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ASSESSING YIELDING ABILITY OF WHEAT GENOTYPES UNDER WATER DEFICIENT STATE

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ABSTRACT

An experiment was conducted during Rabi 2012-13 at the Nuclear Institute of Agriculture (NIA), Tandojam, Pakistan to figure out yield potential of different wheat genotypes under water deficient condition. Twenty newly evolved genotypes through conventional breeding were tested for the effects of water stress on grain yield, yield associated and physiological traits in comparison to four local varieties (Sarsabz, Khirman, TD-1 and Chakwal-86). The experiment was laid out in split plot design with three replications.

Analysis of variance showed highly significant differences among genotypes, treatments and genotype x treatment interaction for grains spike^{-1}, 1000 grain weight (g), grain yield plant^{-1} (g), harvest index, leaf area (cm^{2}) and chlorophyll content. Spikelets spike^{-1} were non-significant in treatment but significantly differed in varieties and treatment x variety interaction. The biological yield was significantly different in treatments and varieties but non-significant in treatment x variety. Significant difference of harvest index was observed in genotypes but neither in treatments nor in treatment x variety interaction. Genotypes, treatments and their interaction showed non-significant differences for spike length.

Average performance of genotypes with one and two irrigation(s) revealed that the lines IBWSN-078-1056 gave more grains spike^{-1} (66.3) and grain yield per plant (8.29 g). The maximum spike length, chlorophyll content, harvest index, biological yield, 1000 grain weight and leaf area was noted in IBWSN-078-1071, 1072, 1078, 1090, 1095 and 1098 respectively. Cultivar Khirman produced more number of spikelets spike^{-1} (23.1) among all genotypes.

Key-words: Wheat, yield reduction, drought, Physiological parameters, Pakistan.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important staple food of the largest proportion of the global population. Wheat is grown under a wide range of agro-climatic conditions and, therefore, thorough awareness of its genetic architecture is the basic to understand the principal of improved cultivar development that could best survive and yield well in the adverse circumstances.

Wheat grain yield of the country are highly affected by biotic and abiotic or environmental stresses (Sial *et al*., 2013). Major biotic stresses include rust (leaf, yellow and stem) and smut diseases whereas environmental constraints which limits crop productivity includes water stress high temperature and salinity stress (Johari *et al.*, 2011). The problems of climate change (increase in temperature and drought) are being addressed at global level which affects several crops including wheat (Reynolds *et al*., 2001). It has been reported that about 20% of arable land has been affected by drought and soil salinization and crop yields has been reduced by 20-30% throughout the world. The main adverse impacts of climate change on agriculture will most probably include temperature variability, different rain fall patterns and increasing rate of evaporation. More precisely agriculture is strongly influenced by weather and climate while farmers are often flexible in dealing with weather and year to year variability; there is nevertheless a high degree of adaptation to the local climatein the form of established infrastructure, local farming practice and individual experience. Water deficit and salt stress are global issues to ensure survival of agricultural crops and sustainable food production (Sial *et al.*, 2010).

Due to global warming the weather patterns are changing all over the world making rainy seasons unpredictable which generally affect not only the total amount of rainfall in a particular season, but also the frequency, duration and severity of water stress in the plants at different stages of growth (Kijne *et al.,* 2003). The stress factors especially drought negatively affects plant growth and development and causes a sharp decrease of plants productivity. However, plant response to drought is a complex physio-chemical process, in which many biological macro and micro molecules are involved (Ingram and Bartels, 1996). Although drought can persist for several years, even a short, intense drought can cause significant damage and harm to the local economy.

In order to have plenty of drought tolerant genotypes of wheat, the existing newly developed germplasm has to go under screening against stresses imposed by the water deficient state. The present research was conducted to assess selected wheat genotypes for their yield potential under short supply of irrigation water so as to select drought-tolerant and high yielding genotypes. The research findings shared in this manuscript will be helpful for wheat breeders to develop high yielding wheat genotypes that would also be tolerant to abiotic stress with following objectives:

1. To observe the effects of water stress on grain yield, yield associated and physiological traits of wheat genotypes.
2. To identify high yielding 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 spike length**, s**pikelets spike^{-1}, grains spike^{-1}, 1000-grain weight, grain yield plant^{-1}**,** Biological yield plant^{-1}, harvest index**,** leaf area and chlorophyll content**.**

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

Analysis of variance showed highly significant differences among genotypes, treatments and genotype x treatment interaction for grains spike^{-1}, 1000 grain weight (g), grain yield plant^{-1} (g), harvest index, leaf area (cm^2) and chlorophyll content. Spikelets spike^{-1}were non-significant in treatment but significantly differed in varieties and treatment x variety interaction. The biological yield was significantly different in treatments and varieties but non-significant in treatment x variety. Significant difference of harvest index was observed in genotypes but neither in treatments nor in treatment x variety interaction. Genotypes, treatments and their interaction showed non-significant differences for spike length. The detailed results are given as under:

Spike length (cm)

The results regarding the spike length are presented in Table 2, which further depicted that overall decrease is observed in T_1 as compared to T_2. Whereas in T_1 (single irrigation) ranged from 9.5 cm in IBWSN-078-1078 followed by IBWSN-078-1067 to 11.8 cm in IBWSN-078-1095 followed by Chakwal-86 (Table 2). At T_2, spike length ranged from 8.8 cm in genotype IBWSN-078-1067 followed by IBWSN-078-1123 to 18.8 cm in genotype IBWSN-078-1071 followed by IBWSN-078-1089. At comparison of both the water stress treatments genotype IBWSN-078-1071 followed by IBWSN-078-1089 showed significant increase in spike length 14.5 cm and 12.1cm, respectively (Table 2). Regarding the trait spike length reduction% in T_1 over T_2 was 2.9 %.

