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IMPACT OF SOIL WATER DEFICIT ON SOME PHYSIOLOGICAL PARAMETERS OF DURUM AND BREAD WHEAT GENOTYPES

SUMMARY

Drought is a worldwide issue that impacts seriously on the security of food production. The aim of this research was to study the effect of soil water deficit on some physiological parameters of durum and bread wheat genotypes. Gas exchange parameters of flag leaf measured by using LI-COR 6400-XT Portable Photosynthesis System. Drought caused of reduction photosynthesis rate (Pn), stomatal conductance (gs), transpiration rate (E), mesophyll conductance (gm), photosynthetic pigments content, leaf area (LA), dry weight (DW), relative water content (RWC) of flag leaf. Leaf specific mass (LSM) was increased under rain-fed condition. Strong relationships were detected between gs and E, between gm and Pn. The Pn was positively and significantly correlated with LA, RWC, and DW but non-significantly correlated with Chl content. Physiological traits can be used as selection criteria for drought resistance.

Keywords: wheat, soil water deficit, gas exchange parameters, yield

INTRODUCTION

Environmental abiotic stresses, such as drought, extreme temperature, cold, heavy metals, or high salinity, severely impair plant growth and productivity worldwide (Anjum et al., 2011). Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factor (Shao et al., 2009). Up to 26% from the usable areas of the Earth is subjected to drought (Blum, 1986). Wheat is one of the four (maize, rice, wheat, soybean) most important crop plant for cultivation area and production in the world. In the field main development stages of wheat (stem elongation, heading-flowering, grain filling) occur when the water deficit in the soil increases in rain fed regions. Wheat is one of the widely cultivated crops in Azerbaijan, where drought is the main limiting factor for its production (Aliyev, 2001). Up to 35% of the 650.000 hectare wheat grown areas is under rain-fed conditions.

Drought affects morphological, physiological, biochemical and molecular processes in plants resulting in growth inhibition, stomata closure with consecutive reduction of transpiration, decrease in chlorophyll content and

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inhibition of photosynthesis and protein changes (Lawlor and Cornic, 2002; Yordanov et al., 2003) to cope with osmotic changes in their tissues. Leaf gas exchange is very susceptible to drought stress. The reduction of Pn results from the closure of stomata due to water deficit, since decrease of g_s is the most efficient way to reduce water loss, and parallel with this the CO₂ diffusion into the leaves restricted, resulting in a decrease in C_i (Cornic 2000). The limitation of CO₂ fixation during water deficit is also influenced by the diffusion of CO₂ from the intercellular spaces to chloroplasts (Loreto et al., 2003; Molnar et al., 2005), and by metabolic factors such as ATP-limited regeneration of ribulose-1,5-bisphosphate (Flexas, Medrano, 2002; Lawlor and Cornic, 2002). The stomatal function in drought-tolerant species is controlled to allow some carbon fixation even in stress conditions; hence, the water use efficiency increases (Brestic and Zivcak, 2013).

Reduced plant size, leaf area, and leaf area index are a major mechanism for moderating water use and reducing injury under drought stress (Mitchell et al., 1998). Drought leads to a decrease in water content, dry biomass, chlorophyll content of leaves of wheat genotypes (Dulai et al., 2006; Changhai et al., 2010). Proline, which is one of the amino acids highly synthesized under drought stress as a messenger, is considered to be one of the first metabolic responses to stress (Hare and Cress, 1997).

The ability of crop plants to acclimate to different environments is directly or indirectly associated with their ability to acclimate at the level of photosynthesis, which in turn affects biochemical and physiological processes and, consequently, the growth and yield of the whole plant (Chandra, 2003). Under field conditions identifying of wheat genotypes with optimal heading time, high photosynthetic activity, well-resistance and superior yield is very important task for researches. The purpose of this research was to study the effect of soil water deficit on some physiological parameters of durum and bread wheat genotypes and to determine physiological traits which can be used for identification high productive and tolerant wheat genotypes.

MATERIAL AND METHODS

Field experiment was carried out in the research area of Plant Physiology and Biotechnology Department of Research Institute of Crop Husbandry located in Absheron peninsula, Baku, during the 2012-2013 growing season. Six durum wheat genotypes (Garagylchyg 2, Vugar, Shiraslan 23, Barakatli 95, Alinja 84, Tartar), seven bread wheat genotypes (Gobustan, Giymatli 2/17, Gyrgyzgul 1, Azamatli 95, Tale 38, 12nd FAWWONN97, 4th FEFWSNN50) were used for this study. Sowing was done at an average density 400 seeds m⁻² with self-propelled mechanical planter in 1 m x 10 m plots, consisting of 7 rows with 15 cm apart. Each genotype was sown with three replications both in irrigated and rain-fed conditions. Irrigated plots were watered at stem elongation, flowering and grain filling stages. Fertilization was applied as N₁₂₀P₆₀K₆₀ per hectare. 30% of the nitrogen applied at planting and the rest at the beginning of stem elongation.

The Pn, gs, Ci, and E were measured with a Portable Photosynthesis System LI-6400 XT (LI-COR Biosciences, Lincoln, NE, USA) during postanthesis grain formation stage.

