ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2017, 33 (1): 1-11

EFFECT OF WATER STRESS ON SOME PHYSIOLOGICAL TRAITS OF BREAD WHEAT GENOTYPES

M. A. Sial[1], S. M. Mangrio[2], H. Bux[2], A. W. Channa[2] and M. Shaikh[1]

[1]Nuclear Institute of Agriculture, Tandojam, Pakistan
[2]Institute of Plant Sciences, University of Sindh, Jamshoro, Pakistan

ABSTRACT

Water stress is the main environmental constraint to the wheat crop. The effects of water stress on some physiological parameters viz., relative water content (%), leaf area, chlorophyll content (%) and osmotic potential of newly evolved wheat genotypes were studied. Significant effects ($P \leq 0.05$) of water stress were observed on studied physiological parameters. Genotypes showed variable response to various water deficit conditions for their physiological traits. The reduction in osmotic potential under water stress is often considered as important adaptive physiological mechanism. The advance lines NIA-8/7, followed by BWM-3, NIA-9/5, NIA-37/6, NIA-10/8, NIA-28/4, NIA-30/5, NIA-25/5, ESW-9525, SI-91196, SI-9590, MSH-14, MSH-36, MSH-22, BWQ-4, BWS-78, BWM-47 showed significantly lower osmotic potential (ranged from -2.0 to -2.85MPa); while genotypes BWS-77, BWM-84, MSH-17 showed comparatively higher osmotic potential (less than -2.0MPa) under severe moisture stress. These results suggested that genotypes with the lowest osmotic potential possess more tolerance to drought as they have capabilities to maintain their osmotic potential under moisture stress. Genotype NIA-10/8 (86.1%), followed by 14 other genotypes had significantly higher relative water content (RWC) percent (above 69.5%) at severe water stress; which suggested that these genotypes could be more drought tolerant. Genotype BWS-78 showed significantly higher chlorophyll (51.67%) than other genotypes.

Keywords: osmotic potential, physiological parameters, water-stress tolerance, wheat

INTRODUCTION

Wheat is an important cereal food crop of Pakistan. The agriculture sector in Pakistan contributes 20.9 percent to GDP and employing 43.5 percent of the workforce while wheat contributes 10.0 % to the value added in agriculture and 2.1 percent to GDP (Pakistan Economic Survey, 2014-15). It has been reported that wheat yields are reduced by more than 50% of their irrigated potential by drought on at least 60 million ha in the developing countries (Reynolds *et al.,* 1999; Ali *et al*., 2010; Jatoi *et al*., 2011). Wheat production is affected due to rust

---

Corresponding author: awabdulwajid440@gmail.com diseases and environmental factors such as water stress, high temperature and salinity (Sial *et al*., 2009; Bux *et al*., 2012). Water stress affects every factor of plant growth and the productivity of a crop modifying the morphology, phenology, physiology, anatomy and biochemistry (Turner and Begg, 1981; Blum, 1988; Rebetzke and Richards, 1999; Akram *et al.,* 2004; Zhang *et al*., 2004; Sial *et al*., 2013). The crop productivity can be enhanced under water-limited conditions through the improvement of particular drought-related traits through breeding strategies by evolving wheat varieties possessing tolerance to water stress (Denadai and Klar, 1995; Samir *et al.,* 1997; Strauss and Agenbag, 2000; Mohammady, 2007; Sial *et al.,* 2007). Several morphological (coleoptile length, seed size, early ground cover, pre-anthesis biomass, thick stem, high tiller survival, stay green), physiological and biochemical (stem reserves/ remobilizations, spike photosynthesis, stomatal conductance, osmotic adjustment, accumulation of abscisic acid (ABA),and leaf anatomical traits (waxiness, pubescence, leaf rolling, thickness) have been reported as drought adaptive traits in wheat (Sayre *et al.,* 1995; Reynolds *et al.,* 1999; Mirbahar *et al.,* 2009). Nowadays in crop plants, osmoprotectants and growth promoters have been considered as short-term solution for alleviating the adverse affects induced through environmental factors such as drought, etc. (Khan *et al.,* 2009). The decrease in osmotic potential is usually considered as an essential adaptive mechanism for drought tolerance when active accumulation of organic and inorganic solutes occurs; which leads to maintain the turgor potential under stress conditions. The present study was therefore conducted to determine the effects of water stress on some physiological parameters of newly developed wheat genotypes. The knowledge developed through this research will be useful for breeding programs in identifying the suitable water stress tolerant genotypes.

