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ORIGINAL ARTICLE

Effect of drought stress on some physiological traits of durum (*Triticum durum* Desf.) and bread (*Triticum aestivum* L.) wheat genotypes

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Drought is a wide-spread problem seriously influencing wheat production and quality worldwide. We aimed to study adaptive changes in physiological parameters of 6 durum and 7 bread wheat genotypes under drought stress. Water stress caused reduction of leaf gas exchange parameters-photosynthesis rate, stomatal conductance, intercellular CO_2 concentration, transpiration rate as well leaf area, dry mass, relative water content, and chlorophyll content. Photosynthesis rate, chlorophyll content were higher in flag leaf of bread wheat genotypes. Photosynthesis rate positively correlated with leaf area, dry mass and relative water content.

Key words: leaf area, photosynthesis rate, stomatal conductance, wheat

Wheat (*Trticum durum* Desf. and *Triticum aestivum* L.) is one of the major crop plants in the human nutrition, is a sources of energy from carbohydrates and proteins. Drought is the most important limiting factor for wheat production in arid and semiarid regions of the world. Under field conditions important stages of wheat development (stem elongation, heading-flowering, grain filling) is accompanied with increase of water deficit in the soil. Wheat is one of the widely cultivated crops in Azerbaijan, where drought is the main limiting factor for its production (Aliyev, 2001).

Moderate to severe water stress drastically affects various morpho-physiological traits in wheat, such as dry matter production, assimilating area, relative water content, and chlorophyll content. Photosynthesis, which is the most significant process influence crop production, is also inhibited by drought stress. The effects can be direct, as the decreased CO_2 availability caused by diffusion limitations through the stomata and the mesophyll (Flexas *et al*., 2004) or the alterations of photochemical reactions (Tang *et al*., 2002) and photosynthetic metabolism (Lawlor and Cornic, 2002). Under field conditions, stomatal regulation of transpiration was shown as a primary event in plant response to water deficit leading to decrease of CO_2 uptake by the leaves (Chaves, 1991, 2002; Cornic and Massacci, 1996). Strengthening of drought during growth period lead to inhibition of photosynthesis through the reactive oxygen species damage to photosynthetic pigments, photosystems I and II, and electron transport proteins. 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). It is revealed that varieties, with higher leaf turgor and RWC under stress conditions are more droughts tolerant and gave higher yield than others (Akram, 2011; Khakwani *et al*., 2011). The present study aims to determine soil water deficit effects on leaf gas exchange, area, dry biomass, chlorophyll and relative water content of six durum wheat (*Triticum durum* Desf.) and seven bread wheat (*Triticum aestivum* L.) genotypes and to determine the relationships between some physiological traits, to identify morpho-physiological traits as indicators of drought tolerance in wheat genotypes.

MATERIALS 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, Gyrmyzygul 1, Azamatli-95, Tale-38, 12nd FAWWON№97, 4th FEFWSN№50) were used for this study. Genotypes grown in 10 m^2 plots (1mx10m) with three replications both under irrigated and rain-fed conditions Given in manuscript physiological parameters were measured during grain formation stage. Photosynthesis rate (P_n), stomatal conductance (g_s), intercellular CO_2 concentration (C_i), transpiration rate (T_r) measured

with a Portable Photosynthesis System LI-6400 XT (LI-COR Biosciences, Lincoln, NE, USA). Photosynthetic pigments content determined following the method of Lichtenthaler (1987) with little 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:

Chl a=(13,36•A_{664}-5,19•A_{648})•25/DW;

