J. appl. Res Plant Sci. Vol. 3(2), 260-269, 2022 eISSN 2708-3004; pISSN: 2708-2997
www.joarps.org https://doi.org/10.38211/joarps.2022.3.2.32

Effect of Water Stress on Growth and Yield Performance of Wheat Genotypes

Tanveer Ali Soomro[1], Tanweer Fatah Abro[1*], Wajid Ali Jatoi[1], Mahboob Ali Sial[2], Abdul Wahid Baloch[1], Khalil Ahmed Laghari[2], Kiran Soomro[1], Marina Kanwal Soomro[1], Mohammad Mustafa Soomro[1], Ali Bakhsh Soomro[1] and Muhammad Daniyal Memon[1]

[1]Department of Plant Breeding and Genetics, Sindh Agriculture University, Tando Jam
[2]Plant Genetics Division, Nuclear Institute of Agriculture (NIA), Tando Jam
*Corresponding Author: fatahtanweer@yahoo.com.

Article Received 07-09-2022, Article Revised 23-09-2022, Article Accepted 26-09-2022

Abstract

Climate change is one of the major threats to wheat cultivation globally. Among abiotic stress, imposed by climate change, drought stress causes a drastic effect on yield and productivity of wheat. Based on this context, research was carried out on eight genotypes including WS-I (Water stress), WS-II, WS-III, WS-IV, WS-V, WS-VI, WS-VII and Khirman (check variety) to check the effect of water stress at the experimental field of Nuclear Institute of Agriculture, Tandojam. The experiment was laid-out in a split-plot design (SPD) with factorial arrangement having four treatments i.e., T_1 (normal six irrigations), T_2 (one irrigation), T_3 (two irrigations) and T_4 (three irrigations) and three replications during Rabi season, 2019-2020 in order to assess the response of wheat genotypes under different water regimes conditions for vegetative, yield and yield-related traits. The results of analysis of variance results showed that genotypes were significantly different for all traits except spike length (cm). Similarly, a significant difference was observed among the treatments for all the traits except harvest index (%). While genotype x treatments interaction showed a significance level for most of the yield associated traits except few characters such as days to 75% heading, grain filling period, plant height (cm), peduncle length (cm), spikelets spike^{-1} and grains spike^{-1} indicating that genotypes perform similarly over the treatment. Maximum mean performance for all the traits was recorded under T_3 treatment compared to the T_2 and T_1. Among the genotypes, WS-1V perform best for grains spike^{-1}, grain weight spike^{-1} (g), 1000-grain weight (g), grain yield plot^{-1} and harvest index (%) under all treatments. However, WS-III also performed consistently under T_2 and T_3 treatment. Thus, genotypes like WS-III and WS-IV could be preferred for growing in those areas where growers face the problem of water shortage. Also, WS-III and WS-IV can be used as donor genotypes for developing drought tolerant varieties.

Keywords: Water stress, Genotypes, Treatment, Abiotic stress, Irrigation

Introduction

Wheat is considered as important staple diet for almost one-third of the total world's population (PARC, 2015; USDA, 2015). The major cultivated species of wheat is hexaploid (2n= 6x =42) and belongs to the Poaceae family. Globally it is the most cultivated crop among cereals accounting for 17% of the crop average worldwide, providing food for about 40% of the world population and 20% calories and protein in human diet (Bhutto *et al.*, 2016). Wheat is the backbone of Pakistan's agriculture as it provides staple food to millions of people in the country (Ali *et al*., 2018). Wheat production severely affect by numerous environmental stresses that heavily reduce its yield and production. Among environmental stresses, drought is the leading factor minimizing the productivity of wheat crop across the world. The efficiency of variety is necessary is produce maximum yield under different biotic and abiotic stress conditions (Ahmad *et al.*, 2003). Different factors in plants contribute in response to water stress (Beltrano and Ronco, 2008). Wheat demand worldwide is increasing, so it is urgent to produce a stable genotype that tolerates water stress and produces a higher yield under water stress conditions. According to Wehner *et al.* (2015) the intensity of drought will frequently increase with global warming affecting crop production on at large scale **(**Wehner *et al*., 2015). Different selection criteria are used to obtain higher yielding varieties, but the most common criteria are mean yield, mean productivity, and relative yield performance under water stress condition (Ahmad *et al.*, 2003). Although, wheat breeders are taking serious effort to improve the wheat varieties for increasing its yield potential but due to drought stress its quite hard to achieve such breeding objective (Blum, 1979). Varieties having ability to sustain different biotic and abiotic stress is prime the objective of many breeding programmes. However, success has been limited due to the unavailability of drought-tolerant genotypes and improper screening techniques in response to well-defined environmental stresses. Considering water stress as an important issue to reduce wheat crop productivity, the current study was conducted to evaluate the wheat genotypes with high yield potential, yield components and quality traits under water stress conditions.

Materials and Methods

The present research was carried out at the Nuclear Institute of Agriculture, Tandojam during Rabi season 2019-2020. The experiment was laid-out in a split-plot design (SPD) with factorial arrangement having four treatments i.e., T_1 (normal six irrigations), T_2 (one irrigation), T_3 (two irrigations) and T_4 (three irrigations) with three replications. Seven drought tolerant advance lines *viz*., WS-I (Water Stress), WS-II, WS-III, WS-IV, WS-V, WS-VI, WS-VII developed by Nuclear Institute of Agriculture, Tandojam, along with one check variety Khirman (drought tolerant) were studied. The data were collected from ten randomly tagged index plants from each genotype per treatment per replication for all yield contributing traits.

The below-mentioned characters were measured in following manner.

Days to 75% heading: Days were counted from sowing to the time when crop reached at 75% heading.

Days to 75% maturity: Days were counted from sowing to the time when crop reached at 75% maturity.

