EVALUATION OF WATER STRESS TOLERANCE IN WHEAT GENOTYPES ON THE BASIS OF PHENOLOGICAL AND MORPHOLOGICAL TRAITS

Khanzada Asifa[1], Zahoor Ahmed Soomro[1], Shah Nawaz Mari[1], Mehboob Ali Sial[2], Munaiza Baloch[1] and Majed M. Albokari[3]

[1]*Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam, Pakistan.*
[2]*Nuclear Institute of Agriculture (NIA), Tandojam, Pakistan.*
[3]*Nuclear Science Research Institute (NSRI), King AbdulAzizCity for Science & Technology (KACST), P.O. Box 6086, Riyadh 11442, Saudi Arabia.*

ABSTRACT

The present studies were carried out at the experimental farm of Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan during wheat growing season 2012-13, to determine the effects of water stress on various Phenological and morphological traits associated with the grain and biomass yield. Twenty newly evolved wheat genotypes developed through conventional breeding at Nuclear Institute of Agriculture Tando Jam were evaluated along with four local varieties (Sarsabz, Khirman, TD-1 and Chakwal-86) under various water stress regimes in field conditions. The experiment was laid out in split plot design with three replications. Results revealed highly significant differences among genotypes, treatments and genotype x treatment interaction for different traits viz., days to 75% booting, grain filling period, days to 75% maturity, tillers plant^{-1}, plant height and peduncle length. Furthermore, significant decrease was observed in days to booting, days to 75% maturity, tillers plant^{-1} at T_1 (66.8, 45.2, 123.4) as compared toT_2 (67.5, 48.1, 126.1) respectively. The maximum number of tillers.m^{-2} and plant height were exhibited by line IBWSN-078-1174. Cultivar Khirman produced longer peduncle (30.9 cm), while TD-1 and Chakwal-86 took minimum number of days for 75% booting and grain filling (59.6 and 36.8) respectively. The genotype IBWSN-078-1078 matured earlier among all genotypes in 118.11 days.

Key-words: Water stress, agro-morphological traits, irrigation doses, wheat, Pakistan.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop for the majority of world's populations. It belongs to family Poaceae (Gramineae). It is the most important staple food of about two billion people (36% of the world population). Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed. Wheat is cultivated over a wide range of climatic conditions and therefore understanding mechanism of heredity of wheat is of great value for geneticist for developing crop varieties to withstand various situations.

Water stress is of common and wide occurrence in nature. It occurs whenever water absorption by the crop is lower than the evaporative demand of the atmosphere. The ability of wheat cultivars to perform reasonably well in variable rainfall and water stressed environments is an important trait for stability of production under drought stress conditions (Pirayvatlov, 2001).Water stress is the most significant environmental stress in agriculture worldwide and improving yield under drought is a major goal of plant breeding (Cattivelli *et al*., 2008).

Rainfed areas play an important role in crop production in Pakistan. Nearly one-fifth of the total wheat acreage in Pakistan is under rainfed and this contributes about 10-12% of the total wheat production in the country (Ahmad *et al*., 1996). Among different factors, drought emerges a serious threat to low productivity for the past few years when no rainfall occurs in most part of the year especially during winter (Kazmi *et al*., 2003).

The critical stages in wheat are crown root, boot and milky stages. At milky stages of wheat, water application is necessary for grain filling and water stresses would cause significant yield reduction, low water availability can also cause physical limitations in plants. Improvement of drought tolerance in crop is a major objective of most crop breeding programs, particularly in arid and semi-arid areas of the world. Although wheat breeders have been effective in increasing yield under productive, cultivated conditions success has been more difficult to achieve in production regions where environmental stresses like water stress occur. Therefore, it is important to determine the stability and performance of newly evolved breeding material under water stress environments and to develop water stress tolerant varieties of wheat.

The present research was conducted to evaluate the performance of newly evolved wheat genotypes under water stress conditions and to select drought-tolerant wheat genotypes that ultimately would yield high. The findings from this research will be helpful for breeders to develop new wheat genotypes tolerant to abiotic stress. The objectives of the present study were:

1. To observe the effects of water stress on agro-morphological traits associated with the grain yield and biomass of the wheat genotypes at various critical growth stages.
2. To identify early maturing wheat genotypes possessing tolerance to water stress.

MATERIALS AND METHODS

The 20 newly evolved wheat genotypes along with 4 local check varieties (Sarsabz, Khirman, TD-1 and Chakwal-86) under two water stress conditions were evaluated for yield, yield contributing and physiological traits. The experiment was laid out in split plot design with three replications arranged in a plot size 3 m x 1.2 m (3.6 m^2) having two rows each of 3 m long and 30 cm apart. After first irrigation thinning was done to maintain 15 cm plant to plant distance. The experimental observations recorded on days to 75 % booting, days to grain filling period, days to 75 % maturity, tillers m^{-2}, peduncle length and plant height.

