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COMPARATIVE TESTING OF OLD WINTER WHEAT VARIETIES UNDER CHANGING CLIMATIC CONDITIONS

Zlatina UHR[1], Evgeniy DIMITROV[1], Rangel DRAGOV[2], Radoslav CHIPILSKI[1], Teodora ANGELOVA[1]

[1]Institute of Plant Genetic Resources, 2 Druzhba Street, Sadovo, Agricultural Academy, Bulgaria
[2]Field Crops Institute, 2 G. Dimitrov Street, Chirpan, Agricultural Academy, Bulgaria

Corresponding author email: dragov1@abv.bg

Abstract

The experiment was conducted in the experimental field of IRGR - Sadovo in the period 2018-2020. The sixteen old varieties of common winter wheat, created in IRGR, were tested in yield for two years. The yield, plant height and physical properties of the grain were obtained: 1000 g kernel weight and test weight (kg/hl). The obtained data are processed by statistical methods - dispersion, variation and analysis of the main components. The results show that the influence of the genotype, environment and their interaction has been proven in all monitored traits. All varieties have significantly higher yields than the standard. The highest grain yield was reported for the varieties Joanna, KM 135, Diamand and Guinness. There is no significant higher 1000 kernel weight and the test weight of only two varieties is significantly higher than the standard. The aim of the study is to test the effect of climate change on the grain yield, plant height and physical properties of old varieties of common winter wheat, as the main food crop, and to assess their resilience to climate change.

***Key words**: old varieties, winter wheat, resistance, climatic changes, yield.*

INTRODUCTION

Wheat is counted among the ‘big three’ cereal crops, with over 600 million tons being harvested annually. For example, in 2007, the total world harvest was about 607 mil. tons compared with 652 mil. tons of rice and 785 mil. tons of maize (http://faostat.fao.org/). However, wheat is unrivalled in its range of cultivation, from 67º N in Scandinavia and Russia to 45º S in Argentina, including elevated regions in the tropics and sub-tropics (Feldman, 1995). It is also unrivalled in its range of diversity and the extent to which it has become embedded in the culture and even the religion of diverse societies (Shewry, 2009).

Despite its relatively recent origins, bread wheat shows enough genetic diversity to allow the development of more than 25.000 species of Feldman et al. (1995), which are adapted to a wide range of moderate environments. In the presence of sufficient water and mineral nutrients and ensuring effective control of pests and pathogens, yields can exceed 10 tons ha^{-1}, showing high similarity to other moderate crops. However, the shortage of water and nutrients and the impact of pests and pathogens cause the average world yield to be low, about 2.8 tons ha^{-1}.

The perspectives for global wheat production in 2021 has been reduced this month, and the latest FAO forecast now stands at 778.8 million tons, although still 4 million tons (0.5%) higher than the 2020 production forecast year. The limitation of the global production forecast is mainly related to the European Union (EU), where less than expected previously planted area led to a decrease of 4 million tons compared to the previous forecast. However, EU production is still expected to increase by 6 percent on an annual basis to 133.3 million tons and, together with favorable prospects in the United Kingdom, the United States and Ukraine, supports the overall positive outlook for world production this year (http://www.fao.org/worldfoodsituation/csdb/en/). One of the challenges facing humanity as a result of climate change is to increase the number of people at risk of starvation compared to reference scenarios with climate change. In 2006, the global estimated number of malnourished people was 820 million, according to FAO data.

Wheat (*Triticum aestivum* L.) is a major food crop and feeds billions of people daily. Its productivity is expected to decrease significantly with increasing temperature. Due to global climate change, wheat yields are expected to decrease by 6% for each 1°C temperature increase. Therefore, wheat yields must increase by 60% by 2050 to meet the food needs of a growing world population (Asseng et al., 2015). The yield of bread wheat is most interesting for breeders. It depends largely on the genotype, the conditions and the interaction between them. The results of the genotype X environment interaction are manifested in the adaptation and stability of the genotypes. When such an interaction exists, the arrangement of the genotypes will be different under different conditions. Productivity stability plays a very important role. In most cases it is typical for the old varieties. The creation of varieties with high and stable yield and good quality is an important and main factor in the wheat production. The environment has a negative effect on yield, but it can be increased by improving the growing conditions with increasing agricultural techniques. The intermittent yield is a result of changes in climatic conditions in the study areas. According to Dotlacil et al. (2000) old varieties with low yields have greater stability in the individual years than these varieties with high yield potential. Genotype x environment interactions complicate the cultivation of superior genotypes (Hintsa & Fetien, 2013). Therefore, an assessment of each genotype without including its interaction with the environment is incomplete (Crossa, 1990).

