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Stability, plasticity, and adaptability of winter bread wheat under rainfed conditions with unstable moisture supply

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Productivity, stability, plasticity, and adaptability of 14 varieties and 1 line of winter bread wheat were studied in Mountenous Shirvan, under rainfed conditions with no stable humidıty, in 2010/2011-2017/2018 vegetation years. Based on hydrometeorological indicators, the climatic conditions of 2010-2011, 2012-2013, 2016-2017, and 2017-2018 vegetation years were considered favorable for the development of winter wheat, and the climatic conditions of 2014-2015 and 2015-2016 were moderate and the climatic conditions of 2011-2012 and 2013- 2014 were found to be unfavorable. In 2011, 2013, 2017, and 2018, the average productivity for all genotypes was the highest and amounted to 61.3, 69.8, 66.9, and 66.6 cwt/ha, respectively. In 2015 and 2016, productivity was moderate, while in 2012 and 2014, it was at a low level. The average productivity over the years was in line with the climatic conditions during the vegetation year. According to the average of 8 years, Gobustan, 7th WON-SA №465, and Gyrmyzy gul 1 genotypes had the highest productivity - 66.4, 63.4, and 60.4 cwt/ha, respectively. Azeri, Bezostaya 1, Murov 2, Ruzi 84, and Sheki 1 varieties showed the lowest results. Taking into account the stability and plasticity of the studied varieties, it was concluded that Bezostaya 1, Ruzi 84, and Sonmez 01 varieties belong to the neutral type with the least plasticity (i.e. the type with wide adaptability). The varieties 7 thWON-SA №465 and Gobustan manifested a specific adaptation with high plasticity, increased productivity in response to high agrophone and favorable climatic conditions, as well as adaptability to adverse conditions. Therefore, the cultivation of these varieties in areas with unstable moisture supply, such as Mountainous Shirvan, and in a high agrophone, creates conditions for obtaining good results. In addition to not being adapted to unfavorable conditions, Tale 38 and Azamatli 95 varieties were found to have narrow adaptability and high plasticity in response to improved conditions.

Keywords: *Winter bread wheat, rainfed conditions, productivity, stability, plasticity, adaptability*

INTRODUCTION

Increasing wheat production and meeting the demand for cereals at the expense of local production is an important aspect of food security. Achieving the predicted level is possible with the use of high-yielding local varieties of cereals. This, in turn, should include highly adaptable and potentially productive varieties that are tolerant to biotic and abiotic stress factors at the level of agrocenosis, agroecosystems, and agroecological landscapes (Zhuchenko, 2001; Aliyev, 2012; Aliyev, Huseynova, 2014). Autumn cereals dominate over spring cereals due to yield potential and early ripeness. They better use natural soil-climate resources, including spring warmness and moisture. Besides, they are less subjected to the spring drought effect. Therefore, autumn cereals are very important for total grain production. The introduction of varieties with high adaptive potential into production is one of the conditions that allow production to be stabilized even in years that differ in humidity and temperature (Samofalova et al., 2019). In this case, the varieties must be ecologically plastic and have an individual reaction to changes in climate and meteorological conditions.

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The study of the reaction to changes in the cultivation conditions of the variety can allow the selection of a variety that meets the needs of agriculture for each ecological region and farm (Al- iev, 2000, 2001; Mameev, Nikiforov, 2015; Pe- trov, Selekhov, 2016). Productivity is an im- portant indicator for assessing the ecological plas-ticity and stability of a variety, as it determinesthe reaction to the improvement of growing con- ditions and also indicates the level of intensity of cultivation technology (Sharma et al., 2012,2013). The adaptability of a variety to environ- mental conditions is judged by its environmental plasticity and yield stability. Plasticity is an adap- tive reaction of genotypes to the effects of environmental factors that cause changes in productivity and other traits of the organism. The term “average productivity of varieties” (P-average) is used to define productive and adaptive potential using a variation of the productivity under a spe- cific condition or region. In this case, the produc- tivity of the variety is compared with the "averageyield of varieties" rather than the standards. To assess the response of any variety to the condi- tions of the vegetation period, its productivity is divided by the average yield, and the value ob- tained indicates the coefficient of adaptability as arelative concept (Mameev, Nikiforov, 2015). Sta- bility is the degree of resilience that characterizesa genotypic adaptive reaction leading to changesin signs and characteristics of the organism against changing environmental factors. Varieties that have moderate intensity and high yield stabil-ity but are not highly productive under any condi- tions are considered ecologically tolerant ones.

