

UDC 633.11:633.112

INDICES OF PRODUCTIVITY, TOLERANCE, AND SENSITIVITY TO DROUGHT IN WINTER BREAD WHEAT UNDER DRYLAND CONDITIONS

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(Presented by Academician of ANAS I.M.Huseynova)

The article presents results of the study of productivity, drought tolerance, and sensitivity indices of 21 genotypes of winter bread wheat under drought, irrigated, and natural conditions in Mountainous Shirvan territory with unstable moisture supply. The productivity of Gobustan and 7 WON-SA № 465 genotypes was shown to be higher than that of other genotypes under all three cultivation conditions. Tale 38 and Gyrmyzy gul 1 varieties showed high results in the irrigated variants. Productivity decreased under drought conditions by an average of 20.4% compared to the irrigated variants. The greatest crop losses were observed in the genotypes, Tale 38, Gyrmyzy gul 1, and 12thIWWYT № 8, respectively, by 29.3, 27.2, and 23.1% under drought conditions. The lowest productivity depression was observed in the genotypes, Sheki 1 (15.0%), Murov 2 (15.5%), 7 WON-SA № 465 (16.6%), and 11thIWWYT № 20 (16.6%). Tale 38 and Gyrmyzy gul 1 had the most plasticity, and Sheki 1, Murov 2, and 7 WON-SA № 465 had stability. The highest values of the stress tolerance index were observed in Gobustan (0.998), 7 WON-SA № 465 (1.132) and Ferrigineum 2/19 (0.930), and the lowest values of the drought sensitivity index were found in Bezostaya 1 (0.666), Sheki 1 (0.768) Sonmez 01 (0.791) and Murov 2 (0.797). Drought sensitivity indices of the Gobustan, Tale 38, and Gyrmyzy gul 1 varieties were equal to 1.249, 1.619, and 1.363, respectively.

Keywords: winter bread wheat, different water supply, productivity, drought tolerance, drought sensitivity

Introduction

The formation of the product appears as an integral result of the morphophysiological and biochemical processes occurring in the plants. Creating high and stable yielding genotypes with optimal morphophysiological and agronomic characteristics by increasing tolerance to abiotic stress factors such as drought, high temperature, and salinity is the main goal of wheat selection programs. Although the creation of stress-tolerant varieties is the main goal of the most breeding programs, to gain success in this field is limited due to the absence of appropriate selection techniques and genotypes responses of which to environmental stress factors differ sharply [13]. For this reason, wheat breeders are looking for methods and sources of genetic improvement of productivity and other agronomic parameters. Determination of some morphological and physiological parameters by express methods in the field, application of molecular

markers, and new technologies can greatly help to achieve the goals. At present, selection work to increase wheat productivity is carried out taking into account other morphophysiological features related to productivity [2; 6;10]. Since the creation of drought-tolerant varieties is an important condition for obtaining high yields of wheat under water deficiency, many studies have been conducted in this direction and significant results have been obtained [1; 3; 4; 5; 7]. Besides, when selecting varieties for arid regions the stability of genotype productivity, drought tolerance index, i.e. adequate productivity under drought conditions, as well as ability of plant to respond to irrigated conditions should be considered, which is useful in terms of genotype broad adaptability [8]. Therefore, to create a highly productive variety that is tolerant to abiotic stress factors characteristic of the climatic conditions of any region, it is important to conduct research in the same region.

Materials and methods

The research was conducted at the Gobustan Regional Experimental Station (RES) of the Research Institute of Crop Husbandry in the 2012-2013 and 2013-2014 vegetation seasons of winter wheat. The experimental field, having a light chestnut soil type, is located at an altitude of 800.0 m above sea level. According to the average multi-year data, the amount of atmospheric precipitation in the region is 350.0-400.0 mm (data from Gobustan Hydrometeorological Station). In the 2012-2013 vegetation year, when the research was conducted, the amount of precipitation was in line with the norm and amounted to 385.3 mm, and in 2013-2014, it was 222.8 mm, which is well below the average multi-year norm (data from Gobustan Hydrometeorological Station).

Twelve varieties and nine lines of bread wheat differing in morphophysiological characteristics were taken as the objects of the research. The sowing was performed in 3 repetitions in the form of randomly placed blocks, the area of each experimental bed was 1.0 m², and the sowing rate was 450 seeds per 1 m². To create a difference in water supply, an artificial drought was created in early May by covering one block with a transparent polyethylene cover, the second block was irrigated and the third block was kept under natural conditions. Wheat samples taken from all variants (3 repetitions, 1m² area) were placed in a threshing machine and then weighed. The average values were calculated for three repetitions and the results were accepted as the productivity per 1 m² (g/m²).

