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Effect of Drought Stress on Physiological Traits, Grain Yield of Durum (*Triticum durum* Desf.) and Bread Wheat (*Triticum aestivum* L.) Genotypes

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We aimed to study the influence of soil water deficit on gas exchange parameters, relative water content, photosynthetic pigment contents of flag leaf, as well as on assimilation area and dry matter of leaves, stem, spike and grain yield of durum and bread wheat genotypes in the 2014-2015 growing season. Water stress caused reduction of photosynthesis rate, stomatal conductance, transpiration rate, an increase of intercellular CO_2 concentration. Water stress severely affected on relative water content, Chl *a, b* and Car (x+c) content, assimilation area formation and dry matter accumulation of sensitive wheat genotypes.

Keywords: *Drought stress, gas exchange, relative water content, chlorophyll, assimilation area, dry matter, grain yield*

INTRODUCTION

With the population growing rapidly and the limited water resources becoming scarcer, maintenance of sustainable productivity of cereal crops is of great importance. Wheat (*Triticum* L.) is one of the main cereal crops for food safety in the world. Global wheat production in 2017 amounted to 754 million tons, which is 2.7 percent more than in 2016 (FAO, 2017). Despite the fact that the conventional selection and the use of new biotechnological tools allow a significant increase in wheat production in recent years, unfavorable factors of the environment greatly affect the production and quality of wheat. Yield safety can only be improved if future breeding attempts will be based on the valuable new knowledge acquired on the processes of the determining plant development and its responses to stress (Barnabas et al., 2008). To accelerate yield improvement, physiological traits at all levels of integration need to be considered in breeding (Long et al., 2015). Physiological approaches have already demonstrated significant genetic gains in Australia and several developing countries of the International Wheat Improvement Network (Reynolds and Langridge, 2016). Drought is the most important limiting factor for crop production and it is becoming an increasingly severe problem in many regions of the world (Izanloo et al., 2008). Wheat is one of the widely cultivated (about 651.000 hectares) crops in Azerbaijan, where drought is the main limiting factor for its production (Aliyev, 2001). Azerbaijan is in the second place of the top 15 wheat-dependent countries (http://necsi.edu, 2011). Drought is a non-uniform phenomenon that influences plants differently depending on the development stage at the time of its occurrence, adversely affects physiology, morphology, growth and yield traits of wheat (Hossain and Da Silva, 2012). Drought stress reduces photosynthetic characteristics, shortens the duration of photosynthesis and promotes the senescence of leaves (Liu et al., 2016). A decrease in photosynthesis rate limits expansion of assimilation area of vegetative organs and the accumulation of dry mass. Drought induces a wide range of molecular, biochemical and physiological alterations in plants, including accumulation of osmolytes, reduction of photosynthesis, stomata closure and the induction of stress-responsive genes (Lata et al., 2015). Higher photosynthetic rates during drought and rapid recovery after re-watering produced less- pronounced yield declines in the tolerant cultivar than the sensitive cultivar (Abid et al., 2018). In wheat, greater genetic variability can be explored with germplasm from its centers of origin and diversity (Dvorak et al., 2011). Ceccareli stated that local varieties have 25-61% of advantage over modern varieties under stressful environments, while modern genotypes have 6-18% of advantage over local varieties under favorable conditions (Ceccareli, 1989).

Drought tolerance is a complex trait controlled by numerous genes, each with minor effects (Bernardo, 2008). Phenotypic, biochemical and genomics-assisted selection methodologies are discussed as leading research components used to exploit genetic variation for drought tolerance

(Mwadzingeni et al., 2016).

The purpose of the study. The purpose of this research was to study the influence of soil water deficit on some physiological traits, grain yield of durum and bread wheat genotypes.

MATERIALS AND METHODS

Field studies were carried out during the 2014/15 growing season at the experimental field of the Department of Plant Physiology and Biotechnology Research Institute of Crop Husbandry, located in the Apsheron peninsula, Baku. Durum wheat genotypes (Garagylchyg 2, Vugar, Shiraslan 23, Barakatli 95, Alinja 84, Tartar, Sharg, Gyrmyzy bugda) and bread wheat genotypes (Nurlu 99, Gobustan, Akinchi 84, Giymatli 2\17, Gyrmyzy gul 1, Azamatli 95, Tale 38, Ruzi 84, Pirshahin 1, 12ndFAWWON№97, 4thFEFWSN№50, Gunashli, Dagdash, Saratovskaya 29) were grown under two conditions: drought (non-irrigation) and irrigated (three irrigations: at seedlings, stem elongation and grain filling). The plot size was 1.05 m x10 m, with 15.0 cm row spacing. Each plot had three replications under drought and irrigation.

