Transactions of the Institute of Molecular Biology & Biotechnologies, MSE AR, vol. 6, No 2, p. 47-52 (2022)

The influence of drought stress on some physiological and biochemical parameters of wheat

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Received: October 25, 2022; Reviewed: November 05, 2022; Accepted: November 09, 2022

Wheat is a staple food and a source of protein and carbohydrates for 35% population in the world. Drought is one of the main environmental factors negatively affects wheat production and quality. We aimed to study the effect of drought stress on some physiological, morphological, biochemical parameters of 5 durum and 8 bread wheat genotypes. The assimilation surface area of leaves, stem, spike and dry biomass in this organ negatively affected by drought stress. Due to water deficiency relative water content, photosynthetic pigments content are reduced. Wheat genotypes responded to drought stress to conserve water by accumulating soluble sugars and proline. The malondialdehyde content increased indicating oxidative stress caused by drought. Genotypic differences for studied parameters was revealed.

***Keywords**: Wheat, assimilation area, dry biomass, relative water content, pigments, soluble sugars, proline, malondialdehyde, drought*

INTRODUCTION

Drought is a major environmental constrain with a deleterious effect on plant development leading to a considerable reduction of crop productivity worldwide (Todorova et al., 2021). In arid and semi-arid regions of the world, water availability is the major limiting factor and due to global climate change, more and more territories are exposed to drought. As well as untimely sowing, improper alternation of plants, lack of appropriate agro technical measures limit the use of water by plants for normal development, the formation of sufficient biomass, the transition to the generative phase and the formation of yield.

Wheat (*Triticum* L.) is one of the most important cereal crops in the world. In some underdeveloped countries of Africa and Asia, wheat is the main source of nutrients (protein, carbohydrates). In 2020/2021, global wheat production was 779.9 million tons from about 224 million hectare of area. Leading wheat producers worldwide were China, European Union, India and Russia (http://www.world-agriculturalproduction.com/crops/wheat.aspx).

Azerbaijan is in the 42rd place in terms of wheat production, which amounted to 1.8 million tons in 2021/2022. The main limiting factors in the wheat yield are drought and high temperatures during heading-flowering and grain ripening. Drought reduces the rate of photosynthesis in leaves, green stem and spike and production of the photoassimiliates and transport to grain. Drought and heat stress significantly reduce photosynthetic efficiency, stomatal conductance, leaf area and water-use efficiency of cereals, i.e., wheat and maize (Farooq et al., 2019). Drought stress is also responsible for oxidative stress damage through production of reactive oxygen species (ROS), particularly in chloroplasts. Drought stress causes reduction of chlorophyll a+b content, an increase of proline, soluble protein and sugar contents in wheat (Sattar et al., 2020). Drought leads to the activation of plant defense systems with several physiological stress reactions resulting in a significant change in metabolite production, altering the nutritional and health values of the harvested products (Abid et al., 2018; Stagnari et al., 2016).

We aimed to study the effect of drought stress on some physiological, biochemical parameters of durum and bread wheat genotypes grown under field condition.

DOI: 10.30546/2709-0752.6.2.2022.47

MATERIALS AND METHODS

Field experiment conducted during the 2021/2022 growing season at the Research Institute of Crop Husbandry, located in the Apsheron peninsula, Baku. Plant materials consisted of 5 durum wheat genotypes (Garagylchyg 2, Vugar, Barakatli 95, Goytepe, Tartar), 8 bread wheat genotypes (Gobustan, Gyrmyzy gul 1, Khazri,Dayirman, Jumhuriyyat 100, Tale 38, Ugur 17, Nurlu 99). Sowing was performed in the third decade of October, at an average density of 400 seeds/m^2 with mechanical planter in 1m x 10 m plots, consisting of 7 rows placed 15 cm apart. Genotypes were grown in irrigated and rainfed plots with two replications. Irrigated plots were watered after the appearance of seedlings, at the stem elongation, anthesis and grain filling stages. Rainfed plots were not irrigated.