Drought sensitivity and tolerance indices were calculated according to the following formulas:

Stress tolerance index $STI = (Y_p \times Y_s) / \hat{Y}_p^2$, tolerance to stress $TOL = Y_p - Y_s$, stress intensity $SI = 1 - \hat{Y}_s / \hat{Y}_p$, stress sensitivity index $SSI = (1 - Y_s / Y_p) / SI$, average productivity

$AP = (Y_s + Y_p) / 2$, geometric mean productivity $GMP = \sqrt{Y_p \times X_s}$, productivity index $PI = Y_s / \hat{Y}_s$, yield stability index $YSI = Y_s / Y_p$ [9; 11; 12]. Where Y_p -productivity under irrigated conditions, Y_s - productivity under drought, $\hat{Y}_p$ - average productivity of all genotypes under irrigated conditions, $\hat{Y}_s$ - average productivity of all genotypes under drought. Statistical analyses of the results were performed using the program JMP 5.0.1.

Results and discussion

Productivity of 19 wheat genotypes differing in morphophysiological characteristics was studied in 2012-2013 and 2013-2014 vegetation years in Mountainous Shirvan under dryland conditions using natural, drought-exposed, and irrigated variants. The results of the study are presented in Table 1. The analysis of dispersion showed a significant difference between the genotypes at the level of 0.01 for this parameter. The difference in the amount of precipitation during the vegetation season was reflected in the productivity of all three variants of the studied genotypes. Thus, in 2013, the average productivity of all genotypes under natural, drought, and irrigated conditions (657, and 728 g/m², respectively) was higher than in 2014 (339, and 518 g/m², respectively). According to average values of two years, the highest parameters were found in the Gobustan and Gyrmyzy gul 1 varieties (557 and 514 g / m²) and the 7 WON-SA № 465 and Ferrigineum 2/19 lines (607 and 549 g / m²) under drought conditions, the Tale 38, Gyrmyzy gul 1, and Gobustan varieties (717, 707 and 717 g / m²) and the 7 WON-SA № 465 and Ferrigineum 2/19 lines (728 and 678 g / m²) under irrigated conditions. The average productivity values showed a 20.4% loss of crops caused by drought compared to the irrigated variants.

Table 1

Productivity of the studied genotypes depending on water supply, g/m²

Samples	Drought-exposed		average	Irrigated		average
	2013	2014		2013	2014	
Bezostaya 1	559 h	311 b, c	435	577 h	480 f, g	529
Gyzyl bughda	566 h	316 b, c	441	633 g, h	467 g	550
Sheki 1	563 h	346 b, c	455	614 g, h	455 g	535
Sonmez 01	661 d, e, f	352 b	507	704 e, f	528 d, e	616
Aran	601 g, h	352 b	477	665 f, g	564 b, c	615
Vostorg	558 h	317 b, c	438	614 g, h	538 c, d, e	576
Murov 2	580 h	312 b, c	446	632 g, h	423 h	528
Gobustan	705 b, c, d	408 a	557	845 a	567 b, c	706
Tale 38	691 c, d, e	322 b, c	507	856 a	577 b	717
Fatima	657 e, f	296 c	477	748 c, d, e	416 h	582
Gyrmyzy gul 1	689 c, d, e	339 b, c	514	803 a, b, c	610 a	707
Zirve 85	681 c, d, e	323 b, c	502	742 c, d, e	479 f, g	611
7WON-SA №465	758 a	456 a	607	830 a, b	626 a	728
Ferrigineum 2/19	750 a, b	347 b, c	549	801 a, b, c	555 b, c, d	678
11thIWWYT №20	685 c, d, e	322 b, c	504	746 c, d, e	462 g	604
12thIWWYT № 6	722 a, b, c	334 b, c	528	795 a, b, c, d	509 e, f	652
12thIWWYT № 8	701 c, d, e	329 b, c	515	763 b, c, d, e	576 b	670
12thIWWYT № 9	628 f, g	316 b, c	472	552?	485 f, g	519?
12thIWWYT № 17	663 d, e, f	304 b, c	484	591?	480 f, g	536?
7WON-SA №477	690 c, d, e	333 b, c	512	742 c, d, e	537 c, d, e	640
4thFEFWSN№ 50	661 d, e, f	326 b, c	494	727 d, e, f	471 g	599
Average	656	336	496	728	515	623
LSD	46**	52**		69**	31.3**	
DI, %	4.3	9.4		5.8	3.7	