MATERIALS AND METHODS

To determine the effects of water stresses at various growth stages, the physiological parameters of wheat genotypes were studied. Twenty one wheat genotypes (advance/mutant lines) and four local check varieties Sarsabz, Thorhi (awn less), Margalla-99 and Chakwal-86 were evaluated at Nuclear Institute of Agriculture (NIA), Tandojam. Four different experiments were conducted with three replications using randomized complete block design (RCBD). Each genotype was sown in four rows 3m of length. The experiments were surrounded with 2.5 m buffer zone to protect from any seepage or leakage of water from neighboring plots/channels. Sowing of wheat genotypes was done in the second week of November under normal planting time. Water stress was imposed at various critical growth stages viz., seedling/tillering, pre-anthesis (booting or ear emergence/heading) and post-anthesis at grain filling period (milky or dough) of crop using four different irrigation levels (single, two, three and four irrigation during entire crop season). First experiment was irrigated once during seedling/tillering stage after two weeks of sowing, then further irrigations were withheld up to ripening. Second experiment was irrigated twice during entire season (one irrigation at seedling/tillering after 14 days of sowing and second at tillering stage after four weeks of sowing) and then further irrigations were stopped up to maturity. Third experiment received 3-irrigations i.e., at seedling/tillering (after two weeks), pre-anthesis (tillering/booting) after 4 weeks of sowing and third at post-anthesis (milky-dough stage) after 94 days of sowing. Fourth experiment was subjected to 4 irrigations each at seedling/tillering (after two weeks of sowing), pre-anthesis (tillering/booting) after 4 weeks of sowing, post-anthesis (milky stage) after 87 days of sowing, and fourth irrigation was applied at post-anthesis (dough stage) after 113 days of sowing.

Physiological parameters studied were osmotic potential, relative water content (RWC), fresh, dry and turgid weight, chlorophyll content and leaf area. Data recorded were subjected to analysis of variance (ANOVA) (two way ANOVA) to see the significant ($P \leq 0.05$) differences among genotypes and treatments and the means were compared using Duncan’s multiple range test (DMRT) through the statistical software Statistix Version (8.1).

Determination of osmotic potential (-MPa)

Five fully expanded leaves from each 25 wheat genotypes were randomly taken from central two rows of each three replications of four water stress treatments. Osmotic potential measurements were performed with calibrated Micro-Osmometer (Model 5004, Precision System INC, USA) by killing the leaf in chloroform vapors immediately after harvest and extracting the cell sap by Shardakov method.

Relative water content (%)

Relative water content (RWC) was determined immediately after excising the next leaf to the flag leaf of each genotype. Fresh weight (FW) of leaves was taken, then floated in distilled water for 24 hours in dark and the turgid weight was recorded on the next day. After taking turgid weight (TW) the samples were oven dried at 70^0C for 48 hours then dry weight (DW) was recorded. The RWC was calculated by formula given below (Barr and Weatherly, 1962):

$$\text{Relative water content (RWC)} = \frac{\text{Fresh weight (FW) - Dry weight (DW)}}{\text{Turgid weight (TW) - Dry weight (DW)}} \times 100$$

Chlorophyll content (%)

The chlorophyll content (CC) was measured by Chlorophyll Meter (Minolta, SPAD-502, Japan). The second leaf from flag leaf was measured at 3 positions for chlorophyll content during heading stage. The chlorophyll content (CC) was calculated with a standard curve of total chlorophyll concentration, according to Shabala *et al.* (1998).

Leaf area (cm^2)

Leaf area was measured with Leaf Area Meter (LI-COR, Lincoln, NE, USA).

RESULTS AND DISCUSSION

Physiological parameters viz., relative water content (%), leaf area, chlorophyll content (%), and osmotic potential of wheat genotypes showed significant ($P \leq 0.05$) effects of various water stresses.

Relative water content (RWC %)

Significant effects of water stress were observed for relative water content (RWC) percent of wheat genotypes, as it was reduced at low water availability. The overall decrease in relative water content (RWC) of all wheat genotypes was linear; as the number of irrigations decreased (one, two, three and four) the RWC percent also decreased (72.5, 81.0, 86.7, 90.5, respectively). Naeem *et al.* (2015) reported that relative water content was decreased due to water shortage.