Table 2. Mean performance for spike length (cm) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	11.3ab	10.8b	11.0b	4.63
IBWSN-078-1059	10.3abc	9.9b	10.1b	4.04
IBWSN-078-1071	10.2abc	18.8a	14.5a	-45.75
IBWSN-078-1072	10.6abc	10.0b	10.3b	6.00
IBWSN-078-1073	10.4abc	10.2b	10.3b	1.96
IBWSN-078-1074	11.4 a	10.9b	11.1b	4.59
IBWSN-078-1174	11.4 a	10.6b	11.0b	7.55
IBWSN-078-1067	9.6 c	8.8b	9.2b	9.09
IBWSN-078-1078	9.5 c	11.5b	10.5b	-17.39
IBWSN-078-1089	11.3 ab	12.9 ab	12.1ab	-12.4
IBWSN-078-1090	10.7 abc	10.3b	10.5b	3.88
IBWSN-078-1091	11.2 abc	10.9b	11.0b	2.75
IBWSN-078-1095	11.8 a	10.7b	11.2b	10.28
IBWSN-078-1069	10.4abc	10.2b	10.3b	1.96
IBWSN-078-1098	10.8 abc	10.5b	10.6b	2.86
IBWSN-078-1101	10.6 abc	10.7b	10.6b	-0.93
IBWSN-078-1102	11.0 abc	11.3b	11.1b	-2.65
IBWSN-078-1113	10.3 abc	10.4b	10.3b	-0.96
IBWSN-078-1123	9.7bc	9.6b	9.6b	1.04
IBWSN-078-1131	10.4 abc	10.0b	10.2b	4.00
Sarsabz	10.3 abc	12.3b	11.3b	-16.26
Khirman	10.6 abc	11.4b	11.0b	-7.02
Chakwal-86	11.6 a	10.1b	10.8b	14.85
T.D-1	10.4 abc	10.6b	10.5b	-1.89
Overall mean	10.7	11.0	10.8	-2.73

The means with similar alphabetic letter are statistically non significant.

Spikelets spike^{-1}

The significant effect of water stress was found on trait spikelets spike^{-1} (Table 3). Stressed treatment T_1 (single irrigation) showed significant differences in trait spikelets spike^{-1}as compared to T_2 (two irrigation). IBWSN-078-1101 had the maximum number of spikelets spike^{-1} (23.3) followed by Khirman while variety TD-1 had the minimum number of spikelets spike^{-1} (17.3) followed by IBWSN-078-1102 under T_1, values have been given in Table 3. At T_2, genotypes varieties TD-1 and Khirman showed highest number of in spikelets spike^{-1} (23.3 and 23.2 respectively), while genotypes IBWSN-078-1059 and IBWSN-078-1069 showed the lowest number of spikelets spike^{-1} 109.4 and 19.6 respectively. The comparative mean performance for spikelets spike^{-1} at both the water stress treatments showed that the variety Khirman could produce significantly more number of spikelets spike^{-1} followed by IBWSN-078-1090 and the lowest number of spikelets spike^{-1} displayed by IBWSN-078-1131. This trait reduced in T_1 over T_2 by 3.5 %.

Grains spike^{-1}

The water stress showed significant effects on grains spike^{-1} from T_1 and T_2. The trait grains spike^{-1} at T_1 (single irrigation) ranged from 45 grains spike^{-1} in TD-1followed by IBWSN-078-1072, to 64.9 grains in genotype IBWSN-078-1102 followed by khirman at T_1 (Table 4). Four newly evolved genotypes and check variety Khirman produced significantly highest (more than 60) grains spike^{-1} at T_1. At treatment two, Khirman produced minimum number of grains spike^{-1} 47.6 while maximum number of grains spike^{-1} producing genotype was IBWSN-078-1056 which produced maximum 71.1 grains spike^{-1} . On overall mean basis of both the water stress treatments, genotype IBWSN-078-1056 produced significantly highest (66.3) number of grains spike^{-1} than all other contesting entries (Table 4). This trait grains spike^{-1} reduced in T_1 over T_2 by 7.1 %.