Chl b=(27,43• A_{648}-8,12•A_{664})•25/DW

Chl(a+b)=(5,24•A_{664}+22,24• A_{648})•25/DW

Car(x+c)=(4,785•A_{470}+3,657•A_{664}-12,76•A_{648})•25/DW

Leaf area (LA, sm^2) measured with an area meter (AAC-400, Hayashi Denkon Co., LTD, Japan). Leaf dry mass was then determined, and Leaf Specific Mass (LSM, leaf dry mass per unit leaf area, mg mm^{-2}) was calculated. The relative water content (RWC) determined gravimetrically. Immediately after cutting at the base of lamina, leaves were preserved within plastic bags and in time transferred to the laboratory. Fresh mass (FW) was determined after removal and turgid mass (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 mass (DW) was measured after oven drying the leaves samples at 105°C for 24 h. RWC was calculated by using the following formula: RWC(%)= (FW-DW)/(TW-DW)x100. Soil moisture content was determined in the 0-20, 20-40, 40-60 cm depths and expressed as percentage of the field moisture capacity, was about 60% in irrigated plots and 30% in non-irrigated plots. Correlations among parameters, standard errors of means were calculated by SPSS software.

RESULTS

Water deficit significantly affected leaf gas exchange parameters (Table 1). The high P_n observed in flag leaf of durum wheat genotypes Alinja 84 and Tartar, bread wheat genotypes Gyrmyzy gul1, Azamatli 95, Tale 38, 4thFEFWSN№50. Deep reduction of P_n detected in genotypes Gobustan (61%), Gyrmyzy gul1(57%), Azamatli 95 (62%), Tale 38 (58%), 12ndFAWWON№97 (45%). The high g_s defined in flag leaf of genotypes Barakatli 95, Gobustan, Gyrmyzy gul1, Azamatli 95, Tale 38, 4thFEFWSN№50. The g_s decreased in the range of 45-85%, slight reduction was detected in flag leaf of genotype Vugar. The C_i reduction was 7-27% and 8-45% among genotypes of durum and bread wheat genotypes, respectively. Strong reduction of C_i was determined in flag leaf of genotypes Gobustan, Gyrmyzy gul1, and 12ndFAWWON№97. The durum wheat genotypes Shiraslan 23, Barakatli 95, Alinja 84 and all bread wheat genotypes were characterized with high T_r under irrigated condition. Water stress caused strong reduction of T_r in genotypes Shiraslan 23 (60%), Barakatli 95 (58%). Gobustan (74%), Gyrmyzy gul1 (71%), Azamatli 95 (61%), 12ndFAWWON№97(70%), slight reduction in genotypes Garagylchyg 2, Vugar and Tartar. 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 T_r. As well the g_m decreased under the influence of soil drought, deeper decrease was observed in genotypes Azamatli 95 and Tale 38. The WUE increased under the influence of drought in most genotypes that can be explained to a more reduction in T_r than in P_n. Table 2 shows correlation between gas exchange parameters under irrigated and rain-fed conditions. Positive and significant correlations were found between P_n and g_s, P_n and T_r, P_n and 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. The C_i negatively correlated with P_n, g_m, and WUE, but positively correlated with g_s.

Higher RWC was observed in genotypes Barakatli -95, Alinja- 84, Tartar, Gyrmyzygul- 1, Tale -38, 12ndFAWWON№97, and 4thFEFWSN№50 (Fig.1). The genotypes Tartar, Gyrmyzygul-1, Tale- 38, 12ndFAWWON№97, and 4thFEFWSN №50 were late heading, and their flag leaves contained relatively more water. Under the influence of water stress significant reduction of RWC was found in genotypes Garagylchyg- 2 (12%), and Giymatli - 2/17(14%). The difference in RWC of irrigated and rain-fed plants was almost imperceptible in genotype Tartar.

A significant decrease in the LA observed in all genotypes (Fig.2). More profound reduction of LA observed in genotypes Shiraslan 23 (44%) and Vugar (35%), Gyrmyzy gul 1(37%), Tale 38 (34%), Garagylchyg 2 (31%), Barakatli 95 (31%), 4thFEFWSN№50 (30%), 12ndFAWWON№97 (28%), Tartar (28%). 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 gul1, Tale 38, 4thFEFWSN№50, and 12ndFAWWON№97) occurs during a severe water shortage.