It is known that the climatic conditions in the Mountainous Shirvan region changed over the years, which had a serious impact on production. Thus, although favorable agrometeorological conditions lead to an increase in crop production, in some years, drought caused by low precipitation, and sometimes accompanied by high temperatures, leads to serious crop losses. In this case, the selection and application of adaptive and relatively plastic varieties in the region would not only create conditions for a significant increase in production in favorable years but also ensure stable production during unfavorable years. From this point of view, the study of productivity, yield stability, plasticity, and adaptability of new varieties under rainfed conditions of Mountenous Shirvan with unstable moisture supply is of great importance.

MATERIALS AND METHODS

The studies were performed on 15 wheat genotypes with contrasting morphophysiological traits and productivity, under the conditions of unstable moisture supply of Mountainous Shirvan in the vegetation years of 2010-2011, 2011-2012, 2012-2013, 2013-2014, 2014-2015, 2015-2016, 2016-2017, and 2017-2018. The experiments were conducted on arable lands of the Gobustan Regional Experimental Station of the Research Institute of Crop Husbandry located in foothills. The area is at an altitude of 800 m above sea level. The soil type is light chestnut and has a weak alkaline environment. The region has rainfed conditions with unstable moisture supply and according to the average multi-year data, the amount of atmospheric precipitation is 350.0-400.0 mm.

The studied genotypes were planted in 3 repetitions in the form of randomly placed blocks with an area of 32.0 m^2 in each experimental unit, the sowing norm was 450 seedlings per 1 m^2.In the full ripeness phase, the experimental units were mowed with a mini-experimental combine "Foton Gushen" and the product was weighed. The results were analyzed using “JMP 5.0.1” and “Genstat” programs.

RESULTS AND DISCUSSION

During the 2010/2011-2017/2018 vegetation years (8 years in total), 14 varieties and 1 line of winter wheat were studied to assess productivity, yield stability, plasticity, and adaptability of new varieties under rainfed conditions of Mountenous Shirvan with unstable moisture supply. Information on climatic conditions from 2010 to 2018, when the research was conducted, was obtained from the Gobustan hydrometeorological station. Based on the above indicators, the climatic conditions of 2010-2011, 2012-2013, 2016-2017, and 2017-2018 vegetation years were considered favorable for the development of winter wheat, and the climatic conditions of 2014-2015 and 2015-

2016 were moderate and the climatic conditions of 2011-2012 and 2013- 2014 were found to be unfavorable. The results of the study of the productivity of varieties during the research years are given in Table 1. As seen in the table, differences in a significance level of 0.01 were observed between the studied genotypes. For each year, the least significant difference (LSD) between the genotypes was determined, and based on this value, the genotypes were assigned to different groups. At the same time, the average productivity for the years is given in Table1. As seen in the table, the average productivity in 2011, 2013, 2017, and 2018 was at the highest level and amounted to 61.3 (C), 69.8 (A), 66.9 (B), and 66.6 (B) cwt/ha, respectively (based on LSD, a designation of the group related to a year is given in the parenthesis). Productivity was at a moderate level in 2015 and 2016, and a low level in 2012 and 2014. As can be seen, the average productivity over the years was consistent with the course of climatic conditions during the vegetation season.