Table 3. Mean performance for spikelets spike^{-1} of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	21.1 a-g	20.9abc	21.0 b-h	0.96
IBWSN-078-1059	20.0 e-h	19.4c	19.7fgh	3.09
IBWSN-078-1071	20.4 c-h	21.3abc	20.8 b-h	-4.23
IBWSN-078-1072	19.0 ghi	19.7c	19.3h	-3.55
IBWSN-078-1073	19.8 fgh	21.6abc	20.7 c-h	-8.33
IBWSN-078-1074	19.2 ghi	22.0abc	20.6 c-h	-12.73
IBWSN-078-1174	20.1 e-h	21.6abc	20.8 c-h	-6.94
IBWSN-078-1067	20.9 b-g	19.6c	20.2 e-h	6.63
IBWSN-078-1078	19.6 f-i	20.8abc	20.2 e-h	-5.77
IBWSN-078-1089	20.6 c-h	21.8 abc	21.2b-h	-5.51
IBWSN-078-1090	22.1 a-e	23.1ab	22.6ab	-4.33
IBWSN-078-1091	22.4 a-d	21.9abc	22.1a-d	2.28
IBWSN-078-1095	20.2 d-h	20.9 abc	20.5d-h	-3.35
IBWSN-078-1069	22.6 abc	21.0abc	21.8a-e	7.62
IBWSN-078-1098	19.9 e-h	20.6bc	20.2e-h	-3.39
IBWSN-078-1101	23.3 a	21.3 abc	22.3abc	9.39
IBWSN-078-1102	18.6 hi	23.1ab	20.8c-h	-19.48
IBWSN-078-1113	21.8 a-f	21.7 abc	21.7a-e	0.46
IBWSN-078-1123	20.0 e-h	21.1 abc	20.5d-h	-5.21
IBWSN-078-1131	19.2 ghi	19.7c	19.4gh	-2.54
Sarsabz	21.2 a-g	21.4 abc	21.3b-f	-0.93
Khirman	23.0 ab	23.2ab	23.1a	-0.86
Chakwal-86	21.6 a-f	21.0 abc	21.3b-f	2.86
T.D-1	17.3 i	23.3a	20.3e-h	-25.75
Overall mean	20.6	21.3	20.9	-3.29

The means with similar alphabetic letter are statistically non significant.

1000-Grain weight (g)

The significant effect of water stress were found on trait 1000-grain weight (g) however, genotypes showed different response at both water stresses. The overall mean 1000-grain weight was significantly decreased (39.8 g) at T_1 as compared to T_2 (41.1 g) water stress treatment (Table 5). At T_1, 1000-grain weight (g) ranged from 35.2g in IBWSN-078-1174 followed by IBWSN-078-1090 to 46.7 g in IBWSN-078-1095 followed by IBWSN-078-1078 (Table 11). At T_2, 1000-grain weight (g) ranged of wheat genotypes from 36.6 g in IBWSN-078-1174 followed by IBWSN-078-1123 to 48.8 g in IBWSN-078-1095 followed by IBWSN-078-1078 (Table 5). Taking overall mean of 1000-grain weight, it was observed that IBWSN-078-1095 produced the significantly higher 1000-grain weight (47.7 g) than all other contesting entries followed by IBWSN-078-1078 (Table 5). IBWSN-078-1123 showed minimum increase in number of 1000 grain weight. This trait 1000-grain weight reduced in T_1 over T_2 by 3.1 %.

Grain yield plant^{-1} (g)

The results indicated that wheat genotype showed significant differences among each other for the trait grain yield plant^{-1} at both water stress treatments (Table 6). Significant decrease was observed in overall mean of grain yield plant^{-1} at T_1 (6.31g) as compared with T_2 (7.61g). At T_1, maximum (7.57g) grain yield plant^{-1} was observed in genotype IBSNW-078-1102 followed by IBWSN-078-1089 and minimum was (5.24 g) in IBSNW-078-1174 (Table 6). Grain yield plant^{-1} at T_2 ranged from 9.72 g in genotype IBWSN-078-1056 followed by IBWSN-078-1074 to 6.65 g in variety TD-1 (Table 6). Taking overall mean of both the treatments, it was observed that IBWSN-078-1056 produced the significantly higher (8.29 g) grain yield plant^{-1} than all other genotypes followed by Sarsabz (Table 6). Regarding the trait grain yield plant^{-1} reduction in T_1 over T_2 was 17.1 %.

Table 4. Mean performance for number of grains spike $^{-1}$ of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	61.6 abc	71.1a	66.3a	-13.36
IBWSN-078-1059	51.0 c-g	54.2 c-g	52.6d-g	-5.91
IBWSN-078-1071	50.7 c-g	59.8 a-g	55.2b-f	-15.22
IBWSN-078-1072	45.1g	48.3fg	46.7g	-6.63
IBWSN-078-1073	60.3 a-d	53.7d-g	57.0b-e	12.29
IBWSN-078-1074	49.7 d-g	59.4 a-g	54.5b-g	-16.33
IBWSN-078-1174	47.8 efg	63.9a-d	55.8b-f	-25.2
IBWSN-078-1067	51.0 c-g	63.6a-d	57.3b-e	-19.81
IBWSN-078-1078	53.4 b-g	55.7 b-g	54.5b-g	-4.13
IBWSN-078-1089	61.6 abc	50.4efg	56.0b-f	22.22
IBWSN-078-1090	56.9 a-f	68.3ab	62.6abc	-16.69
IBWSN-078-1091	56.9 a-f	56.8 b-g	56.8b-f	0.18
IBWSN-078-1095	58.6 a-e	66.8abc	62.7abc	-12.28
IBWSN-078-1069	53.7 a-g	55.0 c-g	54.3c-g	-2.36
IBWSN-078-1098	53.0 b-g	62.2a-e	57.6b-e	-14.79
IBWSN-078-1101	55.4 a-g	62.6a-e	59.0a-e	-11.5
IBWSN-078-1102	64.9 a	61.0a-f	62.9ab	6.39
IBWSN-078-1113	45.7 fg	56.9 b-g	51.3efg	-19.68
IBWSN-078-1123	50.8 c-g	55.1c-g	52.9d-g	-7.8
IBWSN-078-1131	60.6 a-d	57.1 b-g	58.8a-e	6.13
Sarsabz	57.2 a-e	64.3a-d	60.7a-d	-11.04
Khirman	62.3 ab	47.6g	54.6b-g	30.88
Chakwal-86	49.7 dg	56.0 b-g	52.8d-g	-11.25
T.D-1	45.0 g	52.0d-g	48.5fg	-13.46
Overall mean	54.3	58.4	56.3	-7.02

The means with similar alphabetic letter are statistically non significant.