Photosynthetic pigments content (mg g^{-1} DW) was determined following the method of Lichtenthaler (1987) with modifications. About 0.1 g fresh leaves were ground in 96% ethanol for the extraction of chlorophyll and carotenoids. Absorbance of the supernatant was recorded at 664, 648, and 470 nm spectrophotometrically (Genesys 20, Thermo Scientific, USA). Pigments content calculated by the following formulas.

$$\text{Chla} = (13.36 \cdot A_{664} - 5.19 \cdot A_{648}) \cdot 25 / \text{DW} \quad \text{Chlb} = (27.43 \cdot A_{648} - 12 \cdot A_{664}) \cdot 25 / \text{DW}$$

$$\text{Chl (a+b)} = (5.24 \cdot A_{664} + 22.24 \cdot A_{648}) \cdot 25 / \text{DW}$$

$$\text{Car(x+c)} = (4.785 \cdot A_{470} + 3.657 \cdot A_{664} - 12.76 \cdot A_{648}) \cdot 25 / \text{DW}$$

Proline content was measured spectrophotometrically according to Bates et al. (1973) with modifications. About 0.5g leaves homogenized in a pre-chilled pestle and mortar with 5ml of 3% sulphosalicylic acid. Then, homogenate centrifuged at 3500 g (HERMLE Z 400K, Germany) for 15 min at 4°C. The supernatant (0.2 ml) was transferred to plastic tube containing 3% ninhydrin (0.4 ml), and 0.2 ml of 96% acetic acid and 0.2 ml of 3% sulphosalicylic acid were added. Tubes were incubated for 1 h at 96°C in a water-bath and 2 ml of toluene were added to each tube, then stirred, and centrifuged at 3500 g for 15 min at 4°C. The absorbance of the upper phase was measured at 520 nm. Determination of proline was carried out by a calibration curve in 0.01-0.2 mm proline.

Leaf area (LA, cm^2) was measured with an area meter (AAC-400, Hayashi Denkon Co., LTD, Japan). Leaf dry weight was then determined, and Leaf Specific Mass (LSM, leaf dry matter per unit leaf area, mg mm^{-2}) was calculated. The relative water content (RWC) was determined gravimetrically. Immediately after cutting at the base of lamina, leaves were preserved within plastic tubes and in time transferred to the laboratory. Fresh weight (FW) was determined after removal and turgid weight (TW) was measured after saturating leaves in distilled water for 24 h at room temperature. After saturating, leaves were carefully blotted dried with tissue paper. Dry weight (DW) was measured after oven drying the leaves samples at 105°C for 24 h. RWC was calculated by using the following formula: $\text{RWC(\%)} = (\text{FW} - \text{DW}) / (\text{TW} - \text{DW}) \times 100$.

RESULTS AND DISCUSSION

Effect of drought stress on gas exchange parameters. Water deficit significantly affected leaf gas exchange parameters (Table 1). A higher Pn was observed in flag leaf of genotypes Barakatli 95, Alinja 84, Tartar, Giymatli 2\17, Tale 38, 4thFEFWSNSN50 under normal water supply. Water stress caused considerable reduction of Pn in most of genotypes. Less reduction of Pn was observed in genotypes Garagylchyg 2, Giymatli 2\17, Tale 38, 4thFEFWSNSN50. A higher gs of non-stressed plants was observed in flag leaf of durum wheat genotypes and in bread wheat genotypes of Gobustan, Tale 38 and 4thFEFWSNSN50. Drought stress led to deep reduction of gs (37-88%) of wheat genotypes. Drought also led to a decrease in Ci. We observed an increase

of C_i in genotypes Giymatli 2\17 and Azamatli 95 under drought stress. Higher E was detected in flag leaf of durum wheat genotypes Barakatli 95, Tartar, Vugar, Shraslan 23, bread wheat genotypes Tale 38 and 4thFEFWSNN $\text{\textcircled{50}}$ under irrigated condition. Water deficit caused strong reduction of E especially in genotypes Shiraslan 23, Gobustan, Gyrgyzy gul 1. The genotype 12ndFAWWONN $\text{\textcircled{97}}$ with the smallest leaf area showed lowest P_n , g_s and E . The mesophyll conductance (g_m) was calculated as the ratio of P_n to C_i , water use efficiency (WUE) was calculated as the ratio of P_n to E . The g_m decreased, but the WUE increased under the influence of water stress. An increase in WUE could be due to more reduction in E than P_n by water deficit. A sharp increase in the WUE of genotypes Garagylchyg 2, Shiraslan 23, Gobustan, Gyrgyzy gul 1 indicates a strong decrease in the E . Table 2 shows correlation between gas exchange parameters and calculated g_m and WUE under irrigated and rain-fed conditions. Positive and significant correlations were found between P_n and g_s , E , g_m . There was more strong correlation between the P_n and g_m , than the P_n and g_s , indicating the dominance of g_m in reducing of P_n . Negative correlation was observed between P_n and C_i . Positive correlations were observed between g_s and C_i , E . Correlation between E and g_m was positive and significant. Negative and significant correlation was observed between E and WUE.

Effect of water deficit on RWC. Although RWC was higher in non-stressed plants than stressed ones, there were no significant differences between cultivars at these levels of RWC (Fig.1). Higher RWC was observed in genotypes Barakatli 95, Alinja 84, Tartar, Gyrgyzy gul 1, Tale 38, 12ndFAWWONN $\text{\textcircled{97}}$, and 4thFEFWSNN $\text{\textcircled{50}}$.