The results of the average productivity of the studied varieties for all years are given in Figure 1. As seen in the figure, the average productivity for all genotypes was 55.1 cwt/ha. According to the 8-year average values, Gobustan, 7thWON-SA №465, and Gyrmyzy gul 1 varieties showed the highest results - 66.4 (A), 63.4 (B), and 60.4 (C) cwt/ha, respectively. Azeri (H), Bezostaya 1 (H), Murov 2 (H), Ruzi 84, (G), and Sheki 1 (G) varieties showed low productivity, while other studied genotypes were in the middle position (Based on LSD, a group designation of the variety is given in parentheses).

To study yield stability, plasticity, and adaptability of the varieties, AMMI ("Additive main effects of anova along with the multiplicative interaction" effects of Principal Components Analysis) analysis was performed using the "Genstat" program. As a result of the AMMI analysis, a linear dependence of the productivity of varieties on the environmental factor was established, and on the basis of these dependencies, linear regression equations in the form of the formula y = a + bx were obtained for each variety. These equations are given below:

7thWON-SA №465: productivity (cwt/ha)=1.56+1.12*Environmental index

ARAN: productivity (cwt/ha)=2.72+0.92* Environmental index

Azeri: productivity (cwt/ha)=-0.90+0.90*Environmental index

Table 1. Productivity of t ıe studied genotypes by research years

Genotypes	Productivity, cwt/ha								
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Average**
7thWON-SA №465	76.2 b	30.4 abc	79.8 ab	55 a	57.8 b	60.3 ab	74.6 ab	73.1 b	63.4 B
Aran	63.4 e	27.7 bcde	62.8 f	45.9 de	53.2 de	45.3 fg	69.6 cde	60.8 efg	53.6 EF
Azeri	47 h	25.5 de	66.8 de	44.2 efg	48.8 f	37.1 ı	59.6 h	60.4 fg	48.7 H
Bezostaya 1	41.1ı	25.6 de	62.1f	44.6 defg	49.1 f	39.6 hı	61.3 h	63.1 def	48.3 H
Azamatli 95	48.2 h	20.1 f	67.3 de	43.7 efg	57.6 bc	54.2 c	68.3 def	75.7 b	54.4 E
Guneshli	69.7 cd	30.5 abc	74 c	51.1 abc	55.2 bcd	53.4 c	67.9 defg	69.6 c	58.9 D
Murov 2	56.6 g	24.5 e	70 d	41.3 g	43 g	38.3 hı	59.6 h	59.2 g	49.1 H
Gyrmyzy gul 1	73.8 bc	31.5 ab	76.7 bc	53.9 ab	56.8 bcd	53.5 c	67.5 defg	69.6 c	60.4 C
Gyzyl bughda	65.5 de	27.5 cde	63.3 f	45 defg	49.6 ef	44 g	70.4 cd	64.6 d	53.7 EF
Gobustan	82.5 a	31.7 a	81.8 a	54.6 a	63.4 a	62.1 a	75 a	80.4 a	66.4 A
Ruzi 84	50.6 h	26.2 de	70.1 d	45.4 def	48.5 f	51.7 cd	60.5 h	59.4 g	51.6 G
Sonmez 01	57.7 fg	28.8 abcd	62.7f	50.2 bc	55.7 bcd	47.4 ef	66.8 efg	64.3 d	54.2 EF
Sheki 1	58.3 fg	27.4 cde	64.2 ef	41.8 fg	49.7 ef	40.5 h	65.5 fg	62.5 def	51.2 G
Tale 38	70.2 c	26.3 de	76.8 bc	48.3 cd	54 cd	58.5 b	71.7 bc	73.5 b	59.9 CD
Zirve 85	61.9 ef	23.8 ef	68.9 d	44.4 defg	47.4 f	49.2 de	65 g	63.4 de	53 F
Average	61.5 C	27.2 G	69.8 A	47.3 F	52.7 D	49.0 E	66.9 B	66.6B	55.1
LSD (0.01) Variety	4.4	4	3.5	4	3.8	3	3	2.8	1.2
Coefficient of variation, %	4.2	8.7	3	5	4.3	3.7	2.7	2.5	3.9

