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Study of some morphophysiological traits and productivity of winter bread wheat that can be applied in selection under rainfed conditions without moisture supply

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Plant height, flag leaf area, relative water content, stay green period, photosynthesis rate (P_n), stomatal conductance (g_s), transpiration rate (T_r), and productivity of 12 varieties and 9 lines of winter bread wheat with contrasting morphophysiological traits have been studied under various water supply. It was shown that the improvement of water supply in the late period had less effect on plant height, and more effect on flag leaf area, relative water content and stay green period. The relative water content of the flag leaf was 72.9% and 81.1% in drought-exposed and irrigated variants for all genotypes. The relative water content of the flag leaf was higher in Aran, Vostorg, Murov 2, Zirva 85, Tale 38, and Gyrmyzy gul 1 varieties than in other studied genotypes under both drought stress and normal water supply conditions. The study of the stay green period of the flag leaf showed that its average value for all genotypes was 484 GDD under drought stress and 575 GDD under normal water supply conditions. The value of this parameter in Murov 2 and Zirva 85 varieties was higher compared to the other studied genotypes. The highest values of P_n were observed in the varieties Tale 38, Aran, and Gyrmyzy gul 1 in both drought-exposed and irrigated variants. The average productivity of all genotypes under drought was 496 g/m^2, and in the irrigated variants, it amounted to 623 g/m^2. Under drought, the highest productivity was detected in the 7th WON-SA № 465 (607 g/m^2), Gobustan (557 g/m^2), and Ferrigineum 2/19 (549 g/m^2) genotypes. In the irrigated variant, the highest productivity was 728, 717, 707, and 706 g/m^2 in the 7thWON-SA №465, Tale 38, Gyrmyzy gul 1, and Gobustan genotypes, respectively. The results of the study have shown that the potential of the Gyrmyzy gul 1 and Tale 38 varieties is high, and the use of Murov 2 and Zirva 85, and Gyrmyzy gul 1 varieties in hybridization is appropriate.

Keywords: *rainfed conditions, bread wheat, morphophysiological traits, productivity*

INTRODUCTION

Wheat is a plant that occupies an important place in the food supply of people in the world. According to the Food and Agriculture Organization of the United Nations (FAO), wheat is planted on 220-225 million hectares of land in the world and an average of 750 million tons of crops are produced every year (www.fao.org/worldfoodsituation/csdb/en/). In the agricultural production of our republic, wheat occupies the first place in terms of both cultivated area and production. A part of the wheat consumed in our republic is still imported from abroad (worldagriculturalproduction.com/crops/wheat.aspx). Due to the natural climatic conditions, winter cereals are planted most in our country and they are cultivated either with rainfed farming systems or under irrigation conditions where irrigation is possible. It is known that the production process

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can be carried out by applying the cultivation technologies of rainfed farming in places where the amount of total annual rainfall is 250-500 mm. Under such conditions, it is necessary to plant drought-tolerant varieties, whose low productivity leads to a decrease in total grain production. In this regard, the main goal of wheat breeders is to create genotypes with high and stable productivity under drought-stress conditions (Aliyev, 2000, 2001). Under the conditions of drought stress, many changes occur in molecular, biochemical, and physiological processes in the plant aimed at reducing the effect of stress (Bray, et al., 2000). In order to create genotypes that can produce higher yields under stress conditions, it is important to study the physiological and morphological characteristics that play a role in the tolerance of plants to drought (Aliyev, 2000; Allahverdiyev, 2020). The formation of drought tolerance in plants is a very complex and time-consuming process. Therefore, the study of some physiological and morphological characteristics of the plant under different water supply conditions is of great importance (Allahverdiyev, 2016: Hassan et al., 2019). Under drought conditions of Mountainous Shirvan, which are not stably supplied with moisture, drought usually begins in May, at the 47-49 stage of the vegetation of winter bread wheat according to the BBCH (Biologische Bundesanstalt, Bundessortenamt and Chemical Industry) scale. At the same time, in some years, an average or normal supply of moisture in that period was observed. Therefore, in that period, winter bread wheat should use moisture better to gain a high yield. However, not all genotypes respond equally to improving conditions and can increase their productivity. Therefore, it is of scientific and practical importance to study the morphophysiological traits of winter bread wheat during the normal water supply in the late period under rainfed conditions without a stable moisture supply.