Grain filling period: Days were counted from anthesis to the time when crop reached to full maturity.

Plant height (cm): The height measurement of each plant was calculated in centimeter by measuring from the surface of soil to the tip of the spike excluding awns at maturity time.

Peduncle length (cm): Peduncle length of each individual plant was calculated in centimeter (cm) from the last node of the main stem to the initial tip of the spike.

Spike length (cm): Length of every selected plant was calculated in centimeters; the resulted height was recorded as spike length in (cm).

Spikelets spike^{-1}: Spikelets of each selected plants were calculated in numbers.

Grains spike^{-1}: Each spike of selected plant was threshed individually and then grain numbers were counted.

Grain weight spike^{-1} (g): Individual plant was threshed separately by hand and grain weight was measure and yield spike-1 was measure in grams.

1000-grain weight (g): 1000 randomly selected grains were weighted in grams unit on electric balance in the laboratory.

Grain yield plot^{-1} (g): Later to harvesting, the crop was threshed and clean separately for each plot for each genotype per replication per treatment and the grain yield was weighted on electronic balance in grams (g).

Biological yield plot^{-1} (g): After harvesting, the total biomass of plant was tied in bundle and brought into laboratory for weight and biological yield plot^{-1} was recorded in grams.

Harvest index (%): Harvest index was taken by the ratio of grain yield and biological yield. Harvest index (%) was calculated according to the following formula.

$$\text{Harvest Index \%} = \frac{\text{Grain yield plot}-1\ (\text{g})}{\text{Biological yield plot}-1\ (\text{g})} \text{x}100$$

Statistical Analysis: Data were statistically analyzed using the analysis of variance according to Gomez and Gomez (1984) and comparison among the means was calculated by using Tukey LSD test.

Results

Analysis of variance: The results of mean squares from the analysis of variance are presented in Table 1. which indicates that genotypes were significant for days to 75% heading, days to 75% maturity, grain filling period, plant height (cm), peduncle length (cm), spikelets spike^{-1}, grains spike^{-1}, grain weight spike^{-1} (g), 1000-grain weight (g), grain yield plot^{-1} (g), biological yield plot^{-1} (g), harvest index (%) except spike length (cm). In the case of treatments, the significance level was observed for all the traits except harvest index (%). While genotype × treatments interaction showed significance level for most of the yield associated traits except few characters such as days to 75% heading, grain filing period, plant height (cm), peduncle length (cm), spikelets spike^{-1}, and grains spike^{-1} indicating that genotypes perform similarly over the treatments.

Table 1. Mean square of analysis of variance for various quantitative traits of wheat genotypes grown under non-stress and water stress conditions

Characters	Mean Square					
	Replications (D.F. = 2)	Genotypes (D.F. = 7)	Error (a) D.F. = 14	Treatment (D.F. = 3)	G x T (D.F. = 21)	Error (b) (D.F. = 56)
Days to 75% heading	0.0313	29.113**	0.211	62.347**	5.291^{ns}	0.5952
Days to 75% maturity	1.1563	16.446*	4.003	80.347**	7.5933*	1.8512
Grain filling period	0.84375	19.000*	3.065	3.638 ^{ns}	1.67063 ^{ns}	1.21280
Plant height (cm)	11.228	190.504 **	45.439	115.362**	9.737^{ns}	19.492
Peduncle length (cm)	4.0241	55.221 **	4.704	99.646**	4.7774^{ns}	5.9440
Spike length (cm)	7.2003	5.5531^{ns}	3.969	11.345*	0.4992*	0.6029
Spikelets spike^{-1}	2.94000	31.508**	1.793	1.391*	0.93427 ^{ns}	1.16551
Grains spike^{-1}	170.651	403.849**	108.849	417.881*	24.062 ^{ns}	37.786
Grain weight spike^{-1} (g)	0.31849	0.480*	0.2444	0.69995*	2.9387*	0.13476
1000-grain weight (g)	9.4648	11.943 **	0.717	20.3134**	2.3853*	0.7281
Grain yield plot^{-1} (g)	2321.4	52094.0**	116.0	17052.1**	2278.6*	1195.1
Biological yield plot^{-1} (g)	292917	2023274**	225694	189028**	273948**	76548
Harvest index (%)	21.265	146.070**	29.934	8.160 ^{ns}	39.708**	10.225

**,* = Significant at 1 and 5% probability levels, respectively; ns = non-significant

Mean performance of yield and its contributing traits

Days to 75% heading: The data regarding days to 75% heading of wheat genotypes under various water levels was presented in Table 2. The average decline (-3.8, -2.7 and -1.8) was observed in treatment T_1, T_2, and T_3 for days to 75% heading compared to normal irrigations. However, among the genotypes, the minimum days to 75% heading was taken by WS-IV (69.0 days) in T_1 and the maximum days to 75% heading was taken by WS-II (75.7 days) in T_3. In case of genotypes performance, the minimum relative decrease was found in WS-IV (-0.3) in T_3, and the maximum relative decrease was found in WS-VI (-6.5) in T

Table 2. Water effect on days to 75% heading of wheat advance lines grown under non-stress and water stress at initiation of anthesis

Genotypes	Days to 75% heading				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	75.7	71.0	70.3	75.0	-4.7	-5.4	-0.7
WS-II	76.3	73.0	75.3	75.7	-3.3	-1.0	-0.6
WS-III	71.7	70.7	70.7	71.0	-1.0	-1.0	-0.7
WS-IV	71.3	69.0	70.7	71.0	-2.3	-0.6	-0.3
WS-V	75.7	72.3	75.0	72.3	-3.4	-0.7	-3.4
WS-VI	75.7	69.2	70.0	72.7	-6.5	-5.7	-3.0
WS-VII	76.0	71.3	73.0	71.7	-4.7	-3.0	-4.3
Khirman	76.3	72.0	72.3	75.3	-4.3	-4.0	-1.0
Mean	74.8	71.1	72.2	73.1	-3.8	-2.7	-1.8
LSD at 5% (G)		0.6310					
LSD at 5% (T)		0.3251					
LSD at 5% (G x T)		1.2230					