Irrigation treatments

T_1 =	One irrigation	Single irrigation was applied at seedling stage; no further irrigation will be applied. The stress will be imposed during all growth stages except seedling stage
T_2 =	Two irrigations	Two irrigations were applied, first at seedling stage (after 21 days of sowing) and second at booting stage (the stress will be induced during tillering, heading, anthesis, post-anthesis and grain filling period).

Genotypes

V_1 IBWSN-078-1056, V_2 IBWSN-078-1059, V_3 IBWSN-078-1071
V_4 IBWSN-078-1072, V_5 IBWSN-078-1073, V_6 IBWSN-078-1074
V_7 IBWSN-078-1174, V_8 IBWSN-078-1067, V_9 IBWSN-078-1078
V_{10} IBWSN-078-1089, V_{11} IBWSN-078-1090, V_{12} IBWSN-078-1091
V_{13} IBWSN-078-1095, V_{14} IBWSN-078-1069, V_{15} IBWSN-078-1098
V_{16} IBWSN-078-110,V_{17} IBWSN-078-1102, V_{18} IBWSN-078-1113
V_{19} IBWSN-078-1123, V_{20} IBWSN-078-1131, V_{21} Sarsabz
V_{22} Khirman, V_{23} Chakwal-86, V_{24} TD-1

Statistical Analyses

Data recorded from plants were statistically analyzed according to Gomez and Gomez (1984) and the means will be compared by Duncan's Multiple Range Test (DMRT) by MSTATC computer package.

RESULTS

The studies carried out were to evaluate the performance of 20 newly evolved wheat genotypes along with 4 local check varieties (Sarsabz, Khirman, TD-1 and Chakwal-86) under two water stress conditions. The objectives of the studies were to determine the effect of water stress on different phenological and morphological traits during various critical stages of plant growth. Fifteen different traits were studied out of which only six are discussed in this research paper. The results obtained have been given as under:

Analysis of variance

The analysis of variance (ANOVA) was carried out to determine the differences among 24 bread wheat genotypes (twenty advance lines and 4 check varieties) for various phenological and morphological traits associated with the grain yield and biomass as affected by two different water stresses. The overall mean performance of wheat genotypes under both the water stress conditions are represented table wise. The results depicted that the mean squares (ANOVA) for treatments were significantly different at $P \leq 0.01$ from each other for the traits *i.e.* days to grain filling period, days to 75 % maturity, while tillers m^{-2}, were significantly different at $P \leq 0.05$ level, whereas days to 75 % booting, plant height and peduncle length were non- significant. Taking the mean square (MS) for genotypes it was analysed that traits days to 75 % booting, grain filling period, days to75 % maturity, tillers m^{-2}, plant height, peduncle length, were significantly different at $P \leq 0.01$. The mean square (MS) for genotype x treatment (GxE) interaction was also highly significant $P \leq 0.01$ for the traits days to 75 % booting, grain filling period, days to 75 % maturity, tillers m^{-2}, plant height, while peduncle length was significant at $p \leq 0.05$ (Table 1).

Table 1. Mean squares from analysis of variance for different morphological traits of wheat genotype as affected by water stress.

Source of Variation	D.F	Mean Squares (MS)					
		Days to booting Stage	Days to grain filling period	Days to maturity	Tillers m^{-2}	Plant height	Peduncle length
Replications	2	18.8819	6.083	7.132	436.1	6.302	0.4103
Treatments	1	15.3403	312.111**	256.000**	26028.4*	51.672*	8.3955
Error Rep x Trt	2	11.0486	2.028	0.146	954.8	3.225	0.6103
Varieties	23	68.3838**	102.638**	69.140**	9424.9**	307.634**	34.3500**
Trt x Var	23	17.9925**	23.155**	11.826**	1866.6**	16.694*	1.9611**
Error Rep x Trt x Var	92	4.6609	1.396	0.610	156.0	9.848	1.0263
Total	143						

* = Significant at 0.05 level of probability; ** = Significant at 0.01 level of probability; N.S = Non Significant

