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THE STUDY OF PRODUCTIVITY AND YIELD STRUCTURAL ELEMENTS OF WINTER BREAD WHEAT (*T. aestivum* L.) GENOTYPES UNDER RAINFED CONDITIONS

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Abstract. The paper is dealing with the effects of the late drought stress on the productivity and yield components of 12 varieties and 7 lines of winter bread wheat, which differ in morphophysiological characteristics. It was found that drought stress created in the late period decreased productivity, number of spikes per sheaf, number of spikelets per spike, number and mass of grains per spike and mass of 1000 grains by 19.9%, 7.7%, 4.9%, 12.8%, 21,6%, and 10.01%, respectively. As can be seen, of the components directly affected by water stress, the productivity and grain mass per spike were the most depressed, while number of spikes per unit area and number of spikelets per spike was relatively stable. Under late drought stress, Gobustan and Gyrmyzy gul 1 varieties, 7thWON-SA No.465 and Ferrigineum 2/19 lines manifested the highest productivity (557, 515, 607, and 549 g/m², respectively). Under drought stress, the most depressed values for 1000-grain mass were found for the genotypes Tale 38, Gyrmyzy gul 1, 12thIWWYT No.8, and Ferrigineum 2/19, while the least depressed values were found for Sonmez 01, Gobustan, 4thFEFWSN No.50 and 7thWON-SA No.477.

Keywords: *winter bread wheat, drought stress, productivity, stress tolerance, drought sensitivity, yield components.*

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1. Introduction

Low water availability is the main environmental factor limiting plant growth and yield worldwide, and global change will probably make water scarcity an even greater limitation to plant productivity across an increasing amount of land (Chaves *et al.*, 2009). Wheat (*Triticum aestivum* L.) is one of the most widely cultivated crops in the world. Globally wheat is grown in about 220 million hectare, production was 774 million metric tons in 2020/2021 growing year. Wheat productivity is very sensitive to water deficiency and under drought stress, it can be reduced by 50-90% relative to its potential under irrigation (Awan *et al.*, 2017). Currently, the world's wheat productivity

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is about 3.5 t/ha, and it is required to reach 5 t/ha by 2050 to meet population needs. Wheat production can be increased by developing genotypes that are tolerant to abiotic and biotic stress factors, and by increasing the efficiency of mineral nutrition, radiation, and water use (Tshikunde *et al*., 2019). At present, the demand for high-yielding, high-quality, and disease-resistant wheat varieties that meet the requirements of producers and consumers is growing. Under rainfed and irrigated conditions, respectively, 20-30% and approximately 50% of the wheat production increase is known to depend on a variety. It is important to study the morphological and physiological characteristics of genotypes, yield components, their relationship with each other, and productivity to properly direct the work on the development of varieties in breeding programs intended to increase productivity under drought conditions (Aliev, 2001). The ability of a cultivar to produce high and satisfactory yield over a range of stress and non-stress environments is very important (Rashid *et al*., 2003). In general, breeding for drought tolerance involves combining good yield potential in the absence of the stress and the selection of high heritable traits that provide drought stress tolerance (Jones, 2007). Drought caused reductions in days to 50% heading, plant height, number of tillers, spike length and width, thousand grains mass, biological and grain yield, harvest index of wheat genotypes (Bayoumi *et al*., 2008: Al-Tabbal, 2011). Different drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). From this point of view, the study of the effects of water deficiency on yield components and productivity of wheat genotypes with contrasting morphophysiological traits under rainfed conditions is of great importance for the breeding processes.