Measurements. Leaf Chl a, b and Car (x + c) contents were determined following the method of Lichtenthaler (1987), with little modifications. Pigment contents were calculated using the following formulas.

$$\text{Chl a} = (13.36\ A_{664} - 5.19\ A_{648}) \times 25 / DW;$$

$$\text{Chl b} = (27.43\ A_{648} - 8.12\ A_{664}) \times 25/DW;$$

$$\text{Car}(x+c) = (4,785 \cdot A470 + 3,657 \cdot A664 - 12,76 \cdot A648) \cdot 25/DW$$

Leaf area, also projected area of stem and spike measured by using LI-3100 Area Meter (LI-COR Biosciences, Lincoln, Nebrasca, USA). Dry mass determined after oven drying samples at 105°C for 24 h. The flag leaf RWC was determined gravimetrically. RWC was calculated using the following formula: RWC (%) = (FW-DW)/(TW-DW) x 100, where FW-fresh mass, DW-dry mass, TW-turgid mass. Proline content was determined following the method of Bates et al. (1973), with little modifications. The method given by Cakmak and Horst (1991) was followed for malondialdehyde estimation in leaf tissue. The following formula was used to estimate the MDA content: MDA (nmol) = Δ (A 532 nm − A 600 nm)/1.56 × 105, where the absorption coefficient for the calculation of MDA is 156 mmol^{-1} cm^{-1}. Soluble sugars (glucose, fructose, sucrose) content was determined in 80% ethanol by using anthrone reagent.

RESULTS AND DISCUSSION

Assimilation area of leaves, stem and spike was determined at the anthesis (Feekes 10.5.1 growth stage). In this growth stage 2 upper leaves (flag and penultimate leaves) are the major photosynthesizing in wheat. Water stress caused reduction of assimilation area of leaves, stem and spike (Table 1). The reduction of leaf size which results in smaller transpiring area, is an adaptive response to water deficit (Tardieu, 2005). The most assimilation area of leaves, stem and spike was formed in bread wheat genotype Gobustan and durum wheat genotype Tartar. More profound reduction of assimilation area was observed in genotypes Goytepe, Tartar, Gobustan. Water deficiency less affected on assimilation area of genotypes Gyrmyzy gul 1, Khazri and Dayirman. Water scarcity caused a decrease in dry mass of leaves, stem and spike (Table 2). More profound decrease in dry mass of assimilating organs was revealed in genotypes Vugar, Tartar, Tale 38, while less limitation of dry mass was revealed in genotypes Barakatli 95, Khazri, Dayirman, Jumhuriyyat 100. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Zhao et al., 2006). Drought stress caused adaptive changes in dry matter partitioning between leaves, stem and spike of wheat genotypes (Allahverdiyev and Huseynova, 2017).

Relative water content reflects the water potential of leaves and the degree of damage from drought stress. As seen from Table 2 water deficiency more affected on RWC in leaves of genotypes Garagylchyg 2, Gobustan, Khazri, Tale 38, Nurlu 99, while in most genotypes this parameter did not reduce significantly. Closing of stomata in response to water deficiency allows retaining moisture in leaves.

Water stress caused reduction of chlorophyll a, b (Chl a, Chl b) and carotenoids (Car x+c) content in flag leaf of wheat genotypes. Photosynthetic pigments content was higher in wheat genotypes Tale 38, Dayirman, Gyrmyzy gul 1, Jumhuriyyat 100, Khazri and Gobustan. Greater decrease in pigments content under water deficit conditions was revealed in genotypes Vugar, Tale 38, Gyrmyzy gul 1, Nurlu 99, Gobustan. The increased or decreased ratio of Chl (a+b)/Car(x+c) and Chla/b can be explained as the response of pigment content of different genotypes to drought stress. Osmoregulation in plants under low water potential relies on synthesis and accumulation of osmoprotectants or osmolytes such as soluble proteins, sugars, and sugar alcohols, quaternary ammonium compounds, and amino acids, like proline (Ozturk et al., 2020). A significant increase in the content of soluble sugars was found in durum wheat genotypes Garagylchyg 2, Barakatli 95, Tartar and in bread wheat genotype Jumhuriyyat 100 (Fig. 1).