Table 2. Mean performance for days to 75 % at booting stage of wheat genotypes as affected by different water stresses.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Promotion (+) or reduction (-) % in T_1 over T_2
IBWSN-078-1056	64.0 f-i	63.7fg	63.85hij	0.47
IBWSN-078-1059	71.7 ab	70.7ab	71.2ab	1.41
IBWSN-078-1071	69.3 a-e	70.7ab	70.0a-d	-1.98
IBWSN-078-1072	68.0 bcdef	68.7bcd	68.3c-f	-1.02
IBWSN-078-1073	64.0 f-i	70.3ab	67.1efg	-8.96
IBWSN-078-1074	71.0 abc	72.0a	71.5ab	-1.39
IBWSN-078-1174	68.0 b-f	70.3ab	69.1b-e	-3.27
IBWSN-078-1067	66.7 c-g	71.3a	69.0b-e	-6.45
IBWSN-078-1078	65.0 e-h	65.0ef	65.0ghi	0
IBWSN-078-1089	60.3 i	63.0fg	61.6jk	-4.29
IBWSN-078-1090	65.7 d-g	68.7bcd	67.2efg	-4.37
IBWSN-078-1091	66.7 c-g	67.7cd	67.2efg	-1.48
IBWSN-078-1095	64.3 f-i	62.3g	63.3hij	3.21
IBWSN-078-1069	68.3 a-f	72.0a	70.1abc	-5.14
IBWSN-078-1098	71.0 abc	71.3a	71.1ab	-0.42
IBWSN-078-1101	67.0 c-g	71.3a	69.1b-e	-6.03
IBWSN-078-1102	68.0 b-f	63.7fg	65.8fgh	6.75
IBWSN-078-1113	69.0 a-e	70.0abc	69.5b-e	-1.43
IBWSN-078-1123	62.7 ghi	66.3de	64.5hi	-5.43
IBWSN-078-1131	61.0 hi	64.7efg	62.8ij	-5.72
Sarsabz	70 .0a-d	65.0ef	67.5d-g	7.69
Khirman	65.7 d-g	64.3 efg	65.0ghi	2.178
Chakwal-86	72.7 a	72.0a	72.35a	0.97
T.D-1	64.3 f-i	55.0h	59.6k	16.91
Overall mean	66.8	67.5	67.1	-1.04
Reduction (%) in T_1 over T_2	0.97	--	--	--

The means with similar alphabetic letter are statistically non significant.

Table 3. Mean performance for days to grain filling period of wheat genotypes as affected by different water stresses.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Promotion (+) or reduction (-) % in T_1 over T_2
IBWSN-078-1056	50.3 b	55.3a	52.8b	-9.04
IBWSN-078-1059	45.7efg	47.3d	46.5ghi	-3.38
IBWSN-078-1071	45.7efg	49.3c	47.5fgh	-7.3
IBWSN-078-1072	47.7 cde	46.7de	47.2ghi	2.14
IBWSN-078-1073	40.0 jk	47.0de	43.5kl	-14.89
IBWSN-078-1074	38.0 k	42.3i	40.15m	-10.17
IBWSN-078-1174	47.3cde	47.3d	47.3ghi	0
IBWSN-078-1067	40.3 ij	51.7b	46.0ij	-22.05
IBWSN-078-1078	47.3cde	42.0i	44.6jk	12.62
IBWSN-078-1089	49.0bc	44.7fg	46.8ghi	9.62
IBWSN-078-1090	43.7gh	52.0b	47.8fg	-15.96
IBWSN-078-1091	43.0h	44.3gh	43.6kl	-2.93
IBWSN-078-1095	48.3bcd	51.7b	50.0de	-6.58
IBWSN-078-1069	42.7h	52.3b	47.5fgh	-18.36
IBWSN-078-1098	44.0gh	45.3efg	44.6jk	-2.87
IBWSN-078-1101	42.3hi	42.7hi	42.5l	-0.94
IBWSN-078-1102	48.7bc	53.0b	50.8cd	-8.11
IBWSN-078-1113	44.3fgh	48.0cd	46.1hi	-7.71
IBWSN-078-1123	40.3ij	46.3def	43.3kl	-12.96
IBWSN-078-1131	46.3def	48.0cd	47.1ghi	-3.54
Sarsabz	50.0 bc	53.0b	51.5bc	-5.66
Khirman	48.3 bcd	49.3c	48.8ef	-2.03
Chakwal-86	34.7 l	39.0j	36.8n	-11.03
T.D-1	56.7 a	56.7a	56.7a	0
Overall mean	45.2	48.1	46.6	-6.03
Reduction (%) in T_1 over T_2	6.12	--	--	--

The means with similar alphabetic letter are statistically non significant.