Biological yield plant^{-1}(g)

Table 7 exhibited that significant effects of water stress were observed for the trait of biological yield plant^{-1}. Reduction in overall mean of biological yield plant^{-1} was observed at T_1 (22.0 g) as compared to T_2 (24.1 g). The biological yield plant^{-1} showed overall 9.5 % reduction at T_1. At T_1 biological yield plant^{-1} ranged from 17.1 g genotype IBWSN-078-1078 to 28.8 g in IBWSN-078-1090 followed by IBWSN-078-1074 and Chakwal-86 (Table 7). At T_2 (two irrigations), while minimum biological yield plant^{-1} (19.3 g) was recorded from IBWSN-078-1078 the maximum biological yield plant^{-1} producing genotype was IBWSN-078-1090 (33.7 g), followed by Chakwal-86 (Table 7). Genotype IBWSN-078-1090 produced the highest biological yield plant^{-1} (31.2 g) than all other genotypes over both the treatments followed by IBWSN-078-1073 (Table 7).The lowest biological yield plant^{-1}exibited by IBWSN-078-1078. Regarding this trait reduction in T_1 over T_2 was 8.7 %.

Harvest index (%)

Significant effects of water stress were observed for the trait harvest index (Table 8). Reduction in overall mean of harvest index (%) was recorded at T_1 (28.7 %) as compared to T_2 (31.6 %). At T_1, harvest index (%) ranged from 22.2 % in genotype IBWSN-078-1090 to 42.4 % in IBWSN-078-1078 followed by IBWSN-078-1095 (Table 8). Harvest index at T_2, ranged between 23.7 in genotype IBWSN-078-1090 to 43.6 % in IBWSN-078-1095 followed by Sarsabz (Table 8). Genotype IBWSN-078-1095 recorded with highest harvest index (42.7 %) than all other genotypes over both the treatments (Table 8), followed by IBWSN-078-1078 whereas the lowest harvest index displayed by IBWSN-078-1090. This trait harvest index reduced in T_1 over T_2 by 8.7 %.

Table 5. Mean performance for 1000 grain weight (g) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	41.2 cde	43.1def	42.1cde	-4.41
IBWSN-078-1059	41.8 bcd	44.4bcd	43.1c	-5.86
IBWSN-078-1071	39.2 d-h	37.8kl	38.5ijk	3.7
IBWSN-078-1072	39.9 d-g	38.4jkl	39.1g-j	3.91
IBWSN-078-1073	40.0 d-g	40.5hi	40.2fgh	-1.23
IBWSN-078-1074	40.5 c-f	43.9cde	42.2cde	-7.74
IBWSN-078-1174	35.2 j	36.6l	35.9mn	-3.83
IBWSN-078-1067	36.8 hij	41.0gh	38.9g-j	-10.24
IBWSN-078-1078	44.5 ab	46.3b	45.4b	-3.89
IBWSN-078-1089	42.0bcd	43.7cde	42.8c	-3.89
IBWSN-078-1090	36.2 ij	37.9kl	37.0kl	-4.49
IBWSN-078-1091	38.4 e-i	40.3hij	39.3ghi	-4.71
IBWSN-078-1095	46.7a	48.8a	47.7a	-4.3
IBWSN-078-1069	41.8 bcd	42.8 d-g	42.3cde	-2.34
IBWSN-078-1098	37.4 g-j	37.7kl	37.5jkl	-0.8
IBWSN-078-1101	41.1 cde	42.1e-h	41.6c-f	-2.36
IBWSN-078-1102	41.0cde	41.6fgh	41.3def	-1.44
IBWSN-078-1113	37.3 g-j	38.2kl	37.7ijk	-2.36
IBWSN-078-1123	38.1 f-j	37.3kl	37.7ijk	2.14
IBWSN-078-1131	43.2bc	38.9ijk	41.0ef	11.05
Sarsabz	36.3 ij	40.9gh	38.6h-k	-11.25
Khirman	39.6 d-h	45.6bc	42.6cde	-13.16
Chakwal-86	37.6 g-j	37.6kl	37.6jk	0
T.D-1	40.0 d-g	40.9gh	40.4fg	-2.2
Overall mean	39.8	41.1	40.4	-3.16

The means with similar alphabetic letter are statistically non significant.

Physiological traits

Leaf area (cm^2)

Reduction in overall mean of leaf area was recorded at T_1 (18.0 cm^2) as compared to T_2 (24.5 cm^2). Differences among genotypes were observed for leaf area at T_1 which ranged from 11.9 cm^2 in IBWSN-078-1123 to 26.0 cm^2 in Chakwal-86 followed by IBWSN-078-1131 (Table 9). Leaf area at T_2 ranged from 16.5 cm^2 in genotype IBWSN-078-1071 to (35.3 cm^2) in IBWSN-078-1101 followed by IBWSN-078-1089 (Table 9). Five genotypes showed highest values regarding leaf area as compared to check varieties. Genotype IBWSN-078-1101 recorded with significantly the highest leaf area (27.0 cm^2) followed by IBWSN-078-1089 and Chakwal than all other genotypes over both the treatments (Table 9) while the lowest leaf area recorded in IBWSN-078-1123. Regarding the trait leaf area reduction % in T_1 over T_2 was 21.9 %.