Table 1. Effect of drought stress on assimilation area of leaves, stem and spike of wheat genotypes (sm^2)

Genotypes	**Growth cond**	**Area, sm^2**			**stem**	**spike**
		flag	**penultimate**	**VI tier**		
Garagylchyg 2	irrigated	16.4	23.9	22.1	35.0	19.8
	drought	15.4	21.1	12.5	27.8	16.3
Vugar	irrigated	19.0	25.5	30.9	34.3	18.9
	drought	17.6	23.2	20.2	28.6	13.6
Barakatli 95	irrigated	19.9	23.7	19.6	32.1	19.0
	drought	9.5	19.5	19.0	30.3	16.4
Goytapa	irrigated	20.0	26.6	24.8	35.1	21.0
	drought	15.6	14.6	23.2	27.3	17.3
Tartar	irrigated	25.6	30.7	32.1	37.9	20.6
	drought	17.0	21.7	19.0	28.2	19.3
Gobustan	irrigated	30.1	34.2	26.9	44.7	22.1
	drought	22.7	27.9	15.7	38.0	12.9
Gyrmyzy gul 1	irrigated	17.7	21.3	20.8	26.7	11.2
	drought	15.6	19.5	19.6	26.7	10.7
Khazri	irrigated	17.7	26.0	23.6	37.0	13.9
	drought	14.1	24.6	20.0	37.0	12.6
Dayirman	irrigated	17.6	26.1	21.4	34.4	9.6
	drought	16.7	24.6	21.6	32.1	8.5
Jumhuriyyat 100	irrigated	12.3	18.5	21.3	34.1	12.6
	drought	12.2	16.8	20.5	31.3	8.6
Tale 38	irrigated	19.4	24.3	25.0	36.8	15.2
	drought	17.1	20.4	11.0	27.7	14.2
Nurlu 99	irrigated	23.5	23.1	17.7	37.9	13.9
	drought	19.8	22.6	14.5	36.1	12.7
Ugur 17	irrigated	12.7	18.3	17.2	32.1	13.2
	drought	11.1	165	13.8	29.6	14.1

Table 2. Effect of drought stress on dry mass of different organs and relative water content in flag leaf

Genotypes	**Growth cond**	**Dry mass, g**			**RWC, %**
		leaves	**stem**	**spike**	
Garagylchyg 2	irrigated	0.667	2.550	0.793	86.67
	drought	0.579	1.990	0.769	67.02
Vugar	irrigated	0.820	1.870	0.765	88.04
	drought	0.521	0.808	0.548	86.29
Barakatli 95	irrigated	0.657	2.614	0.781	88.86
	drought	0.570	2.364	0.657	83.41
Goytapa	irrigated	0.778	3.741	1.046	82.79
	drought	0.676	2.235	0.919	81.87
Tartar	irrigated	1.221	2.798	0.824	87.96
	drought	0.592	2.202	0.694	87.53
Gobustan	irrigated	0.995	3.219	0.950	83.09
	drought	0.765	2.684	0.832	73.41
Gyrmyzy gul 1	irrigated	0.606	1.797	0.498	87.06
	drought	0.402	1.754	0.486	82.76
Khazri	irrigated	0.821	2.341	0.684	83.12
	drought	0.685	2.320	0.582	73.05
Dayirman	irrigated	0.681	2.090	0.530	84.12
	drought	0.641	1.800	0.431	81.99
Jumhuriyyat 100	irrigated	0.573	1.846	0.495	84.99
	drought	0.537	1.781	0.430	82.65
Tale 38	irrigated	0.860	2.174	0.717	85.18
	drought	0.602	1.665	0.580	79.90
Nurlu 99	irrigated	0.778	3.040	0.985	83.36
	drought	0.650	2.702	0.966	72.92
Ugur 17	irrigated	0.574	1.741	0.598	77.46
	drought	0.438	1.694	0.524	75.71

Table 3. Effect of drought stress on chlorophyll a, b and carotenoids content (mg/g dry mass of leaf)