The study of genetic diversity has both historical value and immediate practical impact on the breeding of cultivated plants. However, diversity itself is limited in use (Novoselovi´c et al., 2016). But it gives breeders an advantage to know the best sources and to include them in cross-breeding schemes. The old varieties are the basis of any selection program. Their use allows the inclusion of valuable qualities in modern varieties. Assessing correlations to determine the extent of relationships between different traits associated with yield is an important issue that reveals a complex chain of associations (Majumder et al., 2008; Mohammadi et al., 2012). Wheat grain yield is a dominant feature of the economic value of the crop (Shewry, 2007). Test weight and 1000 grains weight are important traits for breeding programs in wheat (Aydin et al., 2010). Grain size is one of the most important indirect traits and can be used as a criterion in the early generations of decay. Traits such as optimal plant height and 1000 grains weight are key elements of yield (Li & Gill, 2004; Gupta et al., 2006). The plants height, although not a direct element of productivity, is the focus of breeding programs for wheat. Its importance is due to its direct connection on the one hand with the lodging of plants and on the other with the size of the harvest index (Hedden, 2003).

There are three possibilities for increasing production - creating new higher yielding varieties, testing the suitability of old varieties to changing conditions, and increasing the area. It is also necessary for the varieties to be characterized by both high yields and good traits of physical properties. They are crucial for selling them.

The aim of this research is to study the yield, height and physical properties of old varieties of common winter wheat under changing climatic conditions.

MATERIALS AND METHODS

The experiment was conducted in the experimental field of IPGR - Sadovo in the period 2018-2020. Varietal experiments were performed in a block diagram in three replications, with a size of the experimental plot of 10 m^2. The experiment was done using the technology of cultivation after the bean predecessor, adopted in IPGR. Sowing was carried out in the optimal time. Sadovo 1 was used as a standard. The grain yield was calculated at a standard humidity of 13%.

The main factors influencing the growth and development of wheat are temperature, precipitation and their combination. Their interaction during the important stages of development is especially important. 16 varieties of winter common wheat were monitored on yield and traits: plant height (cm), 1000 grains weight (g) and test weight (kg/hl). Statistical methods were used for evaluation - variance (ANOVA), variation and principal component analysis.

The statistical program SPSS 19 was used. The degree of variation of the traits was determined by a coefficient of variation based on average values for the study period. It is accepted that the variation is considered weak if the coefficient of variation is up to 10%, medium - when it is greater than 10% and less than 20%, and strong - when it is over 20% Dimova & Marinkov (1999). From the analysis of the variant, the influence of the sources of variation - genotype, environment and their interaction on the yield, the 1000 grains weight and the test was calculated.

RESULTS AND DISCUSSIONS

For the first vegetation period it can be summarized that the average monthly temperatures are higher than the perennial ones, and the precipitation was not evenly distributed. In November, rainfall fell, more than the multi-year norm and favored the development of plants. There was a delay in the development of wheat before the rain in April.

After the large amount of precipitation in June, secondary weeding occurred (Figure 1 and Figure 2). The meteorological conditions during the vegetation year 2019-2020 differ from those in the previous year. Conditions during the period from sowing to the end of March are variable and are not the most favorable for the development of wheat due to the snowfall at the end of March and the beginning of April 1 (Figure 3 and Figure 4).