The genotypes Tartar, Gyrgyzy gul 1, Tale 38, 12ndFAWWONN $\text{\textcircled{97}}$, and 4thFEFWSNN $\text{\textcircled{50}}$ were late heading, and their younger flag leaves contained relatively more water. Lower RWC was observed in genotypes Shiraslan 23, Gobustan, Giymatli 2/17, and Azamatli 95. Should be noted that the genotypes Azamatli 95 and Gobustan were the earliest heading. Under the influence of water stress significant reduction of RWC was found in genotypes Garagylchyg 2 (12%), and Giymatli 2/17(14%). A slight decrease of RWC was observed in genotypes Vugar, Alinja 84, Gobustan, Gyrgyzy gul 1, Azamatli 95, Tale 38, 12ndFAWWONN $\text{\textcircled{97}}$, non-significant reduction in genotypes Shiraslan 23, Barakatli 95, and 4thFEFWSNN $\text{\textcircled{50}}$. The difference in RWC of irrigated and rain-fed plants was almost imperceptible in genotype Tartar. In the field, strengthening of water stress occurs gradually, it allows plants to develop various mechanisms of adaptation to resist to water scarcity. Effect of water stress on flag leaf area. Water stress limits the growth of assimilating surface area of flag leaf of tested wheat genotypes (Fig.2). The reduction in leaf size which results in smaller transpiring area, is an adaptive response to water deficit (Tardieu, 2005). A significant decrease in the flag leaf area was observed in all genotypes. More profound reduction of flag leaf area was observed in genotypes Shiraslan 23 (44%) and Vugar (35%), Gyrgyzy gul 1(37%), Tale 38 (34%), Garagylchyg 2 (31%), Barakatli 95 (31%), 4thFEFWSNN $\text{\textcircled{50}}$ (30%), 12ndFAWWONN $\text{\textcircled{97}}$ (28%), Tartar (28%).

Table 1. Gas exchange parameters of *T.durum* Desf. and *T.aestivum* L. genotypes in response to drought stress

Wheat genotypes	Gas exchange of wheat genotypes under irrigated (I) and rainfed (R) conditions						
		per units area and time (m ⁻² s ⁻¹)				C _i , μmol CO ₂ mol ⁻¹	WUE, μmolCO ₂ mmol ⁻¹ H ₂ O
		P _n , μmol CO ₂	g _s , mol H ₂ O	E, mmol H ₂ O	g _m , mol CO ₂		
<i>Triticum durum</i> Desf.							
Garagylchyg 2	I	18.1	0.529	6.13	0.059	303	2.95
	R	16.6	0.223	3.81	0.067	246	4.36
Vugar	I	19.8	0.551	7.31	0.069	288	2.71
	R	12.5	0.135	3.24	0.056	226	3.85
Shiraslan 23	I	16.3	0.568	7.25	0.053	310	2.25
	R	10.8	0.087	2.24	0.037	291	4.82
Barakatli 95	I	22.0	0.555	8.13	0.073	302	2.71
	R	14.3	0.173	4.10	0.064	225	3.49
Alinja 84	I	21.5	0.492	6.94	0.079	273	3.10
	R	13.8	0.144	3.04	0.064	214	4.54
Tartar	I	22.8	0.645	8.50	0.079	289	2.68
	R	16.2	0.173	4.21	0.083	195	3.85
<i>Triticum aestivum</i> L.							
Gobustan	I	16.5	0.717	6.57	0.049	338	2.51
	R	10.4	0.086	1.71	0.033	314	6.08
Giymatli-2/17	I	19.4	0.364	4.78	0.070	279	4.06
	R	16.2	0.209	3.33	0.057	286	4.86
Gyrmyzy gul1	I	14.3	0.366	5.33	0.047	306	2.68
	R	10.3	0.141	1.57	0.039	266	6.56
Azamatli 95	I	17.1	0.325	5.69	0.063	273	3.01
	R	9.8	0.206	3.35	0.034	276	2.80
Tale-38	I	20.7	0.598	6.82	0.066	313	3.04
	R	17.6	0.308	5.36	0.068	256	3.28
12 nd FAWWO N N97	I	13.4	0.352	3.55	0.043	310	3.77
	R	9.04	0.118	2.32	0.030	299	3.90
4 th FEFWSN N50	I	22.0	0.531	7.02	0.078	281	3.13
	R	17.8	0.298	6.47	0.075	236	2.75

Irrigated	Parameters	P_n	g_s	C_i	E	g_m	WUE	Rain-fed
	P_n	1	0.433**	-0.070	0.819**	0.778**	0.058	
	g_s	0.341**	1	0.592**	0.592**	0.019	-0.271*	
	C_i	-	0.459**	0.500**	1	0.156	-	
	E	0.800**	0.366**	-0.305*	1	0.535**	-	
	g_m	0.975**	0.196	-0.622*	0.766**	1	0.445**	
	WUE	0.130	-0.161	-0.228	-	0.163	1	
					0.458**			

**, Correlation is significant at the 0.01 level; *, Correlation is significant at the 0.05 level

Deep reduction can be explained to the fact that the formation of the flag leaf of late-heading wheat genotypes (Vugar, Shiraslan 23, Tartar, Gyrmyzy gull, Tale 38, 4thFEFWSN№50, and 12ndFAWWON№97) occurs at a severe water shortage. A more profound reduction of flag leaf area in these genotypes was compensated with conservation of RWC at high level.