Genotypes	Growth cond.	Chla	Chl b	Car(x+c)	Chla+b	Chla+b/Car(x+c)	Chla/b
Garagylchyg 2	Irrigated	5.77	1.83	1.81	7.60	4.20	3.15
	Drought	5.42	1.78	1.60	7.20	4.49	3.05
Vugar	Irrigated	6.92	2.69	1.94	9.61	4.94	2.58
	Drought	4.69	1.53	1.48	6.22	4.19	3.08
Barakatli 95	Irrigated	8.27	2.60	2.39	10.86	4.55	3.19
	Drought	6.30	2.68	1.65	8.98	5.44	2.35
Goytepe	Irrigated	7.45	2.51	2.21	9.95	4.51	2.97
	Drought	6.01	1.97	1.74	7.98	4.59	3.06
Tartarr	Irrigated	7.48	2.37	2.24	9.85	4.39	3.16
	Drought	6.27	2.42	1.68	8.69	5.16	2.59
Tale 38	Irrigated	9.16	2.93	2.81	12.09	4.30	3.13
	Drought	5.33	1.77	1.65	7.10	4.29	3.00
Dayirman	Irrigated	8.89	3.32	2.47	12.20	4.94	2.68
	Drought	9.42	3.43	2.58	12.85	4.99	2.74
Gyrmyzy gul 1	Irrigated	11.80	4.12	3.25	15.92	4.89	2.86
	Drought	6.92	2.24	2.12	9.16	4.31	3.10
Ugur 17	Irrigated	7.05	2.70	1.93	9.74	5.04	2.61
	Drought	7.27	2.77	1.97	10.04	5.09	2.63
Jumhuriyyat 100	Irrigated	10.56	3.66	2.96	14.17	4.78	2.93
	Drought	8.63	3.04	2.38	11.66	4.91	2.84
Khazri	Irrigated	11.62	4.24	3.21	15.86	4.94	2.74
	Drought	8.57	2.88	2.85	11.45	4.02	2.98
Nurlu 99	Irrigated	6.18	2.13	1.74	8.31	4.76	2.90
	Drought	3.61	1.42	1.01	5.03	4.96	2.55
Gobustan	Irrigated	9.37	2.99	2.82	12.36	4.38	3.13
	Drought	6.38	1.84	1.94	8.21	4.23	3.47

