

## Effect of Heat Stress for Agro-Economic Traits in Bread Wheat (*Triticum Aestivum* L.) Genotypes

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**Abstract:** In the scenario of increasing global warming, heat stress received more importance. Unfortunately, Pakistan is also in the line of most heat affected countries of the world. In this regard, wheat being a most important staple edible crop of Pakistan is highly affected by heat stress. For combating this situation, a study was carried-out on ten bread wheat genotypes *viz.* Moomal, Mehran, Imdad-05, Anmol-91, Benazir, TJ-83, SKD-1, TD-1, Abadgar and Hamal at the Experimental Field, Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam. The experiment was laid-out in a randomized complete block design (factorial arrangement) with three replications during Rabi season, 2016-17 in order to assess the response of wheat genotypes to terminal heat stress tolerance. Wheat genotypes were evaluated in two sowing dates *viz.*, on 24<sup>th</sup> November as a normal planting and late planting on 31<sup>th</sup> December, 2016 considered as heat stress condition. The analysis of variance revealed significant differences among the genotypes under both sowing dates indicating suitability of the experiment to improve bread wheat genotypes for heat tolerance. Reductions in various traits were observed in late planting which indicated visible effects of heat stress on agro-economic traits. On an average plant height (cm), tillers/plant, spike length (cm), spikelets/spike, grains/spike, 1000-grain weight (g) and grain yield/plant (g) were declined by -4.63, -2.49, -3.04, -4.35, -16.29, -14.08 and -9.09 units respectively under the heat stress conditions, while the wheat genotypes like TJ-83, SKD-1 and Mehran showed minimum reductions under heat stress conditions for various traits suggesting their heat tolerance, nonetheless cultivars Moomal and Benazir expressed maximum declines under heat stress expressing their susceptibility to heat stress conditions. The remaining genotypes were found as moderately heat stress tolerant.

**Keywords:** heat stress, yield and its related traits, wheat genotypes

### Introduction

Wheat is one of the most vital species of the Poaceae family grown throughout the world for the persistence of human feeding like bread making and bakery products (Debasis and Khurana, 2001). According to the recent studies, it is reported that 95% of wheat grown in the world is hexaploid type ( $2n = 6x = 42$ ). On the basis of production, wheat is placed at second position next to the rice among cereals crops. Wheat is grown in the world on large scale with different environmental conditions. According to the average global grain yield of major cereal crops which was 2520 million tons in 2013-14, to which wheat contributed approximately 715.5 million tons (Singh *et al.* 2016). It is the cheap source of calories, proteins and carbohydrates in human nutrition. Wheat contributed the major cultivate area in Pakistan, from which 70% is occupied in Rabi (Farooq

*et al.*, 2007). In recent past, it was estimated that the average global temperature will rise about 2 °C over the next 50 years, and this increase in temperature will make many cereal growing regions less suitable (Wrigley, 2006). Climate change is no longer a major concern, particularly when it comes to agriculture. Both systems are interconnected and occur on a worldwide scale. The temperature greater than optimal shows adverse effects on plants, is considered as heat stress (Kumar *et al.*, 2015). In cropping system, high temperature is considered as a major problem worldwide with some unexpected spatial and temporal variations, which are responsible for causing reduced plant growth, development and productivity (Parent *et al.*, 2010). It has been assessed that rise of just 1 °C in temperature during the growing season reduces wheat yields by about 3 to 10% (Ehsan *et al.*, 2018; Elbasyoni, 2018; You *et al.*, 2009). Wheat is considered as a major staple food crop of Pakistan, where the estimated per capita

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use is about 124 Kg which is highest in the world. In Pakistan, to fulfill the local demand of food, the wheat production should increase by least 4% to keep up pace with increasing population growth (Khan *et al.*, 2015). Wheat varieties which are commonly grown in Pakistan are very sensitive to heat stress at a stage of grain filling. During this period, heat stress reduces the growth cycle and forces premature ripening of crop, thus shortens the number of grains/spike, declines seed index and ultimately results in deterioration of grain yield and quality of wheat crop (Din *et al.*, 2010).