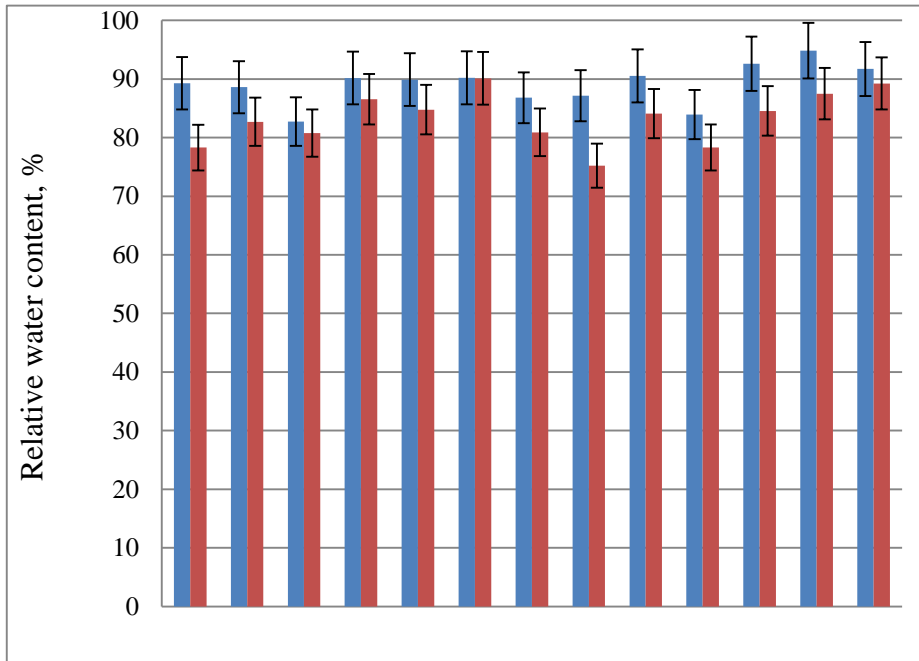


Figure 1. Effect of water stress on flag leaf RWC

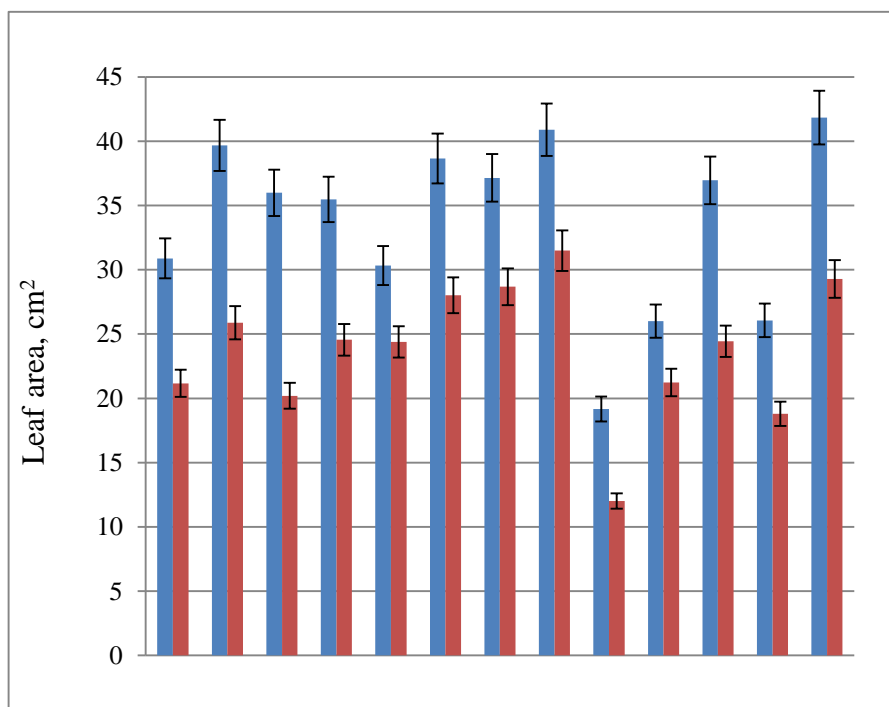


Figure 2. Effect of water stress on flag leaf area

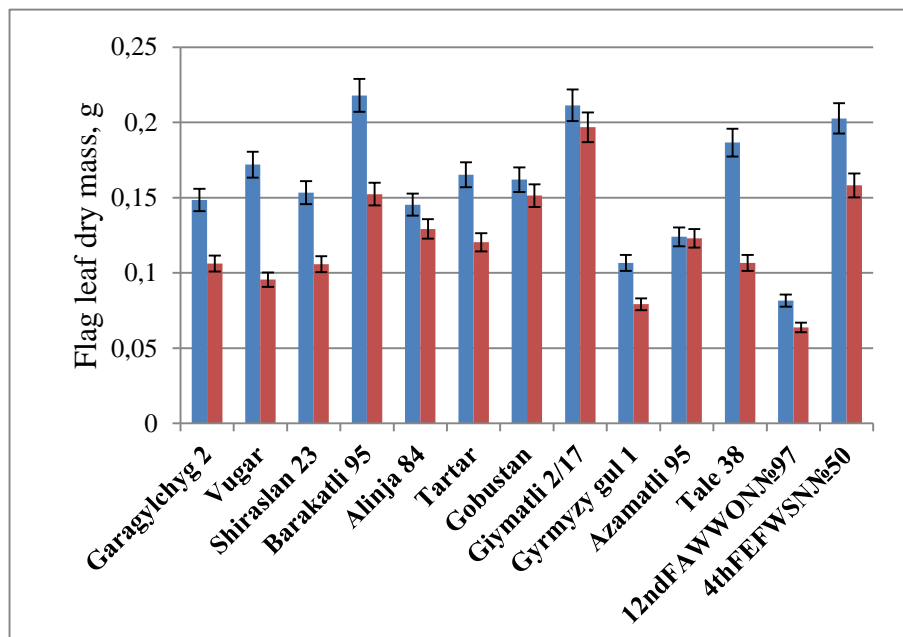


Figure 3. Effect of water stress on flag leaf dry mass

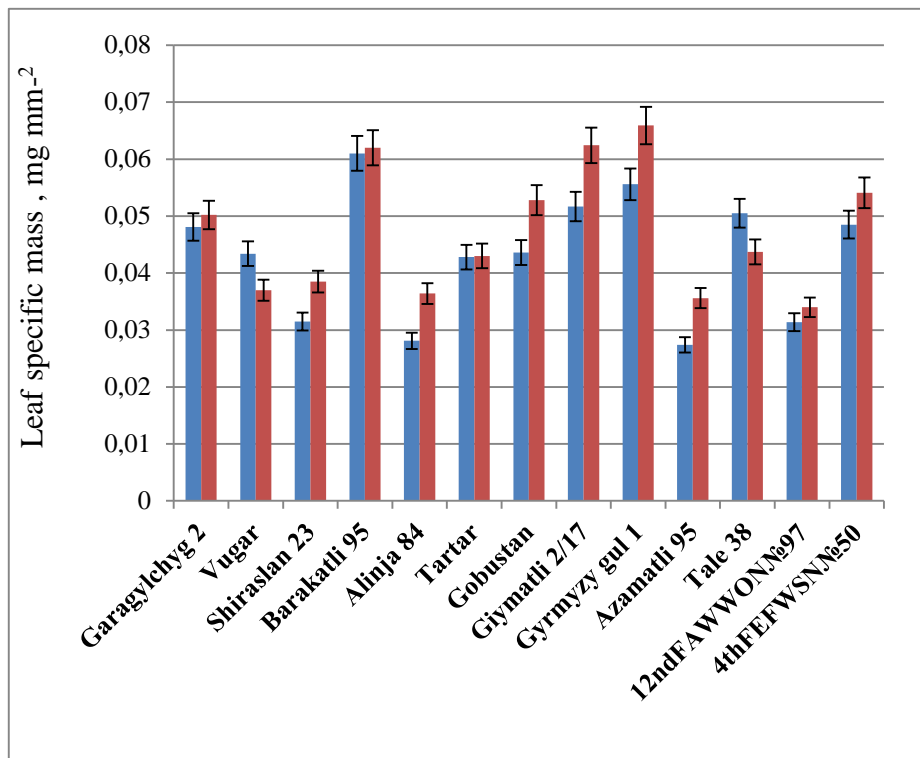


Figure 4. Effect of water stress on leaf specific mass

***Note:** blue bars correspond irrigated plants, red bars correspond rain-fed plants

A more profound reduction of flag leaf area in these genotypes was compensated with conservation of RWC at high level.

Effect of water stress on flag leaf dry biomass. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Zhao et al, 2006). Water scarcity causes a decrease of dry biomass of flag leaf (Fig. 3). As in the case of leaf area, a strong reduction of dry biomass was observed in all genotypes of durum wheat, with exception of Alinja 84, in bread wheat genotypes Gyrgyzy gul 1, Tale 38, 12ndFAWWON№97, 4thFEFWSN№50. A smaller reduction of flag leaf dry biomass under water stress was observed in genotypes Azamatli 95, Gobustan, Giymatli 2/17, Alinja 84. A more profound reduction of flag leaf dry mass was detected in genotypes Vugar (44%) and Tale 38 (43%).

Effect of water stress on Leaf Specific Mass (LSM). LSM was calculated from the ratio of flag leaf dry mass to flag leaf area and it is inverse leaf specific area (LSA). LSM is considered to reflect relative carbon accumulation, at lower nutrient or moisture availabilities or at higher light irradiances, leaves tended to be smaller, with higher LSM, density and thickness (Witkowski and Byron,

1991). It was revealed an increase of LSM under water stress in most wheat genotypes (Fig. 4). Such an increase in the LSM is probably adaptive response to drought and is due to the relatively greater reduction in leaf area than the dry mass. A reduction of LSM was observed in genotypes Vugar and Tale 38, because of the greater reduction in dry mass. A higher LSM was observed in genotypes Barakatli 95, Gyrmzy gul 1, Giymatli 2/17, Tale 38, 4thFEFWSN№50, Garagylchyg 2, lower LSM was observed in genotypes Azamatli 95, Alinja 84, 12ndFAWWON№97, Shiraslan 23. A slight increase in LSM was observed in genotypes Garagylchyg 2, Barakatli 95, Tartar, more profound increase was observed in genotypes Azamatli 95, Alinja 84, Shiraslan 23, Giymatli 2/17, Gobustan, Gyrmzy gul 1.