Water scarcity causes a decrease in DM of flag leaf (Fig.3). As in the case of LA, strong reduction of DM observed in all genotypes of durum wheat, with exception of Alinja 84, in bread wheat genotypes Gyrmyzy gul 1, Tale 38, 12ndFAWWON№97, 4thFEFWSN№50. A more profound reduction of flag leaf dry mass was detected in genotypes Vugar (44%) and Tale 38 (43%).

It was revealed an increase of LSM under water stress in most wheat genotypes (Figure 4). Such an increase in the LSM is probably adaptive response to drought and is due to the relatively greater reduction in LA than the DM. A reduction of LSM was observed in genotypes Vugar and Tale 38, because of the greater reduction in DM. A higher LSM observed in genotypes Barakatli 95, Gyrmyzy gul 1, Giymatli 2/17, Tale 38, 4thFEFWSN№50, Garagylchyg 2.

In general, water stress caused significant declines in photosynthetic pigments content, in the ratio of Chl(a+b)/Car(x+c) and increase in the ratio of Chla/b (Table 3). Photosynthetic pigments were higher among genotypes of bread wheat than durum wheat. 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 Gyrmyzy gul 1, 12ndFAWWON№97, Alinja 84, Tale 38 and Garagylchyg 2. An increase in Chl a/b could be

due to more reduction in Chlb than Chla by water deficit.

Table 4 shows correlations between studied physiological parameters. The P_n was positively and significantly correlated with RWC, LA, and DW. The relationship between P_n and Chl content was positive, but non-significant. The RWC positively and significantly correlated with Chl content. Correlation between LA and DW was positive and significant, correlation between LA and Chl was positive but non-significant.

Table 1. Effect of water stress on gas exchange parameters (Data are mean of 8 measurements)

Wheat genotypes	Experiment condition	P_n, $\mu molCO_2 m^{-2} s^{-1}$	g_s, $molH_2O\ m^{-2} s^{-1}$	C_i, $\mu molCO_2\ mol^{-1}$	T_r, $mmolH_2O m^{-2} s^{-1}$	g_m, $molCO_2 m^{-2} s^{-1}$	WUE, $\mu molCO_2\ mmol^{-1}H_2O$
Garagylchyg 2	Irr.	10,5	0,218	299	3,82	0,035	2,74
	R-f	7,26	0,119	279	2,95	0,026	2,46
Vugar	Irr.	13,4	0,164	285	4,4	0,047	3,04
	R-f	9,17	0,134	257	3,52	0,035	2,61
Shiraslan 23	Irr.	14,9	0,289	282	6,71	0,052	2,22
	R-f	9,56	0,100	213	2,68	0,044	3,56
Barakatli 95	Irr.	15,1	0,469	331	7,91	0,045	1,91
	R-f	9,32	0,133	260	3,31	0,035	2,81
Alinja 84	Irr.	17,9	0,303	259	6,34	0,069	2,82
	R-f	11,1	0,112	207	3,82	0,053	2,90
Tartar	Irr.	18,5	0,235	232	5,35	0,079	3,46
	R-f	13,8	0,134	170	4,27	0,081	3,23
Gobustan	Irr.	18,6	0,481	287	9,2	0,064	2,02
	R-f	7,32	0,07	159	2,4	0,046	3,05
Giymatli-2/17	Irr.	18,7	0,311	252	7,88	0,074	2,37
	R-f	11,9	0,107	179	3,97	0,066	2,99
Gyrmyzy gul1	Irr.	20,1	0,476	291	8,48	0,069	2,37
	R-f	8,6	0,073	175	2,42	0,049	3,55
Azamatli 95	Irr.	19,8	0,499	274	8,54	0,071	2,31
	R-f	7,54	0,112	253	3,36	0,029	2,24
Tale-38	Irr.	19,8	0,482	276	8,42	0,071	2,35
	R-f	8,32	0,121	249	3,63	0,033	2,29
12^{nd}FAWWON №97	Irr.	14,6	0,351	290	7,11	0,050	2,05
	R-f	8,16	0,068	180	2,17	0,045	3,76
4^{th}FEFWSN №50	Irr.	20,1	0,593	294	9,72	0,068	2,06
	R-f	12,7	0,180	246	4,72	0,051	2,69