2. Materials and methods

The research was conducted at the Gobustan Regional Experimental Station of the Research Institute of Crop Husbandry. The experimental site is located at an altitude of 800.0 m above sea level and has a light chestnut soil type. According to the average multi-year data, the atmospheric precipitation amount in the region is 350.0-400.0 mm (data from Gobustan Hydrometeorological Station). The objects of the research were 12 varieties and 7 lines of bread wheat differing in morphophysiological characteristics. Planting was conducted in 3 repetitions in the form of randomly placed blocks using experimental beds of 1.0 m^2 and the sowing rate was 450 seeds per 1 m^2. To make a difference in water supply, late drought conditions were created artificially in early May by covering one block with a transparent polyethylene material, while the second block was irrigated. Before harvesting, 10 characteristic spikes were taken from each of the 3 repetitions, the spikelets were counted and the average number of spikelets per spike was calculated. Then, the grains in the spike were separated, counted, and the average number of grains per spike was determined. Plants of all 3 repetitions were mowed and sheaves were taken, stems with spikes were counted, the average value was calculated, and the result was taken as the number of spikes per 1 m^2 (spikes /m^2). Grains obtained with a threshing machine after mowing sheaves were weighed and an average value was calculated for three repetitions and the result was taken as productivity per 1 m^2 (g/m^2). 250 grains obtained from sheaves were counted and weighed in 4 repetitions, and their mass was taken as the total mass of 1000 grains (g). Stress Tolerance Index (Fernandez, 1992) and Drought Susceptibility Index (DSI) (Fisher and Maurer 1978) were calculated using the following formulas: $STI=(Y_p x Y_s)/(\hat{Y}_p)^2$ and $DSI=(1- (Y_s/Y_p))/ SI$, respectively. Where Y_p and Y_s are the productivity of the genotype under irrigated and drought conditions, $\hat{Y}_p$ and $\hat{Y}_s$ are the average productivity of all genotypes under irrigated and drought conditions. Statistical analyses were performed in the JMP 5.0.1 program.

3. Results

To develop varieties suitable for the climatic conditions of any region, it is important to conduct research in that region and study the productivity and yield components. From this point of view, the productivity of 19 wheat genotypes, which differ in morphophysiological features, was studied in drought-exposed and irrigated variants under rainfed conditions with unstable moisture supply (Mountainous Shirvan region of the Republic of Azerbaijan). The results of the study of the productivity of the studied genotypes, the number of spikes per unit area ($1m^2$), the number of spikelets per spike, the number of grains per spike, the grain mass per spike and the mass of 1000 grains are given in Table 1. The analysis of variance showed a significant difference in these parameters between the genotypes at the 0.01 level. As seen in the table, in the drought variants, the Gobustan and Gyrmyzy gul 1 varieties, the 7thWON-SA №465 and Ferrigineum 2/19 lines formed the highest productivity (557, 515, 607 and 549 g/m², respectively). In the irrigated variants, the Tale 38, Gyrmyzy gul 1 and Gobustan varieties, the 7thWON-SA №465 and Ferrigineum 2/19 lines formed the highest productivity (717, 707, 706, 728 and 678 g/m², respectively). Productivity of the Bezostaya 1, Gyzyl bughda, Sheki 1, Murov 2 and Vostorg varieties was low in both variants. In drought-exposed and irrigated variants, the number of spikes per 1 m^2 was higher in the Gyrmyzy gul 1 (638, 741), Gobustan (635, 684) varieties and in Ferrigineum 2/19 (718, 782), 7thWONSA №465 (693, 758) lines compared to others.

Table 1. Productivity and yield components of the studied genotypes depending on the water supply

Genotypes	variants	Productivity, g/m^2	Number of spikes per m^2	Number of spieklets per spike	Grain number per spike	Grain mass per spike	Thousands kernel mass
Bezostaya 1	Drought	435	579	17.4	33	1.23	38.0
	Irrigation	529	604	18.6	39	1.63	42.2
Gyzyl bughda	Drought	441	592	15.8	28	1.14	40.7
	Irrigation	550	635	16.4	35	1.50	44.2
Sheki 1	Drought	455	605	16.3	32	1.16	36.6
	Irrigation	535	635	17.2	38	1.43	41.0
Sonmez 01	Drought	507	611	15.2	36	1.39	41.1
	Irrigation	616	657	15.8	41	1.71	44.1
Aran	Drought	477	650	17.5	35	1.23	36.3
	Irrigation	615	682	18.5	40	1.58	41.0
Vostorg	Drought	438	564	16.9	35	1.19	34.1
	Irrigation	576	614	18.0	40	1.51	38.2
Murov 2	Drought	446	595	15.7	31	1.14	35.2
	Irrigation	528	622	16.5	36	1.39	38.2
Gobustan	Drought	557	635	15.0	42	1.38	35.4
	Irrigation	706	684	15.7	48	1.77	38.3
Tale 38	Drought	507	594	17.0	42	1.43	36.3
	Irrigation	717	634	18.8	48	2.02	43.3
Fatima	Drought	477	589	14.3	32	1.08	34.7
	Irrigation	582	649	15.0	36	1.36	38.3