Effect of water stress on photosynthetic pigments content. Photosynthetic pigments are important to plants mainly for harvesting light and production of reducing powers (Anjum et al., 2011). In general, water stress caused significant declines in photosynthetic pigments content, in the ratio of $\text{Chl}(a+b)/\text{Car}(x+c)$ and an increase in the ratio of $\text{Chl}a/b$ (Table 3). The decrease in chlorophyll content under drought stress may be the result of pigment photo-oxidation and chlorophyll degradation. Lower values of the ratio $\text{Chl}(a+b)/\text{Car}(x+c)$ indicates water stress damage to the photosynthetic apparatus, which is expressed by faster breakdown of chlorophylls than carotenoids. Photosynthetic pigments were higher among bread wheat genotypes than durum wheat ones. Higher decrease of chlorophyll content was observed in genotypes Vugar (35%), Shiraslan 23 (29%), Barakatli 95 (21%), Gobustan (29%), Giymatli 2/17 (31%), Azamatli 95 (37%), and 4thFEFWSN№50 (28%). A slight decrease was observed in genotypes Gyrmzy gul1, 12ndFAWWON№97, Alinja 84, Tale 38 and Garagylchyg 2. An increase in $\text{Chl } a/b$ could be due to more reduction in $\text{Chl } b$ than $\text{Chl } a$ by water deficit.

Correlations between physiological parameters. Table 4 shows correlations between studied physiological parameters. The P_n was positively and significantly correlated with RWC, LA, and DW.

Correlation between LA and DW was positive and significant, correlation between LA and Chl was positive but non-significant. The DW was positively, non-significantly correlated with LSM. Effect of water stress on proline content. Drought stress increased proline content about eight-tenfold in flag leaf of genotypes Vugar, Alinja 84, Gyrmzy gul 1 and more than tenfold in genotype Tale 38, this increasing role as an osmotic compatible and adjust osmotic potential which resulted in drought stress avoidance in wheat (Fig.5).

Photosynthesis is the primary source of dry matter production and grain yield of crop plants (Shao et al., 2005). Leaf photosynthesis may vary with leaf age, position, leaf surface, and general plant and development stage (Richards, 2000). Variations in daily time course of weather parameters such as light intensity, temperature, relative humidity, etc. also affect leaf gas exchange. According to our results under drought stress g_s plays an important role in the regulation of P_n , E and C_i . The P_n is less limited than E under drought stress.

Table 3. Changes of Chl a, b and Chl (a+b) contents, Car (x+c) content, Chl a/b and Chl (a+b)/Car (x+c) of wheat genotypes under drought stress.

Wheat genotypes		Pigments content of wheat genotypes under irrigated (I) and rainfed (R)conditions					
		mg per g dry weight of leaf				Chl a/b	Chl (a+b)/Car(x+c)
		Chl a	Chl b	Chl (a+b)	Car(x+c)		
T. durum Desf.							
Garagylchyg 2	I	7.14	3.34	10.48	1.76	2.14	5.96
	R	5.50	3.06	8.56	1.18	1.80	7.25
Vugar	I	6.02	2.93	8.95	1.45	2.06	6.16
	R	4.00	1.86	5.86	0.98	2.15	5.97
Shiraslan 23	I	5.68	2.68	8.36	1.41	2.12	5.93
	R	4.08	1.89	5.97	1.02	2.15	5.84
Barakatli 95	I	6.08	2.81	8.89	1.54	2.16	5.76
	R	4.83	2.19	7.02	1.15	2.21	6.09
Alinja 84	I	5.10	2.66	7.76	1.24	1.92	6.26
	R	4.46	2.01	6.47	1.16	2.22	5.57
Tartar	I	4.90	2.51	7.41	1.17	1.96	6.34
	R	6.23	2.69	8.92	1.58	2.32	5.66
T.aestivum L.							
Gobustan	I	6.78	3.30	10.08	1.58	2.06	6.37
	R	5.08	2.57	7.65	1.20	1.98	6.35
Giymatli 2/17	I	5.85	2.68	8.53	1.38	2.18	6.17
	R	4.07	1.84	5.91	1.12	2.21	5.26
Gyrmyzy gul 1	I	7.19	3.22	10.41	1.86	2.23	5.60
	R	7.17	3.06	10.24	1.93	2.34	5.31
Azamatli 95	I	6.68	3.70	10.38	1.38	1.81	7.50
	R	4.43	2.06	6.49	1.12	2.15	5.82
Tale 38	I	7.68	3.54	11.22	1.84	2.17	6.08
	R	6.44	3.13	9.57	1.60	2.06	5.99
12 nd FAWWON №97	I	6.80	3.57	10.37	1.67	1.98	6.21
	R	6.68	3.29	9.97	1.65	2.03	5.98
4 th FEFWSN №50	I	7.14	3.49	10.63	1.80	2.04	5.92
	R	5.20	2.49	7.69	1.34	2.08	5.75

Table 4. Correlations between different physiological parameters

Parameters	P _n	RWC	LA	DW	LSM	Chl
P _n	1					
RWC	0.527**	1				
LA	0.798**	0.321	1			
DW	0.674**	0.116	0.845**	1		
LSM	-0.171	-0.327	-0.201	0.330	1	
Chl	0.274	0.623**	0.113	-0.043	-0.235	1