Note: Irr.-irrigated; R-f- rain fed

Table 2. Correlation coefficients between gas exchange parameters g_m, and WUE.

	Parameters	P_n	g_s	C_i	T_r	g_m	WUE	
Irrigated	P_n	1	0,433**	-0,070	0,819**	0,778**	0,058	**Rain-fed**
	g_s	0,341**	1	0,592**	0,592**	0,019	-0,271*	
	C_i	-0,459**	0,500**	1	0,156	-0,594**	-0,399**	
	T_r	0,800**	0,366**	-0,305*	1	0,535**	-0,445**	
	g_m	0,975**	0,196	-0,622*	0,766**	1	0,244*	
	WUE	0,130	-0,161	-0,228	-0,458**	0,163	1	

**, Correlation is significant at the 0,01 level; *, Correlation is significant at the 0,05

Table 3. Changes of photosynthetic pigments content of wheat genotypes under water stress.

Wheat genotypes		Chl a mg g^{-1}dw	Chl b mg g^{-1}dw	Chl (a+b) mg g^{-1}dw	Car (x+c) mg g^{-1}dw	Chl a/b	Chl (a+b)/Car (x+c)
T. durum Desf.							
Garagylchyg 2	irr.	7,14	3,34	10,48	1,76	2,14	5,96
	r-f	5,50	3,06	8,56	1,18	1,80	7,25
Vugar	irr.	6,02	2,93	8,95	1,45	2,06	6,16
	r-f	4,00	1,86	5,86	0,98	2,15	5,97
Shiraslan 23	irr.	5,68	2,68	8,36	1,41	2,12	5,93
	r-f	4,08	1,89	5,97	1,02	2,15	5,84
Barakatli 95	irr.	6,08	2,81	8,89	1,54	2,16	5,76
	r-f	4,83	2,19	7,02	1,15	2,21	6,09
Alinja 84	irr.	5,10	2,66	7,76	1,24	1,92	6,26
	r-f	4,46	2,01	6,47	1,16	2,22	5,57
Tartar	irr.	4,90	2,51	7,41	1,17	1,96	6,34
	r-f	6,23	2,69	8,92	1,58	2,32	5,66
T. aestivum L.							
Gobustan	irr.	6,78	3,30	10,08	1,58	2,06	6,37
	r-f	5,08	2,57	7,65	1,20	1,98	6,35
Giymatli 2/17	irr.	5,85	2,68	8,53	1,38	2,18	6,17
	r-f	4,07	1,84	5,91	1,12	2,21	5,26
Gyrmyzygul 1	irr.	7,19	3,22	10,41	1,86	2,23	5,60
	r-f	7,17	3,06	10,24	1,93	2,34	5,31
Azamatli 95	irr.	6,68	3,70	10,38	1,38	1,81	7,50
	r-f	4,43	2,06	6,49	1,12	2,15	5,82
Tale 38	irr.	7,68	3,54	11,22	1,84	2,17	6,08
	r-f	6,44	3,13	9,57	1,60	2,06	5,99
12ndFAWWON №97	irr.	6,80	3,57	10,37	1,67	1,98	6,21
	r-f	6,68	3,29	9,97	1,65	2,03	5,98
4thFEFWSN №50	irr.	7,14	3,49	10,63	1,80	2,04	5,92
	r-f	5,20	2,49	7,69	1,34	2,08	5,75