Note: LSD- (Least Significant Difference); DI- dispersion index; a, b, c, d, e, f, g, h, i- the genotype group according to the value of the parameters

The largest crop losses were observed in the varieties, Tale 38 (29.3%), Gyrmyzy gul 1(27.2%), and the line, 12thIWWYT № 8. The lowest crop losses under drought were in Sheki 1 (15.0%) and Murov 2 (15.5%), and in the lines, 7 WON-SA № 465 (16.6%) and 11thIWWYT № 20. As seen in Table 1, the productivity of the Tale 38, Gyrmyzy gul 1, and 12thIWWYT № 8 genotypes is close to the average level in the drought-exposed variants and much higher than the average level in the irrigated variants. The fact that these genotypes are more responsive to improved climatic conditions and increase their productivity more than other genotypes may be an indication of their plasticity. In Sheki 1, Murov 2, 7WON-

SA№465, the decrease in productivity in the drought-exposed variants was low, which, in our opinion, indicates that their stability is higher than that of other genotypes. Based on the productivity of the studied genotypes in the irrigated and drought-exposed variants, drought sensitivity and tolerance indices were calculated and the average results for two years are given in Table 2. Breeders usually pay a lot of attention to the values of AP and GMP, as the degree of drought stress varies depending on the climate changes over the years. As seen in the table, the highest values of average productivity (AP) and geometric mean productivity (AP and GMP) for two years were observed in the Gobustan, Tale 38, Gyrmyzy gul 1 and 7

WON-SA No. 465 genotypes. It should be noted that as TOL is the difference between the productivity of the irrigated and drought-exposed plants, its value can be low in varieties manifested low productivity both under drought

and irrigated conditions. Therefore, according to some authors, the selection process to reduce stress tolerance may eventually lead to the creation of low-yielding varieties under irrigated conditions.

Table 2

Drought stress indices of the studied genotypes (average values of 2013 and 2014)

Genotypes	AP	GMP	TOL	STI	DSI	PI	YSI
Bezostaya 1	482	477	94	0.586	0.666	0.888	0.808
Gyzyl bughda	496	492	109	0.616	1.005	0.901	0.786
Sheki 1	495	493	80	0.623	0.768	0.943	0.838
Sonmez 01	561	557	110	0.790	0.791	1.027	0.803
Aran	546	539	138	0.752	1.032	0.981	0.764
Vostorg	507	499	139	0.645	1.056	0.896	0.749
Murov 2	487	484	82	0.595	0.797	0.906	0.828
Gobustan	632	627	150	0.998	1.249	1.144	0.777
Tale 38	612	600	210	0.909	1.619	1.005	0.683
Fatima	529	526	106	0.696	1.036	0.941	0.795
Gyrmyzy gul 1	611	600	193	0.912	1.363	1.029	0.707
Zirve 85	556	552	109	0.768	0.888	0.999	0.796
7WON-SA №465	668	664	121	1.132	0.833	1.255	0.821
FERRIGINEUM 2/19	613	607	130	0.930	0.864	1.087	0.781
11thIWWYT №20	554	551	101	0.763	0.853	1.000	0.808
12thIWWYT №6	590	585	124	0.862	0.963	1.046	0.782
12thIWWYT №8	593	583	155	0.862	1.032	1.023	0.745
7WON-SA №477	576	570	128	0.820	0.904	0.995	0.775
4thFEFWSN№50	547	543	106	0.743	0.906	0.956	0.801
Average	561	555	125	0.789	0.980	1.001	0.781

Note: AP-average productivity, g/m², GMP- geometric mean productivity, g/m², TOL-stress tolerance, STI-stress tolerance index, DSI-drought sensitivity index, PI-productivity index, YSI-yield stability index

Genotypes having PI values over 1 and the highest YSI values being close to 1 are considered to be more stress-tolerant. According to the two-year averages, the highest values of PI were detected in Gobustan and 7WON-SA №465 (1.144 and 1.255, respectively), and the highest values of YSI were observed in the Murov 2 and Sheki 1 (0.828 and 0.838, respectively) genotypes. It should be noted that the

high PI in the Gobustan and 7WON-SA №465 genotypes was due to their high productivity in the drought-exposed variants, while the high PI in the Murov 2 and Sheki 1 varieties was due to their low productivity under irrigated conditions. It should be noted that the drought-exposed variants of the Murov 2 and Sheki 1 varieties have low productivity.