** Correlation is significant at the 0.01 level

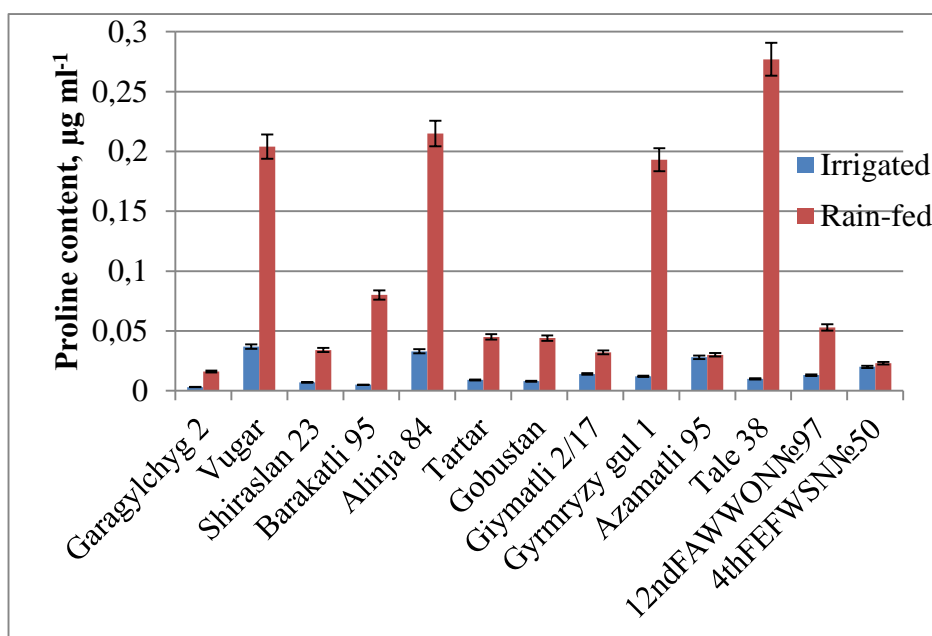


Figure 5. Effect of water stress on proline content

The g_m has a dominance role in the regulation of P_n . This result was in agreement with result of Siddique et al., (1999). During the post anthesis grain formation stage when the drought strengthened the decrease in the P_n could be associated with a reduction of CO_2 in the intercellular spaces. Bread wheat genotypes Tale 38 and 4thFEFWSN50 were characterized by high g_s , P_n and E.

Despite the fact that the gas exchange parameters, leaf area and dry mass strongly influenced by drought, RWC in the flag leaf remained relatively high. This means that the genotypes use different mechanisms of adaptation to maintain the RWC. Water scarcity led to a greater reduction in LA than the DW,

as a result of LSM increased. Our result was in agreement with result of Witkowski and Byron (1991), but according to result Bogale et al., (2011) the LSA of durum wheat genotypes was also increased under water deficit. We found a stronger reduction of the area and dry weight of flag leaf in durum wheat genotypes. Genotypes with higher LSM probably have more photosynthesizing cells and chloroplasts per unit leaf area. The Chl content was higher in the flag leaf of bread wheat genotypes than durum wheat. However flag leaf of durum wheat genotypes retain green color for a longer period than bread wheat genotypes (SPAD units). Drought stress leads to more reduction of Chl b than Chl a. This may be due to the fact that Chl b is a main component of photosystem II, disruption of electron flow and formation of oxidizing radicals under drought stress results in the more decrease of this pigment. The RWC decreased non-significantly, but Chl (a+b) content increased in genotype Tartar under water stress. Perhaps this was associated with more accumulation of antocianes in spike and leaves of this genotype under drought stress. The individual leaf traits play an important role in drought avoidance of wheat genotypes. A smaller area and erect orientation of flag leaf of genotypes Gyrmzy gul 1, Azamatli 95 (in addition leaf rolling), 12ndFAWWON№97, and leaf waxiness of Giymatli 2/17 allows plant to avoid damaging leaf water potential in leaves by reducing the water flow through the leaf surface. Relatively high flag leaf RWC of genotypes Vugar, Barakatli 95, Alinja 84, Tartar, Gyrmzy gul 1, Tale 38, 12ndFAWWON№97 under drought stress perhaps was associated with strong accumulation of proline. Our results showed that strong reduction of flag leaf area and dry mass occurs in genotypes with late heading time. But late heading genotypes have an advantage-photosynthesis in younger flag leaf take place at higher photosynthetically active radiation and this leads to the formation of more assimilates. The P_n was positively and significantly correlated with LA, RWC, DW but non-significantly correlated with Chl content. The relatively high P_n was detected in genotypes Garagylchyg 2, Tartar, Giymatli 2/17, Tale 38, 4thFEFWSN№50 under rain-fed condition. Strong reduction of LA of genotypes Vugar, Barakatli, 95, Alinja 84, Tartar, Gobustan, Gyrmzy gul 1, Tale 38, 12ndFAWWON№97 and 4thFEFWSN№50 allowed to retain the high RWC and non-strong reduction of Chl (a+b) content under rain-fed conditions. These genotypes also showed a relatively high increase in proline content. According to our results the genotypes Vugar, Shiraslan 23, Gobustan and Tale-38 were more sensitive to drought stress. The genotypes Tartar, Gyrmzy gyl-1, Azamatli- 95, 4thFEFWSN№50 were resistance to drought stress

CONCLUSIONS

Drought causes of adaptive changes of physiological parameters. Wheat genotypes survive drought stress through reduction of leaf area, dry mass, gas exchange parameters, photosynthetic pigments. In response to a lack of water stomatal conductance decreases which leads to decrease in the concentration of CO₂ in the intercellular spaces, photosynthesis rate and transpiration rate.