R.D* = Relative decrease due to stress

Days to 75% maturity: The data regarding days to 75% maturity of wheat genotypes under various water levels is presented in Table 3. The average decline (-4.4, -2.7 and -2.0) was observed in treatment T_1, T_2, and T_3 for days to 75% maturity compared to normal irrigations. However, among the genotypes, the minimum days to 75% maturity was observed in WS-VI (129.7) in T_1, and the maximum days to 75% maturity was recorded in WS-I (137.0) in T_3. Comparing the individual genotypes performance, the minimum relative decrease was found in WS-V (-0.2) in T_2, and the maximum relative decrease was found in the WS-VI (-7.6) in T_1.

Table 3. Water effect on days to 75% maturity of wheat advance lines grown under non-stress and water stress at initiation of anthesis

Genotypes	Days to 75% maturity				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	137.3	131.7	132.3	137.0	-5.6	-5.0	-0.3
WS-II	138.0	132.0	136.3	136.7	-6.0	-1.7	-1.3
WS-III	134.0	132.7	132.7	132.0	-1.3	-1.3	-2.0
WS-IV	133.3	131.3	132.0	133.0	-2.0	-1.3	-0.3
WS-V	134.3	132.3	134.1	133.0	-2.0	-0.2	-1.3
WS-VI	137.3	129.7	132.7	133.7	-7.6	-4.6	-3.6
WS-VII	137.7	131.7	135.0	132.3	-6.0	-2.7	-5.4
Khirman	138.3	133.3	133.3	136.3	-5.0	-5.0	-2.0
Mean	136.3	131.8	133.6	134.3	-4.4	-2.7	-2.0
LSD at 5% (G)		1.1127					
LSD at 5% (T)		1.4133					
LSD at 5% (G x T)		2.5062					

Grain filling period: The data on the grain filling period of wheat genotypes under various water levels is presented in Table 4. The average decline (-1.1, -0.6 and -0.9) was noticed in T_1, T_2, and T_3 for grain filling period as compared to normal irrigations. However, among the genotypes the minimum grain filling period was recoded in WS-V (58.0) in T_1, and the maximum grain filling period was counted in WS-VI (62.7) in T_2. While observing genotypes performance, the minimum relative decrease was found in WS-IV (-0.1) in T_1, and the maximum relative decrease was found in WS-II (-2.7) in T_1.

Table 4. Water effect on grain filling period of wheat genotype grown under non stress and water stress at initiation of anthesis

Genotypes	Grain filling period				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	61.7	60.7	61.0	61.2	-1.0	-0.7	-0.5
WS-II	61.7	59.0	61.0	61.0	-2.7	-0.7	-0.7
WS-III	62.3	62.0	62.0	61.0	-0.3	-0.3	-1.3
WS-IV	62.0	61.9	61.3	61.7	-0.1	-0.7	-0.3
WS-V	58.7	58.0	58.1	58.5	-0.7	-0.6	-0.2
WS-VI	62.9	60.7	62.7	61.0	-2.2	-0.2	-1.9
WS-VII	61.7	60.3	61.4	60.7	-1.4	-0.3	-1.0
Khirman	62.0	61.3	61.0	61.0	-0.7	-1.0	-1.0
Mean	61.6	60.5	61.1	60.8	-1.1	-0.6	-0.9
LSD at 5% (G)		0.9006					
LSD at 5% (T)		1.2368					
LSD at 5% (G x T)		2.0813					

Plant height (cm): The observation recorded for plant height (cm) of wheat genotypes under various water levels is present in Table 5. The average decline (-1.7, -5.0 and -3.1) was observed in T_1, T2, and T_3 for plant height (cm) compared to normal irrigations. However, among the genotypes, the maximum plant height (cm) was measured in WS-IV (98.1) in T_1 and minimum plant height (cm) was measured in WS-VII (81.4) in T_3. However, the minimum relative decrease was found in WS-III (-0.2) in T_3, and the maximum relative decrease was found in WS-VI (-6.4) in T_2.

Table 5. Water effect on plant height (cm) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Plant height (cm)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	93.7	90.0	88.0	90.1	-3.7	-5.7	-3.6
WS-II	98.9	97.0	94.2	97.0	-1.9	-4.7	-1.9
WS-III	95.1	93.7	94.2	94.9	-1.4	-0.9	-0.2
WS-IV	96.5	98.1	91.4	93.8	1.6	-5.1	-2.7
WS-V	100.0	93.8	92.1	93.8	-6.2	-7.9	-6.2
WS-VI	93.3	92.1	86s.9	90.2	-1.2	-6.4	-3.1
WS-VII	86.2	89.9	83.2	81.4	3.7	-3.0	-4.8
Khirman	99.6	95.4	93.6	97.4	-4.2	-6.0	-2.2
Mean	95.4	93.8	90.5	92.3	-1.7	-5.0	-3.1
LSD at 5% (G)		3.6107					
LSD at 5% (T)		4.7615					
LSD at 5% (G x T)		8.2305					

Peduncle length (cm): The data regarding to peduncle length (cm) of wheat genotypes under various water levels is present in Table 6. The average decline (-4.0, -4.5 and -2.6) was observed in T_1, T_2, and T_3 for peduncle length (cm) compared to normal irrigations. However, the maximum peduncle length (cm) was recorded by Khirman (48.6) in T_3, and the minimum peduncle length (cm) was recorded by WS-I (38.3) in T_2. The minimum relative decrease was found in WS-I (-0.3) in T_1, and the maximum relative decrease was found in WS-V (-7.4) in T_1.