Measurements: Gas exchange parameters (photosynthesis rate- P_n, stomatal conductance- g_s, intercellular CO_2 concentration- C_i, transpiration rate- E) were measured using LI-COR 6400XT Portable Photosynthesis System (LI-COR Biosciences, Lincoln, NE, USA) at the anthesis growth stage. Measurements were carried out between 10:00 and 12:00 a.m. Data logging started after 45 seconds of the insertion of leaves into chamber. Leaf Chl a, b and Car (x+c) contents were determined following the method of Lichtenthaler (1987), with little modifications. The leaf, stem plus sheath and spike dry mass was measured after oven drying at 105 °C for 24 h. Leaf area per stem (LAS), also projected area of stem multiplied by 3.14 according to Kvët and Marshall (1971), and spike multiplied by 2 according to Alvaro et al., (2008) were measured with an area meter (AAC-400, Hayashi Denkon Co, LTD, Japan). The flag leaf RWC was determined gravimetrically. RWC was calculated using the following formula: RWC (%) = (FW-DW)/(TW-DW)x100, where FW-fresh mass, DW-dry mass, TW-turgid mass.

Statistical analysis: Mean values were calculated by Excel program. Correlation among traits was calculated by SPSS 16 software.

RESULTS

Stomatal conductance, net photosynthesis rate and transpiration rate decreased significantly in flag leaf of genotypes in response to drought stress at anthesis (Table 1). A decrease of stomatal conductance, net photosynthesis rate and transpiration rate amounted to an average 45%, 44%, 37% in the sensitive genotypes Garagylchyg 2, Vugar, Shiraslan 23, Barakatli 95, Alinja 84, Tartar, Nurlu 99, Gobustan, Akinchi 84, Giymatli 2/17, Azamatli 95, Tale 38, Ruzi 84, Pirshahin 1, 12ndFAWWON№97 and Saratovskaya 29. A relatively less decrease of g_s, P_n and E was revealed in the genotypes Sharg, Gyrmyzy bugda, Gyrmyzy gul 1, 4thFEFWSN№50, Gunashli and Dagdash. The intercellular CO_2 concentration in flag leaf of most genotypes increased under drought condition.

Although the RWC in flag leaf was maintained at a relatively high level at the heading and postanthesis grain formation stages, genotypic variations in this trait was revealed at the early milky ripe stage (Fig. 1). The RWC of most genotypes was around 70% under normal water supply. The lowest RWC was detected in the genotypes Nurlu 99, Azamatli 95, Pirshahin 1 and Gunashli, with early heading time. Despite the fact that the RWC was maintained at a high level under normal water supply, there was a strong decline under water stress conditions in the genotypes Garagylchyg 2, Shiraslan 23, Akinchi 84, Tale 38, Ruzi 84, 12ndFAWWON№97 and 4thFEFWSN№50. A relatively higher RWC under normal water supply and slight decrease of this trait was revealed in the genotypes Vugar, Tartar, Sharg, Gyrmyzy bugda, Giymatli 2/17 and Dagdash. We consider these genotypes as drought tolerant.

A relatively high Chl a+b content was detected in flag leaf of the genotypes Garagylchyg 2, Tartar, Gyrmyzy bugda, Gobustan, Giymatli 2/17, Gyrmyzy gul 1, 4thFEFWSN№50 and Saratovskaya 29 under irrigation (Table 2). A relatively low Chl a+b content was detected in the genotypes Shiraslan 23, Sharg, Nurlu 99, Akinchi 84, Azamatli 95, Dagdash. Water stress caused reduction in Chl a, b and Car (x+c) content in all genotypes with exception Azamatli 95. A strong reduction of pigments under water stress was observed in the genotypes of durum wheat Garagylchyg 2, Tartar, Sharg, Gyrmyzy bugda, in the genotypes of bread wheat Gobustan, Akinchi 84, Giymatli 2/17 and Gunashli. Photosynthetic apparatus of some durum wheat genotypes (Vugar, Shiraslan 23, Barakatli 95), and bread wheat genotypes (Gyrmyzy gul 1, Azamatli 95, Tale 38, 12ndFAWWON№97, Dagdash, Pirshahin 1, Saratovskaya 29) were relatively tolerant to water stress. A decrease of Chl a/b ratio was observed in 11 genotypes, while an increase in 10 genotypes. A Chl a/b ratio remained unchanged in the genotype Ruzi 84. In comparison with Chl a and b, Car (x+c) were more resistant to water deficiency, as a result, the Chl (a+b)/Car (x+c) ratio is reduced in most genotypes. An increase in Chl (a+b)/Car (x+c) ratio was detected in some genotypes.