MATERIALS AND METHODS

The research was carried out at the Gobustan Regional Experimental Station (GRES) of the Research Institute of Crop Husbandry. The experimental site is located at an altitude of 800.0 m above sea level, and the soil cover belongs to the open chestnut soil type. According to average multi-year data, the amount of atmospheric precipitation in the region is 350.0-400.0 mm. 12 varieties and 9 lines of winter bread wheat, which differ in morphophysiological traits, were taken as the research objects. The area of each experimental bed was 1.0 m^2, and planting was performed in 3 replicates in the form of randomly placed blocks, and the seeding rate was 450 seeds per 1 m^2. At the beginning of May, artificial drought conditions were created by covering one block with a transparent polyethylene cover, and the second block was irrigated. Before harvesting, the height of 10 plants in each block was measured and the average height (cm) of the genotype was found. After completing the development, the width and length of the flag leaf of 10 plants were measured from the middle part (Kalaycı et al., 1998). The area of the leaf was calculated by multiplying the product of the width by the length by a factor of 0.72.

Relative water content (RWC) was determined in mature flag leaves (Turner, et. al., 2001). For this, the samples were taken at the hottest time of the day (between 14^{00} and 15^{00} hours). The stay green (SG) period of flag leaves was determined in Growing Degree Days (GDD) based on SPAD values (total chlorophyll content) measured on different dates (Choelho and Dale, 1980). The parameters of photosynthetic gas exchange - photosynthetic rate - P_n, stomatal conductance - g_s, and transpiration rate - T_r were measured using a LI-COR 6400 XT (LI-Cor Biosciences, Lincoln, USA) Portable Photosynthesis System equipped with a 6 cm^2 leaf chamber (Sharkey, 2016). The sheaves from every 3 repetitions (1 m^2) of the variants were threshed and weighed on a scale. The average value for three replicates was calculated and the obtained result was taken as productivity per 1 m^2 (g/m^2). Statistical analyses were performed in JMP 5.0.1 software.

RESULTS AND DISCUSSION

It is observed that the drought usually occurs after earing under rainfed conditions not provided with stable moisture. Therefore, some morphological and physiological characteristics and productivity of winter bread wheat under conditions of water supply improvement and water shortage in the late period were studied and the relationship between them was considered. The results of the study of plant height, flag leaf area, leaf relative water content, the stay-green period of the flag leaf, and photosynthetic gas exchange parameters, which are important morphological and physiological parameters of wheat, are given in Tables 1 and 2. As seen in Table 1, the average plant height for all genotypes was 98.0 and 105.6 cm under conditions of water scarcity and normal water supply, respectively. During the improvement of water supply, the increase in plant height was 7.8%, which is slightly more compared to the drought-exposed variant. The growth in plant height was by 11.4, 10.6, 10.0, and 10.5%, respectively, in the Aran, Gyrmyzy gul 1, 12thIWWYT №8, and 7thWON-SA №477 genotypes, which was more compared to other studied genotypes. Gyzyl bughda, Sheki 1, Sonmez 01, Murov 2, Gobustan, Zirva 85, 7thWON-SA №465, and 12thIWWYT № showed a lower growth. The obtained results showed that the improvement of water supply in the late period increased the plant height of the early-earing genotypes less than that of the late-earing genotypes. The area of the flag leaf was 19.1 and 22.7 cm^2 on average for all genotypes during water shortage and improvement of water supply in the late period. In both research variants, the flag leaf area of the genotypes Bezostaya 1, Sheki 1, Aran, 12thIWWYT №9, and 7thWON-SA №477 was larger compared to that of Fatima, Gyrmyzy gul 1, Ferrigineum 2/19, and 12thIWWYT №6. Under the conditions of improved water supply, the area of the flag leaf of the Tale 38, Fatima, and Gyrmyzy gul 1 varieties increased by 24.8, 27.4, and 26.6% respectively, being higher than that of the other genotypes. We believe this feature creates better conditions for grain filling due to the greater increase in the area of photosynthesis during the improvement of water supply in the late period.