Note: irr.-irrigated; r-f.-rain-fed

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

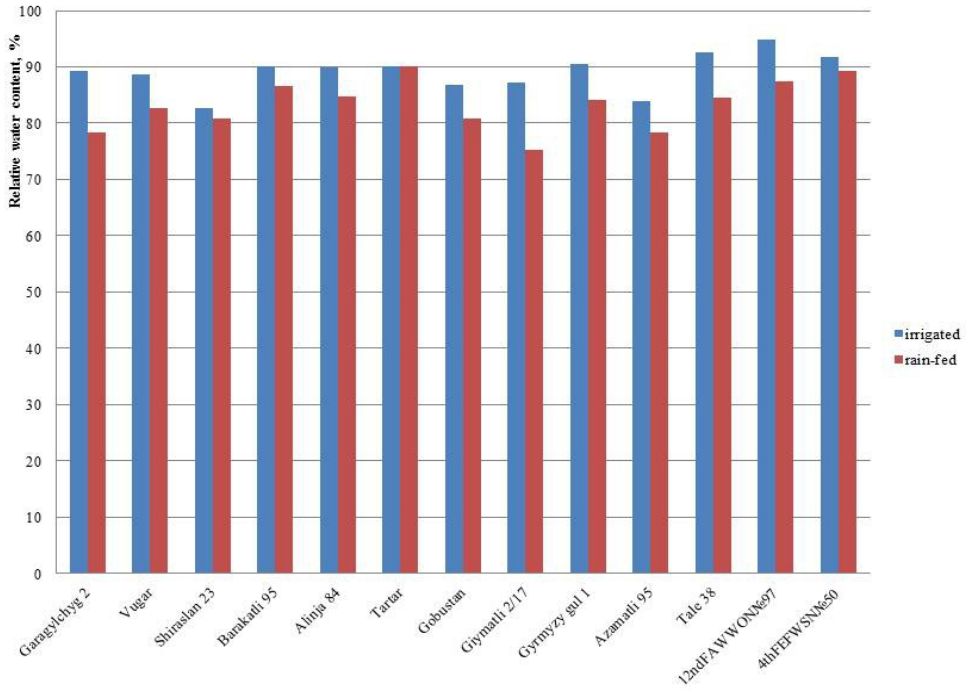

Figure 1. Effect of water stress on flag leaf RWC. Data are mean of five replications.