Chlorophyll content (%)

Chlorophyll content (%) of wheat genotypes showed significant effects of water stress conditions (Table 10). Overall mean chlorophyll content was significantly decreased at T_1 (39.9 %) as compared to T_2 (48.4 %). At T_1 (single irrigation), chlorophyll content percent ranged from 32 % in genotype IBWSN-078-1078 to 45.2 % in IBWSN-078-1059 followed by TD-1 (Table 10), whereas IBWSN-078-1101 showed minimum chlorophyll content (41.81%) while IBWSN-078-1072 showed maximum chlorophyll content (54.6 %) at T_2 followed by TD-1 (Table 10). Genotype IBWSN-078-1072 and TD-1 produced significantly the highest chlorophyll content % at both water stress treatments (Table 10), whereas the lowest chlorophyll content (3.82 %) displayed by IBWSN-078-1078. Regarding the trait chlorophyll content reduction % in T_1 over T_2 was 17.5 %.

Table 6. Mean performance for grain yield plant^{-1} (g) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	6.87a-f	9.72a	8.29a	-29.32
IBWSN-078-1059	6.19bc-j	7.19de	6.69d-i	-13.91
IBWSN-078-1071	6.06c-j	7.66 b-e	6.86d-i	-20.89
IBWSN-078-1072	5.32j	6.93e	6.12hi	-23.23
IBWSN-078-1073	6.74a-h	7.86 b-e	7.30b-f	-14.25
IBWSN-078-1074	5.73f-j	9.02ab	7.37b-e	-36.47
IBWSN-078-1174	5.24 j	7.67b-e	6.45f-i	-31.68
IBWSN-078-1067	6.03cd-j	7.88b-e	6.95c-i	-23.48
IBWSN-078-1078	6.77a-g	7.48cde	7.125b-g	-9.49
IBWSN-078-1089	7.32ab	6.96e	7.14bc-g	5.17
IBWSN-078-1090	6.29b-j	7.95b-e	7.12b-g	-20.88
IBWSN-078-1091	6.19b-j	7.01de	6.60e-i	-11.7
IBWSN-078-1095	7.18a-d	8.38 a-d	7.78abc	-14.32
IBWSN-078-1069	5.93e-j	7.63 b-e	6.78d-i	-22.28
IBWSN-078-1098	6.02d-j	6.67e	6.34ghi	-9.75
IBWSN-078-1101	6.68 a-h	6.86e	6.77d-i	-2.62
IBWSN-078-1102	7.57 a	7.50cde	7.53a-d	0.93
IBWSN-078-1113	5.57g-j	7.39de	6.48e-i	-24.63
IBWSN-078-1123	5.52hij	7.52cde	6.52e-i	-26.6
IBWSN-078-1131	7.25abc	6.83e	7.04b-h	6.15
Sarsabz	7.03a-e	8.80abc	7.91ab	-20.11
Khirman	6.57a-i	7.51cde	7.04b-g	-12.52
Chakwal-86	5.91e-j	7.58cde	6.74d-i	-22.03
T.D-1	5.44ij	6.65e	6.04i	-18.2
Overall mean	6.31	7.61	6.96	-17.08

The means with similar alphabetic letter are statistically non significant.

DISCUSSION

Spike length (cm): On average, genotypes IBWSN-078-1071 and IBWSN-078-1089 showed significant increase in spike length (14.5 and 12.1cm respectively) The results regarding the spike length depicted that all genotypes showed significant differences among each other for trait spike length. (El-Moneim *et al*., 2008) detected the water stress treatments relative to control treatment was calculated susceptibility index also calculated for each genotype under severe water stress treatment. The main effect of water stress significant for susceptibility index (S) of grain yield plant^{-1}, spike length and some other traits.

Spikelets spike^{-1} The significant effect of water stress was found on trait spikelets spike^{-1}. T_1 showed significant differences in trait spikelets spike^{-1}. IBWSN-078-1101 had the maximum number of spikelets spike^{-1}(23.3) while check variety TD-1 had the minimum number of spikelets spike^{-1} (17.3). At T_2, genotypes IBWSN-078-1102 and IBWSN-078-1090 along with check varieties Khirman and TD-1 showed significant increase in their spikelets spike^{-1}. The comparative mean performance for spikelets spike^{-1} at both the water stress treatments showed that the Khirman variety could produce significantly more number of spikelets spike^{-1}. Same results were recorded by Hassan (2003) and reported that drought stress reduced the plant height, number of kernels spike^{-1}, 100-kernel weight, number of spikelets spike^{-1}, main spike yield and grain yield, regardless of the plant growth stage.