Days to 75 % booting stage

The results indicated that genotypes showed significant difference for days taken to booting stage in both the water stress conditions. Overall days to booting stage decreased at T_1 (66.8) as compared to T_2 (67.5). Days to booting stage of wheat genotypes in single irrigation ranged from 60.3 in IBWSN-078-1089 to 72.7 in Chakwal-86 (Table 2), while in two irrigation ranged from 55.0 in T.D-1 to 72.0 in IBWSN-078-1069 and Chakwal-86. The variety Chakwal-86 displayed highest days to booting (72.7) at T_1 while T.D-1 displayed lowest number of days to booting (55.0) at T_2 as compared to rest of the genotypes included in the research. Taking overall mean of days taken to booting stage of wheat genotypes, it was observed in the check variety Chakwal-86 took significantly the highest days (72.3) than other contesting genotypes (Table 2), the lowest days to booting (59.6) taken by variety T.D-1. Regarding the trait days to days to booting reduction % in T_1 over T_2 was 0.97 %.

Days to grain filling

Genotypes showed significant difference for days taken to grain filling period in both the water stress treatments. Overall mean grain filling period was significantly decreased at single irrigation T_1 (45.2) as compared to T_2 (48.1). Grain filling period of wheat genotypes ranged from 34.7 and 39.0 days in Chakwal-86 to 56.7 in TD-1 at T_1 and T_2 respectively (Table 3), among four checks, Chakwal-86 took less period to grain filling (Table 3). Taking overall mean of days taken to grain filling period of wheat genotypes, it was observed that the check variety TD-1 took significantly more days (56.7 days) followed by IBWSN-078-1056 (52.8 days), Sarsabz (51.5 days), IBWSN-078-1102 (50.8days) and IBWSN-078-1095 (50 days) whereas lowest days to grain filling period displayed

by Chakwal-86 (36.8) as compared to other contesting genotypes (Table 3). Regarding the trait days to grain filling period reduction % in T_1 over T_2 was 6.12 %.

Table 4. Mean performance for days to75 % maturity of wheat genotypes as affected bywater stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Promotion (+) or reduction (-) % in T_1 over T_2
IBWSN-078-1056	120.7ghi	126.0fg	123.3i	-4.21
IBWSN-078-1059	129.0ab	128.3cd	128.6b	0.55
IBWSN-078-1071	127.7 bc	129.3bc	128.5b	-1.24
IBWSN-078-1072	129.7a	127.0ef	128.3b	2.13
IBWSN-078-1073	120.7 ghi	127.0ef	123.8ghi	-4.96
IBWSN-078-1074	121.0 gh	126.7fg	123.8ghi	-4.5
IBWSN-078-1174	128.7 ab	128.0de	128.3b	0.55
IBWSN-078-1067	122.7f	126.7fg	124.7fg	-3.16
IBWSN-078-1078	118.3 k	118.0k	118.1l	0.25
IBWSN-078-1089	119.0 jk	117.7k	118.3l	1.1
IBWSN-078-1090	128.0bc	133.0a	130.5a	-3.76
IBWSN-078-1091	127.7c	124.7h	125.8de	2.41
IBWSN-078-1095	119.3ijk	121.3j	120.3k	-1.65
IBWSN-078-1069	126.6cd	130.0b	128.3b	-2.62
IBWSN-078-1098	127 c	129.3bc	128.1bc	-1.78
IBWSN-078-1101	125.3 de	126.7fg	126.0d	-1.1
IBWSN-078-1102	120.7 ghi	126.7fg	123.7hi	-4.74
IBWSN-078-1113	122.0 fg	128.0de	125.0ef	-4.69
IBWSN-078-1123	119.0 jk	123.3i	121.1jk	-3.49
IBWSN-078-1131	120.0 hij	123.3i	121.6j	-2.68
Sarsabz	123.0f	125.7gh	124.3fgh	-2.15
Khirman	120.7 ghi	122.7i	121.7j	-1.63
Chakwal-86	124.7e	130.0b	127.3c	-4.08
T.D-1	120.7 ghi	126.0fg	123.3i	-4.21
Overall mean	123.4	126.1	124.7	-2.14
Reduction (%) in T_1 over T_2	2.12	--	--	--

The means with similar alphabetic letter are statistically non significant.

Days to 75 % maturity

Table 4 exhibited the significant difference of genotypes for days taken to maturity period in both the water stress treatments. Overall mean for days to maturity significantly decreased at single irrigation T_1 (123.4 days) as compared to T_2 (126.1 days). At T_1, days to maturity of wheat genotypes ranged from 118.3 days in IBWSN-078-1078 and 1069 to 129.7 days in genotype IBWSN-078-1072. At T_2, days taken to maturity were increased which ranged from 117.7 days in IBWSN-078-1089 to 133.7 days in genotype IBWSN-078-1090 (Table 4). Among four checks, Chakwal-86 took more days to maturity (Table 4) at T_2. Taking overall mean of days to maturity, it was observed that two advance lines IBWSN-078-1090 took significantly more days 130.50 to get mature as compared to other all entries (Table 4).While the lowest days at 75 % maturity (118.1) took by genotype IBWSN-078-1078. Regarding the trait days to 75 % maturity reduction % in T_1 over T_2 was 2.12 %.