Gyrmyzy gul 1	Drought	514	638	16.6	46	1.36	31.3
	Irrigation	707	741	17.1	50	1.74	36.2
Zirve 85	Drought	502	599	17.4	40	1.45	36.6
	Irrigation	611	638	18.0	44	1.71	40.0
7thWONSA№465	Drought	607	693	16.5	42	1.37	34.6
	Irrigation	728	758	17.4	47	1.74	38.0
Ferrigineum 2/19	Drought	549	718	14.2	38	1.20	31.6
	Irrigation	678	782	15.1	44	1.53	36.2
11thIWWYT№20	Drought	504	587	15.8	40	1.34	34.5
	Irrigation	604	631	16.5	45	1.64	38.3
12thIWWYT№ 6	Drought	528	589	15.3	41	1.32	33.8
	Irrigation	652	668	16.1	46	1.74	38.1
12thIWWYT№ 8	Drought	515	621	16.6	39	1.15	31.1
	Irrigation	670	680	17.3	43	1.53	36.8
7thWON-SA №477	Drought	512	562	15.7	35	1.40	43.8
	Irrigation	640	628	16.7	41	1.86	47.2
4th FEFWSN №50	Drought	494	581	16.7	40	1.35	36.2
	Irrigation	599	643	17.9	46	1.67	38.8
Average	Drought	498	611	16.1	37	1.28	35.9
	Irrigation	623	662	16.9	42	1.63	39.9
LSD	Drought	49**	58**	0.61**	2.52**	0.05**	0.74**
	Irrigation	50**	41**	0.60**	32**	0.06**	0.88**
CV %	Drought	6.9	6.0	2.3	4.15	2.0	1.6
	Irrigation	4.8	3.9	2.2	4.5	2.3	1.7

Note: LSD-least significant difference, **-significant at the 0.01 level, *- significant at the 0.05 level. CV- coefficient of variation

Whereas, in the Bezostaya 1 (579, 604), Vostorg (564, 614), Gyzyl Bughda (592, 635) and Murov 2 (595, 622) varieties, and in the 12thIWWYT №9 (566, 621), 12thIWWYT №17 (590, 633) 7thWONSA №477 (562, 628) lines this parameter was low. In both variants, the highest values of number of spikelets per spike were found in Aran (17.5, 18.5), Bezostaya 1 (17.4, 18.6), Zirve 85 (17.4, 18.0), Tale 38 (17.0, 17.8) and Vostorg (16.9, 18.0), the lowest values were observed in Fatima (14.3, 15.0), Gobustan (15.0 15.7), Sonmez 01 (15.2, 15.8), and Ferrigineum 2/19 (14.2, 15.1). Grains were counted in the spikes of the studied genotypes, and according to this parameter, both variants of the Gobustan (42, 48), Gyrmyzy gul 1 (46, 50), Tale 38 (42, 48), and 7thWONSA №465 (42, 47) genotypes manifested higher results than others.The number of grains per spike in the Gyzyl bughda (28, 35), Murov 2 (31, 36), Fatima (32, 36), Sheki 1 (32, 38), Bezostaya 1 (33, 39), and 12thIWWYT №9 (35,39) genotypes was low. In both variants, the grain mass per spike was high in Tale 38 (1.43, 2.02 g), Gobustan (1.38, 1.77 g), Zirve 85 (1.45, 1.71 g), and 7thWONSA №477 (1.40, 1.67 g), whereas, this parameter was low in Fatima (1.08, 1.36 g), Murov 2 (1.14, 1.39 g), Gyzyl bughda (1.14, 1.50 g), Sheki 1 (1.16, 1.43 g), Ferrigineum 2/19 (1.15, 1.53 g) and 12thIWWYT №8 (1.15, 1.53 g). The highest values of the mass of 1000 grains in the drought-exposed and irrigated variants were detected in the varieties Gyzyl bughda (40.7, 44.2 g), Sonmez 01 (41.1, 44.1 g), and Bezostaya 1 (38.0, 42.2 g). among the lines, in 7th WONSA №477 (43.8, 47.2 g) and 12thIWWYT №9 (37.8, 42.5 g). The lowest values of this parameter were observed in the genotypes Gyrmyzy gul 1 (31.3, 36.2 g), Ferrigineum 2/19 (31.0, 36.2 g), and 12thIWWYT № 8 (31.1, 36.8 g).