Wheat is grown in winter season so it is called winter cereal crop and needs nearly low temperature ranging from 12 to 22 °C considered as optimum temperature for its reproductive phase and development (Farooq *et al.*, 2011). Whereas high temperatures can cause significant morpho-physiological damages which accelerates leaf senescence (Wang *et al.*, 2011), reduces photosynthesis (Ristic *et al.*, 2007), decreases starch biosynthesis (Zhao *et al.*, 2008). Chlorophyll content, canopy temperature depression, biomass, thousand grain weight and grain yield are all effected (Singh *et al.*, 2016). Bala *et al.* (2014) observed that heat stress significantly reduced grain yield, number of grains per spike, plant height, grain-filling time, peduncle length, peduncle weight and 1000-grain weight. Similarly, according to Rane *et al.* (2007), the lethal stage of heat stress is responsible for shortening of grain filling period, consequently improper grain filling affects over-all yield of wheat crop. The yield of grain per plant, biological yield per plant and the yield of grain per spike suffered under late sown conditions (Singh *et al.*, 2011). Due to delay in sowing, the total biomass at maturity and yield/m<sup>2</sup> decreases significantly. It is observed that higher temperatures are linked with limitation of water and due to these limitations rapid shrinkage of grain volume can occur (Mitra and Bhatia, 2008). Wheat grain yield is highly affected by biotic and abiotic or environmental stresses (Khavarinejad and Karimov, 2012; Sial *et al.*, 2012; Shamsi *et al.*, 2010). Major biotic stresses include rust (leaf, yellow and stem) and other diseases whereas, environmental constraints which limits crop productivity includes water stress, high temperature and salinity stress (Johari *et al.*, 2011). It is reported that about 20% of arable land has been affected by drought and soil salinization therefore crop yields have been reduced by 20-30% throughout the world. The main adverse impacts of climate change on agriculture most probably include

temperature variability, different rain fall patterns and increasing rate of evaporation (Elbasyoni, 2018). The environmental changes at global level not only put forward challenges to agriculture sector, but also provide opportunities to boost up crop yields in water stressed environment (Sial *et al.*, 2009; Reynolds *et al.*, 2001). The development of improved germplasm, adapted to the water stress environment, will result in improvement of resources and contribute to sustainable food security. Thus present study is designed to evaluate the popular varieties for their heat tolerance in field condition.

## Materials and Methods

An experiment was conducted at Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam. A randomized complete block design with factorial arrangement, where sowing dates were main factor and genotypes were considered as sub-factor. The trial was laid-out in three replications during Rabi season, 2016-17 in order to evaluate the effect of heat stress on agro-economic traits in bread wheat. Two sowing dates were *viz.*, recommended planting (24<sup>th</sup> November, 2016) and late planting (31<sup>th</sup> December, 2016), under normal and heat stress conditions respectively were used Table 1. Ten genotypes like Moomal, Mehran, Imadad-05 Anmol-91, Benazir, TJ-83, SKD-1, TD-1, Abadgar and Hamal were evaluated for plant height (cm), tillers/plant, spike length (cm), spikelets/spike, grains/spike, 1000-grain weight (g) and grain yield/plant (g). The data was obtained on five randomly tagged index plants from each genotype per replication for the selected traits. The data was statistically analyzed (Statisti 8.1) by using analysis of variance according to Gomez and Gomez (1984). All the inputs like irrigation and fertilizer were given as recommended for the wheat crop.

**Table 1.** Meteorological data during the experiment 2016-2017

Month	Temperature ( °C )	
	Minimum	Maximum
November-2016	14.00	30.00
December-2016	10.20	24.20
January-2017	7.50	24.00
February-2017	10.00	25.50
March-2017	15.50	32.00
April-2017	22.40	40.90
May-2017	24.50	42.50

The significance of mean squares from analysis of variance (Table 2) revealed that heat stress caused significant impact on plant height, tillers/plant, spike length, spikelets/spike, grains/spike, 1000-grain weight, grain yield/plant. Also significant differences existed among the genotypes for all the agro-economic traits studied that could allow wheat breeders to select the heat tolerant varieties on the basis of morpho-yield characters. The mean squares from analysis of variance for genotype x, the treatment interaction were also significant for all the studied traits. The significance of genotypes x treatment interactions showed that genotypes performed variably over the stress conditions. These interactions could also help wheat breeders to select the best performing varieties based on one or more reliable heat tolerant indicators.