Similarly, fresh, turgid and dry weight of leaves of wheat genotypes also showed overall decrease due to various water stress conditions (2-4). Genotype NIA-10/8 showed comparatively more relative water content (86.1 %) than other genotypes at severe water stress (single irrigation); however, genotypes SI-9590, BWM-84 and ESW-9525 had significantly the lowest RWC (56.7, 56.0 and 60.4% respectively) (Table 1). Other 5 genotypes BWM-3, NIA-8/7, NIA-37/6, SI-91196 and BWS-78 had also increase (>79.0 %) in relative water content (RWC) percent, which suggests that these genotypes have potential to retain more water content in their cell sap under high water stress. Relative water content (RWC) percent ranged from 56.0 to 86.1% at single irrigation. At two irrigations, four genotypes BWM-84, SI-9590, NIA-30/5 and BWM-47 showed significant reduction in RWC (%) as compared to all other genotypes. At three irrigations, RWC (%) increased and ranged from 74.5 % in MSH-22 to 94.4% in MSH-14. In well-irrigated trial, ESW-9525 and NIA-8/7 showed significant increase (>95.0%) in RWC (%) (Table1). The studies have shown that the increase in the drought stress, decreases the relative water content and total chlorophyll in wheat genotypes (Keyvan, 2010; Allahverdiyev *et al*., 2015).

Leaf area (cm^2)

The significant ($P\leq 0.05$) effects of various water stresses were observed on leaf area of wheat genotypes. Mean leaf area showed decrease with high moisture stress, whereas it increased with low water stress. Three genotypes NIA-30/5, MSH-36 and ESW-9525 showed overall decrease (32.8, 32.6 and 32.7 cm respectively) in leaf area; while SI-91196 BWS-78, NIA-8/7, Chakwal-86, NIA-25/1, MSH-22, BWM-84, BWS-77, Margalla-99, NIA-10/8 and Sarsabz had high mean leaf area (40.3 to 48.7 cm) at various water stresses (Table 2). Genotype SI-91196 had the highest (45.5 cm) leaf area, followed by NIA-25/1 (42.4 cm) and Chakwal-86 (41.7 cm) at severe water stress (single irrigation). At moderate water stress (two irrigation), a genotype NIA-8/7 had shown comparatively more leaf area (54.97 cm), followed by other 11 genotypes which is showing significantly ($P \leq 0.05$) less reduction with water stress conditions than all other contesting genotypes and check varieties (Table 2). In a study, Gupta *et al.* (2001) also found higher leaf diffusive resistance of water stress at anthesis in some of wheat cultivars studied. Reduction in leaf area (LA) by water stress is an important cause of reduced crop yield through decline in photosynthesis (Rucker *et al*., 1995). Allahverdiyev *et al*. (2015) reported significant ($P\leq 0.05$) decline in leaf area in test wheat cultivars, because the surface area of leaf is limited due to water stress condition. Hammad and Ali (2014) studied growth traits of wheat as affected by various water stress conditions and concluded that the leaf area surface was negatively affected by water stress.

Table 1. Relative water content (%) of wheat genotypes as affected by various water stresses

Genotypes	**Relative water content (%)**				
	Single irrigation	**Two irrigations**	**Three irrigations**	**Four irrigations**	**Mean**
BWM-3	81.00 abc	87.70 ab	76.47 a	89.97 abc	83.8
NIA-8/7	83.77 ab	93.87 a	92.90 a	95.93 a	91.6
NIA-9/5	74.70 abc	87.67 ab	84.20 a	94.80 ab	85.3
NIA-37/6	79.20 abc	86.07 ab	88.60 a	92.20 abc	86.5
NIA-10/8	86.17 a	88.33 ab	88.67 a	92.07 abc	88.8
NIA-25/1	76.50 abc	80.40 ab	86.43 a	90.67 abc	83.5
NIA-28/4	70.33 abc	73.63 abc	84.40 a	91.63 abc	80.0
NIA-30/5	69.90 abc	72.57 bc	91.90 a	89.90 abc	81.1
NIA-25/5	67.30 bcd	80.13 ab	91.73 a	92.17 abc	82.8
ESW-9525	60.47 ef	81.27 ab	84.40 a	95.63 a	80.4
SI-91196	79.20 abc	88.67 ab	93.73 a	93.80 ab	88.9
SI-9590	56.73 f	71.33 bc	83.80 a	83.97 cde	74.0
MSH-14	73.00 abc	85.27 ab	94.43 a	94.60 ab	86.8
MSH-17	65.07 cde	75.43 abc	93.93 a	86.33 bcd	80.2
MSH-36	69.37 abc	82.10 ab	92.93 a	89.50 abc	83.5
MSH-22	72.40 abc	85.80 ab	74.53 a	90.47 abc	80.8
BWQ-4	72.80 abc	76.30 abc	84.50 a	91.43 abc	81.3
BWS-77	71.37 abc	76.00 abc	86.53 a	89.23 abc	80.8
BWM-84	56.03 f	57.83 c	79.17 a	83.17 de	69.1
BWS-78	80.93 abc	85.03 ab	94.07 a	94.67 ab	88.7
BWM-47	63.53 def	70.80 bc	77.30 a	82.00 e	73.4
Sarsabz	77.53 abc	86.03 ab	89.70 a	89.67 abc	85.7
Thorhi	75.20 abc	77.10 abc	77.67 a	86.60 bcd	79.1
Margalla-99	77.33 abc	86.83 ab	86.80 a	91.47 abc	85.6
Chakwal-86	72.27 abc	87.97 ab	88.40 a	91.27 abc	85.0
Mean	72.5	81.0	86.7	90.5	82.7