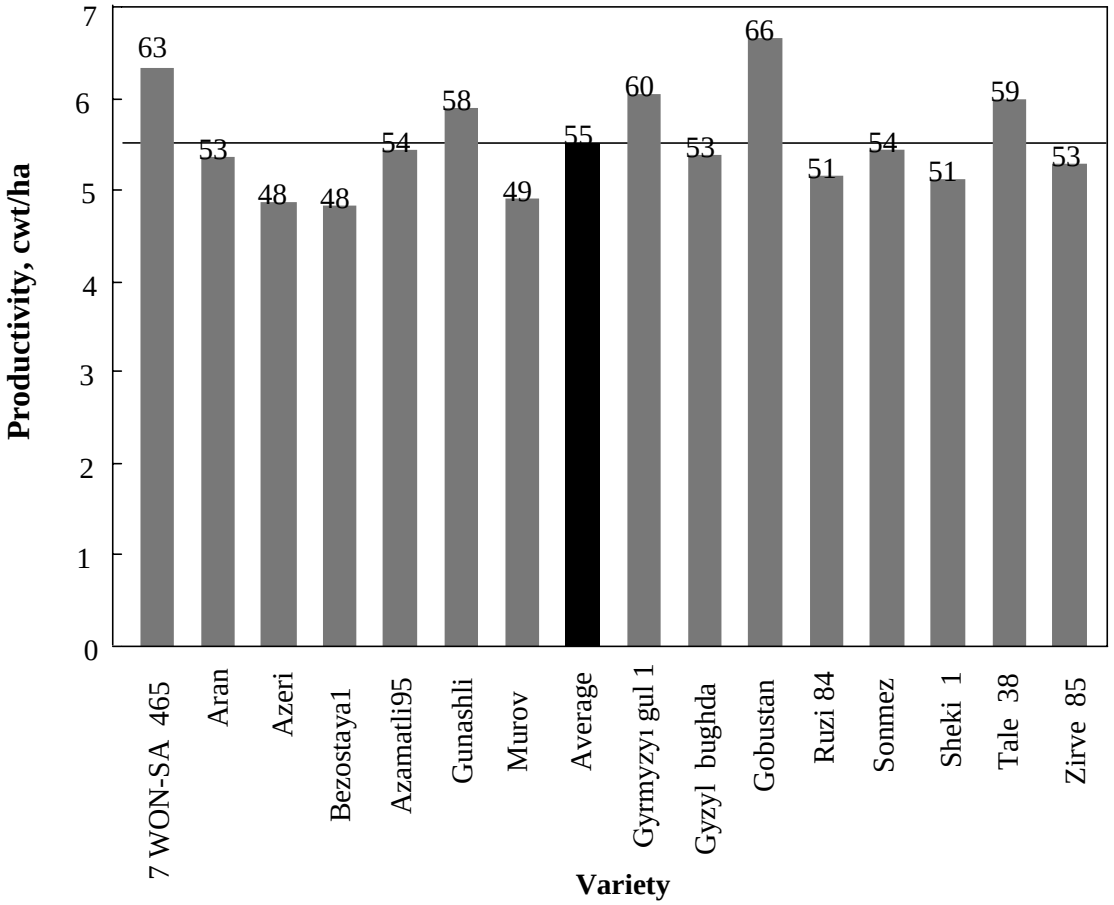

Fig. 1. The average productivity of the studied genotypes during all research years