Tillers m^{-2}

The trait number of tillers m^{-2} showed significant reduction at T_1 (457.6) as compared to T_2 (484.6). The results indicated that genotypes showed significant difference for trait tillers m^{-2} ranged from 389.3 tillers m^{-2} in IBWSN-078-1071 to 530 in IBWSN-078-1078 at T_1 (Table 5). Whereas the results obtained T_2 for trait tillers m^{-2} at T_2 ranged from 384 tillers in IBWSN-078-1095 to 594.7 in IBWSN-078-1174 (Table 5). Six advanced lines produced the highest no of tillers m^{-2} (more than 500 tillers m^{-2}) with compared to the check variety Chakwal-86 (490) (Table

5). IBWSN-078-1098 produced lowest number of tillers m^{-2} (378.6) and IBWSN-078-1078 produced highest number of tillers m^{-2} (536.6) depicted by the overall mean. Regarding the trait tillers m^{-2} reduction % in T_1 over T_2 was 5.55 %.

Table 5. Mean performance for number of tillers m^{-2} of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Promotion (+) or reduction (-) % in T_1 over T_2
IBWSN-078-1056	472.0 def	538.7bc	505.3bc	-12.39
IBWSN-078-1059	450.6 g-j	468.0hij	459.3gh	-3.72
IBWSN-078-1071	389.3 m	430.7k	410.0j	-9.61
IBWSN-078-1072	488.0 bcd	488.0fgh	488.0def	0
IBWSN-078-1073	436.0 jk	520.0bcd	478.0ef	-16.15
IBWSN-078-1074	485.3 bcd	518.7cde	502.0bcd	-6.44
IBWSN-078-1174	465.3 efg	594.7a	530.0a	-21.76
IBWSN-078-1067	441.3 ij	461.3j	451.3hi	-4.34
IBWSN-078-1078	530.6 a	542.7b	536.6a	-2.23
IBWSN-078-1089	436.0 jk	469.3hij	452.6hi	-7.1
IBWSN-078-1090	417.3 kl	466.7hij	442.0i	-10.58
IBWSN-078-1091	465.3 efg	485.3ghi	475.3ef	-4.12
IBWSN-078-1095	392.0 m	384.0l	388.0k	2.08
IBWSN-078-1069	458.6 f-i	496.0 efg	477.3ef	-7.54
IBWSN-078-1098	405.3 lm	352.0m	378.6k	15.14
IBWSN-078-1101	462.6 efg	513.3de	487.9def	-9.88
IBWSN-078-1102	480.0 b-e	510.7def	495.3cd	-6.01
IBWSN-078-1113	446.6 g-j	461.3j	453.9hi	-3.19
IBWSN-078-1123	497.3 b	529.3bcd	513.3b	-6.05
IBWSN-078-1131	492.0 bc	517.3cde	504.6bc	-4.89
Sarsabz	442.6 hij	462.7ij	452.6hi	-4.34
Khirman	436.0 e-h	457.3j	446.6gh	-4.66
Chakwal-86	493.3 bc	488.0fgh	490.6cde	1.09
T.D-1	474.6 c-f	473.3 g-j	473.9fg	0.27
Overall mean	457.6	484.6	471.1	-5.57
Reduction (%) in T_1 over T_2	5.55	--	--	--

The means with similar alphabetic letter are statistically non significant.

Plant height (cm)

The effect of water stress was observed on plant height as a reduction on some extent was observed in plant height with decrease in irrigation. Plant height varied in genotypes ranged from 69 cm in TD-1followed by IBWSN-078-1078 to 103.4 cm in Khirman followed by IBWSN-078-1113 (Table 6) at T_1, whereas 68.1 in T.D-1 followed by IBWSN-078-1074 to 106.3 in IBWSN-078-1174 followed by Khirman in T_2. It was depicted from the result of overall mean that T.D-1 showed lowest plant height (68.5 cm) followed by IBWSN-078-1178 while Chakwal-86 showed taller plant in height (103.3 cm) followed by IBWSN-078-1174. Regarding the trait Plant height reduction % in T_1 over T_2 was -1.31 %.