Water stress limited the expansion of the assimilation area of leaves, stem and spike, as well as the accumulation of biomass in these organs (Table 3). At the milky ripe stage the assimilating area of the leaves decreases due to senescence of the leaves in the underlying layers, which is accelerated under condition of water deficiency. A strong reduction of the assimilation area of leaves, stem and spike was detected in the genotypes Garagylchyg 2, Shiraslan 23, Akinchi 84, Tale 38, 12ndFAWWON№97 and Dagdash. A deep limitation in biomass of leaves and stem in the condition of water deficiency was detected in the genotypes Tartar, Sharg, Gyrmyzy bugda, Nurlu 99, Gobustan, Azamatli 95, Pirshahin 1. A strict decrease in the biomass of leaves was not accompanied by a similar decrease in the biomass of the stem in some genotypes, such as, Akinchi 84, Giymatli 2/17, Ruzi 84, 12ndFAWWON№97, 4thFEFWSN№50 and Gunashli. A strong reduction of spike biomass was revealed in the genotypes Sharg, 4thFEFWSN№50, Gunashli, Dagdash and Saratovskaya 29.

Table 1. Effect of drought stress on gas exchange parameters (I - irrigated, D - drought).

Wheat genotypes	Growth condition	Gas exchange parameters			
		P_n, µmol CO_2 m^{-2} s^{-1}	g_s, mol H_2O m^{-2} s^{-1}	C_i, µmol CO_2 mol^{-1}	E, mmol H_2O m^{-2} s^{-1}
Triticum durum Desf.					
Garagylchyg 2	I	12.10	0.142	223.5	2.56
	D	6.55	0.087	250.4	1.79
Vugar	I	13.24	0.142	206.5	2.65
	D	6.68	0.072	219.5	1.45
Shiraslan 23	I	16.77	0.138	159.0	2.57
	D	7.36	0.086	225.6	1.81
Barakatli 95	I	13.16	0.158	223.0	2.89
	D	7.07	0.078	227.1	1.55
Alinja 84	I	11.03	0.128	223.0	2.43
	D	8.31	0.078	201.6	1.65
Tartar	I	16.31	0.177	235.0	3.13
	D	8.75	0.078	180.6	1.68
Sharg	I	14.23	0.132	182.0	2.54
	D	11.73	0.113	189.6	2.22
Gyrmyzy bugda	I	11.73	0.102	166.0	1.98
	D	8.13	0.075	190.4	1.54
Triticum aestivum L.					
Nurlu 99	I	15.64	0.164	202.0	3.13
	D	4.96	0.115	302.0	2.35
Gobustan	I	12.92	0.159	225.4	3.01
	D	5.86	0.083	256.8	1.87
Akinchi 84	I	13.63	0.186	235.2	3.48
	D	8.82	0.086	195.5	1.91
Giymatli 2/17	I	15.36	0.143	186.2	2.98
	D	7.24	0.098	245.6	2.18
Gyrmyz gul 1	I	8.43	0.087	204.2	1.83
	D	6.21	0.066	210.5	1.53
Azamatli 95	I	12.56	0.146	220.0	2.67
	D	6.89	0.065	176.4	1.41
Tale 38	I	14.97	0.167	206.0	2.76
	D	6.78	0.066	195.0	1.42
Ruzi 84	I	11.66	0.145	229.5	2.56
	D	8.09	0.074	193.0	1.52
Pirshahin 1	I	10.81	0.121	217.0	2.27
	D	5.94	0.089	260.3	1.84
12ndFAWWON№97	I	10.37	0.119	224.0	2.23
	D	6.03	0.072	234.0	1.46
4thFEFWSN№50	I	13.56	0.118	175.0	2.41
	D	9.74	0.101	213.0	2.01
Gunashli	I	9.20	0.131	242.0	2.53
	D	6.11	0.115	281.0	2.17
Dagdash	I	15.21	0.150	193.0	2.72
	D	12.70	0.098	146.0	2.04
Saratovskaya 29	I	11.11	0,121	206.0	2.34
	D	4.54	0,075	273.5	1.56