Table 2. Stability parameters of the studied varieties related to productivity

Varieties	Productivity, cwt/ha	b		a	VC, %	R^2
		b	±Standard deviation			
7thWON-SA № 465	63.4	1.12	0.09	1.56	5.4	0.96
Aran	53.6	0.92	0.1	2.72	6.9	0.94
Azeri	48.7	0.9	0.13	-0.9	9.7	0.89
Bezostaya 1	48.3	0.84	0.16	1.72	12.7	0.82
Azamatli 95	54.4	1.13	0.2	-7.73	14.1	0.83
Guneshli	58.9	1	0.06	3.64	3.8	0.98
Murov 2	49.1	1.01	0.1	-6.44	7.9	0.94
Gyrmyzy gul 1	60.4	1.01	0.1	4.82	6.1	0.95
Gyzyl bughda	53.7	1	0.11	-1.22	7.6	0.93
Gobustan	66.4	1.19	0.12	0.64	6.8	0.94
Ruzi 84	51.6	0.87	0.12	3.75	8.5	0.9
Sonmez	54.2	0.84	0.08	7.8	5.4	0.95
Sheki 1	51.2	0.95	0.08	-1.04	5.5	0.96
Tale 38	59.9	1.18	0.08	-4.95	5.3	0.97
Zirve 85	53	1.04	0.05	-4.37	3.8	0.98
Average	55.1					

Bezostaya 1 productivity (cwt/ha)= 1.72+0.84*Environmental index
Azamatli 95 productivity (cwt/ha)= -7.73+1.13*Environmental index
Guneshli productivity (cwt/ha)=3.64+1.00* Environmental index
Murov 2 productivity (cwt/ha)=-6.44+1.01* Environmental index
Gyrmyzy gul 1 productivity (cwt/ha)=4.82+1.01* Environmental index
Gyzyl bughda productivity (cwt/ha)=-1.22+0.10* Environmental index
Gobustan productivity (cwt/ha)=0.64+1.19* Environmental index
Ruzi 84 productivity (cwt/ha)=3.75+0.87* Environmental index
Sonmez 01 productivity (cwt/ha)=7.80+0.84* Environmental index
Sheki 1 productivity (cwt/ha)=-1.04+0.95* Environmental index
Tale 38 productivity (cwt/ha) =-4.95+1.18* Environmental index
Zirve 85 productivity (cwt/ha)=-4.37+1.04* Environmental index

In these equations, the environmental index (EI) is the average productivity of all genotypes during a year. Based on the regression equations, stability parameters were determined by The Finlay-Wilkinson regression method (Finlay, Wilkonson, 1963) and the results are given in Table 2.

Parameters "a" and "b" (parameters required to assess the stability of the variety), the standard error of the "b" parameter, the coefficient of variation (VC, %), and the degree of significance - R^2 are given in the table. The parameters R^2 and VC are used to test the reliability of the regression equation without being directly related to the stability itself and have been proposed by Eberhart and Russell (Eberhart, Russell, 1966). R^2 and VC are a measure of the deviation between real values and values calculated by the regression equation. Low values of R^2, as well as high values of VC, indicate large deviations. Due to these deviations, the "a" and "b" values obtained for a variety as a result of regression analysis are considered to be unreliable. In our study, there was no problem with the reliability of the regression equations because all R^2 values were above acceptable limits (0.82-0.98).