Peduncle length (cm)

The significant effect of water stress was found on trait peduncle length (cm), however genotypes showed different response at various water stresses (single and two irrigations), where as in overall mean little bit reduction or decrease observed in T_1 as compare toT_2. At T_1, peduncle length ranged from 19.5 cm in variety TD-1 followed by IBWSN-078-1078 to 31.0 cm in Khirman followed by IBWSN-078-1113 (Table 7). At T_2, peduncle length (cm) ranged from 19.3cm in variety TD-1followed by IBWSN-078-1095 and 1098 to 31.9 cm in genotypes IBWSN-078-1174 followed by Khirman (Table 7). IBWSN-078-1174 genotypes had the long peduncle as compared to all other

entries. Taking overall mean of peduncle length, it was observed that drought tolerant check variety Khirman produced the significantly long peduncle followed by IBWSN-078-1174 as compared to other entries (Table 7), whereas the shortest peduncle length 19.4 obtained by T.D-1 followed by IBWSN-078-1078. Regarding the trait peduncle length reduction % in T_1 over T_2 was 1.7 %.

Table 6. Mean performance for plant height (cm) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Promotion (+) or reduction (-) % in T_1 over T_2
IBWSN-078-1056	99.1 a-d	101.2 abc	100.1abc	-2.08
IBWSN-078-1059	97.1 b-f	99.8bcd	98.4bcd	-2.71
IBWSN-078-1071	97.0 b-f	97.4 cde	97.2b-e	-0.41
IBWSN-078-1072	98.7 a-e	98.2 b-e	98.4bcd	0.51
IBWSN-078-1073	96.2 b-g	93.6 e-h	94.9 d-h	2.78
IBWSN-078-1074	88.7 jk	88.3h	88.5 jk	0.45
IBWSN-078-1174	99.4 abc	106.3a	102.8a	-6.49
IBWSN-078-1067	94.3 d-h	96.4 c-f	95.3 d-h	-2.18
IBWSN-078-1078	83.7 l	90.8fgh	87.2k	-7.82
IBWSN-078-1089	91.3 g-j	95.6 c-g	93.4fgh	-4.5
IBWSN-078-1090	92.4 f-j	91.6fgh	92.0hij	0.87
IBWSN-078-1091	93.7 e-i	91.6fgh	92.6ghi	2.29
IBWSN-078-1095	89.0 ijk	88.9h	88.9ijk	0.11
IBWSN-078-1069	96.6 b-f	96.1 c-g	96.3d-g	0.52
IBWSN-078-1098	88.2 jk	88.8h	88.5jk	-0.68
IBWSN-078-1101	89.7 hij	93.7 e-h	91.7hij	-4.27
IBWSN-078-1102	93.1 f-j	100.0 bcd	96.5c-f	-6.9
IBWSN-078-1113	100.8 ab	95.2 d-g	98.0bcd	5.88
IBWSN-078-1123	94.3 c-g	93.4 e-h	93.8e-h	0.96
IBWSN-078-1131	84.5 kl	90.6 gh	87.5k	-6.73
Sarsabz	97.3 b-f	96.1 c-g	96.7c-f	1.25
Khirman	103.4a	103.8 ab	103.6a	-0.39
Chakwal-86	100.3ab	101.2 abc	100.7ab	-0.89
T.D-1	69.0m	68.1i	68.5l	1.32
Overall mean	93.2	94.4	93.8	-1.27
Reduction (%) in T_1 over T_2	-1.31	--	--	

The means with similar alphabetic letter are statistically non significant.

DISCUSSION

The major losses in the crop yield worldwide are due to water scarcity than any other stress. Nevertheless, substantial reduction in wheat grain yields had been observed due to water deficiency, depending on the crop developmental stages. Studies had shown that the water stress at different growth stages of wheat significantly reduced total dry matter (biomass) yield, grain yield, harvest index and grain yield components of wheat. The characters studied under stress conditions for the above twenty four genotypes are discussed as under:

Days to 75 % booting stage

Overall days to booting stage decreased at T_1 (66.8) as compared to T_2 (67.5). The variety Chakwal-86 displayed highest days to booting (72.7) at T_1 while TD-1 displayed lowest number of days to booting (55.0) at T_2 as compared to rest of the genotypes included in the research. Taking overall mean of days taken to booting stage of wheat genotypes, it was observed that the genotype IBWSN-078-1069 and check variety Chakwal-86 took

significantly the highest days (70.1days) than other contesting genotypes (Table 2). The lowest days to booting 59.6 was taken by variety TD-1. The previous workers like (Mustatlea *et al.*, 2003) also obtained reduction in days to booting in drought and suggest the dwarf varieties perform better in drought condition.