Table 1. Some morphological and physiological parameters of wheat genotypes under different water supplies

Genotypes	Plant height, cm		Flag leaf area, cm^2		RWC, %		Stay-green period, GDD	
	drought	**irrigation**	**drought**	**irrigation**	**drought**	**irrigation**	**drought**	**irrigation**
Bezostaya 1	106.3	115.8	24.5	27.3	77.4	84.0	460	528
Gyzyl bughda	106.0	111.8	21.6	25.1	66.8	69.2	469	560
Sheki 1	114.8	121.7	22.3	26.2	76.1	85.6	478	548
Sonmez 01	114.5	121.7	17.6	20.2	72.7	77.0	501	582
Aran	84.2	93.8	23.2	24.9	82.6	89.2	479	570
Vostorg	75.1	81.8	18.9	21.4	85.6	90.9	468	534
Murov 2	96.5	102.3	19.7	22.7	83.5	86.6	587	662
Gobustan	97.9	104.2	18.9	21.8	76.0	83.5	466	583
Tale 38	89.2	96.7	21.4	26.7	83.4	88.2	469	549
Fatima	93.0	99.3	14.6	18.6	66.3	73.2	480	582
Gyrmyzy gul 1	75.7	83.7	12.8	16.2	79.1	88.8	532	630
Zirva 85	91.0	96.7	19.0	23.2	75.4	83.8	557	657
7thWONSA№465	101.5	108.0	17.3	20.7	73.6	80.9	487	597
Ferrigineum 2/19	89.4	97.5	12.1	14.8	70.7	72.8	486	577
11thIWWYT№20	104.8	113.0	18.7	23.0	69.4	86.3	490	573
12thIWWYT№ 6	106.3	113.0	13.5	15.9	59.1	69.2	437	559
12thIWWYT№ 8	93.2	102.5	18.8	21.8	72.5	85.7	469	580
12thIWWYT№ 9	101.8	111.0	23.4	28.1	63.7	86.7	443	522
12thIWWYT№ 17	109.7	118.3	21.8	27.1	60.1	67.4	420	535
7thWON-SA №477	108.0	119.3	26.0	31.4	67.7	71.3	504	586
4th FEFWSN №50	97.5	104.5	17.9	22.3	69.5	83.5	476	554
Average	**98.0**	**105.6**	**19.1**	**22.7**	**72.9**	**81.1**	**484**	**575**
LSD	**4.6****	**5.0****	**0.95****	**1.2****	**5.42****	**5.5****	**34.0***	**40.0***
CV, %	**3.2**	**3.2**	**6.1**	**5.8**	**5.9**	**5.4**	**6.5**	**7.1**

Note: Relative water content (RWC), Growing Degree Days (GDD), LSD-least significant difference, CV (%) – coefficient of variation, **-significant at the 0.01 level, *- significant at the 0.05 level.

Table 2. Photosynthetic gas exchange parameters

Genotypes	P_n µmol CO_2 $m^{-2}s^{-1}$		g_s mol H_2O $m^{-2}s^{-1}$		T_r mmol H_2O $m^{-2}s^{-1}$	
	drought	**irrigation**	**drought**	**irrigation**	**drought**	**irrigation**
Bezostaya 1	13.0	19.8	0.096	0.353	2.77	7.48
Gyzyl bughda	11.2	22.9	0.077	0.456	2.26	8.33
Sheki 1	14.1	23.7	0.108	0.353	3.16	7.74
Sonmez 01	11.8	21.4	0.083	0.404	2.21	6.76
Aran	16.6	22.2	0.128	0.381	3.50	7.05
Vostorg	14.0	17.9	0.137	0.429	3.54	7.69
Murov 2	11.8	22.2	0.094	0.362	2.63	7.07
Gobustan	9.8	15.6	0.074	0.278	2.46	6.03
Tale 38	17.1	23.9	0.199	0.480	5.06	9.06
Fatima	13.8	19.0	0.147	0.397	2.74	6.68
Gyrmyzy gul 1	15.8	24.3	0.145	0.517	2.64d.	8.07
Zirva 85	12.1	18.9	0.130	0.429	2.63	7.08
7thWON-SA №465	8.1	20.9	0.062	0.451	1.52	7.59
Ferrigineum 2/19	10.6	20.3	0.069	0.395	1.86	7.08
11thIWWYT №20	14.0	23.7	0.200	0.442	3.20	8.06
12thIWWYT №6	9.7	21.8	0.078	0.372	2.16	7.67
12thIWWYT №8	13.0	21.3	0.096	0.422	2.76	7.44
12thIWWYT №9	11.8	19.3	0.088	0.255	2.52	5.77
12thIWWYT №17	9.7	23.1	0.060	0.363	1.65	7.08
7thWON-SA №477	8.8	22.3	0.079	0.438	2.02	7.55
4th FEFWSN №50	8.9	18.3	0.086	0.312	2.14	6.16
Average	**12.1**	**21.1**	**0.103**	**0.395**	**2.58**	**7.31**
LSD	**0.78****	**1.05****	**0.0096****	**0.0301****	**0.27****	**0.52****
CV, %	**5.7**	**4.4**	**8.2**	**6.5**	**9**	**6.2**