It can be concluded that although PI and

YSI indicate the genotype's tolerance to stress, they do not guarantee that the genotype will produce high yields under stress. On the other hand, the intensity of stress (SI) also varies depending on the climatic conditions of the year, and it is useful to take into account when assessing the tolerance of the genotype. The parameters characterize the genotype's stress tolerance and sensitivity are the Stress Tolerance Index (STI) and the Drought Sensitivity Index (DSI). Thus, the high productivity of the genotype under both irrigated and drought conditions leads to its high values. Here, the high productivity of the genotype in both variants indicates that it is more tolerant, which makes it more useful to use this parameter as a selection criterion. In our study, the highest STI values for the two-year average were 0.998, 0.930, and 1.132, respectively, in the Gobustan, Ferrigineum 2/19, and 7WON-SA №465 genotypes. In the Gobustan and 7WON-SA №465 genotypes, the high values of STI were due to their high productivity under both drought and irrigated conditions. Thus, it can be concluded that the stress tolerance index does not fully disclose the productivity of the genotype under drought conditions, so its application as a selection criterion requires an additional parameter, which may be a drought sensitivity index. The intensity of drought stress (SI) (severity) calculated according to the average value of the results of all genotypes studied also play a role in the determination of DSI. Since the intensity of stress is constant for any given year, it suggests that the genotype with high productivity under drought will have a low DSI and vice versa. Therefore, low values of the drought sensitivity index less than 1 indicate that the genotype has low drought sensitivity, and high values above 1 indicate high sensitivity to drought. In our research, the highest values of this parameter were observed in the Gobustan (1.249), Tale 38 (1.619), and Gyrmyzy gul 1 (1.363) varieties.

This result was expected for Tale 38 and Gyrmyzy gul 1, given that they were created for irrigated conditions and their potential productivity was high under irrigation and was moderate under drought. Although the productivity in the drought-exposed Gobustan variety was higher than the average level, the high value of DSI is attributed to its high potential under irrigated conditions. The lowest values for DSI were observed in the varieties, Bezostaya 1 (0.666), Sheki 1 (0.768), Sonmez 01 (0.791), and Murov 2 (0.797), and in the lines, 7WON-SA №465 (0.833), Ferrigineum 2/19 (0.864), and 11thIWWYT № 20 (0.853). The productivity of the Bezostaya 1, Sheki 1, Sonmez 01, and Murov 2 varieties, which have low values for DSI, was below average under both drought and irrigated conditions. Therefore, despite their low DSI, planting under drought conditions led to crop losses. It should be noted that the most discussed aspect of the DSI calculation method is very low values of this parameter compared to the productivity levels [8]. For this reason, when selecting a variety for arid regions, the genotype's yield stability and drought tolerance index, i.e. its ability to both giving sufficient production under drought and responding to irrigated conditions, should also be taken into account, which is beneficial for the broad adaptability of the genotype.

Conclusions

Among the studied genotypes, the Tale 38 and Gyrmyzy gul 1 varieties were found to have high plasticity, while Sheki 1, Murov 2, and 7WON-SA №465 were found to have high stability. Low DSI, under optimal conditions, sometimes leads to a decrease in total production. Therefore, when planting the varieties in the regions, it is expedient to take into account also their plasticity. Thus, the genotypes, Gobustan, 7WON-SA №465, and Ferrigineum 2/19 were identified as the most suitable for cultivation under dryland conditions of Mountainous Shirvan.