The average monthly temperatures in April alone were lower than the norm, with temperatures higher than 1.94°C in December and 6.47°C in January. During the important phases of spinning, hatching and pouring the grain, no lack of moisture was reported. The rainfall in April and May favored the formation of a higher stem compared to the typical varieties, large grain and the formation of high yields. The figure with the meteorological data shows that the precipitation during the vegetation year is more than the norm, but it is not evenly distributed. The second growing season of the study as a whole can be defined as very favorable for ordinary winter wheat. Confirmation of this are the high yields obtained.

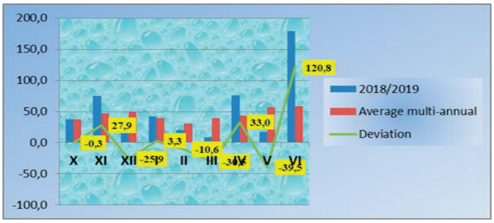

Figure 1. Sums of month rainfall (mm) during vegetation year 2018-2019

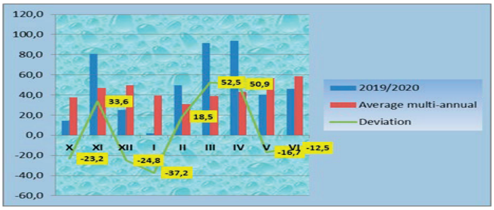

Figure 2. Sums of month rainfall (mm) during vegetation year 2019-2020

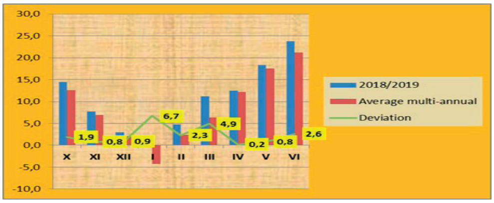

Figure 3. Average temperature sum (t°C) of months during vegetation year 2018-2019

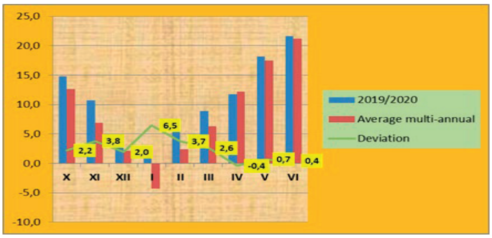

Figure 4. Average temperature sum (t°C) of months during vegetation year 2019-2020

On average for the two years of testing, the highest grain yield was reported for the varieties Joanna, KM 135, Diamond and Guinness (Table 1).

Yields from the old varieties in the present study ranged from 431.5 kg/da for cultivar Sadovo 1 to 651.5 kg/da for Joanna.

It is noteworthy that the average yield of all participants is proven to be higher than that of the standard variety. The variation in this indicator is a marginal 10.2% between low and medium variation. It is the highest in this indicator compared to the other two, ie the grain yield is the most variable in the present study.

On average for test period, the highest plant height was reported for the varieties Bononiya, Mustang and Sadovo 552. With the smallest height of the stem are the varieties Yoana, KM 135, Geya 1, Diamant, Pobeda, Sadovska beliya and Niky. The differences are statistically proven. The highest plant height in the present study ranged from 105.3 cm for cultivar Mustang to 82.5 cm for Lysil (Table 1).

The 1000 grains weight is one of the most important indirect traits, characterizing the grain size, its mill quality (relative content of endosperm, potential yield of flour with low ash content) and its quality as seed (Popov et al., 1965; Filipov, 2004; Stoeva et al., 2009; Yanchev & Ivanov, 2012; Delibaltova et al., 2014; Taneva et al., 2014; Ivanov, 2019). Water deficit during the grain setting period can cause grain yield decrease by reducing grain weight per spike and 1000 kernel weight (Genç et al., 1987; Koç et al., 1994).The trait 1000 grains weight does not show a proven higher 1000 grains weight compared to the standard. Six varieties have a proven lower weight per 1000 grains (Table 2). The maximum value is for the Mustang variety and the lowest for the Guinness variety. Our previous studies obtained similar results: the influence of genotype on the trait mass per 1000 grains is significant (Angelova et al., 2020). The variation is low.