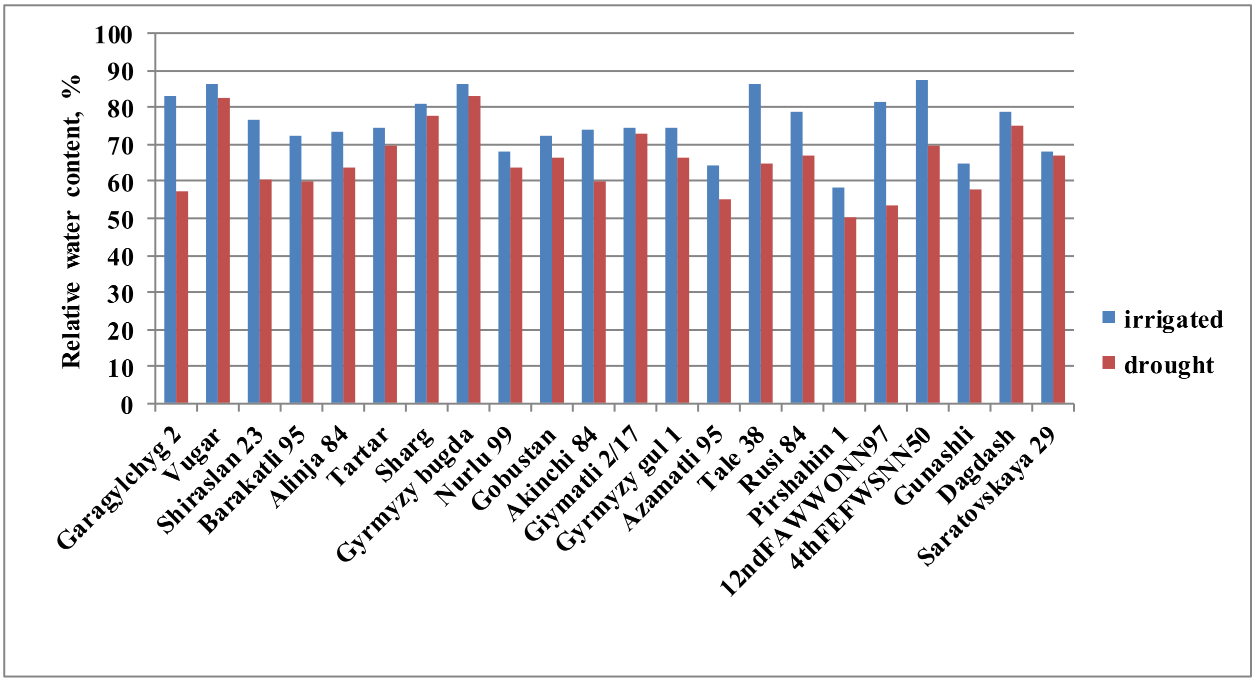

Fig. 1. Effect of drought stress on relative water content of flag leaf

Table 2. Effect of drought stress on Chl a, b and Car (x+c) content.

Wheat genotypes		Chl a	Chl b	Chl (a+b)	Car (x+c)	Chl a/b	Chl (a+b)/Car (x+c)
Triticum durum Desf.							
Garagylchyg 2	I	7.51	2.65	10.15	2.29	2.84	4.43
	D	4.89	1.88	6.77	1.73	2.60	3.92
Vugar	I	6.82	2.38	9.20	2.16	2.87	4.26
	D	5.87	2.04	7.91	1.71	2.88	4.63
Shiraslan 23	I	5.23	1.92	7.15	1.47	2.73	4.86
	D	5.15	1.77	6.92	1.65	2.91	4.19
Barakatli 95	I	7.16	2.65	9.81	2.02	2.70	4.85
	D	6.60	2.52	9.12	1.87	2.62	4.87
Alinja 84	I	6.59	2.47	9.06	1.87	2.66	4.85
	D	5.41	1.89	7.29	1.65	2.86	4.43
Tartar	I	7.48	2.93	10.41	2.16	2.55	4.83
	D	5.98	2.38	8.36	1.78	2.52	4.69
Sharg	I	6.52	2.34	8.86	1.90	2.78	4.66
	D	5.09	1.66	6.75	1.63	3.07	4.15
Gyrmyzy bygda	I	7.63	2.54	10.17	2.14	3.01	4.76
	D	6.06	2.05	8.11	1.77	2.96	4.57
Triticum aestivum L.							
Nurlu 99	I	4.32	1.62	5.94	1.27	2.67	4.69
	D	4.14	1.53	5.67	1.16	2.70	4.91
Gobustan	I	7.82	2.80	10.62	2.15	2.79	4.94
	D	4.85	1.61	6.45	1.41	3.01	4.58
Akinchi 84	I	6.51	2.43	8.95	1.95	2.68	4.60
	D	4.78	1.81	6.59	0.74	2.65	8.92
Giymatli 2/17	I	7.78	2.72	10.50	2.24	2.86	4.70
	D	6.18	2.19	8.37	1.72	2.82	4.87
Gyrmyzy gul 1	I	7.96	2.96	10.92	2.26	2.69	4.84
	D	7.71	2.84	10.55	2.25	2.72	4.67
Azamatli 95	I	4.87	2.09	6.95	1.34	2.33	5.20
	D	5.23	1.95	7.18	1.46	2.67	4.92
Tale 38	I	7.22	2.57	9.79	2.07	2.81	4.73
	D	6.56	2.48	9.03	1.90	2.65	4.75
Ruzi 84	I	6.76	2.36	9.12	1.93	2.86	4.73
	D	5.58	1.95	7.54	1.58	2.86	4.77
Pirshahin 1	I	7.01	2.54	9.55	2.01	2.76	4.76
	D	6.31	2.25	8.56	1.88	2.80	4.55