Table 6. Water effect on peduncle length (cm) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Peduncle length (cm)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	40.3	40.0	38.3	38.6	-0.3	-2.0	-1.7
WS-II	46.4	42.8	41.9	45.4	-3.6	-4.5	-1.0
WS-III	46.2	42.7	42.0	42.4	-3.5	-4.2	-3.8
WS-IV	45.8	41.9	41.8	43.6	-3.9	-4.0	-2.2
WS-V	49.7	42.3	43.6	46.7	-7.4	-6.1	-3.0
WS-VI	47.2	43.1	41.5	42.0	-4.1	-5.7	-5.2
WS-VII	45.8	42.5	42.2	43.5	-3.3	-3.6	-2.3
Khirman	49.8	44.0	44.1	48.6	-5.8	-5.7	-1.2
Mean	46.4	42.4	41.9	43.9	-4.0	-4.5	-2.6

LSD at 5% (G)	1.9939
LSD at 5% (T)	1.5322
LSD at 5% (G x T)	4.0240

Spike length (cm): The data regarding to spike length (cm) of wheat genotypes under various water levels is present in Table 7. The average decline (-1.1, -0.8 and -1.8) was observed in T_1, T_2, and T_3 for spike length (cm) compared to normal irrigations. Among the genotypes, the maximum spike length (cm) was recorded in WS-II (12.7) in T_3, and the minimum spike length (cm) was recorded in WS-IV (9.9) in T_1. In the case of genotypes performance, the minimum relative decrease was found in WS-VII (-0.1) in T_2, and the maximum relative decrease was found in WS-I (-3.0) in T_3.

Table 7. Water effect on spike length (cm) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Spike length (cm)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	13.0	11.9	11.9	10.0	-1.1	-1.1	-3.0
WS-II	13.7	12.4	12.6	12.7	-1.3	-1.1	-1.0
WS-III	11.7	10.7	11.0	9.8	-1.0	-0.7	-1.9
WS-IV	11.4	9.9	11.1	10.2	-1.5	-0.3	-1.2
WS-V	12.5	11.0	11.1	10.2	-1.5	-1.4	-2.3
WS-VI	12.0	11.0	11.4	10.1	-1.0	-0.6	-1.9
WS-VII	12.0	11.0	11.9	10.2	-1.0	-0.1	-1.8
Khirman	11.7	11.0	10.9	10.5	-0.7	-0.8	-1.2
Mean	12.3	11.1	11.5	10.5	-1.1	-0.8	-1.8
LSD at 5% (G)		0.6350					
LSD at 5% (T)		1.4074					
LSD at 5% (G x T)		1.8326					

Spikelets spike^{-1}: The data of spikelets spike^{-1} of wheat genotypes under various water levels is given in Table 8. The average decline (-0.8, -0.6 and -1.0) was observed in T_1, T_2, and T_3 for spikelets spike^{-1} compared to normal irrigations. However, among the genotypes, the maximum spikelets spike^{-1} was recorded by WS-I (20.3) in T_2, and the minimum spikelets spike^{-1} was recorded by WS-IV (17.6) in T_1 followed by WS-VII (17.6) in T_3. In the case of genotypes performance, the minimum relative decrease was found in WS-IV (-0.1) in T_2, and the maximum relative decrease was found in WS-IV (-1.9) in T_1.

Table 8. Water effect on spikelets spike^{-1} of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Spikelets spike^{-1}				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	20.9	20.0	20.3	19.4	-0.9	-0.6	-1.5
WS-II	19.3	18.9	19.0	19.1	-0.4	-0.3	-0.2
WS-III	19.9	19.5	18.3	18.1	-0.4	-1.6	-1.8
WS-IV	19.5	17.6	19.4	18.2	-1.9	-0.1	-1.3
WS-V	19.5	19.1	18.9	20.0	-0.4	-0.6	0.5
WS-VI	20.1	19.1	19.7	19.6	-1.0	-0.4	-0.5
WS-VII	20.0	19.2	19.0	17.6	-0.8	-1.0	-2.4
Khirman	19.9	19.1	19.5	19.2	-0.8	-0.4	-0.7
Mean	19.9	19.1	19.3	18.9	-0.8	-0.6	-1.0
LSD at 5% (G)		0.8829					
LSD at 5% (T)		0.9459					
LSD at 5% (G x T)		1.8971					

Grains spike^{-1}: The data of grains spike^{-1} of wheat genotypes under various water levels is presented in Table 9. The average decline (-9.5, -6.0 and -8.1) was observed in T_1, T_2, and T_3 for grains spike^{-1} compared to normal irrigations. The maximum grains spike^{-1} was recorded in WS-I (71.1) in T_2, and the minimum grains spike^{-1} was recorded in WS-IV (58.5) in T_1. The minimum relative decrease was found in WS-I (-3.0) in T_2, and the maximum relative decrease was found in WS-V (-16.8) in T_1.