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NƏMLİKLƏ TƏMİN OLUNMAMIŞ DƏMYƏ ŞƏRAİTİNDƏ PAYIZLIQ YUMŞAQ BUĞDANIN MƏHSULDARLIĞI, QURAQLIĞA TOLERANTLIQ VƏ HƏSSASLIQ İNDEKSLƏRİ

A.A. Cahangirov

Məqalədə payızlıq yumşaq buğdanın 21 genotipinin məhsuldarlığı, quraqlığa tolerantlıq və həssaslıq indekslərinin Dağlıq Şirvanın nəmliklə stabil təmin olunmamış şəraitində quraqlıq, suvarma və təbii şəraitdə öyrənilməsinin nəticələri verilmişdir. Göstərilmişdir ki, Qobustan və 7 WON-SA № 465 genotiplərinin məhsuldarlığı hər üç becərmə şəraitində digər genotiplərdən yuxarı olmuşdur. Tale 38 və Qırmızı gül 1 sortları isə suvarma variantında yüksək nəticə göstərmişlər. Məhsuldarlıq quraq variantda suvarmaya nisbətən ortalama olaraq 20,4% azalmışdır. Quraqlıq şəraitində ən çox məhsul itkisi Tale 38, Qırmızı gül 1 və 12thIWWT № 8 genotiplərində olmaqla uyğun olaraq 29,3, 27,2 və 23,1% təşkil etmişdir. Məhsuldarlığın ən az depressiyası isə Şəki 1 (15,0%), Murov 2 (15,5%), 7 WON-SA № 465 (16,6%), və 11thIWWT № 20 (16,6%) genotiplərində müşahidə edilmişdir. Ən çox plastikliyə Tale 38 və Qırmızı gül 1, stabiliyə isə Şəki 1, Murov 2 və 7 WON-SA № 465 genotipləri malik olmuşlar. Quraqlığa tolerantlıq indeksinin ən yüksək qiymətləri Qobustan (0,998), 7 WON-SA № 465 (1,132) və Ferrigineum 2/19 (0,930), quraqlığa həssaslıq indeksinin ən kiçik qiymətləri isə Bezostaya 1 (0,666), Şəki 1 (0,768) Sönməz 01 (0,791) və Murov 2 (0,797) sortlarında müşahidə edilmişdir. Qobustan, Tale 38 və Qırmızı gül 1 sortlarının quraqlığa həssaslıq indeksləri uyğun olaraq 1,249, 1,619 və 1,363-ə bərabər olmuşdur.

Açar sözlər: payızlıq yumşaq buğda, fərqli su təminatı, məhsuldarlıq, quraqlığa tolerantlıq, quraqlığa həssaslıq

УРОЖАЙНОСТЬ, ИНДЕКСЫ ТОЛЕРАНТНОСТИ И ЧУВСТВИТЕЛЬНОСТИ К ЗАСУХЕ ОЗИМОЙ МЯГКОЙ ПШЕНИЦЫ В УСЛОВИЯХ НЕОБЕСПЕЧЕННОЙ БОГАРЫ

А.А. Джахангиров

В статье представлены результаты исследования показателей урожайности, индексы толерантности и чувствительности к засухе 21 генотипа озимой мягкой пшеницы при искусственной засухе, орошения и в естественных условиях Нагорного Ширвана с нестабильным влагообеспечением. Показано, что во всех трех условиях выращивания урожайность генотипов Гобустан и 7th WON-SA № 465 выше, чем у других генотипов. Сорта Тале 38 и Гырмызы гюль 1 показали высокие результаты при орошении. Урожайность снизилась в условиях засухи в среднем на 20,4% по сравнению с орошаемым вариантом. Наибольшие потери урожая наблюдались у генотипов Тале 38, Гырмызы гюль 1 и 12thIWWYT № 8, соответственно на 29,3, 27,2 и 23,1% в условиях засухи. Наименьшее снижение продуктивности наблюдалось у генотипов Шеки 1 (15,0%), Муров 2 (15,5%), 7th WON-SA № 465 (16,6%) и 11thIWWYT № 20 (16,6%). Наибольшей пластичностью обладали сорта Тале 38 и Гырмызы гюль 1, а устойчивостью - Шеки 1, Муров 2 и 7 WON-SA № 465. Наибольшие значения индекса толерантности к засухе наблюдались у генотипов Гобустан (0,998), 7th WON-SA № 465 (1,132) и Ferrugineum 2/19 (0,930), а самые низкие значения индекса чувствительности к засухе – у Безостая 1 (0,666).), Шеки 1 (0,768), Сонмез 01 (0,791) и Муров 2 (0,797). Показатели индекса чувствительности к засухе сортов Гобустан, Тале 38 и Гырмызы гюль 1 составили 1,249, 1,619 и 1,363 соответственно.

Ключевые слова: озимая мягкая пшеница, различное водообеспечение, урожайность, толерантность к засухе, чувствительность к засухе