Means denoted by the same letters in a column are not significantly different among each other at $P < 0.05$; each value is the mean of 3 replicates.

Chlorophyll content (%)

The overall reduction in chlorophyll content (%) was observed at severe and moderate (47.9 and 48.9%, respectively) water stress. The chlorophyll content (%) of wheat genotypes increased with increase in irrigation applications as 51.3 and 53.4% (three and four irrigations, respectively). Differential response of wheat genotypes was observed for chlorophyll content (%) at various water stress conditions. Eighteen genotypes showed less reduction in their leaf chlorophyll (%); however, BWS-78 showed comparatively less reduction in chlorophyll % than other genotypes at severe stress (Table 3). Other genotypes BWM-3 and NIA-8/7 also showed less reduction (50.8 and 50.03%, respectively) in chlorophyll content (%) at severe stress. This indicates that these genotypes could be more tolerant to water stress as compared to other genotypes. MSH-36 and NIA-28/4 showed more significant ($P \leq 0.05$) reduction at severe stress as both had less chlorophyll content (43.6 and 44.4%, respectively). Six genotypes

NIA-8/7, NIA-10/8, NIA-25/1, SI-91196, MSH-14, and BWS-78 showed significant ($P \leq 0.05$) increase in chlorophyll content (%) than other all genotypes at medium water stress (two irrigations) conditions. These findings suggest that these genotypes maintain their chlorophyll content under stress conditions, hence could produce more yield under harsh environments. A decrease in total chlorophyll with drought stress implies a lowered capacity for light harvesting. Since the production of reactive oxygen species is mainly driven by excess energy absorption in the photosynthetic apparatus, this might be avoided by degrading the absorbing pigments (Mafakheri *et al*., 2010). Naeem *et al*. (2015) observed decrease in total chlorophyll content under lower water supply treatments. Chachar *et al.* (2016) recorded the reduction in chlorophyll content with increase of water stress condition.

Table 2. Leaf area (cm^2) of wheat genotypes as affected by various water stresses