Table 7. Mean performance for biological yield plant^{-1} (g) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	20.8b-e	23.5b-e	22.1c-g	-11.49
IBWSN-078-1059	24.2abc	26.5bcd	25.3bcd	-8.68
IBWSN-078-1071	19.6b-e	22.9b-e	21.2d-g	-14.41
IBWSN-078-1072	18.6cde	20.8de	19.7efg	-10.58
IBWSN-078-1073	25.2ab	28.6ab	26.9b	-11.89
IBWSN-078-1074	25.4ab	28.0abc	26.7b	-9.29
IBWSN-078-1174	21.6b-e	24.8b-e	23.2b-f	-12.9
IBWSN-078-1067	21.3b-e	23.4b-e	22.3c-g	-8.97
IBWSN-078-1078	17.1e	19.3 e	18.2g	-11.4
IBWSN-078-1089	18.7cde	21.0 de	19.8efg	-10.95
IBWSN-078-1090	28.8a	33.7 a	31.2a	-14.54
IBWSN-078-1091	21.9b-e	21.9de	21.9c-g	0
IBWSN-078-1095	17.7de	20.5e	19.1fg	-13.66
IBWSN-078-1069	19.5b-e	20.0e	19.7efg	-2.5
IBWSN-078-1098	22.7b-e	23.2b-e	22.9b-f	-2.16
IBWSN-078-1101	22.8a-e	24.2b-e	23.5b-e	-5.79
IBWSN-078-1102	20.2b-e	23.0b-e	21.6c-g	-12.17
IBWSN-078-1113	20.9b-e	22.4cde	21.6c-g	-6.7
IBWSN-078-1123	22.0b-e	25.0b-e	23.5b-e	-12
IBWSN-078-1131	23.0a-e	24.1b-e	23.5b-e	-4.56
Sarsabz	22.2b-e	21.1de	21.6c-g	5.21
Khirman	24.6abc	26.5bcd	25.5bc	-7.17
Chakwal-86	25.4ab	28.3abc	26.8b	-10.25
T.D-1	23.7a-d	25.2b-e	24.4bcd	-5.95
Overall mean	22.0	24.1	23.0	-8.71

Grains spike^{-1} Four newly evolved genotypes and check variety Khirman produced significantly highest (more than 60) grains spike^{-1} at T_1. The maximum number of grains spike^{-1} were produced by IBWSN-078-1056 (71.1), while Khirman produced minimum number of grains spike^{-1}.On overall mean basis, genotype IBWSN-078-1056 produced significantly higher (66.3) number of grains spike^{-1}. Drought stress before the anthesis in spring wheat also reduces the number of grains spike^{-1} (Ismail *et al*., 1999).

1000-Grain weight (g) The significant effect of water stress was found on this important trait. 1000-grain weight (g) or seed index is considered as one of the most important yield contributing trait in wheat and also serves as best indicator of stress tolerance via kernel weight. Some studies on the wheat and other grain crops have shown that plant water deficit during grain filling substantially effects grain weight (Rahman and Yoshida, 1985), due to early senescence, cessation of grain filling (Hossain *et al*., 1990) and shortening of the grain filling period (Royo *et al*., 2000). The overall mean 1000-grain weight was significantly decreased (39.8 g) at T_1 as compared to T_2 (41.1 g) water stress treatment. The 1000-grain weight (g) at T_2 ranged from 36.6 g to 48.8 g. It was observed that IBWSN-078-1095 produced the significantly highest 1000-grain weight than all other contesting entries over both the treatments.The yield components like grain number and grain size were decreased under pre-anthesis drought stress treatment in wheat (Edward and Wright, 2008).

Table 8. Mean performance for harvest index (%) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	36.3 a-d	41.4 ab	37.2ab	-12.32
IBWSN-078-1059	26.3 def	27.7 cd	27.0gh	-5.05
IBWSN-078-1071	30.8 c-f	34.0 a-d	32.4b-g	-9.41
IBWSN-078-1072	28.6 def	33.6a-d	31.1c-g	-14.88
IBWSN-078-1073	27.5def	27.7cd	27.6fgh	-0.72
IBWSN-078-1074	22.7 ef	32.3a-d	27.5fgh	-29.72
IBWSN-078-1174	24.5 ef	31.4bcd	27.9e-h	-21.97
IBWSN-078-1067	28.5 def	33.8a-d	31.1c-g	-15.68
IBWSN-078-1078	43.9 a	41.2ab	41.8a	6.55
IBWSN-078-1089	42.0ab	33.6a-d	36.7abc	25
IBWSN-078-1090	22.2 f	23.7d	22.9h	-6.33
IBWSN-078-1091	28.7 def	32.2a-d	30.4c-h	-10.87
IBWSN-078-1095	41.8 ab	43.6a	42.7a	-4.13
IBWSN-078-1069	32.6 b-e	38.2 abc	34.3a-e	-14.66
IBWSN-078-1098	26.5 def	29.1cd	27.8e-h	-8.93
IBWSN-078-1101	29.5 def	28.5cd	29.0ef-h	3.51
IBWSN-078-1102	40.5 abc	33.0 a-d	35.3.a-d	22.73
IBWSN-078-1113	21.8 def	33.1a-d	29.9d-h	-34.14
IBWSN-078-1123	25.6 ef	30.8bcd	28.2e-h	-16.88
IBWSN-078-1131	31.5 c-f	28.4cd	29.9d-h	10.92
Sarsabz	32.4 b-f	41.7abc	37.0b-f	-22.3
Khirman	31.9 b-f	29.9bcd	28.9c-g	6.69
Chakwal-86	26.0 ef	28.1cd	26.3gh	-7.47
T.D-1	23.2 ef	26.5cd	24.8gh	-12.45
Overall mean	28.7	31.6	30.1	-9.18

The genotypes with similar letters are statistically non significant.