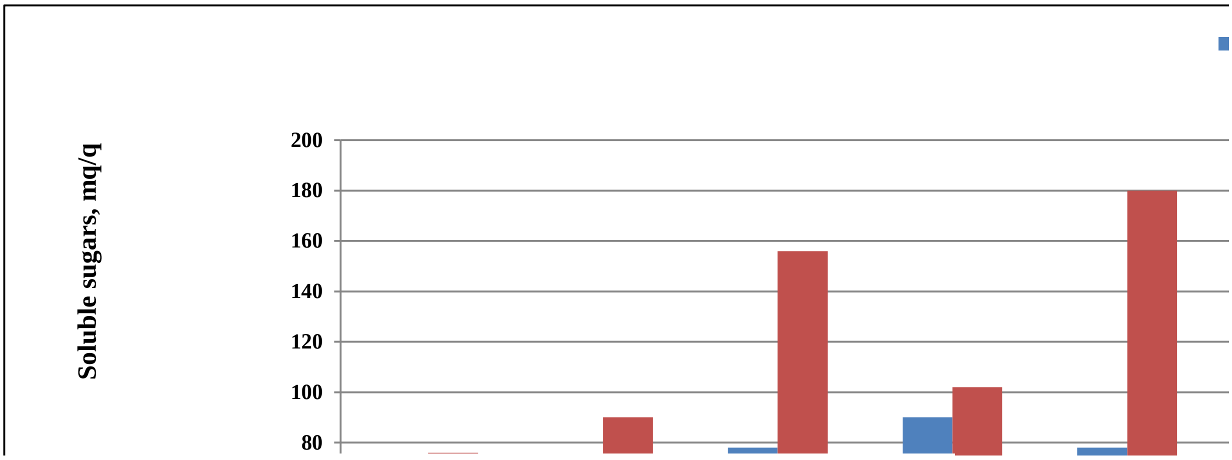

Fig 1. Effect of drought stress on soluble sugar content in leaves

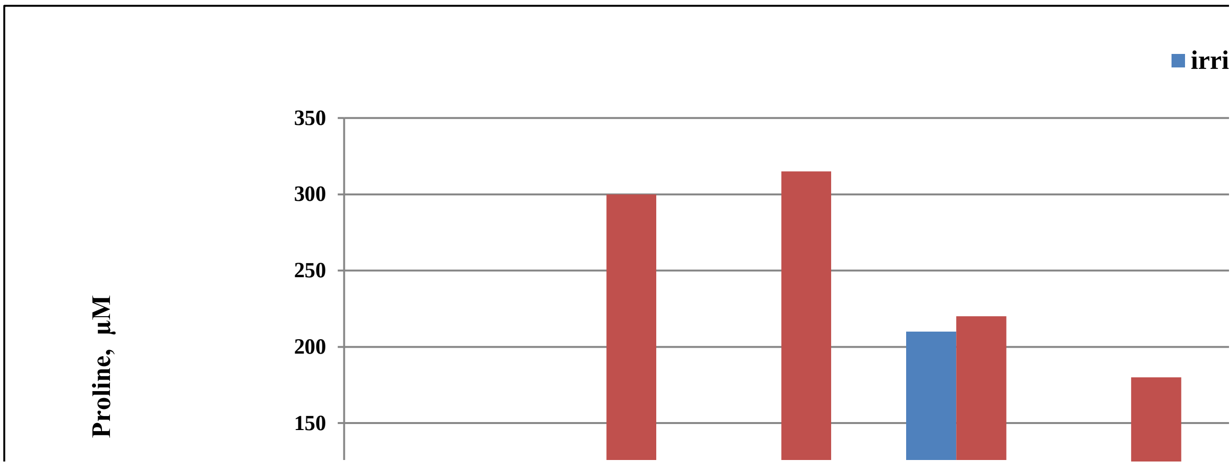

Fig. 2. Effect of drought stress on proline content in flag leaf of wheat genotypes

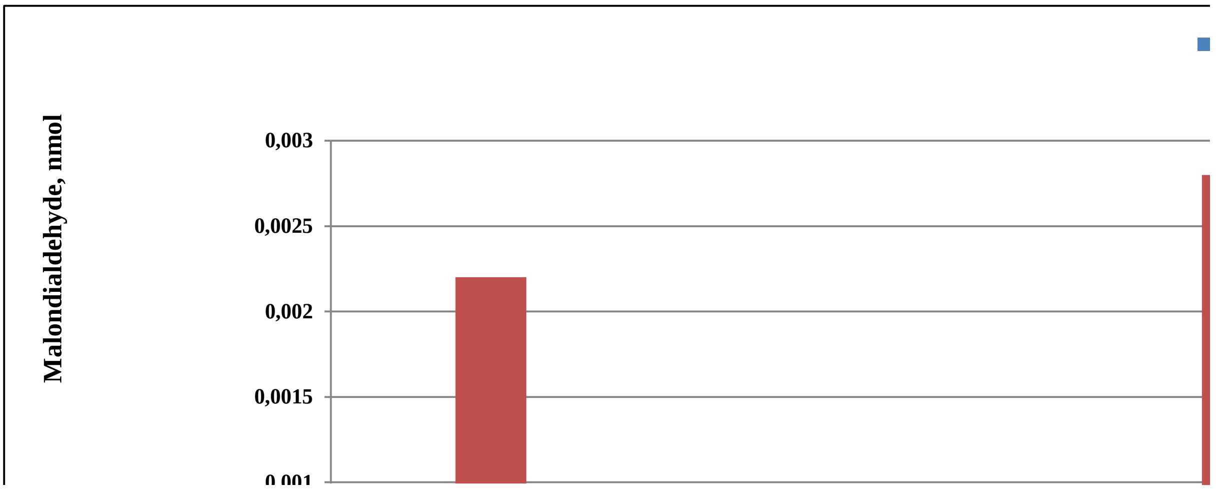

Fig. 3. Effect of drought on malondialdehyde content

However, an increase in the content of proline was significant in genotypes Vugar, Barakatli 95, Goytepe, Gobustan, Nurlu 99, Jumhuriyyat 100 and Khazri (Fig. 2). Malondialdehyde (MDA) is one of the key products of lipid peroxidation by reactive oxygen species (Weng et al., 2015). The MDA content is an indicator of membrane lipid peroxidation which could reflect the degree of damage at adverse conditions.

The MDA content increased under drought conditions in all genotypes, indicating oxidative stress damage (Fig. 3). About 10fold increases in malondialdehyde content was revealed in genotypes Vugar, Tartar, Gobustan, Jumhuriyyat 100, indicating their succebility to drought stress.

CONCLUSION

Drought leads to adaptive responses in physiological, biochemical parameters in wheat. The assimilation surface area and dry biomass of leaves, stem, and spike decreased in response to water deficit. The relative water content and the content of photosynthetic pigments in the flag leaf decreased in the condition of water deficiency. The content of osmoprotective compounds, soluble sugars and proline increased in response to water deficiency. An increase in the content of malondialdehyde in wheat genotypes indicates the presence of oxidative stress under the influence of drought. Genotypic differences in the studied parameters, as well as changes in the drought conditions were revealed.

REFERENCES

Abid M., Ali S., Qi L.K., Zahoor R., Tian Z., Jiang D., Snider J.L., Dai T. (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.