Table 7. Mean performance for peduncle length (cm) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Promotion (+) or reduction (-) % in T_1 over T_2
IBWSN-078-1056	29.3 bc	30.1abc	29.7a-e	-2.66
IBWSN-078-1059	28.9 b-e	30.0bcd	29.4 b-f	-3.67
IBWSN-078-1071	28.9 bcd	29.6b-f	29.2 c-g	-2.36
IBWSN-078-1072	29.7 abc	30.0bcd	29.9a-d	-1.0
IBWSN-078-1073	28.6 b-f	27.9 f-k	28.2gh	2.51
IBWSN-078-1074	26.0 hij	25.8l	25.9j	0.78
IBWSN-078-1174	29.1 bc	31.9a	30.5 ab	-8.78
IBWSN-078-1067	28.3 c-g	29.3 b-g	28.8 d-g	-3.41
IBWSN-078-1078	24.5j	26.4 i-l	25.4j	-7.2
IBWSN-078-1089	26.7 ghi	27.6 g-l	27.1hi	-3.26
IBWSN-078-1090	27.2 f-i	27.1 h-l	27.1h	0.37
IBWSN-078-1091	27.5 d-h	26.9 h-l	27.2h	2.23
IBWSN-078-1095	25.7 ij	26.0 kl	25.9ij	-1.15
IBWSN-078-1069	28.7 b-f	28.6c-h	28.6efg	0.35
IBWSN-078-1101	26.5 hi	27.7g-k	27.1hi	-4.33
IBWSN-078-1098	25.8 ij	26.1i-l	25.9ij	-1.15
IBWSN-078-1102	27.3 e-i	29.8b-e	28.5efg	-8.39
IBWSN-078-1113	30.1 ab	28.3d-i	29.2 c-g	6.36
IBWSN-078-1123	28.4 c-f	28.0e-j	28.2gh	1.43
IBWSN-078-1131	24.7 j	26.9h-l	25.8j	-8.18
Sarsabz	29.0 bcd	27.9f-k	28.4fg	3.94
Khirman	31.0 a	30.8ab	30.9a	0.65
Chakwal-86	29.6 abc	30.5abc	30.0abc	-2.95
T.D-1	19.5 k	19.3m	19.4k	1.04
Overall mean	27.5	28	27.7	-1.79
Reduction (%) in T_1 over T_2	1.7			

The means with similar alphabetic letters are statistically non significant.

Days to grain filling

The overall mean performance for days to grain filling period is given in Table 3. Significant effects of water stress were observed on this trait. The varying response of genotypes was observed for days taken to grain filling period in both the water stress conditions. Overall mean grain filling period significantly was decreased at single irrigation T_1 (45.2) as compared to T_2 (48.1). Two new genotypes and local check Sarsabz also took significantly more days to grain filling period. Grain filling period of six advanced genotypes and two check varieties Sarsabz and Khirman showed significant increase at T_2. It was observed that the check variety TD-1 took significantly more days (56.7) followed by IBWSN-078-1056 (52.8 days), Sarsabz (51.5 days), IBWSN-078-1095 (50 days) and IBWSN-078-1102 (50.8 days) than other contesting genotypes, when both the water stress treatments compared.

Days to 75 % maturity

The results indicated significant difference for maturity period of wheat genotypes under both the water stress treatments for days to maturity is given in Table 4. However days to maturity were significantly $P \leq 0.01$ decreased at single irrigation T_1 (123.4 days) as compared to T_2 (126.1 days). Similar results were reported by (Asif *et al.*, 2004) who evaluated ten lines of bread wheat of diverse origin developed by various research institutes in the country in 2001-02 under rain-fed conditions. Significant variation was observed for all traits studied, i.e. days to

heading, days to maturity, plant height, test weight and grain yield. Three genotypes showed early maturity than all 4 check varieties at T_1 whereas, Chakwal-86 took more days to maturity at T_1. Days taken to maturity were increased at T_2 which ranged from 118 days in IBWSN-078-1078 to 133.7 days in genotype IBWSN-078-1090. The check variety Chakwal-86 took more days to maturity at T_2. It was observed by comparing both the treatments that three advance lines significantly took more days to maturity as compared to other genotypes.

Tillers m^{-2}

The number of tillers m^{-2} showed significant reduction at T_1 (457.6) as compared to T_2 (484.6).Six genotypes produced the highest numbers of tillers m^{-2} (more than 500 tillers) as compared to the high check variety Chakwal-86. (Shah *et al*., 1997) studied drought resistance for three diploid wheat relatives and examined under non-stress and water stress conditions. He found the effect of drought stress as compared to non-stress and reported the reduction of number of tillers due to stress.

Plant height

The effect of water stress was observed on plant height as a reduction in irrigation. Plant height varied in genotypes ranged from 69 cm in TD-1 to 103.4 cm in Khirman. At T_1, the highest plant height was observed in check variety Khirman. The differences for trait plant height of wheat genotypes were also observed at T_2 ranged from 68.1 cm in check variety TD-1 to 106.3 cm in genotype IBWSN-078-1174. Similar results were observed by Gupta *et al*. (2001). They evaluated two spring wheat cultivars, Kalyansona and C-306, for yield and yield attributes and noted that water stress caused significant reduction in plant height, leaf area, grain number, test weight and yield.