Note: P_n- photosynthetic rate, g_s - stomatal conductance - g_s, T_r - transpiration rate - T_r. LSD-least significant difference, CV (%) – coefficient of variation, **-significant at the 0.01 level, *- significant at the 0.05 level.

The relative water content of the flag leaf was 72.9% and 81.1% in drought and irrigation variants for all genotypes. The relative water content of the flag leaf in the varieties Aran, Vostorg, Murov 2, Zirva 85, Tale 38, and Gyrmyzy gul 1 was higher than in other studied genotypes under both drought stress and normal water supply conditions.

The study of the stay-green period of the flag leaf, which is one of the physiological parameters that play an important role in the grain filling and productivity of winter wheat, showed that its average value for all genotypes was 484 GDD under drought stress conditions, and 575 GDD under normal water supply conditions. The value of this parameter in Murov 2 and Zirva 85 varieties was higher than in other studied genotypes (Table 1). The relative water content of the flag leaf in the mentioned genotypes was also higher, which indicates that it is appropriate to use those genotypes in the hybridization process.

Carbon dioxide (CO_2) assimilation rate (P_n), stomatal conductance (g_s), and transpiration rate (T_r), which are the parameters of photosynthetic gas exchange, were measured between 11^{00}-12^{00} in the flag leaf during the milk ripeness phase in drought and irrigation variants. The results of the measurements are given in Table 2. The analysis of variance showed that there were significant differences between the studied genotypes at the 0.01 level of significance in all measurements for the values of photosynthetic gas exchange parameters. As seen in Table 2, the average values of CO_2 assimilation rate, stomatal conductance, and transpiration rate for all genotypes under drought and irrigated conditions were 12.1 and 21.1 µmol CO_2 $m^{-2}s^{-}1$; 0.103 and 0.395 mol H_2O $m^{-2}s^{-1}$; 2.58 and 7.31 mmol H_2O $m^{-2}s^{-1}$, respectively.

The highest values of P_n were found in the varieties Tale 38, Aran, and Gyrmyzy gul 1 in both drought and irrigation variants. It should be noted that the highest values of the stomatal conductance in both variants were detected in the Tale 38 and Gyrmyzy gul 1 genotypes. The rate of transpiration was the highest in the Tale 38 variety in both drought and irrigation variants and was 5.06 and 9.06 mmol H_2O $m^{-2}s^{-1}$, respectively.

As seen, the rate of photosynthesis, stomatal conductance, and transpiration rate were higher in the irrigation variant than in the drought variant, which was the result of the declining water content in the soil below the norm.

As a result of the research, it was found that because the stomatal conductance was more sensitive to water deficit, its value was on average 73.9% lower in the drought variant compared to that of the irrigation variant. The most differences between variants were observed in the genotypes Gyzyl bughda, Gyrmyzy gul 1, 7thWON-SA №465, Ferrigineum 2/19, 12thIWWYT №17, and 7thWON-SA №477, respectively, 83.1, 87.4, 86.3, 82.5, 83.5 and 82.5%, and the least differences were found in the genotypes Aran (66.4%), Tale 38 (58.5%), Fatima (63.0%), 11 IWWYT №20 (54.8%), and 12 IWWYT №9 (65.5%). It was observed that the genotypes with high values of stomatal conductance also had high values of T_r, which indicates that T_r is mainly regulated by stomatal conductance. Thus, the study of photosynthetic gas exchange parameters showed differences between genotypes. At the same time, considering a higher value of this parameter as well as other superior morphophysiological traits, it was concluded that the Gyrmyzy gul 1 variety is appropriate for the hybridization program.