Genotypes	**Leaf area (cm^2)**				
	Single irrigation	**Two irrigations**	**Three irrigations**	**Four irrigations**	**Mean**
BWM-3	33.83 cde	36.00 bc	37.67 bcd	43.13 abc	37.7
NIA-8/7	36.77 bcd	54.97 a	44.20 abc	50.40 abc	46.6
NIA-9/5	35.17 cde	31.97 c	40.83 abc	48.40 abc	39.1
NIA-37/6	29.50 gh	34.40 bc	38.27 bcd	41.10 bcd	35.8
NIA-10/8	36.77 bcd	32.57 bc	44.73 abc	54.93 ab	42.3
NIA-25/1	42.43 ab	38.67 abc	47.93 ab	50.00 abc	44.8
NIA-28/4	35.00 cde	33.60 bc	35.73 bcd	40.80 bcd	36.3
NIA-30/5	32.43 def	26.57 c	34.43 cd	37.60 def	32.8
NIA-25/5	31.70 efg	34.57 bc	37.63 bcd	42.93 abc	36.7
ESW-9525	27.30 h	29.70 c	37.03 bcd	36.73 ef	32.7
SI-91196	45.50 a	44.03 abc	47.90 ab	57.33 a	48.7
SI-9590	37.53 bcd	33.40 bc	36.20 bcd	44.60 abc	37.9
MSH-14	35.27 cde	32.97 bc	38.90 bcd	44.60 abc	37.9
MSH-17	29.67 gh	31.77 c	41.17 abc	39.07 cde	35.4
MSH-36	31.87 efg	37.57 abc	30.43 d	30.67 f	32.6
MSH-22	39.23 bc	35.73 bc	47.10 abc	55.00 ab	44.3
BWQ-4	30.73 fgh	35.27 bc	39.97 bcd	42.60 abc	37.1
BWS-77	36.50 bcd	38.53 abc	45.70 abc	53.93 abc	43.7
BWM-84	39.17 bc	42.10 abc	43.93 abc	50.27 abc	43.9
BWS-78	38.07 bcd	50.03 ab	52.93 a	50.20 abc	47.8
BWM-47	34.03 cde	38.47 abc	45.67 abc	37.87 def	39.0
Sarsabz	33.90 cde	42.50 abc	41.57 abc	43.07 abc	40.3
Thorhi	35.10 cde	38.33 abc	43.07 abc	42.73 abc	39.8
Margalla-99	34.53 cde	42.67 abc	46.90 abc	47.47 abc	42.9
Chakwal-86	41.67 ab	42.43 abc	46.50 abc	52.87 abc	45.9
Mean	35.35	37.55	41.86	45.53	40.07

Means denoted by the same letters in a column are not significantly different among each other at $P < 0.05$; each value is the mean of 3 replicates.

Table 3. Chlorophyll content (%) of leaves of wheat genotypes as affected by various water stresses

Genotypes	**Chlorophyll content (%)**				
	Single irrigation	**Two irrigations**	**Three irrigations**	**Four irrigations**	**Mean**
BWM-3	50.83 ab	48.47 ab	53.13 abc	51.57 bc	51.0
NIA-8/7	50.03 abc	51.53 a	47.70 cd	51.57 bc	50.2
NIA-9/5	49.67 abc	49.67 ab	55.40 a	50.70 c	51.4
NIA-37/6	45.67 bcd	47.93 ab	47.70 cd	51.30 bc	48.2
NIA-10/8	48.40 abc	52.37 a	48.77 bcd	53.90 abc	50.9
NIA-25/1	49.83 abc	50.57 a	54.53 ab	56.73 ab	52.9
NIA-28/4	44.40 de	47.90 ab	53.23 abc	52.87 abc	49.6
NIA-30/5	45.67 bcd	48.60 ab	50.17 abc	51.20 bc	48.9
NIA-25/5	44.80 cde	49.63 ab	52.07 abc	53.53 abc	50.0
ESW-9525	47.63 abc	49.80 ab	49.50 abc	51.53 bc	49.6
SI-91196	49.97 abc	52.70 a	52.93 abc	54.60 abc	52.6
SI-9590	45.03 cde	49.60 ab	54.77 ab	53.67 abc	50.8
MSH-14	48.77 abc	51.43 a	53.07 abc	53.23 abc	51.6
MSH-17	45.67 bcd	49.60 ab	54.00 ab	53.30 abc	50.6
MSH-36	43.63 e	48.13 ab	52.03 abc	53.03 abc	49.2
MSH-22	47.80 abc	48.93 ab	53.20 abc	55.00 abc	51.2
BWQ-4	49.10 abc	49.10 ab	50.87 abc	56.17 abc	51.3
BWS-77	49.30 abc	49.27 ab	51.50 abc	53.33 abc	50.9
BWM-84	49.30 abc	47.67 ab	50.53 abc	56.23 abc	50.9
BWS-78	51.67 a	52.13 a	52.43 abc	52.63 abc	52.2
BWM-47	47.87 abc	39.40 c	49.53 abc	51.73 bc	47.1
Sarsabz	49.73 abc	48.33 ab	51.70 abc	57.67 a	51.9
Thorhi	49.40 abc	49.37 ab	46.27 d	54.77 abc	50.0
Margalla-99	46.63 abc	44.03 bc	47.10 cd	53.90 abc	47.9
Chakwal-86	46.70 abc	48.43 ab	51.30 abc	51.77 abc	49.6
Mean	47.90	48.98	51.34	53.44	50.41

Means denoted by the same letters in a column are not significantly different among each other at $P< 0.05$; each value is the mean of 3 replicates.