Table 1. Study characteristics of common wheat varieties

Genotype	Yield, mean	Differ.	Sign.	PH, mean	Differ.	Sign.
Sadovo 1 st.	431.5			97.8		
Bononiya	527.6	96.0	+++	104.5	6.7	+++
Niky	531.0	99.5	+++	92.5	-5.3	--
Lysil	619.7	188.2	+++	82.5	-15.3	---
Sad. beliya 1	573.1	141.6	+++	98.8	1.0	n.s
Tsarevets	526.3	94.8	+++	98.5	0.7	n.s
Pobeda	515.2	83.6	+++	103.2	5.3	--
Mustang	607.2	175.6	+++	105.2	7.3	+++
Geya 1	604.7	173.1	+++	83.7	-14.2	---
Diamant	613.1	181.6	+++	103.2	5.3	--
Murgavets	594.9	163.3	+++	97.2	-0.7	n.s
Sadovo 552	532.4	100.8	+++	105.3	7.5	+++
Sadovo 772	527.4	95.9	+++	98.5	0.7	n.s
Guinness	612.0	180.5	+++	99.3	1.5	n.s
Yoana	651.5	219.9	+++	82.8	-15.0	--
KM 135	628.8	197.3	+++	89.0	-8.8	--
Mean	568.5			96.4		
Minimum	431.5			82.5		
Maximum	651.5			105.3		
Std.Dev.	57.7			8.0		
Coef.Var..%	10.2			8.3		
Stand. error	14.4			2.0		
GD 5%	11.0			3.6		
GD 1%	14.6			4.7		
GD 0.1%	18.9			6.2		

The test weight in only two varieties is significantly higher than the standard, and in 7 it is proven to be lower (Table 2). The variation is low. The highest value was reported for a variety in Bononia, and the lowest in Pobeda.

Table 2. Study characteristics of wheat varieties

Genotype	1000 GW, mean	Differ.	Sign.	TW, mean	Differ.	Sign.
Sadovo 1 st.	45.4			75.5		
Bononiya	45.2	-0.2	n.s	80.2	4.7	+++
Niky	43.4	-1.9	--	72.8	-2.8	--
Lysil	46.8	1.5	n.s	72.9	-2.6	--
Sad. beliya 1	44.1	-1.2	n.s	71.4	-4.1	---
Tsarevets	40.2	-5.1	---	74.6	-0.9	n.s
Pobeda	43.1	-2.2	--	68.3	-7.2	---
Mustang	47.4	2.1	+	71.7	-3.8	---
Geya 1	44.6	-0.8	n.s	72.8	-2.7	--
Diamant	41.7	-3.6	---	77.5	2.0	-
Murgavets	45.2	-0.2	n.s	75.7	0.2	n.s
Sadovo 552	46.1	0.7	n.s	75.9	0.4	n.s
Sadovo 772	44.1	-1.2	n.s	74.2	-1.3	n.s
Guinness	39.2	-6.2	---	77.6	2.1	+
Yoana	43.8	-1.6	n.s	76.1	0.5	n.s
KM 135	44.2	-1.2	n.s	75.3	-0.3	n.s
Mean	44.0			74.5		
Minimum	39.2			68.3		
Maximum	47.4			80.2		
Std.Dev.	2.2			2.9		
Coef.Var..%	5.0			3.8		
Stand. error	0.5			0.7		
GD 5%	11.0			1.7		
GD 1%	14.6			2.2		
GD 0.1%	18.9			2.9		

The results show that the influence of the genotype, environment and their interaction has been proven for all monitored traits.The strongest influence in the formation of the grain yield, the 1000 grains weight and the test weight, expressed by η, is the influence of the medium. In the three studied traits it is over 61% and the strongest grain yield reaches 82% (Table 3).