Grain yield plant^{-1} The overall mean performance for grain yield plant^{-1} indicated that wheat genotype showed significant differences among each other for at both water stress treatments. Significant decrease was observed in overall mean of grain yield plant^{-1} at T_1 (6.31 g) as compared with T_2 (7.61 g). At T_1, maximum (7.57 g) grain yield plant^{-1} was observed in genotype IBSNW-078-1102 and minimum was (5.24 g) in IBSNW-078-1174. Our results are in agreement with (Desalgen*et al.*, 2001) who also reported the significant effects of water stress on grain yield and its associated traits. Genotype IBWSN-078-1056 on average basis, produced the significantly highest (8.29 g) grain yield plant^{-1} than all other genotypes.

Biological yield plant^{-1} Significant effects of water stress were observed for the trait of biological yield plant^{-1}. Reduction in overall mean of biological yield plant^{-1} was observed at T_1 (22.0 g) as compared to T_2 (24.1 g). Biological yield plant^{1} ranged from (17.1 g) genotype IBWSN-078-1078 to (28.8 g) in IBWSN-078-1090 at T_1. The maximum biological yield plant^{-1} producing genotype was IBWSN-078-1090 (33.7 g), while minimum biological yield plant^{-1} (19.3 g) was recorded from IBWSN-078-1078. Genotype IBWSN-078-1090 produced the highest biological yield (31.2 g) than all other genotypes over both the treatments. The adverse effect of drought on the yield previously was studied by (Anges *et al.*, 2002), further they reported water stress was inversely related to the plant size and there is reduction of shoot biomass.

Table 9. Mean performance for leaf area (cm^2) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	18.8c-f	23.5b	21.1bc	-20
IBWSN-078-1059	18.4c-f	20.9b	19.7bc	-11.96
IBWSN-078-1071	19.0cde	16.5 b	17.7bc	15.15
IBWSN-078-1072	20.4bcd	19.4 b	19.9bc	5.15
IBWSN-078-1073	21.0bc	17.4 b	19.2bc	20.69
IBWSN-078-1074	13.3gh	21.8b	17.5bc	-38.99
IBWSN-078-1174	14.8fgh	19.4b	17.1bc	-23.71
IBWSN-078-1067	16.3d-g	22.7b	19.5bc	-28.19
IBWSN-078-1078	17.3c-g	21.6b	19.4bc	-19.91
IBWSN-078-1089	19.5b-e	32.2b	25.8bc	-39.44
IBWSN-078-1090	16.1efg	21.9b	19.0bc	-26.48
IBWSN-078-1091	17.5c-g	24.3b	20.9bc	-27.98
IBWSN-078-1095	18.8c-f	27.2b	23.0bc	-30.88
IBWSN-078-1069	18.6c-f	22.5b	20.5bc	-17.33
IBWSN-078-1098	19.8bcde	21.7b	20.7bc	-8.76
IBWSN-078-1101	18.8c-f	35.3 ab	27.0ab	-46.74
IBWSN-078-1102	18.5c-f	22.7b	20.6bc	-18.5
IBWSN-078-1113	13.8gh	27.5b	20.6bc	-49.82
IBWSN-078-1123	11.9h	19.7b	15.8c	-39.59
IBWSN-078-1131	23.3ab	17.3b	20.3bc	34.68
Sarsabz	16.3d-g	23.8b	20.0bc	-31.51
Khirman	15.9e-h	25.9b	20.9bc	-38.61
Chakwal-86	26.0a	25.7b	25.8bc	1.17
T.D-1	18.1c-f	22.9b	20.5bc	-20.96
Overall mean	18	24.5	21.2	-26.53

The means with similar alphabetic letter are statistically non significant.

Harvest index (%) Significant effects of water stress were observed for the trait harvest index. Reduction in overall mean of harvest index (%) was recorded at T_1 (28.7 %) as compared to T_2 (31.6 %). (Emam *et al.*, 2007) conducted field experiments in Iran, during the 2003-04 cropping season, to study the effects of drought stress on yield and yield components including harvest index of nine bread wheat and one durum wheat genotypes. Post-flowering drought stress reduced the grain yield and yield components in all genotypes. The mean of each trait significantly decreased under drought stress conditions, except for spikelet number $spike^{-1}$ and ear number m^{-2}. Genotype IBWSN-078-1078 recorded with highest harvest index (36.7 %) than all other genotypes over both the treatments.

Leaf area (cm^2) The overall mean performance for leaf area revealed the significant effects of water stress on wheat genotypes. Significant differences among genotypes were observed for leaf area at T_1 which ranged from (11.9 cm^2) in IBWSN-078-1123 to (26.0 cm^2)in Chakwal-86. Genotype IBWSN-078-1101 recorded with significantly the highest leaf area (27 cm^2) than all other genotypes over both the treatments. Development of optimal leaf area is important to photosynthesis and dry matter yield. Water deficit stress mostly reduced leaf growth and in turn the leaf areas in many species of plant like soybean (Zhang *et al.*, 2004).

Table 10. Mean performance for chlorophyll content (%) of wheat genotypes as affected by water stress.