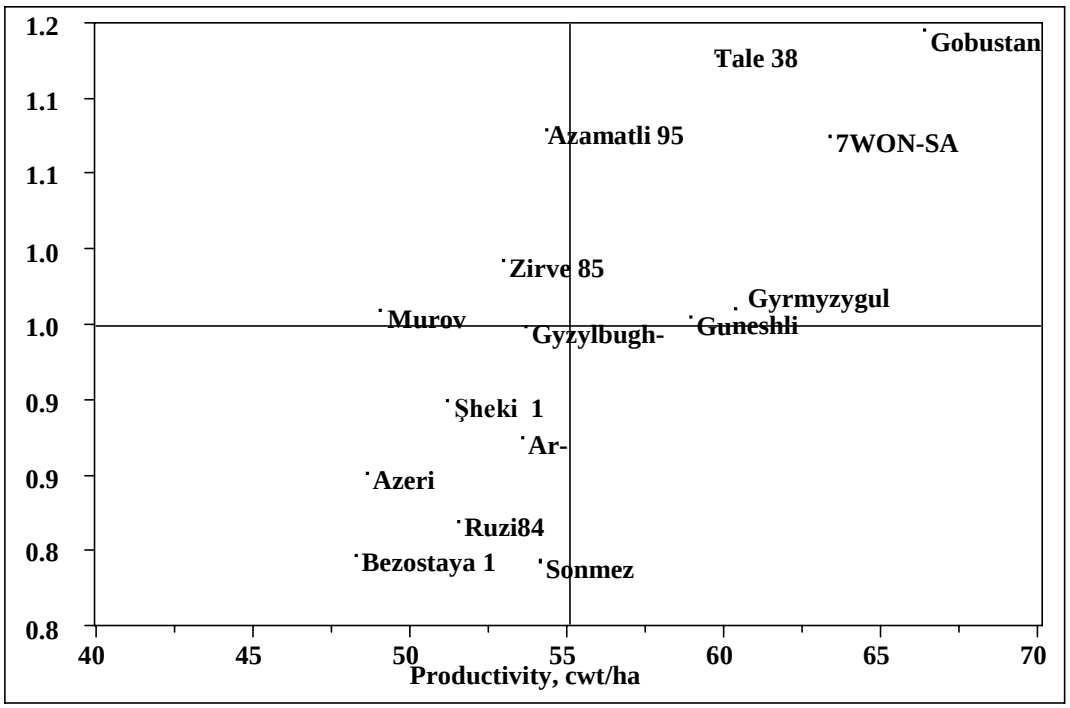

Fig. 2. Stability diagram constructed using productivity and "b" values.

The differences in the VC values were not considered significant because VC varied depending on the productivity levels and the values of R^2 were higher. The parameter "a" in the table is the expected productivity of the varieties at a point where the population average is theoretically zero. The parameter "b" indicates the increase in the productivity of varieties per unit of average productivity of the population in response to improved environmental conditions. High values of the "a" parameter indicate adaptability of the variety while the "b" values close to one indicate high stability of the variety. Therefore, values of "a" and "b" must be evaluated together when considering the yield stability of varieties. As seen in Table 2, 7thWON-SA №465, Aran, Bezostaya 1, Guneshli, Gyrmyzy gul 1, Gobustan, Ruzi 84, and Sonmez 01 varieties with positive values of the "a" parameter were considered as plants adapted to unfavorable conditions. Other studied varieties with negative values of "a" were unsuitable for unfavorable conditions. The varieties 7thWON-SA №465 and Gobustanın showing high values of the "b" parameter (1.12 and 1.19, respectively) were found to have wider adaptability. Azamatli 95 and Tale 38, which have negative values of "a", were considered to be highly adaptable to improved conditions, and as expected due to the high values of "b" (1.13 and 1.18), they were sensitive to adverse conditions. As mentioned above, the "b" values close to 1 indicate the high stability of the variety. The stability diagram constructed using the values of productivity and "b" is presented in Figure 2.