Table 9. Water effect on grains spike^{-1} of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Grains spike^{-1}				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	74.1	70.0	71.1	63.5	-4.1	-3.0	-10.6
WS-II	68.8	60.0	58.8	63.4	-8.8	-10.0	-5.4
WS-III	71.3	64.9	60.5	62.2	-6.4	-10.8	-9.1
WS-IV	68.2	58.5	63.4	62.5	-9.7	-4.8	-5.7
WS-V	78.0	61.2	70.2	67.9	-16.8	-7.8	-10.1
WS-VI	72.8	61.2	69.1	61.7	-11.6	-3.7	-11.1
WS-VII	69.2	61.8	66.1	60.0	-7.4	-3.1	-9.2
Khirman	74.5	63.7	69.6	70.8	-10.8	-4.9	-3.7
Mean	72.1	62.7	66.1	64.0	-9.5	-6.0	-8.1
LSD at 5% (G)		5.0272					
LSD at 5% (T)		7.3695					
LSD at 5% (G x T)		11.895					

Grain weight spike^{-1} (g): The data recording to grain weight spike^{-1} (g) of wheat genotypes under various water levels is presented in Table 10. The average decline (-0.4, -0.3 and -0.4) was observed in T_1, T_2, and T_3 for grain weight spike^{-1} (g) compared to normal irrigations. The maximum for grain weight spike^{-1} (g) was recorded WS-V (3.1) in T_2 followed by WS-II (3.1) in T_3 minimum for grain weight spike^{-1} (g) was recorded by WS-I (2.2) in T_3. Comparing the genotypes performance, the minimum relative decrease was found in WS-I (-0.1) in T_1, and the maximum relative decrease was found in WS-V (-1.1) in T_1.

Table 10. Water effect on grain weight spike^{-1} (g) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Grain weight spike^{-1} (g)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	2.7	2.6	2.4	2.2	-0.1	-0.3	-0.5
WS-II	3.3	2.9	3.0	3.1	-0.4	-0.3	-0.2
WS-III	3.0	2.8	2.5	2.8	-0.2	-0.5	-0.2
WS-IV	3.0	2.5	2.6	2.7	-0.5	-0.4	-0.3
WS-V	3.5	2.4	3.1	2.9	-1.1	-0.4	-0.6
WS-VI	3.0	2.6	2.8	2.5	-0.4	-0.2	-0.5
WS-VII	2.7	2.5	2.5	2.4	-0.2	-0.2	-0.3
Khirman	3.2	2.7	3.0	3.0	-0.5	-0.2	-0.2
Mean	3.1	2.6	2.7	2.7	-0.4	-0.3	-0.4
LSD at 5% (G)		0.3002					
LSD at 5% (T)		0.3493					
LSD at 5% (G x T)		0.6590					

1000-grain weight (g): The data recording to 1000-grain weight (g) of wheat genotypes under various water levels is presented in Table 11. The average decline (-1.9, -2.1 and -1.3) was observed in T_1, T_2, and T_3 for 1000-grain weight (g) compared to normal irrigations. However, among the genotypes, the maximum for 1000-grain weight (g) was recorded by WS-V (39.5) in T_3, and the minimum for 1000-grain weight (g) was recorded by WS-I (34.7) in T_2. In case of genotypes performance, the minimum relative decrease was found in WS-III (-0.1) in T_3, and the maximum relative decrease was found in WS-I (-4.0) in T_2.

Table 11. Water effect on 1000-grain weight (g) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	1000-grain weight (g)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	38.7	34.9	34.7	35.4	-3.8	-4.0	-3.3
WS-II	38.8	36.8	37.0	38.6	-2.0	-1.8	-0.2
WS-III	38.4	37.4	38.0	38.3	-1.0	-0.4	-0.1
WS-IV	39.7	38.4	37.4	38.0	-1.3	-2.3	-1.7
WS-V	39.8	39.0	38.2	39.5	-0.8	-1.6	-0.3
WS-VI	39.3	37.3	36.8	39.0	-2.0	-2.5	-0.3
WS-VII	39.5	37.9	37.5	36.6	-1.6	-2.0	-2.9

Khirman	40.1	37.5	37.6	38.4	-2.6	-2.5	-1.7
Mean	39.3	37.4	37.2	38.0	-1.9	-2.1	-1.3
LSD at 5% (G)		0.6978					
LSD at 5% (T)		0.5983					
LSD at 5% (G x T)		1.4325					

R.D* = Relative decrease due to stress

Grain yield plot^{-1} (g): The data recording to grain yield plot^{-1} (g) of wheat genotypes under various water levels is presented in Table 12. The average decline (-69.9, -27.6 and -20.7) was observed in T_1, T_2, and T_3 for grain yield plot^{-1} (g) compared to normal irrigations. However, among the genotypes, the maximum for grain yield plot^{-1} (g) was recorded by WS-IV (1093.3) in T_3, and the minimum for grain yield plot^{-1} (g) was recorded by Khirman (805.0) in T_1. In case of genotypes performance, the minimum relative decrease was found in WS-III (-0.2) in T_1, and the maximum relative decrease was found in variety Khirman (-147.7) in T_1.

Table 12. Water effect on grain yield plot^{-1} (g) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Grain yield plot^{-1} (g)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	948.3	856.7	914.0	936.3	-91.6	-34.3	-12.0
WS-II	998.3	993.4	996.7	986.7	-4.9	-1.6	-11.6
WS-III	1063.3	1061.3	1056.7	1054.7	-2.0	-6.6	-8.6
WS-IV	1059.7	1029.3	1043.0	1093.3	-30.4	-16.7	33.6
WS-V	1050.7	979.3	1036.3	1006.7	-71.4	-14.4	-44.0
WS-VI	949.7	862.0	926.0	940.0	-87.7	-23.7	-9.7
WS-VII	1023.0	899.7	968.7	969.7	-123.3	-54.3	-53.3
Khirman	952.7	805.0	883.7	893.0	-147.7	-69.0	-59.7
Mean	1005.7	935.8	978.1	985.1	-69.9	-27.6	-20.7
LSD at 5% (G)		28.272					
LSD at 5% (T)		7.6070					
LSD at 5% (G x T)		53.418					

R.D* = Relative decrease due to stress

Biological yield plot^{-1} (g): The data regarding to biological yield plot^{-1} (g) of wheat genotypes under various water levels is presented in Table 13. The average decline (-228.5, -176.0 and -71.6) was observed in T_1, T_2, and T_3 for biological yield plot^{-1} (g) compared to normal irrigations. However, among the genotypes, the maximum for biological yield plot^{-1} (g) was recorded by WS-IV (3900.5) in T_3, and Khirman in (2066.7) T_1 recorded minimum for biological yield plot^{-1} (g). In the case of genotypes performance, the minimum relative decrease was found in WS-VII (-9.4) in T_3, and the maximum relative decrease was found in variety Khirman (-766.6) in T_1.