The productivity of wheat depends on the soil and climatic conditions in which it is grown, cultivation techniques, and genotypic characteristics. Potential plant productivity is the productivity of an adapted genotype in the absence of biotic and abiotic stresses under optimal maintenance conditions (Sanmartin & Acevedo, 2001).

However, when plants are grown under natural conditions, they are often affected by one or another stress factor. As one of the main natural factors is water deficiency, the creation of drought-tolerant varieties for the high productivity of wheat is an important task for increasing crop production. Successful research was conducted in this area (Aliev 1998; 2001). The productivity of wheat depends mainly on the number of spikes per unit area, the number of grains per spike, and the grain mass per spike. The highest productivity amounted to 607 g/m^2 was observed in the drought-exposed variant of the 7thWON-SA№465 line. The Gobustan variety showed the second result with 557 g/m^2. The drought-exposed variants of the varieties Tale 38 and Gyrmyzy gul 1 created for irrigation conditions were not high-yielding. Our studies have once again confirmed that the Tale 38 and Gtrmyzy gul 1 varieties have a high potential for irrigated areas. The Gobustan variety and the 7thWON-SA №465 line were able to increase their productivity in response to improved conditions while relatively high-yielding in the drought-exposed variant, which showed that they also have high productivity potential. An average production loss was 19.9% in the drought-exposed variants compared to the irrigated genotypes (Table 2). In this case, the most yield loss occurred in the varieties Tale 38 - 29.3%, Gyrmyzy gul 1 - 27.2%, and the 12thIWWYT №8 line - 23.1%. The lowest yield loss under drought occurred in Sheki 1 and Murov 2 by 15.0% and 15.5%, respectively and in the lines 7thWON-SA №465 and 11thIWWYT №20 by 16.6%.. The 7thWON-SA №465 was highly productive under drought conditions and its productivity increased when conditions improved, which showed its superiority under rainfed conditions with unstable moisture supply.

Based on the productivity of the studied genotypes under irrigated conditions and drought stress, the stress tolerance index (STI) and drought susceptibility index (DSI) were calculated and the results are given in the figure. The relative productivity of any genotype compared to other genotypes exposed to the same drought stress is called its stress tolerance (Hall, 1993).

Table 2. The difference in productivity and yield components between drought-exposed and irrigated variants

Genotypes	Productivity,g/m^2	Number of spikes per m^2	Number of spieklets per spike	Grain number per spike	Grain mass per spike	1000 grains mass
Bezostaya 1	17.8	4.2	6.5	15.4	24.5	10.0
Gyzyl bughda	19.8	6.8	3.7	20.0	24.0	7.9
Sheki 1	15.0	4.7	5.2	14.7	18.9	10.7
Sonmez 01	17.7	7.0	3.8	12.3	18.7	6.8
Aran	22.4	4.6	5.4	13.8	22.2	11.6
Vostorg	24.0	8.1	6.1	13.8	21.2	10.7
Murov 2	15.5	4.3	4.8	13.9	18.0	8.0
Gobustan	21.1	7.2	4.5	12.5	22.0	7.5
Tale 38	29.3	6.4	4.5	11.6	29.2	16.2
Fatima	18.0	9.2	4.7	11.1	20.6	9.3
Gyrmyzy gul 1	27.3	13.8	2.9	9.0	21.8	13.4
Zirve 85	17.8	6.1	3.3	9.2	15.2	8.4
7thWONSA№465	16.6	8.5	5.2	11.7	21.3	9.0
Ferrigineum 2/19	19.0	8.1	6.0	13.8	21.6	12.7
11thIWWYT№20	16.6	7.1	4.2	10.1	18.3	9.9
12thIWWYT№ 6	19.0	11.9	5.0	12.0	24.1	11.2
12thIWWYT№ 8	23.1	8.8	4.0	10.5	24.8	15.4
7thWON-SA №477	20.0	10.4	6.0	14.8	24.7	7.1
4th FEFWSN №50	17.5	9.7	6.7	13.2	19.2	6.8
Average	**19.9**	**7.7**	**4.9**	**12.8**	**21.6**	**10.1**

In our study, the highest values of STI were found in the Gobustan, Tale 38, Gyrmyzy gul 1, 7thWON-SA №465, and Ferriginem 2/19 genotypes which amounted to 0.998, 0.909, 0.912, 1.132, and 0.930, respectively. The high values of this parameter in the Tale 38 and Gyrmyzy gul 1 varieties were due to their very high productivity in the irrigated variants (717 and 707 g/m^2, respectively). In these varieties, the productivity was moderate under drought. In contrast to the mentioned varieties, in the Gobustan, 7thWON-SA №465, and Ferriginem 2/19 genotypes, the high values of STI were because of their high productivity under both drought and irrigated conditions.