Continued table 2

12ndFAWWON№97	I	6.97	2.51	9.48	2.04	2.77	4.64
	D	6.12	2.43	8.55	1.72	2.52	4.97
4thFEFWSN№50	I	7.68	2.78	10.46	2.23	2.76	4.70
	D	6.17	2.29	8.45	1.88	2.70	4.50
Günəşli	I	7.26	2.72	9.98	1.92	2.67	5.20
	D	5.08	1.95	7.03	1.44	2.61	4.87
Dagdash	I	6.39	2.14	8.52	1.99	2.99	4.28
	D	5.66	2.00	7.66	1.93	2.83	3.97
Saratovskaya 29	I	7.80	2.97	10.78	2.06	2.62	5,24
	D	7.00	2.53	9.53	2.05	2.77	4.66

Table 3. Effect of drought stress on assimilation area and dry mass of leaves, stem and spike (milky ripe stage).

Wheat genotypes	Growth condition	Assimilation area, cm^2			Dry mass, g		
		leaves	stem	spike	leaves	stem	spike
Triticum durum Desf.							
Garagylchyg 2	I	69.04	115.58	34.09	0.415	2.959	2.142
	D	48.81	86.68	29.22	0.304	2.628	2.515
Vugar	I	64.64	106.26	29.00	0.368	2.954	2.104
	D	58.00	101.80	30.18	0.360	2.934	2.492
Shiraslan 23	I	65.04	108.74	31.17	0.390	3.020	2.088
	D	46.11	84.83	26.11	0.301	2.489	2.094
Barakatli 95	I	53.80	103.87	36.02	0.394	3.454	1.794
	D	55.41	100.47	34.07	0.364	2.691	1.784
Alinja 84	I	64.57	99.91	28.41	0.342	2.642	1.913
	D	36.76	83.23	26.51	0.249	2.181	1.726
Tartar	I	71.51	108.64	36.78	0.488	3.007	2.415
	D	62.34	89.55	34.97	0.305	2.316	2.447
Sharg	I	80,49	158.48	43.16	0.552	4.322	2.523
	D	58.93	133.75	39.88	0.373	3.533	1.881
Gyrmyzy bugda	I	76.98	171.92	30.23	0.462	3.674	1.556
	D	48.39	129.31	29.48	0.338	2.781	1.914
Triticum aestivum L.							
Nurlu 99	I	38.24	68.33	21.16	0.228	1.834	2.047
	D	17.18	65.81	18.23	0.112	1.477	1.786
Gobustan	I	49.63	81.07	20.41	0.301	2.503	2.251
	D	31.63	67.68	18.64	0.192	1.964	2.181
Akinchi 84	I	45.23	115.38	27.06	0.275	2.924	1.925
	D	24.28	82.82	23.34	0.191	2.420	1.917
Giymatli 2/17	I	63.54	99.16	24.24	0.443	2.552	2.493
	D	38.08	90.37	20.80	0.262	2.368	2.141
Gyrmyzy gul 1	I	48.55	68.58	16.48	0.302	1.621	1.547
	D	41.56	35.17	12.12	0.271	1.341	1.423
Azamatli 95	I	39.16	93.62	24.30	0.274	2.180	2.282
	D	28.30	86.99	19.21	0.199	1.563	2.156
Tale 38	I	47.75	121.26	32.42	0.333	2.593	1.812
	D	38.08	83.59	23.10	0.292	1.895	1.651
Ruzi 84	I	41.71	89.77	27.94	0.341	2.580	2.399
	D	28.37	83.49	25.78	0.222	2.162	2.024
Pirshahin 1	I	40.63	96.73	24.62	0.357	2.914	2.390
	D	28.49	72.14	22.54	0.214	1.989	2.081
12ndFAWWON№97	I	21.47	73.29	17.50	0.133	1.235	1.105
	D	9.24	55.26	12.03	0.068	1.053	0.992
4thFEFWSN№50	I	74.71	132.18	42.71	0.400	2.233	2.215
	D	41.66	103.90	41.76	0.243	1.908	1.711
Gunashli	I	39.33	71.59	28.78	0.276	2.194	2.599
	D	23.71	61.79	27.49	0.166	1.823	1.922
Dagdash	I	67.19	163.97	28.95	0.431	3.184	1.857
	D	52.57	103.21	23.35	0.360	2.529	1.231
Saratovskaya 29	I	45.84	114.70	16.36	0.256	1.983	0.913
	D	30.59	100.94	14.43	0.183	1.663	0.708