Osmotic potential (-MPa)

Some genotypes performed well under moisture stress as they maintained a significant ($P\leq 0.05$) lower osmotic potential, however others couldn't compete under stress conditions as they have shown higher osmotic potential. The osmotic potential under water stress is considered as a mechanism to maintain turgor pressure, which is brought about by the accumulation of solutes in cell sap. It has been reported that the plants with lower osmotic potential (more -ve values) are known as drought tolerant. Significant ($P\leq 0.05$) differences among genotypes were observed for osmotic potential at severe stress while in other water stress treatments non-significant ($P\leq 0.05$) differences were recorded between genotypes. Increase in moisture stress showed significant ($P\leq 0.05$) marked effects on the leaf osmotic potential of all the genotypes. The mean osmotic potential gradually decreased with the increase in moisture stress; however genotypes showed different response to various moisture stresses.

Table 4. Osmotic potential (-MPa) of wheat genotypes as affected by various water stresses

Genotypes	Osmotic potential (-MPa)				
	Single irrigation	Two irrigations	Three irrigations	Four irrigations	Mean
BWM-3	2.460 abc	1.816 a	1.798 a	1.693 a	1.94
NIA-8/7	2.855 a	2.472 a	1.898 a	1.916 a	2.29
NIA-9/5	2.347 abc	2.169 a	1.459 a	1.700 a	1.92
NIA-37/6	2.300 abc	2.032 a	1.652 a	1.588 a	1.89
NIA-10/8	2.725 ab	2.466 a	2.001 a	1.761 a	2.24
NIA-25/1	1.891 bc	1.824 a	1.603 a	1.520 a	1.71
NIA-28/4	2.002 abc	1.901 a	1.796 a	1.891 a	1.90
NIA-30/5	2.181 abc	2.157 a	1.738 a	1.937 a	2.00
NIA-25/5	2.318 abc	2.116 a	1.734 a	1.676 a	1.96
ESW-9525	2.501 abc	2.376 a	1.790 a	1.466 a	2.03
SI-91196	2.729 ab	2.363 a	1.935 a	1.807 a	2.21
SI-9590	2.122 abc	2.065 a	1.620 a	1.197 a	1.75
MSH-14	2.593 abc	2.343 a	1.687 a	1.616 a	2.06
MSH-17	1.835 c	1.992 a	1.855 a	1.516 a	1.80
MSH-36	2.296 abc	2.132 a	1.540 a	1.305 a	1.82
MSH-22	2.182 abc	2.231 a	1.728 a	1.453 a	1.90
BWQ-4	2.470 abc	2.231 a	1.885 a	1.718 a	2.08
BWS-77	1.897 bc	2.106 a	1.664 a	1.540 a	1.80
BWM-84	1.958 bc	2.285 a	1.739 a	1.525 a	1.88
BWS-78	2.638 abc	2.306 a	1.866 a	1.900 a	2.18
BWM-47	2.055 abc	1.936 a	1.499 a	1.759 a	1.81
Sarsabz	2.121 abc	2.211 a	1.941 a	1.850 a	2.03
Thorhi	2.303 abc	1.872 a	1.531 a	1.784 a	1.87
Margalla-99	2.097 abc	1.809 a	1.960 a	1.812 a	1.92
Chakwal-86	2.156 abc	2.108 a	1.671 a	1.382 a	1.83
Mean	2.28	2.13	1.74	1.65	1.95

Means denoted by the same letters in a column are not significantly different among each other at $P < 0.05$; each value is the mean of 3 replicates.

The decrease in leaf osmotic potential of wheat genotypes under severe water stress could be due to the reduction in water content as a result of its loss from cell due to dehydration. Under water stress conditions, osmotic adjustment helps in maintaining growth and other physiological functions of plants and therefore, a genotype with high osmotic adjustment under drought could be the high yielding (Steven, *et al.,* 1990; Singh and Singh, 1989). Genotype NIA-8/7 showed the comparatively lower osmotic potential (higher -ve values i.e., 2.85 -MPa) than all other genotypes at severe stress (single irrigation). Genotypes showing below osmotic potential (ranging from 1.83 to 2.85 -MPa) at severe stress were NIA-8/7, BWM-3, NIA-9/5, NIA-37/6, NIA-10/8, NIA-28/4, NIA-30/5, NIA-25/5, ESW-9525, SI-91196, SI-9590, MSH-14, MSH-36, MSH-22, BWQ-4, BWS-78, BWM-47 and all four checks; which indicated that these genotypes possess more tolerance to water stress (Table 4). The actual plant water status in leaves depends on the osmotic conditions of cells and transport of water from the shoots (Lawlor and Cornic 2002). During the inhibition of water transport from the root, osmotic regulation may actively influence water potential in assimilating tissues and limit the detrimental effects of water deficiency on photosynthesis. Chachar *et al*. (2016) and Hammad and Ali (2014) recorded enhancement in osmotic potential (OP) with increase in various water stresses in used wheat cultivars.