Genotypes	T_1 (Single irrigation)	T_2 (Two irrigations)	Overall mean	Reduction or Promotion (%) in T_1 over T_2
IBWSN-078-1056	44.8ab	51.2a-d	48.0ab	-12.5
IBWSN-078-1059	45.2a	50.9b-e	48.0ab	-11.2
IBWSN-078-1071	43.2a-d	48.7d-i	45.9bcd	-11.29
IBWSN-078-1072	43.2a-e	54.6a	48.9a	-20.88
IBWSN-078-1073	43.6abc	49.8b-g	46.7abc	-12.45
IBWSN-078-1074	40.3c-g	52.1abc	46.2bcd	-22.65
IBWSN-078-1174	40.0d-g	49.3cd-h	44.6 c-g	-18.86
IBWSN-078-1067	33.6ijk	46.8f-j	40.2 jk	-28.21
IBWSN-078-1078	32.0k	44.5jkl	38.2k	-28.09
IBWSN-078-1089	33.1jk	47.6e-j	40.3ijk	-30.46
IBWSN-078-1090	40.2c-g	45.5ijk	42.8 e-h	-11.65
IBWSN-078-1091	38.7fgh	49.1c-h	43.9 d-g	-21.18
IBWSN-078-1095	36.1hij	46.0hijk	41.0hij	-21.52
IBWSN-078-1069	41.5b-f	50.2b-f	45.8bcd	-17.33
IBWSN-078-1098	36.9ghi	48.4d-i	42.6e-i	-23.76
IBWSN-078-1101	40.3c-g	41.8l	41.0hij	-3.59
IBWSN-078-1102	39.2fgh	49.3c-h	44.2d-g	-20.49
IBWSN-078-1113	39.8efg	48.1d-i	43.9d-g	-17.26
IBWSN-078-1123	41.1c-f	46.7g-j	43.9d-g	-11.99
IBWSN-078-1131	40.8c-f	48.8c-i	44.8c-f	-16.39
Sarsabz	42.0ab	48.0d-i	45.0cde	-12.5
Khirman	36.3hij	48.8c-i	42.5 f-j	-25.61
Chakwal-86	41.7b-f	43.0kl	42.3 g-j	-3.02
T.D-1	44.9ab	52.8ab	48.8a	-14.96
Overall mean	39.9	48.4	44.1	-17.56

The means with similar alphabetic letter are statistically non significant.

Chlorophyll content (%)

Chlorophyll content (%) of wheat genotypes showed significant effects of water stress conditions. Overall mean for chlorophyll content was significantly decreased at T_1 (39.9 %) as compared to T_2 (48.4 %). IBWSN-078-1072 showed maximum chlorophyll content (54.6 %) while IBWSN-078-1101 showed minimum chlorophyll content (41.8 %) at T_2. IBWSN-078-1072 and TD-1 produced significantly the highest chlorophyll content % at both water stress treatments. (Ashraf *et al*., 1994) observed reduction in chlorophyll (a, b and total) in *Triticum aestivum* under the stress.

CONCLUSION

It is concluded that highly significant differences among genotypes, treatments and genotype x treatment interaction for different yield and yield associated traits viz., spike length (cm), peduncle length (cm), spikelets spike^{-1}, grains spike^{-1}, 1000-grains weight (g), grain yield plant^{-1} (g), biological yield plant^{-1}, harvest index (%), leaf area (cm^2) and chlorophyll content (%).

The genotype IBWSN-078-1078 showed better performance in grain yield plant^{-1} and superiority in more than three yield components followed by IBWSN-O78-1095 and IBESN-078-1101 at T_1 whereas genotype IBWSN-078-1174 showed superiority in four yield components followed by IBWSN-078-1089 and IBWSN-078-1056 at $T_{2.}$

Genotype IBWSN-078-1078 recorded with the highest harvest index (36.7 %) than all other genotypes over both the treatments. While genotype IBWSN-078-1101 was recorded with the highest leaf area (19.7 cm^2) than all other genotypes over both the treatments, whereas genotype IBWSN-078-1072 and TD-1 produced the highest chlorophyll content at both water stress treatments.

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

Source of Variation	D.F	Mean Squares (M.S)								
		Spike length	Spikeletes spike^{-1}	Grains spike^{-1}	1000 grain wt.	Grain yield plant^{-1}	Biological yield plant^{-1}	Harvest index	Leaf area	Chlorophyll content
Replications	2	6.66518	0.4643	119.085	2.2861	1.2117	16.826	37.516	22.582	0.02
Treatments	1	3.71847ns	20.4530ns	613.718*	57.4438**	61.0612**	157.984*	147.704ns	923.603**	2589.11**
Error Rep x Trt	2	6.64429	5.0137	26.411	0.5509	0.4937	3.247	10.592	1.412	1.14
Varieties	23	5.89597ns	5.4968**	127.890**	47.7824**	1.8331**	54.335**	165.293**	42.998**	48.83**
Trt x Var	23	5.87242ns	4.7516**	87.218*	6.7961**	1.2790**	2.370ns	28.682ns	43.728**	18.33**
Error Rep x Trt x Var	92	6.72915	2.0793	49.722	1.9909	0.5814	12.254	41.512	6.818	3.96
Total	143									

* = Significant at 0.05 level of probability
** = Significant at 0.01 level of probability
ns = Non Significant