It is important to study the productivity of winter wheat genotypes under different water supply conditions. In Figure 1, the productivity of studied genotypes is given according to the average of two years. As seen in the Figure, the average productivity of all genotypes in the drought variant was 496 g/m^2, and in the irrigation variant, it was 623 g/m^2.

The highest productivity (607 g/m^2) in the drought variant was observed in the 7WON-SA № 465 line. Gobustan and Ferrigineum 2/19 genotypes followed it with 557 and 549 g/m^2. In the drought variant, the lowest productivity was detected in the Bezostaya 1, Vostorg, and Gyzyl bughda varieties (435, 438, and 441 g/m^2, respectively). In the irrigation variant, the highest productivity was 728, 717, 707, and 706 g/m^2, in the genotypes 7WON-SA № 465, Tale 38, Gyrmyzy gul 1, and Gobustan, respectively.

Due to the lodging of irrigation variants of the 12thIWWYT № 9 and 12thIWWYT №17 varieties, if their results are not taken into account, the average reduction of productivity for all genotypes in the drought variant compared to irrigation was 20.0% (Figure 2).

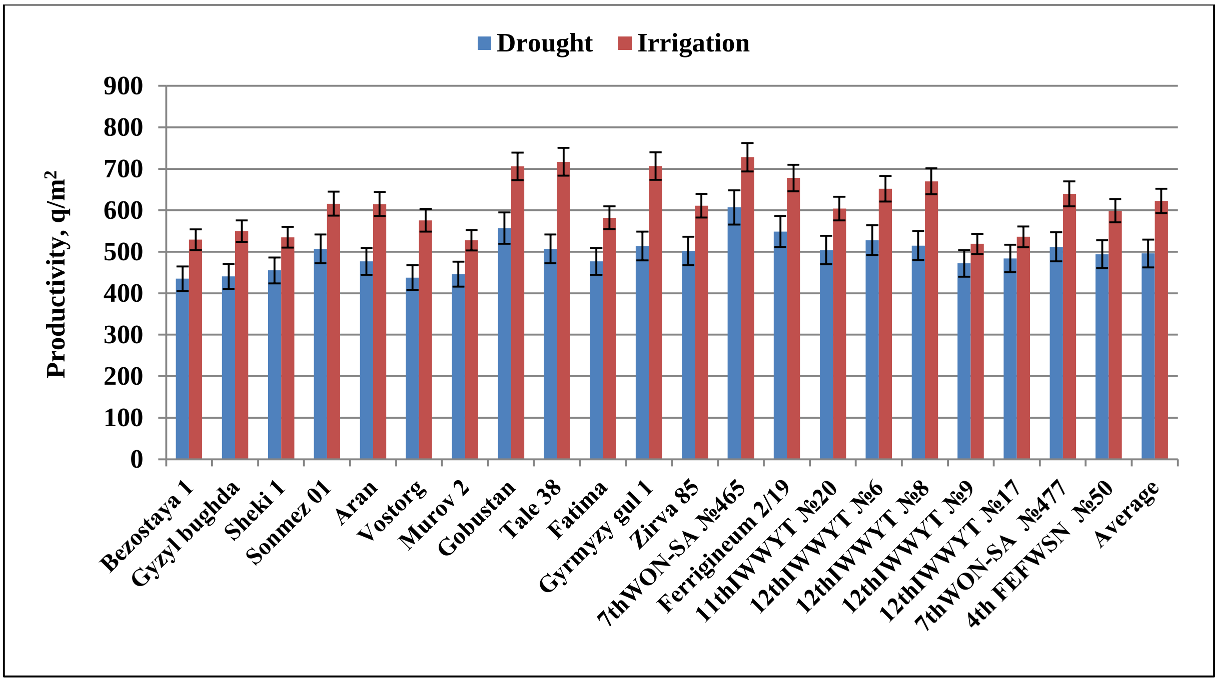

Fig. 1. Productivity of drought-exposed and irrigated genotypes.