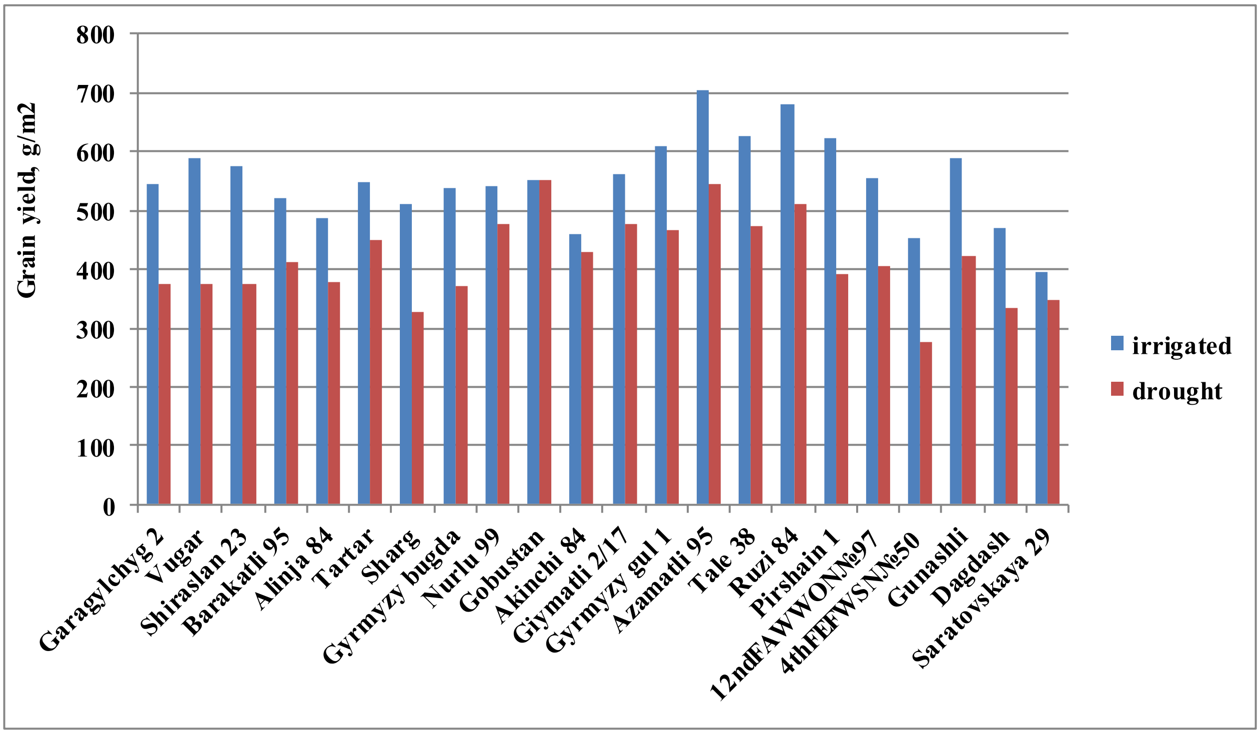

Fig. 2. Effect of drought stress on grain yield of wheat genotypes.

Reductions in grain yield under drought stress were strongly expressed in the genotypes Garagylchyg 2, Vugar, Shiraslan 23, Sharg, Gyrmyz bugda, Pirshahin 1, 4thFEFWSN№50, Gunashli and Dagdash (Fig.2). A slight decrease in grain yield was revealed in the genotypes Tartar, Nurlu 99, Gobustan, Akinchi 84, Giymatli 2/17 and Saratovskaya 29.

DISCUSSIONS

Photosynthetic responses to water stress have been the subject of studies and debates for decades, in particular, concerning which are the most limiting factors (stomatal or mesophyll limitations, photochemical and/or biochemical reactions) for photosynthesis under water stress (Flexas and Medrano, 2002; Lawlor and Cornic, 2002). Reduction of stomatal conductance in response to water deficiency is the main reason for the decrease in the rate of photosynthesis. However, during prolonged drought other non-stomatal factors play a dominant role in limiting the rate of photosynthesis. Our long-term gas exchange studies in wheat showed that relationship between photosynthesis rate and mesophyll conductance (calculated as the ratio of P_n to C_i) is more strong than relationship between photosynthesis rate and stomatal conductance (Allahverdiyev et al., 2015). An increase in C_i indicates non-stomatal limitation of photosynthesis. High gas exchange characteristics (P_n, g_s, E) of the genotypes Tartar, Sharg, Giymatli 2/17, Tale 38, Pirshahin 1, 4thFEFWSN№50, Dagdash positively associated with assimilation area formation and dry mass accumulation.