CONCLUSION

It has been concluded that all the studied physiological parameters viz., relative water content, leaf area, chlorophyll content and osmotic potential of newly developed wheat genotypes showed significant reduction at water stress conditions. The severe water stress (single irrigation) showed more effects to the physiological traits as compared to other irrigation levels (two and three) and the control. Our preliminary findings suggested that the newly advance genotypes NIA-8/7, BWM-3, NIA-9/5, NIA-37/6, NIA-10/8, NIA-28/4, NIA-30/5, NIA-25/5, ESW-9525, SI-91196, SI-9590, MSH-14, MSH-36, MSH-22, BWQ-4, BWS-78 and BWM-47 possesses some genetic improvement for the tested physiological traits; which reflected their tolerance to water stress conditions. The present detailed studies of new genotypes could be useful to the breeders during selection of water stress tolerant genotypes. The genotypes endowed with basic physiological traits will be used for future breeding programme as the potentially better drought-tolerant genotypes.

REFERENCES

Akram, H. M., M. S. Iqbal, M. Saeed, A. Yar, A. Ali, K. A. Sahi and M. A. Nadeem. 2004. Drought tolerance studies of wheat genotypes. Pak. J. Biol. Sci., 7 (1): 90-92.

Ali, A. M., A. N. Boyce and S. S. Barakbah. 2010. Spike traits and characteristics of durum and bread wheat genotypes at different growth and developmental stages under water-deficit conditions. Aust. J. Basic Appl. Sci., 4 (2): 144-150.

Allahverdiyev, T. I. 2015. Physiological traits of durum wheat (*Triticum durum* Desf.) and bread wheat (*Triticum aestivum* L.) genotypes under drought stress. Agril. Sci., 6: 848-859.

Allahverdiyev, T. I., J. M. Talai., I. M. Huseynova, J. A. Aliyev. 2015. Effect of drought stress on some physiological parameters, yield and yield components of durum (*Triticum durum* desf.) and bread (*Triticum aestivum* L.) wheat genotypes. Ekin. J. Crop Breed. Genet., 1-1: 50-62.

Barr, H. D. and P. E. Weatherley. 1962. A re-examination of the relative turgidity technique for estimating water deficit in leaves. Aust. J. Biol. Sci., 15:413-428.

Blum, A. 1998. Improving wheat grain filling under stress by stem reserve mobilisation. Euphytica, 100 (1): 77-83.

Bux, H., A. Rasheed, M. A. Sial, A. G. Kazi, A. Z. Napir and A. M. Kazi. 2012. An overview of stripe rust of wheat (*Puccinia striiformis* f. sp. *tritici*) in Pakistan. Archives of Phytopathology and Plant Protection (UK). 45 (19): 2278-2289.

Chachar, M. H., N. A. Chachar, Q. Chachar, S. M. Mujtaba, S. Chachar, Z. Chachar. 2016. Physiological characterization of six wheat genotypes for drought tolerance. Inter. J. Res. Granthaalayah, 4 (2): 184-196.

Denadai, I. A. M. and A. E. Klar. 1995. Drought resistance in four wheat cultivars: physiological parameters. Scientia Agricola, 52 (2): 274-281.

Gupta, N. K., S. Gupta and A. Kumar. 2001. Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages. J. Agron. Crop Sci., 186: 55-62.

Hammad, S. A. R. and O. A. M. Ali. 2014. Physiological and biochemical studies on drought tolerance of wheat plants by application of amino acids and yeast extract. Annals Agril. Sci., 59 (1): 133-145.

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

Keyvan, S. 2010. The effects of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. J. Anim. Pl. Sci., 8 (3): 1051-1060.

Khan, S. U., A. Bano, J. U. Din and S. S. Tahir 2009. Sacylic acid induced physiological and biochemical changes in wheat under drought stress conditions. Pak. J. Sci. Ind. Res., 52 (2): 75-79.