**Plant height (cm).** The plant height ranged from a minimum of 65.00cm (TD-1) to a maximum of 84.60 (Mehran-89cm) under non-stress condition, while in heat stress condition, plant height ranged from minimum of 60.53cm (TD-1) to a maximum of 84.40 cm (Abadgar) (Table 3). The minimum reduction due to heat stress was recorded in TJ-83 (-3.27 cm) followed by Hamal (-4.33 cm) and TD-1(-4.47 cm), whereas maximum reduction was measured in Moomal (-8.80), although Abagar (9.20 cm) showed no any reduction in plant height under heat stress condition. The minimum plant height was noticed in TD-1 (65.00 cm) followed by SKD-1 (72.20 cm) and Benazir (72.27cm), whereas maximum plant height was recorded in Mehran (84.60 cm) under non-stress conditions. The minimum plant height was recorded in TD-1 (60.53 cm) followed by SKD-1 (65.00 cm) and Benazir (66.00 cm) whereas the maximum plant height was recorded in Abadgar (84.40 cm) under heat stress condition.

**Tillers/plant.** Maximum range of tillers/plant of 11.00 were observed in genotype TD-1 and minimum was recorded in Benazir and SKD-1 (8.73) under non-stress condition, while the maximum tillers/plant ranged from 8.33 (TD-1) to a minimum in Benazir and Hamal each (6.07) in heat stress conditions (Table 3). The minimum relative decrease was noted in SKD-1 (-1.33) closely followed by Anmol-91 (-1.87) and TJ-83 (-1.93) and maximum decrease was noted in Hamal (-3.47) under heat stress conditions. The maximum tillers/plant were counted in TD-1 (11.00) closely followed by Mehran (9.73) and Hamal (9.53) and minimum in Benazir and SKD-1 (8.73) under non-stress conditions. Whereas in heat stress condition maximum tillers/plant were noted in TD-1 (8.33) closely followed by SKD-1 (7.40) and Anmol-91 (7.20) and minimum were found in Benazir and Hamal (6.07).

**Spike length (cm).** In non-stress, the range of spike length (cm) was measured maximum in TD-1 (13.67cm) and minimum in Anmol-91 (10.00 cm), while in heat stress condition, maximum spike length (cm) was recorded in TJ-83 (12.93 cm) and minimum in Anmol-91 (7.33 cm) (Table 4). The minimum relative decrease in spike length (cm) was observed in TJ-83 (-0.53 cm) followed by Benazir (-2.47), Anmol-91, SKD-1 and Hamal (2.67 cm each) and maximum reduction was recorded in Imdad-05 (-5.07 cm) under heat stress condition. The maximum spike length (13.67 cm) was recorded in TD-1 and closely followed by TJ-83 and Benazir (13.47 and 13.33 cm) respectively, whereas the minimum spike length (10.00 cm) was noted in Anmol-91 under non-stress condition. The maximum spike length was recorded in TJ-83 (12.93 cm) followed by Benazir and TD-1 (10.87 and 10.27 cm) respectively

**Table 2.** Mean squares from analysis of variances of wheat genotypes for various traits grown under non stress and heat stress conditions

Characters	Mean squares				
	Replication (D.F. = 2)	Genotypes (D.F. = 9)	Treatments (D.F. = 1)	G x T (D.F. = 9)	Error (D.F. = 38)
Plant height	9.99	185.94**	322.01**	40.27**	6.22
Tillers/plant	0.86	2.34**	93.25**	0.62**	0.36
Spike length	1.09	9.11**	138.62**	2.20**	0.39
Spikelets/spike	5.32	22.74**	283.40**	5.92**	1.29
Grains/spike	2.22	255.96**	3978.83**	25.49**	3.47
1000-grain weight	0.82	85.05**	2973.70**	27.59**	0.77
Grain/yield plant	1.97	10.30**	1239.15**	7.04**	1.10