Table 3. ANOVA - Influence of the sources of variation on the studied traits

Trait	Sources of variation	SS	df	MS	F exp.	F tab.	η	Sign.
Yield	Genotype, Factor A	300003.5	15	20000.2	443.5	3.0	10.1	***
	Environment, Factor B	2426022.1	1	2426022.1	53793.1	11.9	82.0	***
	Interactio, A x B	230675.8	15	15378.4	341.0	3.0	7.8	***
	Error	2886.3	64	45.1			0.1	
	Total	2959587.7	95				100.0	
PH	Genotype, Factor A	5695.2	15	379.7	79.4	3.0	51.4	***
	Environment, Factor B	3901.5	1	3901.5	816.0	11.9	35.2	***
	Interactio, A x B	1177.8	15	78.5	16.4	3.0	10.6	***
	Error	306.0	64	4.8			2.8	
	Total	11080.5	95				100.0	
1000 GW	Genotype, Factor A	434.7	15	29.0	29.7	3.0	19.4	***
	Environment, Factor B	1578.7	1	1578.7	1619.0	11.9	70.6	***
	Interactio, A x B	160.7	15	10.7	11.0	3.0	7.2	***
	Error	62.4	64	1.0			2.8	
	Total	2236.4	95				100.0	
TW	Genotype, Factor A	737.3	15	49.2	47.8	3.0	17.5	***
	Environment, Factor B	2565.8	1	2565.8	2495.8	11.9	61.0	***
	Interactio, A x B	839.9	15	56.0	54.5	3.0	20.0	***
	Error	65.8	64	1.0			1.6	
	Total	4208.7	95				100.0	

SS - sum of squares; gf - degrees of freedom; MS - variance; F exp. - F experimental; F tab. - F tabular; η - force of influence of the factor (%); *** - proved at α = 0.001.

The strength of the genotype influence is also significant, but the values of η are much lower and range from 19.4 for the 1000 grains weight to 10.1 for the grain yield. Only in the case of plant height is the influence of the genotype higher than that of the environment. The strength of the influence of the genotype 51.4%, and the environment is 35.2. The strength of the impact of the interaction is also low (7.2 of 20.0).According to a number of authors (Fufa et al., 2005; Akcura et al., 2006; Kaya et al., 2006; Tsenov et al., 2006; Plamenov & Spetsov, 2008) the impact of the conditions of the year on the productivity and quality of the common winter wheat is more important than the influence of genotypes. In our previous studies in southern Bulgaria, it was established through the analysis of the variant that climatic conditions have the strongest influence on the yield of the general variation (Uhr & Chipilski, 2017; Ivanov et al., 2018). In the cultivation of foreign varieties under the conditions of Dobrudzha also the factor year was determining for the formation of the production potential of the studied foreign wheat cultivars (Chamurliyski et al., 2015).

Based on the data for the studied indicators of yield, height and physical properties of the grain, a factor analysis was performed by the method of the main components of 15 old varieties of common winter wheat and the Sadovo 1 standard. According to Rymuza et al. (2012) the applied principal component analysis (PCA) method allows a complex assessment of the relationships between the characteristics. The greatest distinctive force, which diversifies the studied plants, is manifested by the 1000 grains weight and grain yield. Our results from the application of PCA are presented in Tables 4, 5, 6 and Figures 5 and 6. The values of the two components for each of the studied traits were calculated empirically (Table 4). The analysis shows that the first component justifies 36.819% of the total variation, and the second - 30.842%. The two factors together justify 67.661% of the total variation in experience. This relatively small percentage illustrates the existence of complex relationships between the studied traits. For example, the signs of yield and plant height are related to the first component. The second component is correlated with the test weight and 1000 grains weight (Table 5).

Table 4. Component analysis of the variance in the studied traits

Comp.	Total	% of Variance	Cumulative,%
1	1.473	36.819	36.819
2	1.234	30.842	67.661
3	0.797	19.932	87.593
4	0.496	12.407	100.0

Table 5. Explained significant components by traits

№	Trait	Component	
		1	2
1	Yield	-0.809	0.340
2	Plant hight	0.870	0.015
3	1000 grain weight	-0.184	-0.732
4	Test weight	0.167	0.763