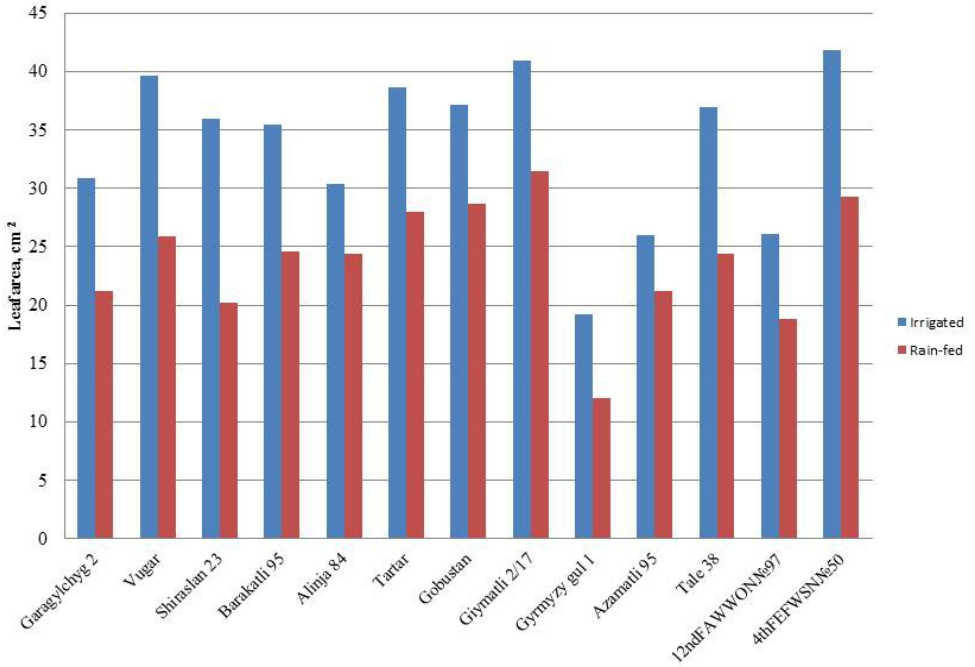

Figure 2. Effect of water stress on flag leaf area. Data are mean of five replications.

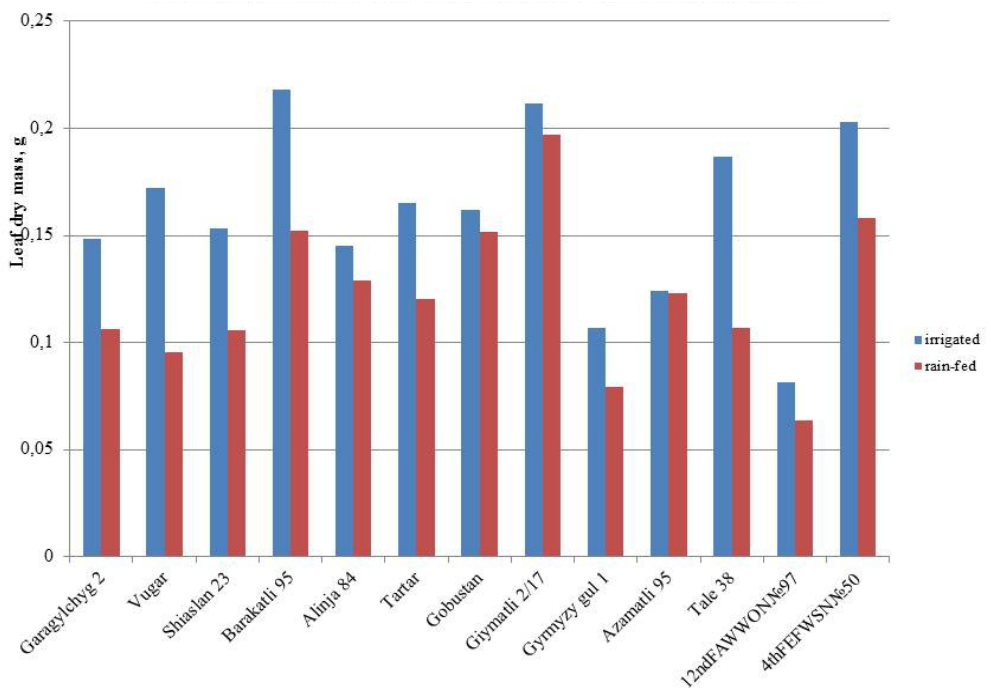

Figure 3. Effect of water stress on flag leaf dry biomass. Data are mean of five replications.