Increasing the area and dry mass of leaves is delayed due to the suppression of photosynthesis. The relative water content positively correlated with photosynthesis rate, leaf area, dry mass and chlorophyll content. This trait can be used as selection criteria for drought resistance.

REFERENCES

- Aliyev J.A (2001) Physiological bases of wheat breeding tolerant to water stress. Proceedins of the 6th International Wheat Conference, Budapest, Hungary, 2000. In: Wheat in a Global Environment (Bedo Z., Lang L., eds.), Kluwer Academic Publishers, Dordrecht, Boston, London 9:693-698.
- Anjum SA, Xie X, Wang L, Salem MF, Man Cand Lei W (2011) Morphological, physiological and biochemical responses of plants to drought stress. *African Journal of Agricultural Research* 6(9): 2026-2032.
- Bates LS, Waldren RP, Teare ID.(1973) Rapid determination of free proline for water-stress studies. *Plant and Soil*, 39: 205-207.
- Blum A (1986) Breeding crop varieties for stress environments. *Critical Reviews in Plant Sciences* 2: 199-237.
- Bogale A, Tesfaye K, Geleto T (2011) Morphological and physiological attributes associated to drought toleranxe of Ethiopian durum wheat genotypes under water deficit condition. *Journal of Biodiversity and Environmental Sciences* 1(2):22-36.
- Brestic M, Zivcak M (2013) PSII fluorescence techniques for measurement of drought and high temperature stree signal in crop plants: protocols and applications. In: Rout GR, Das AB (eds) *Molecular Stress Physiology of Plants*. Springer Dordrecht: 87-131.
- Chandra S (2003) Effects of leaf age on transpiration and energy exchange of *Ficus glomerata*, a multipurpose tree species of central Himalayas. *Physiol.Mol.Biol. Plants*, 9: 255-260.
- Changhai S, Baodi D, Yubzhou Q, Yuxin L, Lei S, Mengyu L, Haipai L (2010) Physiological regulation of high transpiration efficiency in winter wheat under drought conditions. *Plant Soil Environ.*, 56 (7): 340-347.
- Cornic G (2000) Drought stress inhibits photosynthesis by decreased stomatal aperture-not by affecting ATP synthesis. *TIBS* 5:187-188.
- Dulai S, Molnar I, Pronay J, Csernak A, Tarnai R, Molnar-Lang M. (2006) Effects of drought on photosynthetic parameters and heat stability of PSII in wheat and in *Aegilops* species originated from dry habitats. *Acta Biologica Szegediensis* 50(1-2): 11-17.
- Flexas J, Medrano H. (2002) Drought-inhibition of Photosynhesis in C3 plants: Stomatal and Non-stomatal Limitations Revisited. *Annals of Botany* 89: 183-189.
- Hare PD, Cress WA (1997) Metabolic implications of stress induced proline accumulation in plants. *Plant Growth Regul.* 21: 79-102.
- Lawlor DW, Cornic G. (2002) Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant, Cell & Environment* 25: 275-294.

- Lichtenthaler HK (1987) Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes.- *Methods in Enzymology* 148: 350-382.
- Loreto F, Centritto M, Chartzoulakis K (2003) Photosynthetic limitations in olive cultivars with different sensitivity. *Plant Cell Environ* 26: 595-601.
- Mitchell JH, Siamhan D, Wamala MH, Risimeri JB, Chinyamakobvu E, Henderson SA, Fukai S (1998) The use of seedling leaf death score for evaluation of drought resistance of rice. *Field Crops Research* 55: 129-139.
- Molnar I, Dulai S, Csernak A, Pronay J, Molnar-Lang M (2005) Photosynthetic responses to drought stress in different *Aegilops* species. *Acta Biol Szeged* 49(1-2):141-142.
- Richards A (2000) Selectable traits to increase crop photosynthesis and yield of grain crops. *Journal of Experimental Botany* 51:447-458.
- Shao HB, Liang ZS, Shao MA, Wang BC (2005) Changes of some physiological and biochemical indices for soil water deficits among 10 wheat genotypes at seedling stage. *Colloids Surf. B: Biointerfaces* 42(2): 107-211.
- Shao HB, Chu LY, Jaleel CA, Manivannan P, Panneerselvam R, Shao MA (2009) Understanding water deficit stress-induced changes in the basic metabolism of higher plants-biotechnologically and sustainably improving agriculture and the ecoenvironment in arid regions of the globe. *Crit. Rev.Biotechnol.*, 29:131-151.
- Siddique MRB, Hamid A, Islam MS (1999) Drought stress effects on photosynthetic rate and leaf gas exchange of wheat. *Bot.Bull.Acad.Sin.* 40: 141-145.
- Tardieu F (2005) Plant tolerance to water deficit: physical limits and possibilities for progress. *Comptes Rendus Geoscience* 337: 57-67.