\*\* = Significant at 1 % probability level

and minimum spike length was recorded in Anmol-91 (7.33 cm) under heat stress condition

**Spikelets/spike.** In non-stress, the maximum range of spikelets/spike was counted in Benazir (23.67) and the minimum in Hamal (16.33). In heat stress, maximum spikelets/spike were counted in TJ-83 and TD-1 (18.00 each) and the minimum were recorded in Abadgar (12.33). The minimum relative decrease in spikelets/spike was observed in SKD-1(-1.80) followed by Hamal and TJ-83 (-2.67 and -3.07) respectively where

maximum reduction was recorded in Abadgar (-8.13) under heat stress over non stress condition (Table 4). The maximum spikelets/spike were noted in Benazir (23.67) narrowly followed by TD-1 (23.00), whereas the minimum spikelets/spike were calculated in Hamal (16.33) under non stress condition. The maximum spikelets/spike were recorded in TJ-83 and TD-1 (18.00) followed by Moomal and SKD-1 (17.53 and 17.27 respectively) whereas the minimum spikelets/spike were recorded by Abadgar (12.33) under heat stress condition.

**Table 3.** Mean performance for plant height (cm) and tillers/plant of wheat genotypes grown under non stress and heat stress condition

Genotypes	Plant height (cm)		R.D.*	Tillers/plant		R.D.*
	Non-stress	Heat stress		Non-stress	Heat stress	
Moomal	78.80	70.00	-8.80	9.20	6.67	-2.53
Mehran	84.60	76.00	-8.60	9.73	6.40	-3.33
Imadad-05	77.40	70.67	-6.73	8.80	6.27	-2.53
Anmol-91	73.53	67.67	-5.87	9.07	7.20	-1.87
Benazir	72.27	66.00	-6.27	8.73	6.07	-2.67
TJ-83	74.87	71.60	-3.27	8.87	6.93	-1.93
SKD-1	72.20	65.00	-7.20	8.73	7.40	-1.33
TD-1	65.00	60.53	-4.47	11.00	8.33	-2.67
Abadgar	75.20	84.40	-9.20	9.00	6.40	-2.60
Hamal	80.80	76.47	-4.33	9.53	6.07	-3.47
Mean	75.47	70.83	-4.63	9.26	6.77	-2.49
LSD at 5% (G)	2.91			0.70		
LSD at 5% (T)	1.30			0.31		
LSD at 5% (G x T)	4.12			0.99		

R.D\* = Relative decrease under heat stress over the non-stress

**Table 4.** Mean performance for spike length and spikelets/spike of wheat genotypes grown under non stress and heat stress condition

Genotypes	Spike length (cm)		R.D.*	Spikelets/spike		R.D.*
	Non-stress	Heat stress		Non-stress	Heat stress	
Moomal	12.13	9.00	-3.13	21.33	17.53	-3.80
Mehran	12.07	8.67	-3.40	20.33	16.93	-3.40
Imadad-05	12.73	7.67	-5.07	20.67	15.47	-5.20
Anmol-91	10.00	7.33	-2.67	17.07	13.67	-3.40
Benazir	13.33	10.87	-2.47	23.67	16.67	-7.00
TJ-83	13.47	12.93	-0.53	21.07	18.00	-3.07
SKD-1	12.33	9.67	-2.67	19.07	17.27	-1.80
TD-1	13.67	10.27	-3.40	23.00	18.00	-5.00
Abadgar	13.07	8.67	-4.40	20.47	12.33	-8.13
Hamal	12.33	9.67	-2.67	16.33	13.67	-2.67
Mean	12.51	9.48	-3.04	20.30	15.95	-4.35
LSD at 5% (G)	0.73			1.32		
LSD at 5% (T)	0.32			0.59		
LSD at 5% (G x T)	1.03			1.87		