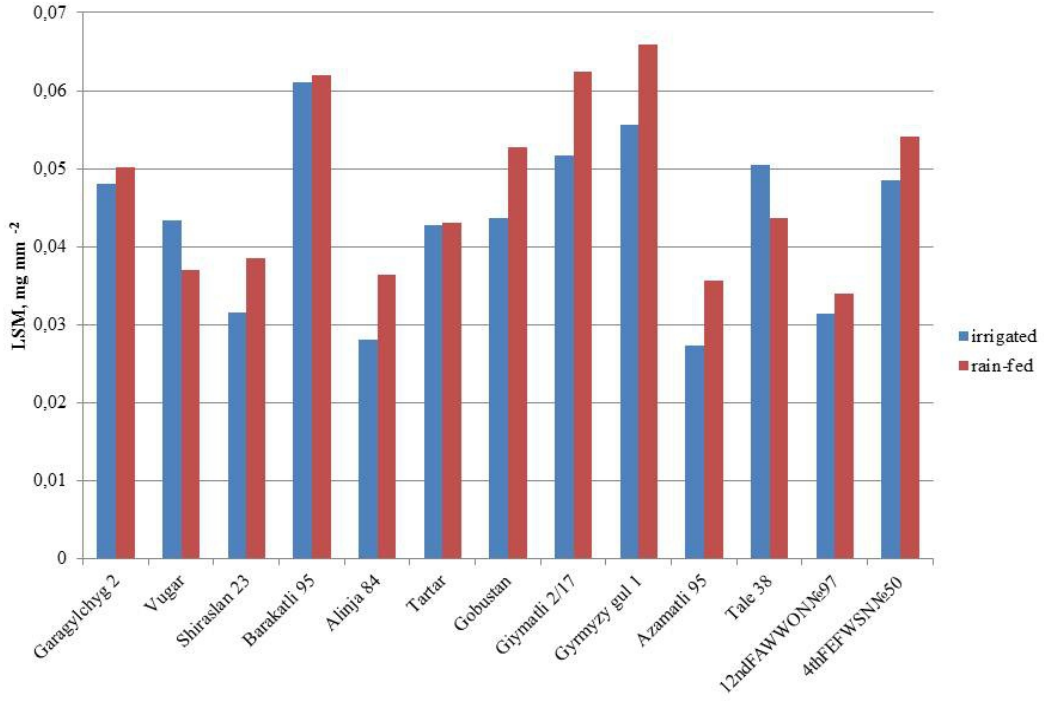

Figure 4. Effect of water stress on LSM.

DISCUSSION

Soil water deficit causes decrease of leaf gas exchange parameters. Our result is in agreement with results of Changhai *et al*., (2010), Wu and Bao, (2011), Shan *et al*., (2012). The P_n was higher among genotypes of bread wheat than durum wheat. The g_s regulate P_n, T_r and C_i. According to correlation studies the g_m has a dominance role in the regulation of P_n. This result is in agreement with result of Siddique *et al*., (1999). Despite the fact that the leaf gas exchange

parameters, LA and DM strongly influenced by drought, RWC remained relatively high. Stomatal responses are more closely linked to soil moisture content than to leaf water status. Although LA and DM was positively correlated with P_n and were relatively higher in genotypes Barakatli 95, Giymatli 2\17, Tale 38 and 4thFEFWSN№50 under irrigated condition, strongly affected by drought stress. Therefore, large LA may be good selection trait under irrigated condition. In breeding retains a large LA that is conducive to greater yield potential, then when stress occurs a large part of this LA, which is a dry matter investment, will be irreversibly desiccated and lost (Blum, 2005). In genotypes with early heading period (Garagylchyg 2, Alinja 84, Gobustan, Giymatli 2/17, Azamatli 95) LA reduction was greater than DM, as a result LSM increased. Our result is in agreement with result of Witkowski and Byron (1991). Drought stress more affected on DM of late heading genotypes. Photosynthetic pigments are important to plants mainly for harvesting light and production of reducing powers (Anjum *et al*., 2011). The decrease in Chl content under drought stress may be the result of pigment photo-oxidation and degradation. 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, Chl (a+b) content of genotypes Tartar, Gyrmyzy gyl1did not reduce significantly, we can consider these genotypes as drought resistant.

CONCLUSION

Physiological traits of wheat genotypes are strongly influenced under soil water deficit. Wheat genotypes survive water scarcity by adaptive changes in morphological traits and in the course of physiological, biochemical processes. Grain formation stage is very sensitive to water scarcity. Traits, such as optimal heading time, high RWC, photosynthesis rate, and chlorophyll content can be used as good selection criteria for breeding of wheat genotypes under rain-fed condition.

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