Peduncle length

The results indicated significant differences among genotypes at $P \leq 0.05$ for this important trait. The varying results were observed regarding the parameter peduncle length, in both treatments which emphasize that peduncle length was reduced as water irrigation was stopped at critical stage. The significant effect of water stress was found on trait peduncle length (cm) however, genotypes showed different response at various water stresses. At T_1, peduncle length ranged from 19.5 cm in variety TD-1 to 31.0 cm in Khirman. At T_2, peduncle length ranged from 19.3 cm in check variety TD-1 to 31.9 cm in genotypes IBWSN-078-1174. IBWSN-078-1174 genotypes had the long peduncle as compared to all other entries. On overall mean basis, Khirman and seven other genotypes could produce the significantly long peduncle as compared to other entries. The other workers like Nouri *et al*. (2011) and Ali *et al*. (2013) also observed the reduction in plant structure with the reduction in water stress.

Conclusions

Drought stress from anthesis to maturity, especially if accompanied by heat stress, it affects every morphological and physiological aspects of wheat plant and significantly reduces the final yield so it is concluded that highly significant differences among genotypes, treatments and genotype x treatment interaction for different phenological and morphological traits *viz.*, days to 75 % booting, grain filling period, days to 75 % maturity, tillers $plant^{-1}$, plant height and peduncle length.

Significant decrease was observed in days to booting, days to 75% maturity, tillers $plant^{-1}$ at T_1 (66.8, 45.2, 123.4) as compared toT_2 (67.5, 48.1, 126.1) respectively. The maximum number of tillers m^{-2} and plant height were exhibited by line IBWSN-078-1174. Cultivar Khirman produced longer peduncle (30.9 cm), while TD-1 and Chakwal-86 took minimum number of days for 75% booting and grain filling (59.6 and 36.8) respectively. The genotype IBWSN-078-1078 matured earlier among all genotypes in 118.11 days.

REFERENCES

Ahmad, N., M. Rashid and A.G. Vaees (1996). *Fertilizers and their use in Pakistan*. NFDC Pub. No. 4/96. Planning Commission NFDC, Islamabad, Pakistan.

Ali, A., N. Ali, N. Ullah, F. Ullah, M. Adnan and Z. A. Swati (2013). Effect of drought stress on the physiology and yield of the Pakistani wheat germplasms. *Int. J. of Adv. in Res & Tech*., 2(7): 419-430.

Asif, M., M.Y. Mujahid, N.S. Kisana, S.Z. Mustafa and I. Ahmad (2004). Heritability, genetic variability and path coefficient of some traits in spring wheat. *Sarhad J. of Agric*., 20(1): 87-91.

Cattivelli, L., F. Rizza, F.W. Badeck, E. Mazzucotelli, A.M. Mastrangelo, E. Francia, C. Mare, A. Tondelli and A.M. Stanca (2008). Drought tolerance improvement in crop plants: An integrated view from breeding to genomics. *Field Crop Res*., 105: 1-4.

Gomez.K.A and A.A.Gomez (1984). *Statistical procedures in Agriculture research* (2nd ed). John Wiley and Sons, New York

Gupta, N.K., S. Gupta and A. Kumar (2001). Effect of water stress on physiological attributes and their relationship with growth and yield in wheat cultivars at different growth stages. *J. of Agron*., 86: 1437-1439.

Kazmi, R.H., M.Q. Khan and M.K. Abbasi (2003). Effects of water stress on the performance of wheat grown under controlled conditions at Rawalakot Azad Jamu & Kashmir. *Sarhad J. of Agric*., 19(1): 61-63.

Mustatlea, P., N.N. Saulescu, G. Ittu, G. Pauneascu, I. Stere, N. Tanislave, M.C. Zamfir and I. Voinea (2003). Genotypic differences in drought resistance of wheat as revealed in the dry year 2002. Analele-Institulide-Cercetari-pentru-cereales-si-Plante-Tehnice, Fundulea, 70: 7-16.

Nouri, A., A. Etminan, A. Jaime, T.D. Silva and R. Mohammadi (2011). Assessment of yield, yield-related traits and drought tolerance of durum wheat. *Sabrao J. of Bre.and Gen*., 43(2): 5:8-16.

Pirayvatlov, A.S. (2001). Relations among yield potential drought tolerance and stability of yield in bread wheat cultivars under water deficit conditions. Proceedings of the 10th Australian Agronomy**.**

Shah, S.H., F.L. Stoddard and J.G. Waines (1997). The effect of moisture stress on bread wheat, rye, barley and *Dasy pyrumvillosum*. *J. of Gen and Br*., 50(4): 343-350.

(*Accepted for publication March 2015*)