R.D\* = Relative decrease under heat stress over the non-stress

**Grains/spike.** In non stress (Table 5) the maximum range of grains/spike were counted in TD-1 (70.00) and minimum were counted in Anmol (49.20). While in heat stress the maximum grains/spike were counted in TJ-83 (53.33) and minimum were counted in Anmol-91 (31.73). The minimum relative decrease in grains/spike was shown by Mehran (-7.07) closely followed Imdad-05 and TJ-83 (-12.40 and -15.33) respectively. The maximum grains/spike were obtained by TD-1 (70.00) followed TJ-83 and Moomal (68.67 and 67.53) respectively whereas the minimum grains/spike were acquired by Anmol-91 (49.20) in non-stress condition, while in heat stress condition the maximum grains/spike were obtained by TJ-83 (53.33) followed by Moomal and Mehran (51.00 and 48.00) respectively and the minimum grains/spike were obtained from Anmol-91 (31.73) in heat stress condition.

**1000 grain weight (g).** In non-stress, the maximum range in 1000 grain weight (Table 5) was weighed in TD-1 (53.43 g) and minimum was counted in Anmol-91 (39.80 g). While in heat stress condition the maximum range of 1000 grain weight was observed in Mehran-89 (40.00 g) and the minimum was counted in Abadgar (26.03 g). The lowest relative decrease percentage however was recorded by Mehran (-6.17 g) followed by TJ-83 (-9.83 g) and Hamal (-10.33 g). The maximum relative decrease was showed by Benazir (-17.97) under heat stress condition. The highest 1000 grain weight (g) exhibited by genotype TD-1 (53.43 g) followed by Moomal and Benazir (50.57 and 48.47 g) respectively

and minimum by Anmol-91 (39.80 g) in non-stress condition, while in heat stress condition, the higher 1000 grain weight (g) was obtained from Mehran (40.00) closely followed by TJ-83, Moomal and TD-1 (38.33, 36.00 and 36.00 g) respectively and the minimum 1000 grain weight (g) was acquired by Abadgar (26.03) in heat stress condition.

**Grain yield/plant (g).** The higher grain yield/plant is the ultimate goal of all the plant breeders. The increment of all other characters provides a better background to increase the grain yield/plant. In our experiment maximum grain yield/plant was ranged from 21.03g (Moomal) to minimum 16.40 g (Abadgar) in non-stress condition (Table 6), while in heat stress condition, maximum range of 11.33 g was recorded from TD-1 and minimum of 6.10 g from SKD-1. The greatest performance was observed in TJ-83 with minimum reduction of -5.90 g followed by Hamal and Abadgar (-7.1 and -7.40 g) respectively under heat stress condition. The maximum relative decrease percentage was shown by Moomal (-11.70 g) in terminal heat stress condition. The maximum grain yield/plant was obtained by Moomal (21.03 g) followed by Benazir and TD-1 (20.53 and 20.23 g) respectively and the minimum by Abadgar (16.40 g) in non-stress condition, while in heat stress condition the maximum grain yield/plant was shown by TD-1 (11.33 g) closely followed by TJ-83 (11.00) and the minimum grain yield/plant was obtained from SKD-1 (6.10 g).

**Table 5.** Mean performance for grains/spike and 1000 grain weight of wheat genotypes grown under non stress and heat stress condition

Genotypes	Grains/spike		R.D.*	1000 grain weight (g)		R.D.*
	Non-stress	Heat stress		Non-stress	Heat stress	
Moomal	67.53	51.00	-16.53	50.57	36.00	-14.57
Mehran	55.07	48.00	-7.07	46.17	40.00	-6.17
Imdad-05	54.40	42.00	-12.40	47.50	30.37	-17.13
Anmol-91	49.20	31.73	-17.47	39.80	27.67	-12.13
Benazir	65.00	45.67	-19.33	48.47	30.50	-17.97
TJ-83	68.67	53.33	-15.33	48.17	38.33	-9.83
SKD-1	57.13	40.00	-17.13	44.70	28.83	-15.87
TD-1	70.00	47.67	-22.33	53.43	36.00	-17.43
Abadgar	54.93	37.67	-17.27	45.40	26.03	-19.37
Hamal	62.00	44.00	-18.00	42.67	32.33	-10.33
Mean	60.39	44.11	-16.29	49.69	32.61	-14.08
LSD at 5% (G)	2.17			1.02		
LSD at 5% (T)	0.97			0.45		
LSD at 5% (G x T)	3.07			1.45		

