing (November 21) instead of late sowing (December 21). He further reported that wheat yield can be raised significantly by selection of heat tolerant cultivars. Contradictory results were reported by Singh *et al.* (2011) who stated that 1000-grain weight and biological yields were least affected by late sown crop and this variation might be selection of cultivars which they studied.

Summarized results pertaining to tolerance and sensitivity levels under high heat stress condition over optimum condition

The summarized results (Table 6 & 7) regarding categorization of various genotypes for their tolerance/sensitivity levels in three different locations revealed that three genotypes viz. DH-7, DH-11 and Lu-26s were found tolerant and these genotypes showed < 40 percent reduction in 4 variables. The genotypes DH-16 and Kiran-95 were categorized as sensitive showing < 40 percent reduction in < 2 variables. The genotype DH-1, DH-6 DH-14, DH-18 and DH-21 were medium tolerant which showed < 40 percent reduction in 3 variables. The effect of different sowings (temperature stress) conditions on various plant growth parameters in wheat genotypes under significant variations were found to exist among genotypes and various sowing dates based on their interactions. Temperature stress condition had adverse effect on all the parameters i.e. productive tillers plant^{-1}, spikelets spike^{-1}, grain weight plant^{-1} and 1000-grain weight in all the locations. Tahir *et al.* (2008), Burio *et al.* (2011) and Iqbal *et al.* (2017) suggested that productive tillers, length of spike, grains spike^{-1}, grain weight plant^{-1} and 1000-grain weight were related to yield through their direct effected through late sowing.

Conclusion

The result of the field experiment showed that wheat genotypes DH-1, DH-6, DH-7, DH-11, DH-14, DH-18, DH-21 and Lu26s had better tolerance to temperature showing < 40 % reduction in different growth parameters.

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