Table 6. Explained significant components by varieties

№	Variety	Component	
		1	2
1	Sadovo 1	-1.512	-0.484
2	Bononiya	-0.971	0.965
3	Niky	-0.118	-0.391
4	Lysil	1.514	-1.237
5	Sadovska beliya 1	-0.152	-0.651
6	Tsarevets	-0.582	0.994
7	Pobeda	-1.083	-1.139
8	Mustang	-0.263	-1.300
9	Geya 1	1.278	-0.650
10	Diamant	-0.006	1.530
11	Murgavets	0.221	0.022
12	Sadovo 552	-1.013	-0.197
13	Sadovo 772	-0.580	-0.175
14	Guinness	0.265	2.178
15	Yoana	1.845	0.394
16	KM 135	1.159	0.141

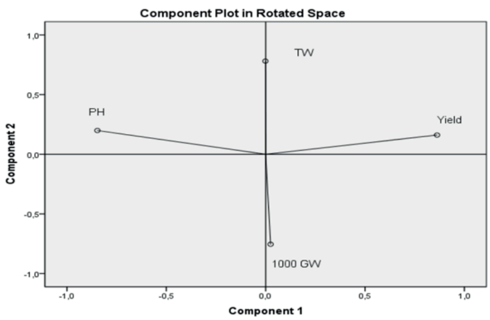

Figure 5. PC analysis of traits in common winter wheat

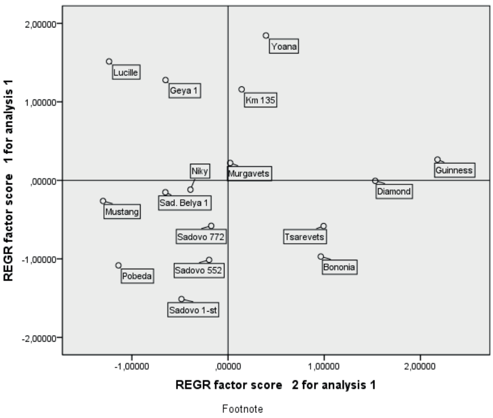

Figure 6. PC analysis of 15 wheat genotypes

The distribution of the varieties, according to their values for the first and second components, is presented in Table 6 and Figure 6. The first component includes the varieties Sadovo 1, Bononia, Lucil, Gaia 1, Murgavets, Sadovo 552, Sadovo 772, Joanna and KM 135. The second component includes Niki, Sadovska belia, Tsarevets, Pobeda, Mustang, Diamant and Guinness. By placing the figures next to each other, the connection of the varieties in groups can be determined by a certain feature. The closer the points of the varieties are to the point of a Figure 5 shows the PC analysis of the traits included in the study. Figure 5 shows that the test weight and the 1000 grain weight are in a very strong negative correlation. This means that varieties with larger grains have a lower test weight. Plant height and yield are also very strongly negatively correlated, ie. varieties with lower plant heights have higher yields. There are no reliable positive correlations between the individual traits. Figure 6 shows a PC analysis of the common wheat genotypes included in the study. When comparing the two figures (Figures 5 and 6), the separation of the genotypes into groups can be assessed according to certain traits. Compared to the examined traits from Figure 5, it can be seen which variety is characterized by which trait. The Diamond and Guinness varieties are characterized by yield. The varieties Joanna and KM 135 with the test weight. The varieties Mustang, Sadovska beliya and Niki are characterized by the plants height. These varieties, which are located on the periphery of the figure, are characterized for the most part by the rays of the features of Figure 5. On the other hand, those located in the middle of Figure 6 are more balanced with respect to all the traits.

CONCLUSIONS

The influence of genotype, environment and their interaction is significant for all studied traits.

The strength of the influence of the environment is the range from 61 to 82% in terms of yield, test weight and 1000 kernel weight. The genotype is determining for the plants height , but the difference with the influence of the environment is not large.

Based on the PC analysis, it was found that the Diamant and Guinness varieties are characterized by yield. The varieties Joana and KM 135 with the test weight. The varieties Mustang, Sadovska beliya and Niki are characterized by the plant height.

On average for the two years of testing, the highest grain yield was reported for the varieties Yoana, KM 135, Diamant and Guinness. They can be re-listed in the institute's variety list and offered to farmers as resistant to climate change.

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