Despite the fact that gas exchange parameters of wheat genotypes are severely reduced at the booting, heading, flowering stages, a significant decrease in RWC and the Chl a, b and Car (x+c) contents was observed at grain ripening stages. In fact, although components of plant water relations are affected by reduced availability of water, stomatal opening and closing are more strongly affected (Anjum et al., 2011). In our opinion, a strong reduction of stomatal conductance allows keeping RWC at a relatively high level. There was positive and significant relationships between RWC and Car (x+c) under water stress (Allahverdiyev et al., 2018). The reduction of RWC and photosynthetic pigment contents were not significant in the genotypes Vugar, Gyrmyzy gul 1, Dagdash and Saratovskaya 29.

Flag and penultimate leaves, as well as spike and stem are the main assimilating surfaces at the heading, flowering and initial stages of kernel ripening. Our results showed that, an increase in the assimilation area of stem continued until watery ripe, while an increase in dry mass continued until milky ripe (Allahverdiyev and Huseynova, 2017). Translocation of photoassimilates from leaves to stem and further from leaves, stem and vegetative parts of spike into grains is accelerated under water deficiency. Spike dry mass decreases under drought conditions due to insufficiency of sources.

The grain yield is the total output of all agronomical, morphological traits, physiological and biochemical processes. An average grain yield of durum and bread wheat genotypes was 539.3 and 558.4 g/m^2 under irrigated, 382.8 and 443.2 g/m^2 under water stress conditions, respectively. The reduction of grain yield constituted 29% for the durum wheat genotypes and 22% for the bread wheat genotypes.

On the basis of a decrease in gas exchange parameters, relative water content and Chl a, b and Car(x+c) contents of flag leaf, as well as a decrease in the assimilation area of leaves, stem and spike, we can conclude that some genotypes, such as Garagylchyg 2, Alinja 84, Tartar, Akinchi 84, Tale 38 and Gunashli, Pirshahin 1, 12ndFAWWON№97 are sensitive to drought stress. A deep decrease in grain yield of the genotypes Garagylchyg 2, Shiraslan 23, Sharg, Gyrmyzy bugda, Pirshahin 1, Gunashli, 4thFEFWSN№50 is more related with the limitation of biomass in leaves, stem and spike.

Despite weak correlations between physiological characteristics and grain yield, modern wheat genotypes, such as Tale 38, 4thFEFWSN№50 with high rate of photosynthesis, stomatal conductance and transpiration rate, as well as modern wheat genotypes, such as Vugar, Gyrmyzy gul 1, Dagdash with high indexes of relative water content and photosynthetic pigment contents under drought stress can be used in wheat breeding for improving productivity and drought tolerance. The classical tallest wheat genotypes, such as Sharg, Gyrmyzy bugda, Saratovskaya 29 show physiological tolerance to water stress. However, non-sufficient translocation of photoassimilates from leaves and stem into grains in the tallest genotypes, also less tillering capacity lead to low grain yield in a unit of area.

REFERENCES

Abid M., Ali Sh., Qi L.K., et al. (2018) Physiological and biochemical changes during drought and recovery periods at tillering and jointing stages in wheat (*Triticum aestivum* L.). *Scientific Reports*. **8:** 4615. DOI.10.1038/s41598-018-21441-7.

Aliyev J.A. (2001) Physiological bases of wheat breeding tolerant to water stress. Proceedings of the 6th International Wheat Conference, Budapest, Hungary, 2000. In: *Wheat in a Global Environment* (Z.Bedo, L.Lang, eds.). Dordrecht, Boston, London: Kluwer Academic Publishers, **9:** 693-698.

Allahverdiyev T., Huseynova I. (2017) Influence of water deficit on photosynthetic activity, dry matter partitioning and grain yield of different durum and bread wheat genotypes. *Cereal Research Communications*, **43:** 432-441.

Allahverdiyev T.I., Talai J.M., Huseynova I.M., Aliyev J.A. (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 Journal of Crop Breeding and Genetics*, **1:** 50-62.

Allahverdiyev T., Jahangirov A., Talai J., Huseynova I. (2018) Dry matter remobilization, yield and yield components of durum (*Triticum durum* Desf.) and bread (*Triticum aestivum* L.) wheat genotypes under drought stress. *Pakistan Journal Botany*, **50:** 1745-1751,

Alvaro F., Isidro J., Villegas, D. et al. (2008) Breeding Effects on Grain Filling, Biomass Partitioning, and Remobilization in Mediterranean Durum Wheat. *Agronomy Journal,* **100:** 361-370.

Anjum S., Xie X., Wang L.C. et al. (2011) Morphological, physiological and biochemical responses of plants to drought stress. *African Journal of Agricultural Research*, **6:** 2026-2032.

Barnabas B., Jager K., Feher A. (2008) The effect of drought and heat stress on reproductive processes in cereals. *Plant Cell Environ.,* **31**: 11-38.

Ceccarelli S. (1989) Wide adaptation. How wide? *Euphytica*, **36:** 265-273.