R.D.\* = Relative decrease under heat stress over the non-stress

**Table 6.** Mean performance for grain yield/plant of wheat genotypes grown under non stress and heat stress condition

Genotypes	Grain yield/plant		R . D . *
	Non-stress	Heat stress	
Moomal	21.03	9.33	-11.70
Mehran	16.43	9.00	-7.43
Imdad-05	19.33	8.22	-11.11
Anmol-91	16.60	8.20	-8.40
Benazir	20.53	9.26	-11.28
TJ-83	16.90	11.00	-5.90
SKD-1	17.73	6.10	-11.63
TD-1	20.23	11.33	-8.90
Abadgar	16.40	9.00	-7.40
Hamal	16.47	9.33	-7.13
Mean	18.17	9.08	-9.09
LSD at 5% (G)	1.22		
LSD at 5% (T)	0.54		
LSD at 5% (G x T)	1.73		

R.D\* = Relative decrease under heat stress over the non-stress

## Results and Discussion

Global warming is the burning issue of present day world. In the scenario of increasing population of human and decreasing trend of green land portion, it is observed that heat stress will be increasing in coming years. Due to increasing world population, the necessities of food will also be increased. On one side, the world population is continuously increasing and on the other side cultivable land is decreasing, so it will be a massive issue in future, for human food. That's why there is dire need of research on wheat crop to develop heat tolerant varieties or the varieties which mature earlier, thus escape the terminal heat stress. The effect of different sowing dates related to high temperatures on ten bread wheat genotypes were studied and the observations were recorded on various yield and yield contributing traits. The results described in previous chapter are discussed as under.

The mean squares from analysis of variance (Table 2) indicated that heat stress imposed significant impact on plant height, tillers/plant, spike length, spikelets/spike, grains/spike, 1000-grain weight and grain yield/plant. There also existed significant differences among the genotypes for all the yield and its associated traits studied that could allow wheat breeders to select the heat tolerant genotypes for one or more morph-yield attributes. Genotype  $\times$  treatment interactions was also significant for all the traits. The significance of genotype  $\times$  treatment interaction showed that genotypes performed differently over the stress condition. These interactions

also could help wheat breeders to select the best performing varieties based on one or more reliable heat tolerant indicators. Similarly Abd-El-Rahman *et al.* (2014) evaluated 12 bread wheat genotypes at two sowing dates (November 15 and December 15) in order to make the normal and heat stress conditions. The results showed notable changes in genotypes for the influence of sowing date on the studied characters, except for days to 50% heading, spikelets/spike, grains/spike and grains/plant. Furthermore, genotypes  $\times$  sowing date interaction (G  $\times$  S) expressed notable changes for plant height and 1000-kernel weight. For the other characters, G  $\times$  S expressed no significant changes under the normal temperature, whereas the yield ranged remained 1.55 to 2.80 ton/ha.

The minimum decline was observed in genotypes such as TJ-83, Hamal and TD-1 for plant height, tillers/plant, spike length and spikelets/spike, whereas the maximum reduction was recorded in genotypes Abadgar, SKD-1, Anmol-91 and TJ-83 under the heat stress in late sowing condition for above the traits. Terminal heat stress reduced the number of grains per spike to a significant extent in wheat. The lowest reduction was observed in Mehran followed by Imdad-05 and TJ-83 under the heat stress condition. Our results are in agreement with El-Nakhawy *et al.* (2015) who showed that sowing date of 16<sup>th</sup> December averagely increased the plant height, productive tillers/plant, spike length, spikelets/spike, grain weight/plant, 100-grain weight, grain yield/ha by 20, 17, 33, 75, 85, 7, 21 and 10% respectively, over rest of the sowing dates. While genotypes showed significant changes to these characters from level of increments, *viz.*, 29, 59, 164, 166, 179, 111, 203 and 46% by varieties F-10 and F-50 for all the evaluated characters respectively. The best combination was phenotypically observed in terms of heat tolerance under arid conditions shown by interaction of F-10 and F-50 in December plantation. Abd-El-Rahman *et al.* (2014) evaluated 12 bread wheat genotypes at two sowing dates (November 15<sup>th</sup> and December 15<sup>th</sup>) in order to observe heat effects on different morphological traits. They found notable changes in genotypes on the studied characters, except for spikelets/spike, grains/spike and grains/plant. They also found that under normal temperature, the yield ranged between 1.55 to 2.80 ton/ha. Whereas, at heat stress condition, the yield range stood between 1.20-2.42 ton/ha and observed that up to 16% yield losses occurred by heat stress. The findings of positive direct effect between spikelets number per