Alllahverdiyev T.I., Huseynova I.M. (2017) Influence of water deficit on photosynthetic activity, dry matter partitioning and grain yield of different durum and bread wheat genotypes. *Cereal Research Communications*, **45(3):** 432-441.

Bates L., Waldren R., Teare I. (1973) Rapid determination of free proline for water-stress studies. *Plant and Soil*, **39:** 205-207.

Cakmak I., Horst W.J. (1991) Effect of Aluminium on Lipid Peroxidation, Superoxide Dismutase, Catalase, and Peroxidase Activities in Root Tips of Soybean (*Glycine max*). *Physiol. Plant.*, **83:** 463–468.

Farooq M., Hussain M., Ul-Allah S., Siddique K.H. (2019) Physiological and agronomic approaches for improving water-use efficiency in crop plants. *Agricultural Water Management*, **219:** 95–108.

http://www.world-agriculturalproduction.com/crops/wheat.aspx

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

Ozturk M., Unal B.T., Garcia-Caparros P., Khursheed A., Gul A., Hasanuzzaman M. (2021) Osmoregulation and its action during the drought stress in plants. *Physiologia Plantarum*, **172 (2):** 1321-1335.

Sattar A., Sher A., Ijaz M., Ul-Allah S., Rizwan M.S., Hussain M., Jabrah Kh., Cheema M.A. (2020) Terminal drought and heat stress alter physiological and biochemical attributes in flag leaf of bread wheat. *PLoS ONE*, **15(5):** e0232974.

Shahid S., Ali Q., Ali S., Al-Misned F.A., Maqbool S. (2022) Water deficit stress tolerance potential of newly developed wheat genotypes for better yield based on agronomic traits and stress tolerance indices: Physio-biochemical responses, lipid peroxidation and antioxidative defense mechanism. *Plants (Basel),* **11(3):** 466; doi: 10.3390/ plants11030466

Stagnari F., Galieni A., Pisante M. (2016) Drought stress effect on crop quality. In book: *Water Stress and Crop Plants.a Sustainable approach* (Ed. by Parviz Ahmed), **2:** 375-392.

Todorova D., Sergiev I., Katerova Z., Shopova E., Dimitrova L., Brankova L. (2021) Assessment of the Biochemical Responses of Wheat Seedlings to Soil Drought after Application of Selective Herbicide. *Plants (Basel),* **10(4):** 733; doi: 10.3390/plants10040733.

Weng M., Cui L., Liu F., Zhang M., Shan L., Yang Sh., Deng X. (2015) Effects of drought stress on antioxidant enzymes in seedlings of different wheat genotypes. *Pak.J.Bot.*, **47(1):** 49-56.

Quraqlıq stresinin buğdanın bəzi fizioloji və biokimyəvi göstəricilərinə təsiri

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Buğda dünya əhalisinin təxminən 35%-nin davamlı ərzaq, zülal və karbohidrat mənbəyidir. Quraqlıq buğdanın istehsalına və keyfiyyətinə mənfi təsir göstərən əsas əlverişsiz ətraf mühit amillərindən biridir. Tədqiqatın məqsədi quraqlıq stresinin 5 bərk və 8 yumşaq buğda genotiplərinin bəzi fizioloji, morfoloji, biokimyəvi göstəricilərini tədqiq etmək olmuşdur. Quraqlıq stresi şəraitində buğdanın müxtəlif assimilyasiyaedici orqanlarının (gövdə üzərində yuxarıdan 3 yarus yarpaqlar, gövdə və sünbül) sahəsi və onlarda toplanan quru biokütlə azalmışdır. Flaq yarpağın nisbi su tutumu və fotosintezedici piqmentlərin miqdarı su çatışmazlığı şəraitində azalmışdır. Su çatışmazlığına cavab olaraq yarpaqlarda osmoprotektor birləşmələr olan həll olan şəkərlərin və prolinin miqdarı artmışdır. Membran lipidlərinin peroksidləşmə məhsulu olan malondialdehidin miqdarı quraqlığın təsirinə məruz qalan bitkilərdə artmışdır. Bitkilərin quraqlıq stresinə cavabının genotipik xüsusiyyətləri aşkar olunmuşdur.

Açar sözlər: *Buğda, assimilyasiya sahəsi, quru biokütlə, nisbi su tutumu, piqmentlər, həll olan şəkərlər, prolin, malondialdehid, quraqlıq stresi*