Dvorak J., Luo M.C., Akhunov E. (2011) N.I.Vavilov's theory of centres of diversity in the light of current understanding of wheat diversity, domestication and evolution. *Czech Journal of Genetics and Plant Breeding*, **47:** 820-827.

FAO (Food and Agriculture Organization). (2017) FAO Cereal Supply and Demand Brief**.** World wheat market. www.fao. org/world food situation/csdb/en/.Rome.

Flexas J., Medrano H. (2002) Drought-inhibition of Photosynthesis in C_3 Plants: Stomatal and Non-stomatal Limitations Revisited. *Annals of Botany*, **89:** 183-189.

Hossain A., Da Silva J.A. (2012) Phenology, growth and yield of three wheat (*Triticum aestivum* L.) varieties as affected by high temperature stress. *Notulae Sci. Biol*., **4:** 97-109.

http://necsi.edu (2011).

Izanloo A., Condon A.G., Langridge P., Tester M., Schnurbusch T. (2008) Different mechanisms of adaptation to cyclic water stress in two South Australian bread wheat cultivars. *J. Exp. Bot.*, **59:** 3327-3346.

Kvët J., Marshall K. (1971) Assessment of leaf area and other assimilating plant surfaces: Plant photosynthetic production. *Manual of methods. The Hague*, **14:** 517-555.

Lata C., Muthamilarasn M., Prasad M. (2015) Drought stress responses and signal transduction in plants. In: *Elucidation of Abiotic Stress*

Signaling in Plants (ed. G.K.Pandey). New-York: Springer, 195-225.

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

Lichtenthaler H. (1987) Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes. *Methods in Enzymology*, **148:** 350-382.

Liu E.K., Mei X.R., Yan C.R. et al. (2016) Effects of water stress on photosynthetic characteristics, dry matter translocation and WUE in two winter wheat genotypes. *Agricultural Water Management*, **167:** 75-85.

Long S.P., Marshall-Colon A., Zhu X-G. (2015) Meeting the global food demand of the future by engineering crop photosynthesis and yield potential. *Cell*, **161:** 56-66.

Mwadzingeni L., Shimelis H., Dube E. et al. (2016) Breeding wheat for drought tolerance: Progress and technologies. *Journal of Integrative Agriculture*, **15:** 935-943.

Reynolds M., Langridge P. (2016) Physiological breeding. *Current Opinion in Plant Biology*, **31:** 162-171.

Quraqlıq Stresinin Bərk Buğda (*Triticum durum* Desf.) və Yumşaq Buğda (*Triticum aestivum* L.) Genotiplərinin Fizioloji Əlamətlərinə və Dən Məhsuldarlığına Təsiri

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Tədqiqat işində torpaqda su çatışmazlığının müxtəlif bərk və yumşaq buğda genotiplərinin qaz mübadiləsinə, nisbi su tutumuna, fotosintetik piqmentlərin miqdarına, yarpaq, gövdə, sünbülün assimilyasiya sahəsi və quru biokütləsi, dən məhsuldarlığına təsiri öyrənilmişdir. Su stresi flaq yarpaqda fotosintezin sürətinin, ağızcıqların keçiriciliyinin, transpirasiya sürətinin azalmasına, hüceyrəarası sahələrdə CO_2 qatılığının artmasına səbəb olmuşdur. Su stresi bəzi həssas genotiplərin nisbi su tutumunun, xlorofil a, b və karotinoidlərin miqdarının, yarpaq, gövdə, sünbülün assimilyasiya sahəsi, quru biokütləsi və dən məhsuldarlığının kəskin azalmasına səbəb olmuşdur.

Açar sözlər: *Quraqlıq stresi, qaz mübadiləsi, nisbi su tutumu, assimilyasiya sahəsi, quru biokütlə, dən məhsuldarlığı*

Влияние Засухи На Физиологические Показатели и Урожайность Зерна Твердой (*Triticum durum* Desf.) и Мягкой (*Triticum aestivum* L.) Пшеницы

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Изучено влияние дефицита влаги на газообмен, относительное содержание воды, содержание фотосинтетических пигментов, площадь ассимиляции листьев, стеблей, колоса, сухую биомассу и урожайность зерна различных генотипов твердой и мягкой пшеницы. Водный стресс способствовал уменьшению скорости фотосинтеза, транспирации и проводимости устьиц флагового листа, а также увеличивал концентрацию CO_2 в межклеточном пространстве. У некоторых, чувствительных к дефициту влаги генотипов, под действием водного стресса наблюдалось резкое уменьшение относительного содержания воды в тканях, хлорофилла *a, b* и каротиноидов, площади ассимиляции листьев, стеблей, колоса, сухой биомассы и урожайности зерна.

Ключевые слова: *Засуха, газообмен, относительное содержание воды, площадь ассимиляции, сухая биомасса, урожайность зерна*