Decreased productivity of a genotype under drought stress determines its susceptibility to drought (Blum, 1993). The highest values of this parameter were observed in the Gobustan (1.249), Tale 38 (1.619), and Gyrmyzy gul 1 (1.363) varieties (Figure). This result was expected for Tale 38 and Gyrmyzy gul 1, given that they were created for irrigated conditions and their potential productivity under irrigated conditions was high and moderate under drought. In the Gobustan variety, although the productivity of the drought-exposed variant was above the average level, the reason for the high value of DSI is the high potential of the variety even under irrigated conditions. As seen in the figure, the lowest values of DSI were detected for the varieties, Bezostaya 1 (0.666), Sheki 1 (0.768), Sonmez 01 (0.791), and Murov 2 (0.797), and the lines, 7thWON-SA №465 (0.833), Ferrigineum 2/19 (0.864) and 11thIWWYT №20 (0.853). The low values of DSI in the varieties Bezostaya 1, Sheki 1, Sonmez 01 and Murov 2 are due to their low productivity under irrigated conditions rather than their high productivity under drought. Therefore, despite the low DSI values, planting them under drought conditions can lead to crop loss. The 7thWON-SA №465 line showed high and close productivity under both irrigated and drought conditions and therefore the DSI value of this genotype was low.

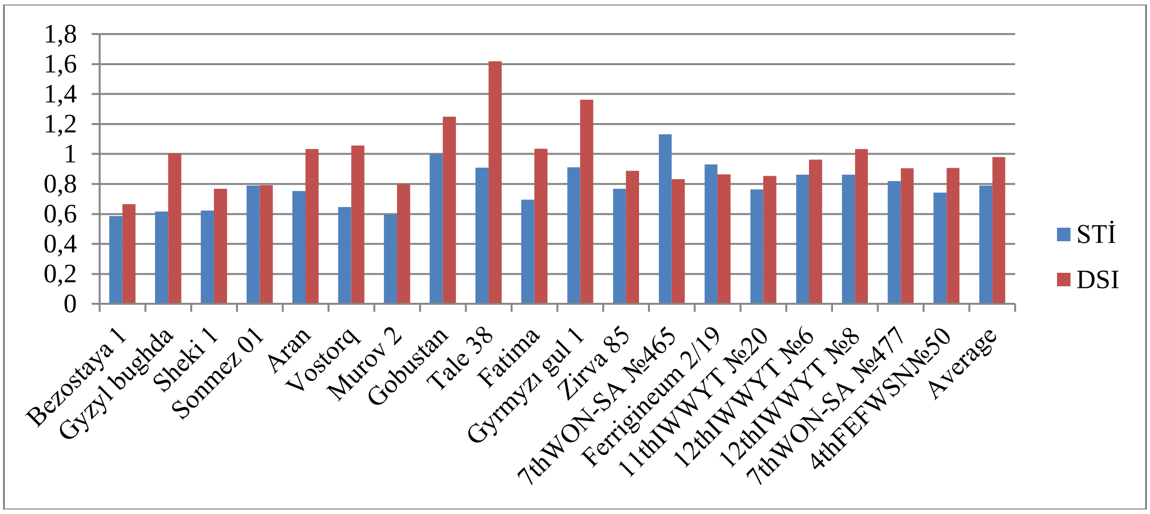

Fig 1. Stress Tolerance Index (STI) and Drought Susceptibility Index (DSI)

The 7thWON-SA №465, one of the three lines in the study with the lowest DSI value, was also preferred for its productivity and other morphophysiological characteristics, especially in late-onset drought stresses where early maturity is important. A high level of positive correlation (r = 0.97 **) was observed between the stress tolerance index and productivity in both variants. No significant correlation was observed between DSI and productivity. In our opinion, this is attributed to the involvement of many parameters in the formation of productivity, which ultimately led to the lack of a direct link between DSI and productivity.