As seen in Fig. 2, Murov 2, Gyzyl bughda, Guneshli, and Gyrmyzy gul 1 varieties with "b" values close to one (1.01, 1.00, 1.00, and 1.01, respectively) were characterized as varieties with the highest yield stability. Figure 2 was divided into four sections to determine the adaptability of the varieties to different environmental conditions. The varieties with low adaptability under favorable conditions - Murov 2, Zirve 85, and Azamatli 95 were placed in the 1st section (upper left), Tale 38, Gobustan, 7thWON-SA №465, Gyrmyzy gul 1, and Guneshli showing high adaptability to favorable conditions - in the 2nd section (upper right). Gyzyl bughda, Sheki 1, Aran, Azeri, Ruzi 84, Bezostaya 1, and Sonmez 01 were placed in the 3rd section (lower left) as varieties badly adapted to unfavorable conditions. Section 4 (lower right) was to include varieties that were well adapted to unfavorable conditions, but none of the varieties studied matched this section. Taking into account the stability and plasticity of the studied varieties, it was concluded that Bezostaya 1, Ruzi 84, and Sonmez 01 having the "b" values much less than one (the main parameter determining stability and plasticity) were considered to be neutral varieties with the least plasticity (i.e. a type with wide adaptability). The productivity of these varieties was less reduced in unfavorable climatic conditions than in the case of ecologically plastic, i.e. intensive types. Since such varieties can be more cost-effective, it is advisable to cultivate them extensively. The varieties 7thWON-SA №465 and Gobustan having positive values of "a" and "b" showed adaptability to adverse conditions and high plasticity that determine their specific adaptation. These varieties not only increased their productivity by responding to high agrophone and favorable climatic conditions but also adapted to unfavorable conditions. Therefore, the cultivation of these varieties in areas with unstable moisture supply, such as Mountainous Shirvan, and in a high agrophone, creates conditions for good results. Tale 38 and Azamatli 95, which were not adaptable to unfavorable conditions, had negative values of "a", high values of "b", and were found to have high degrees of adaptability and high plasticity in response to improved conditions. It is expedient to cultivate these varieties in a high agrophone and well-watered conditions. The variety Gyrmyzy gul 1 manifested adaptability to unfavorable conditions (the "a" value was positive) and yield stability (the "b" value is close to 1), which indicated that it could be planted under unfavorable conditions. Taking into account other morphophysiological features and the high yield of this variety in favorable years, it is expedient to cultivate it in a high agrophone under irrigated conditions.

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Nəmliklə stabil təmin olunmamış dəmyə şəraitində payızlıq yumşaq buğdanın məhsuldarlıq stabilliyi, plastikliyi və adaptivliyi

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2010/2011-2017/2018-ci vegetasiya illərində Dağlıq Şirvanın nəmliklə stabil təmin olunmamış dəmyə şəraitində payızıq yumşaq buğdanın 14 sortu və 1 xəttinin məhsuldarlığı, məhsuldarlıq stabilliyi, plastikliyi və sortun adaptivliyi öyrənilmişdir. Hidrometeoroloji göstəricilər əsasında 2010-2011, 2012-2013, 2016-2017 və 2017-2018-ci vegetasiya illərinin iqlim şəraitinin payılıq buğdanın inkişafı üçün əlverişli, 2014-2015 və 2015-2016-cı illərin iqlim şəraitinin orta, 2011-2012 və 2013-2014-cü illərin iqlim şəraitinin isə əverişsiz olduğu müəyyən edilmişdir. 2011, 2013, 2017 və 2018-ci illərdə bütün genotiplər üzrə orta məhsuldarlıq uyğun olaraq 61,3, 69,8, 66,9 və 66,6 sent/ha təşkil etməklə ən yuxarı səviyyədə olmuşdur. Məhsuldarlığa görə 2015 və 2016-cı illər orta, 2012 və 2014-cü illər isə aşağı səviyyədə olmuşdur. İllər üzrə orta məhsuldarlıq, vegetasiya ilində iqlim şəraitinin gedişi ilə uyğunluq təşkil etmişdir.