Table 13. Water effect on biological yield plot^{-1} (g) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Biological yield plot^{-1} (g)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	3478.9	3450.7	3400.2	3460.9	-28.2	-78.7	-18.0
WS-II	3700.0	3600.0	3566.7	3400.0	-100.0	-133.3	-300.0
WS-III	3750.0	3700.0	3733.3	3700.7	-50.0	-16.7	-49.3
WS-IV	3966.7	3600.4	3800.8	3900.5	-366.3	-165.9	-66.2
WS-V	3000.5	2900.0	2833.3	2970.4	-100.5	-167.2	-30.1
WS-VI	2866.7	2750.4	2800.0	2800.3	-116.3	-66.7	-66.4
WS-VII	2800.0	2500.0	2720.4	2790.6	-300.0	-79.6	-9.4
Khirman	2833.3	2066.7	2133.3	2800.2	-766.6	-700.0	-33.1
Mean	3299.5	3071.0	3123.5	3228.0	-228.5	-176.0	-71.6
LSD at 5% (G)		226.27					
LSD at 5% (T)		335.57					
LSD at 5% (G x T)		537.77					

R.D* = Relative decrease due to stress

Harvest index (%): The data recording to harvest index (%) of wheat genotypes under various water levels is present in Table 14. The average decline (-2.8, -2.5 and -2.4) was observed in treatment T_1, T_2, and T_3 for harvest index (%) compared to normal irrigations. However, among the genotypes, the maximum for harvest index (%) was recorded by WS-IV (39.7) in T_3, and the minimum for harvest index (%) was recorded by WS-I (25.0) in T_1. In the case of genotypes performance, the minimum relative decrease was found in WS-VI (-0.1) in T_2, and the maximum relative decrease was found in WS-IV (-9.9) in T_1.

Table 14. Water effect on harvest index (%) of wheat genotype grown under non-stress and water stress at initiation of anthesis

Genotypes	Harvest index (%)				R.D.* Over		
	Normal Irrigations	T_1 1-Irrig.	T_2 2-Irrig.	T_3 3-Irrig.	T_1	T_2	T_3
WS-I	28.1	25.0	27.9	25.9	-3.1	-0.2	-2.2
WS-II	30.1	28.1	28.6	29.0	-2.0	-1.5	-1.1
WS-III	30.5	28.7	28.4	30.3	-1.8	-2.1	-0.2
WS-IV	40.7	30.8	31.0	39.7	-9.9	-9.7	-1.0
WS-V	35.5	33.8	33.4	31.1	-1.7	-2.1	-4.4
WS-VI	33.2	31.9	33.1	30.0	-1.3	-0.1	-3.2
WS-VII	37.6	36.2	35.2	31.8	-1.4	-2.4	-5.8
Khirman	40.6	39.2	39.0	39.2	-1.4	-1.6	-1.4
Mean	34.5	31.7	32.1	32.1	-2.8	-2.5	-2.4
LSD at 5% (G)		2.6151					
LSD at 5% (T)		3.8646					
LSD at 5% (G x T)		6.2068					