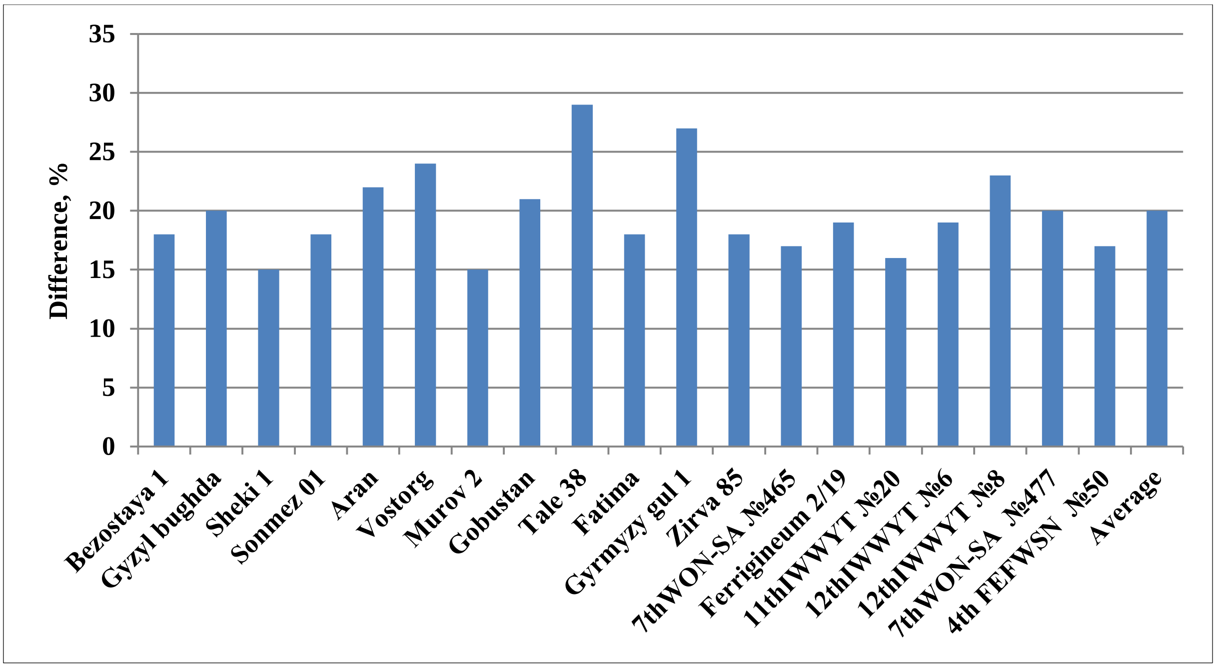

Fig. 2. Differences in the productivity of irrigation and drought variants, %.

Among the variants, the greatest reduction in productivity was observed in the varieties Tale 38 (29.3%), Gyrmyzy gul 1 (27.3%), Vostorg (24.0%) and in the line 12^{th}IWWYT № 8 (23.1%), and the smallest reduction was observed in the genotypes Sheki 1 (15.0), Murov 2 (15.57 WON-SA №465 (16.6%), and 11^{th}IWWYT№ 20 (16.6%).

As seen in Figure 1, the productivity of the genotypes Tale 38, Gyrmyzy gul 1, and 12^{th}IWWYT № 8 in the drought variant was close to the average level, and in the irrigation variant, it was much higher than the average level. The fact that those genotypes respond more to optimal climatic conditions and increase their productivity more than other genotypes is an indication of their high plasticity. Sheki 1, Murov 2, and 7WON-SA № 465 had a low productivity reduction in the drought variant, which, we believe, indicates that their stability is higher than that of other genotypes.

CONCLUSIONS

Thus, the study of the effect of the improvement of water supply in the late period on some morphophysiological traits of winter bread wheat under rainfed conditions without a stable moisture supply showed that it had a small effect on the plant height, and a greater effect on the area of the flag leaf, relative water content, and the stay-green period of the flag leaf. Genotypic differences were observed in the values of the studied parameters. The higher relative water content of the flag leaf and the stay-green period of the genotypes Gyrmyzy gul 1, Murov 2, and Zirva 85 confirmed their relevance for the hybridization in the breeding program of winter wheat. The Gobustan variety and the line 7^{th}WONSA №465 had the highest productivity under drought stress conditions. Since other morphophysiological parameters of those genotypes were also favorable, it was recommended to plant them in rainfed areas without a stable moisture supply. The Tale 38 and Gyrmyzy gul 1 varieties were found to have high potential, which showed their relevance for planting under irrigated conditions. It was found that stomatal conductance is more sensitive to water deficit, the rate of transpiration and photosynthesis depends on stomatal conductance, and at the same time, the rate of transpiration is more sensitive to stomatal conductance than the rate of photosynthesis.

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