8 ilin ortalamasına görə Qobustan, 7thWON-SA №465 və Qırmızı gül-1 genotipləri uyğun olaraq 66,4, 63,4 və 60,4 sent/ha ilə məhsuldarlığın ən yuxarı, Azəri, Bezostaya-1, Murov-2, Ruzi-84 və Şəki-1 sortları isə ən aşağı nəticələrini göstərmişlər. Tədqiq edilən sortların stabillik və plastikliyini nəzərə alaraq belə bir nəticəyə gəlinmişdir ki, Bezostaya-1, Ruzi-84 və Sönməz-01 sortları plastikliyi ən az olan neytral tipə aid sortlar olaraq görülmüşlər (yəni geniş adaptivliyə malik olan tip). 7thWON-SA №465 və Qobustan sortları yüksək plastiklik göstərməklə spesifik adaptasiyaya malik olmuş, yüksək aprofona və əlverişli iqlim şəraitinə qarşılıq verərək məhsuldarlıqlarını artırmış, eyni zamanda əlverişsiz şəraitə də uyumluluq göstərmişlər. Ona görə də bu sortların Dağlıq Şirvan kimi nəmliklə stabil təmin olunmamış bölgələrdə və yüksək aqrofonda yetişdirilmələri yüksək nəticələrin alınmasına şərait yaradır. Tale-38 və Əzəmətli-95 sortlarının əlverişsiz şəraitə uyumlu olmamaları ilə yanaşı, yaxşılaşan şərtlərə yüksək səviyyədə qarşılıq verməklə dar adaptasiyaya və yüksək plastikliyə malik olmaları müəyyən edilmişdir.

Açar sözlər: *Payızlıq yumşaq buğda, dəmyə şərait, məhsuldarlıq, stabillik, plastiklik, adaptivlik*

Стабильность урожайности, пластичность и адаптивностъ озимой мягкой пшеницы в условиях богары с нестабильным влагообеспечением

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Продуктивность, стабильность урожайности, пластичность и адаптивность 14 сортов и 1 линии озимой мягкой пшеницы исследовали в условиях богары Нагорного Ширваниа с нестабильным влагообеспечением в 2010/2011-2017/2018 вегетационных годах. По гидрометеорологическим показателям климатические условия 2010-2011, 2012-2013, 2016-2017 и 2017-2018 вегетационных годов признаны благоприятными для развития озимой пшеницы. Климатические условия 2014-2015 и 2015-2016 гг. – оценены как средние, 2011-2012 и 2013-2014 гг. - признаны неблагоприятными. В 2011, 2013, 2017 и 2018 годах средняя продуктивность по всем генотипам была самой высокой и составила 61,3, 69,8, 66,9 и 66,6 ц/га соответственно. В 2015 и 2016 годах продуктивность была средней, а в 2012 и 2014 годах – низкой. Средняя урожайность по годам соответствовала климатическим условиям вегетационногых годов. В среднем за 8 лет наибольшую продуктивность имели генотипы Гобустан, 7thWON-SA №465 и Гырмызы гюль-1, значения продуктивности которых составили 66,4, 63,4 и 60,4 ц/га соответственно. Самые низкие результаты показали сорта Азери, Безостая-1, Муров-2, Рузи- 84, и Шеки- 1. С учетом устойчивости и пластичности изучаемых сортов сделан вывод, что сорта Безостая- 1, Рузи- 84 и Сонмез- 01 относятся к нейтральному типу с наименьшей пластичностью (т.е. к типу с широкой адаптивностью). У генотипов 7thWON-SA №465 и Гобустан проявилась специфическая адаптация с высокой пластичностью и повышенной продуктивностью в ответ на высокий агрофон и благоприятные климатические условия, а также приспособленность к неблагоприятным условиям. Поэтому выращивание этих сортов в районах с неустойчивой влагообеспеченностью, таких как Нагорный Ширван, и в условиях высокого агрофона создает возможности для получения хороших результатов. Помимо неприспособленности к неблагоприятным факторам, сорта Тале-38 и Азаматли-95 обладают узкой адаптивностью и высокой пластичностью в ответ на улучшение условий.

Ключевые слова: *Озимая мягкая пшеница, богарные условия, урожайность, устойчивость, пластичность, адаптивность*