Yield-determining components reduced under drought stress. It was found that under drought stress plant height, spike length and width, number of spikes per unit area, number of spikelets per spike and grain yield decreased (Allahverdiyev *et al*., 2015; Saleem, 2003). Other researchers noted that the number of grains per spike and the number of spikes per 1 m^2 were more sensitive to water stress, while the grain mass per spike was a relatively stable parameter (Zhu, 2002). Drought stress, along with other components that determine the productivity of wheat, has a significant impact on the number of spikes per unit area. It was noted that it is possible to get the maximum yield from the genotype, which has optimal architectonic, is intensively cultivated, and has 700-800 spikes per 1m^2 area (Protiċ *et al*., 2009). In our experiments, the average value of the number of spikes per 1m^2 was 611 for all genotypes in the drought-exposed variants, and 662 in irrigated variants. As can be seen, the difference between the variants was not very big, which, in our opinion, was because of the late irrigation. The genotypes with the high number of spikes per sheaf were found to belong to the modern and those with the small numbers of spikes to oldest varieties. Modern varieties also passes higher tillering ability. The number of spikes per 1m^2 decreased under drought by 7.7% compared to irrigated conditions (Table 2).

There was no wide variation between the studied genotypes in the number of spikelets per spike. The value of this parameter was larger by 4.7% in the irrigated variants compared to the drought-exposed plants. Studies have also shown that the number of spikelets per spike is less sensitive to water deficiency compared to other elements of the spike (Allahverdiyev *et al*., 2015). There were reports on the important role of the grain number per spike in plant productivity. According to some authors, the number of grains per spike plays an important role in the yield formation (Peltonen-Sainio *et al*., 2007), while others stated the importance of the mass of grains per spike (Garcia Del Moral *et al*., 2003). The difference between the irrigated and drought-exposed variants in the number of grains per spike was 21.6% (Table 2). The largest difference in this parameter between the variants was found in the Bezostaya 1 (15.4%), Gyzyl bughda (20.0%), Sheki 1 (14.7%), and 7thWON-SA №477 (14.8%) genotypes, while the smallest difference was observed in the Gyrmyzy gul 1 and Zirve 85 varieties. The grain mass per spike in the drought-exposed variants of the Sonmez 01, Gobustan, Tale 38, Zirve 85 and 7thWON-SA №477 genotypes was higher compared to other genotypes. It should be noted that the high value of this parameter in the drought-exposed variants of Sonmez 01 and 7thWON-SA №477 was related to a higher 1000 grain mass. Whereas, in the varieties Gobustan, Tale 38 and Zirve 85, it is attributed to the high number of grains per spike. The thousand grain mass was depressed by an average of 10.1% in the drought-exposed variant compared to the irrigated variant. A decline in 1000 grain mass under drought stress may be associated with a decrease in the efficiency of metabolite formation and disruption of the translocation of photosynthetic assimilates within plants (Iqbal *et al*. 1999). On the other hand, the shortening of the vegetation period accelerates the maturation of the grain, which causes the grains to remain tiny (Khakwani *et al*., 2011). We found that the mass of 1000 grains in the Gyzyl bughda, Sonmez 01, and 7thWON-SA №477 genotypes was higher than in other genotypes in both experimental variants. The largest difference between irrigated and drought-exposed variants was observed in the Tale 38 (16.2%) and Gyrmyzy gul 1 (13.5%) varieties, the 12thIWWYT №8 (15.5%) and Ferrigineum 2/19

(12.7%) lines, while the smallest difference was detected in the varieties Sonmez 01 (6.8%) and Gobustan (7.6%) and in the lines 4thFEFWSN №50 (6.7%) and 7thWON-SA №477 (7.2%).

4. Conclusion

Thus, the results of the study showed that the rainfed conditions with unstable moisture decreased productivity, the number of spikes per sheaf, the number of spikelets per spike, the number of grains per spike, the mass of grains per spike, and the mass of 1000 grains. Of the components directly affected by water stress, the productivity and the mass of grains per spike were the most depressed, while the number of spikelets per spike was relatively stable. As the grain mass per spike depends on both the number of grains per spike and the mass of 1000 grains, its decrease was the highest. Less reduction of productivity due to water deficiency was reveiled in genotypes Seki 1, Murov 2, 7thWON-SA №465 and 11thIWWYT№20.

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