spike with yield determined in the study is in agreement with the studies of (El-Ameen, 2012; Mahmood *et al.*, 2006; Abd El-Majeed, 2005; Sial *et al.*, 2005; Gupta *et al.*, 2004) they also reported that heat stress caused a significant reduction in the number of grains per spike under high temperature conditions. These finding are also supported by Hamam *et al.* (2015), they found a decline of 18.13% in grains numbers per spike due to heat stress

Seed index is one of the most important yield contributing traits while terminal heat stress is the major environmental factor which reduces the size and boldness of grain. Menshawy (2007) reported higher reductions in kernel weight under the late planting which could be accounted by the reduction in grain filling period. In our case, the minimum reduction was recorded in Mehran followed by TJ-83 and Hamal, whereas the maximum reduction was found in Abadgar in heat stress conditions. This reduction may be attributable to high temperatures affecting the grain maturity which resulted in shrunk kernels. Increasing grain yield per plant and yield contributing traits is the ultimate goal of wheat breeders. According to Hays *et al.* (2007) stress occurring after anthesis often cause detrimental effects on wheat grain yield by hastening maturity, triggering pre-mature senescence, shortening grain filling duration and reducing net assimilates and 1000-grain weight. In current study, the best performance was shown by the genotype TJ-83 with minimum decrease followed by genotypes Hamal and Abadgar. In normal condition, the grain yield per plant maximum ranged was obtained from genotype Moomal and minimum in Abadgar, whereas under heat stress condition, maximum grain yield per plant was recorded by the genotype TD-1 and by SKD-1. Abdullah *et al.* (2007) reported that traits such as 1000-grain weight, test weight and flour yield declined progressively with delayed sowing. El-Ameen (2012) reported that delay in the sowing resulted in a substantial reduction in grain yield by 63.34%, while the genotypes under favorable conditions performed well for grain yield. Our results are in agreement with those of (Hossain *et al.*, 2015; Abd-El-Rahman *et al.*, 2014; Alam *et al.*, 2014; Mondal *et al.*, 2013) they also reported that heat stress reduced grain yield up to 40, 45 and 49.5%, respectively and sigh *et al.* (2016) Hamam *et al.* (2015), Hossain *et al.* (2015) reported that terminal heat stress reduced the seed index similar to our results. Furthermore Bala and Sikder (2018a and 2018b) they reported that at heat stress condition values of all the

parameters such as plant height and grain yields were reduced compared to normal condition. Elbasyoni (2018) who observed that cultivar “Sids12” was stable and outperformed other tested cultivars under combined sowing dates across environments. However, cultivar “Gemmeiza9” was more stable and outperformed other cultivars across environments under the recommended sowing date. Moreover, cultivar “Gemmeiza12” was the ideal cultivar for the late sown condition.

## Conclusion

The analysis of variance revealed significant differences among all the genotypes under normal and high temperatures indicating the suitability of experiment to improve bread wheat genotypes for heat tolerance. The varieties SKD-1, TJ-83 and Mehran showed minimum reductions for various traits under heat stress conditions, thus showing their tolerance to heat stress while TD-1 and TJ-83 expressed maximum declines under terminal heat stress conditions for all the studied traits, showing their susceptibility to heat stress. In non-stress as well as under heat stress conditions, the highest values were recorded by the genotypes TD-1, Moomal and Benazir.

**Conflict of Interest.** The authors declare no conflict of interest.

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