Lawlor, D. W. and G. Cornic 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant, Cell Environ., 25 (2): 275-294.

Mafakheri, A., A. Siosemardeh, B. Bahramnejad, P.C. Struik, E. Sohrabi. 2010. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Aust J. Crop Sci., 4 (8): 580-585.

Mirbahar, A. A., G. S. Markhand, A. R. Mahar, S. A. Abro and N. A. Kanhar. 2009. Effect of water stress on yield and yield components of wheat (*Triticum aestivum* L.) varieties. Pak. J. Bot., 41 (3): 1303-1310.

Mohammady, D. S. 2007. Physiological characters associated with water-stress tolerance under pre anthesis water-stress conditions in wheat. Wheat Information Service, 104: 1-13.

Naeem, M. K., M. Ahmad, M. Kamran, M. K. N. Shah and M. S. Iqbal. 2015. Physiological responses of wheat (*Triticum aestivum* L.) to drought stress. Int. J. Plant Soil Sci., 6 (1): 1-9.

Pakistan Economic Survey. 2014-15. Ministry of Finance Food, Agriculture and Livestock, Federal Bureau of Statistics, Government of Pakistan, pp. 06.

Rebetzke, G. J. and R. A. Richards. 1999. Genetic improvement of early vigour in wheat. Aust. J. Agric. Res., 50: 291-301.

Reynolds, M. P., B. Skovmand, R. M. Trethowan and W. H. Pfeiffer. 1999. Evaluating a concept model for drought tolerance. *In:* Using molecular markers to improve drought tolerance. J. M. Ribaut (Ed.), Mexico, D. F. CIMMYT.

Rucker, K. S., C. K. Kevin, C. C. Holbrook and J. E. Hook. 1995. Identification of peanut genotypes with improved drought avoidance traits. Peanut Sci., 22 (1): 14-18.

Samir, K., M. El-Mourid and M. Ismaili. 1997. Study of relationships between agronomic performance and physiological parameters of three durum wheat cultivars. Al-Awamia, 98: 67-81.

Sayre, K. D., E. Acevedo and R. B Austin. 1995. Carbon isotope discrimination and grain yield for three bread wheat germplasm groups grown at different levels of water stress. Field Crops Res., 41: 45-54.

Shabala, S. N., S. I. Shabala, A. I. Martynenko, O. Babourina and I. A. Newman. 1998. Salinity effect on bioelectric activity, growth, Na^+ accumulation and chlorophyll fluorescence of maize leaves: a comparative survey and prospects for screening. Aust. J. Plant Physiol., 25: 609-16.

Sial, M. A., J. Akhter, A. A. Mirbahar, K. D. Jamali, N. Ahmed and H. Bux. 2013. Genetic studies of some yield contributing traits of F_2 segregating generation of bread wheat. Pak. J. Bot., 45 (5): 1841-1846.

Sial, M. A., M. U. Dahot, B. N. Mangan, S. M. Mangrio, M. A. Arain and M. H. Naqvi. 2007. Improvement of bread wheat for low water requirements through conventional and mutation breeding. Annals Agric. Sci., 45 (2): 607-619.

Sial, M. A., M. U. Dahot, M. A. Arain, G. S. Markhand, S. M. Mangrio, M. H. Naqvi, K. A. Laghari and A. A. Mirbahar. 2009. Effect of water stress on yield and yield components of semi-dwarf bread wheat (*Triticum aestivum* L.). Pak. J. Bot., 41 (4): 1715-1728.

Singh, T. and B. Singh. 1989. Leaf water polential and stomatal conductance of wheat as affected by water stress. Indian J. Plant Physiol., 32: 278-280.

Steven, W. R., H. T. Ngugen and A. S. Holaday. 1990. Leaf water contents and gas exchange parameters of two wheat genotypes differing in drought resistance. Crop Sci., 30: 105-108.

Strauss, J. A. and G. A. Agenbag. 2000. The use of physiological parameters to identify drought tolerance in spring wheat cultivars. South Afr. J. Plant Soil, 17 (1): 20-29.

Turner, N. C. and J. E. Begg. 1981. Plant water relations and adaptation to stress. Pl. Sci., 58: 97-131.

Zhang, Y. Q., Q. Yu, C. M. Liu, J. Jiang and X. Zhang. 2004. Estimation of winter wheat evapotranspiration under water stress with two semi empirical approaches. Agron. J., 96: 159-168.

(Accepted: October 09, 2016)