Discussion

Wheat grain yield is highly influenced by many diseases and other stresses which reduce crop productivity at wider scale (Shamsi *et al.*, 2010). Water stress is highly notable among environmental stresses as 20% of arable land is widely affected by drought and soil salinization and crops yield minimized by 20-30% across the world (Johari *et al.*, 2011). According to our finding, the mean squares from the analysis of variance indicated that genotypes, treatments and genotype x treatments were significant for most of the studied characters which indicating that genotypes performed differently over the environments. While genotype × treatments interaction were non-significant for days to 75% heading, grain filling period, plant height (cm), peduncle length (cm), spikelets spike^{-1}, and grains spike^{-1} which indicated that genotypes perform similarly at different irrigation. The current results indicate that enough amount of genetic variability was present among the studied genotypes. Our results were also supported by Ajmal *et al.* (2009) who also noticed that genotypes showed remarkable variation for grain yield and its related characters. Similarly, our results also in agreement with Jatoi *et al.* (2011) who declared that analysis of variance denoted significant variation between treatments and genotypes. The treatments x cultivar interactions were also significant for all the traits except grain yield plant^{-1}. The data days to 75% heading of wheat genotypes expressed average decline (-3.8, -2.7 and -1.8) in T_1, T_2, and T_3 for days to 75% heading compared to normal irrigations. The present results indicate that irrigation regimes caused remarkable effect on days to 75% heading and as WS-IV took minimum days to heading and considered as earlier mature variety. Current findings are also supported by Shahryari *et al.* (2013) who worked on the relationship among yield and its related characters in bread wheat and significant differences among cultivars for days to heading were found. Earliness is an important attribute in wheat varieties. The earlier genotype mature is considered as desirable due to its ability to avoid drought, heat stress and other major biotic stresses. Table 3. indicate the data regarding to days to 75% maturity of wheat genotypes under various water levels. The average decline (-4.4, -2.7 and -2.0) was observed in T_1, T_2, and T_3 for days to 75% maturity compared to normal irrigations. Our results are in agreement with those of Ngwako and Mashiqa (2013) they reported a remarkable variation in the genotypes for days taken to maturity and grain yield. Grain filling period is of equal importance compare to other featured traits of wheat as grain weight is determined during grain filling process. Therefore, vegetative improvement in wheat grain filling period must be noticed (Tiwari, 2007). The average decline (-1.1, -0.6 and -0.9) was noticed in T_1, T_2, and T_3 for grain filling period compared to normal irrigations. The present results determine that irrigation regimes significantly impact grain filling period thus reducing the number of irrigations will cause adverse effect on genotype yield potential. Sayed and Gadallah (1983) mentioned that longer grain filling period increase photo assimilates resulting higher yield but high intensity of temperature during grain filling will drastically reduce the kernel weight and grain yield due to reduction of grain filling duration. Plant height is an important in terms of morphogenesis and grain yield of wheat. The average decline (-1.7, -5.0 and -3.1) was observed in T_1, T_2, and T_3 for plant height (cm) compared to normal irrigations. Our findings are confirmed with Kumar (2017) who observed a significant variation for plant height at single irrigation and two irrigations levels. The importance of peduncle length affecting yield and other associated traits in wheat are taken into consideration but still not fully elucidated. The knowledge of plant natural response will help to produce genetically adaptable varieties for ever increasing feed demand of population. The average decline (-4.0, -4.5 and -2.6) was observed in T_1, T_2, and T_3 for peduncle length (cm) compared to normal irrigations. Present results showed that irrigation regimes play an important role to increase peduncle length. Similar results were found by Amiri *et al*. (2013) who studied the effect of terminal drought on wheat and found significant effect on peduncle length due to water stress. Table 7 indicate data regarding spike length (cm) of wheat genotypes under various water levels. The average decline (-1.1, -0.8 and -1.8) was observed in T_1, T_2, and T_3 for spike length (cm) compared to normal irrigations. Present results are in agreement with Kumar (2017) who observed that the TD-I produced maximum spike length (12.8 cm) and achieved more 1000-grain weight (44.9 g), while Khirman produced taller plants (98.6 cm) and higher main spike yield (2.26 g) and Sarsabz produced maximum spikelets spike^{-1} (25.5) under normal and stress condition. The data of spikelets spike^{-1} of wheat genotypes under various water levels is given in Table 8. The average decline (-0.8, -0.6 and -1.0) was observed in T_1, T_2, and T_3 for spikelets spike^{-1} compared to normal irrigations. However, among the genotypes, maximum spikelets spike^{-1} was recorded by WS-I (20.3) in T_2, and minimum spikelets spike^{-1} was recorded by WS-IV (17.6) in T_1 followed by WS-VII (17.6) in T_3. Present results suggested that advance line WS-IV has great potential to sustain water stress and could be suggested as drought tolerant genotypes. The data of grains spike^{-1} of wheat genotypes under various water levels is present in Table 9. The average decline (-9.5, -6.0 and -8.1) was observed in T_1, T_2, and T_3 for grains spike^{-1} compared to normal irrigations. Similar findings were reported by Ngwako and Mashiqa (2013) report that a remarkable variation was observed in the genotypes for grains spike^{-1} and number of irrigations had significant effect on grains spike^{-1} as compared to control irrigation. Muhammad *et al*. (2012) reports grains number spike^{-1} was improved markedly by increase in the irrigation frequency. The data recording to grain weight spike^{-1} (g) of wheat genotypes under various water levels is present in Table 10. The average decline (-0.4, -0.3 and -0.4) was observed in T_1, T_2, and T_3 for grain weight spike^{-1} (g) compared to normal irrigations. In the present study genotypic variation in response to water stress for grain weight spike^{-1} was found. Drought stress negatively affect the grain weight spike^{-1} and similar results were also found by researchers such as Liu *et al.* (2015) and Qaseem *et al.* (2019). 1000-grain weight is important grain yield characters which helps to calculate the overall grain yield of wheat genotypes. The 1000-grain weight is determined by average value of individual grain weight depending upon the position within the ear and within the spikelet. The average decline (-1.9, -2.1 and -1.3) was observed in T_1, T_2, and T_3 for 1000-grain weight (g) compared to normal irrigations. Our finding is in confirmation with Sial *et al*. (2012) as their results showed that genotypes NIA-8/7, NIA-9/5, BWM-3, NIA-28/4, MSH -36 and NIA-25/5 showed greater seed index value and less spike sterility under severe water stress conditions, suggesting these genotypes as less responsive to moisture stress, and possessing relative tolerance to moisture stress. The breeding programs efficiency in diverse environment can be improved by acquiring knowledge of relationship between grain yield and its related traits. The average decline (-69.9, -27.6 and -20.7) was observed in T_1, T_2, and T_3 for grain yield plot^{-1} (g) compared to normal irrigations. Ngwako and Mashiqa (2013) reported that a remarkable variation was noted in the genotypes for yield. More number of irrigations during entire growth period increased grain yield by 16.71% as compared to control irrigation. The data recording to biological yield plot^{-1} (g) of wheat genotypes under various water levels is present in Table 13. The average decline (-228.5, -176.0 and -71.6) was observed in T_1, T_2, and T_3 for biological yield plot^{-1} (g) compared to normal irrigations. Other researchers like Khakwani *et al*. (2012) reported that water stress significantly decreased all the measured traits. The data recording to harvest index (%) of wheat genotypes under various water levels is present in Table 14. The average decline (-2.8, -2.5 and -2.4) was observed in T_1, T_2, and T_3 for harvest index (%) compared to normal irrigations. Khakwani *et al*. (2012) reported that water stress significantly decreased all the measured traits. Other researcher like Ngwako and Mashiqa (2013) performed breeding studies to investigate the influence of irrigation on the varietal performance of bread wheat genotypes

Conclusion

The present study suggested that wheat genotypes grown under three irrigations have significant impact on growth and yield performance. Thus, recommended for grower to apply minimum three irrigation under water stress condition. Moreover, advance line WS-IV exhibit maximum performance for the yield and its contributing traits under water stress condition thus can be recommended as water stress tolerant genotype.

References

Ahmad, R., Qadir, S., Ahmad, N., & Shah, K. H. (2003). Yield potential and stability of nine wheat varieties under water stress conditions. *International Journal of Agriculture and Biology*, **5**(1): 7-9.

Ajmal, S. U., Zakir, N., & Mujahid, M. Y. (2009). Estimation of genetic parameters and character association in wheat. *Journal of Agriculture and Biological Science*, **1**(1): 15-18.

Ali, A., Sadaqat, H. A., Kashif, M., & Wahid, M. A. (2018). Exploration of breeding potential for genetic biofortification and yield in spring wheat (*Triticum aestivum* L.). *Pakistan Journal of Agricultural Sciences*, **55**(4): 793-799.

Amiri, R., Bahraminejad, S., & Jalali-Honarmand, S. (2013). Effect of terminal drought stress on grain yield and some morphological traits in 80 bread wheat genotypes. *International Journal of Agriculture and Crop Sciences*, **5**(10): 1145. 1145-1153.

Beltrano, J., & Ronco, M. G. (2008). Improved tolerance of wheat plants (*Triticum aestivum* L.) to drought stress and rewatering by the arbuscular mycorrhizal fungus Glomus claroideum: Effect on growth and cell membrane stability. *Brazilian Journal of Plant Physiology*, **20**(1): 29-37.

Bhutto, A. H., Rajpar, A. A., Kalhoro, S. A., Ali, A., Kalhoro, F. A., Ahmed, M., Raza, S., & Kalhoro, N. A. (2016). Correlation and regression analysis for yield traits in wheat (*Triticum aestivum* L.) genotypes. *Natural Science*, **8**(03): 96-104.

Blum, A. (1979). Genetic improvement of drought resistance in crop plants. A case for sorghum. 495-545. In Hussell, H. and R. C. Staples (Eds.). Stress Physiology Crop Plants. Wiley Inter science, New York.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedures for agriculture research (Second Edition). John Wilay and Sons. New York. 680.

Jatoi, W. A., Baloch, M. J., Kumbhar, M. B., Khan, N. U., & Kerio, M. I. (2011). Effect of water stress on physiological and yield parameters at anthesis stage in elite spring wheat cultivars. *Sarhad Journal of Agriculture*, **27**(1): 59-65.

Johari-Pireivatlou, M., & Maralian, H. (2011). Evaluation of 10 wheat cultivars under water stress at Moghan (Iran) condition. *African Journal of Biotechnology*, **10**(53): 10900-10905.

Khakwani, A. A., Dennett, M. D., Munir, M., & Abid, M. (2012). Growth and yield response of wheat varieties to water stress at booting and anthesis stages of development. *Pakistan Journal of Botany*, **44**(3): 879-886.

Kumar, K. (2017). Breeding for water stress tolerance in Bread wheat (*Triticum aestivum* L.). M.Sc. Thesis Dissertation Submitted to Department of Plant Breeding and Genetic, Sindh Agriculture University, Tandojam, Sindh, Pakistan.

Liu, E. K., Mei, X. R., Yan, C. R., Gong, D. Z., & Zhang, Y. Q. (2016). Effects of water stress on photosynthetic characteristics, dry matter translocation and WUE in two winter wheat genotypes. *Agricultural Water Management*, **167**: 75-85.

Muhammad, A., Muhammad, M., Amjed, A., Hassan, S. W., Arif, H., Shahbaz, A., & Javed, M. A. (2012). Growth, yield components and harvest index of wheat (*Triticum aestivum* L.) affected by different irrigation regimes and nitrogen management strategy. *Science International (Lahore)*, **24**(2): 215-218.

Ngwako, S., & Mashiqa, P. K. (2013). The effect of irrigation on the growth and yield of winter wheat (*Triticum aestivum* L.) cultivars. *International Journal of Agriculture and Crop Sciences*, **5**(9): 976-982.

PARC. (2015). Wheat in Pakistan: A status paper. National coordinator wheat plant sciences division Pakistan Agricultural Research Council Islamabad, Pakistan. 1-9.

Qaseem, M. F., Qureshi, R., & Shaheen, H. (2019). Effects of pre-anthesis drought, heat and their combination on the growth, yield and physiology of diverse wheat (Triticum aestivum L.) genotypes varying in sensitivity to heat and drought stress. *Scientific reports*, **9**(1): 1-12.

Sayed, H. I., & Gadallah, A. M. (1983). Variation in dry matter and grain filling characteristics in wheat cultivars. *Field Crops Research*, **7**: 61-71.

Shahryari, R., Eshgh, A. G., Mollasadeghi, V., & Serajamani, R. (2013). Separating correlation coefficients into direct and indirect effects of important morphological traits on grain yield in 28 bread wheat genotypes under terminal drought stress. *Int J Farming and Allied Sciences*, **2**(24): 1210-1216.

Shamsi, K., Petrosyan, M., Noor-Mohammadi, G., & Haghparast, R. (2010). The role of water deficit stress and water use efficiency on bread wheat cultivars. *Journal of Applied Biosciences*, **35**: 2325-2331.

Sial, M. A., & Laghari, K. A. (2012). Genetic improvement of drought tolerance in semi-dwarf wheat. *Science Technology and Development*, **31**(4): 335-340.

Tiwari, K. N., Paul, D. K., & Gontia, N. K. (2007). Characterization of meteorological drought. *Hydrology*, **30**(1-2): 15-27.

USDA. (2015). Pakistan grain and feed annual. USDA foreign agricultural service. 1-4.

Wehner, G. G., Balko, C. C., Enders, M. M., Humbeck, K. K., & Ordon, F. F. (2015). Identification of genomic regions involved in tolerance to drought stress and drought stress induced leaf senescence in juvenile barley. *BMC Plant Biology*, **15**(1): 1-15

.