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ANALYSIS FOR GRAIN YIELD AND SOME QUALITY TRAITS IN BULGARIAN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

A major priority of the breeding programs is the development of varieties and hybrid plants combining high productivity and a level of qualitative parameters. Equally topical is the problem of achieving their stable level of expression under uncertain climatic environments. Within three vegetative growth periods (2018, 2019 and 2020) characterized with different levels of abiotic stress, 20 varieties of common winter wheat were investigated. The criteria for setting up of the working collection were the genotypes to be included in the Varietal List of Republic of Bulgaria and to cover the groups' quality levels. The trials were carried out at two locations: the Institute of Agriculture – Karnobat and Dobrudzha Agricultural Institute – General Toshevo. These regions have specific soil and climatic conditions and are characterized with different risk factors for the development of the cereal crops. The variance analysis showed that the environmental conditions had a significant percent in the total variation of grain yield, the number of productive tillers, 1000 kernel weight and test weight. Concerning these traits, a genotype x environment interaction was also established. The cultivars with high mean yield from the two locations were Rada, Kristalina, Kalina, Katarzhina and Bozhana. The correlation between productivity and quality was successfully broken in Lazarka, Pchelina and Merilin, which belong to the group of strong wheat genotypes. Under the specific technology for conducting the field experiments we used, cultivars Pchelina and Merilin from group A were with expectedly high levels of wet gluten content and W index. The values determined for Lazarka were lower but less variable. In the group of medium wheat genotypes with increased strength, worth mentioning are Enola, Kristalina, Rada and Katarzhina.

Keywords: winter wheat, genotype-environment interactions, grain yield, quality traits

INTRODUCTION

The agricultural branch of economy and the agrarian sector in particular are the most affected by the change of the climatic factors and this is manifested in different aspects. The challenge to breeding is searching for new approaches to decrease the negative effect and achieve sustainable production. Most often, the consequences of the climatic change are identified as higher frequency of occurrence of extreme climatic phenomena and biotic stress, higher percent of polluted soils and loss of biological diversity. The areas with cereals occupy the greatest portion of the arable land in Bulgaria. In the recent years, serious technological solutions and innovative production systems were introduced. They are the result of the increasing competence of the Bulgarian farmers, the modernizing of the agricultural machines and equipment, but also of the distribution of new breeding achievements. Within the context of the dynamic market situation and the demands of

the consumers, the models of cereal crops were reconsidered. Traits related to the resistance to stress were identified, which ensured the efficiency of the breeding process. The studies were directed toward improvement of the resources used – soil, water, fertilizers. The introduced plant protection products were focused on the reduction of the harmful effects on the environment. The main goals were sustainable production and a high added value.

The aim of this investigation was analysis on the productivity of some qualitative parameters of the Bulgarian common winter wheat varieties introduced in practice.

MATERIALS AND METHODS

Within three vegetative growth seasons (2018, 2019, 2020), twenty common winter wheat cultivars were studied, which were characterized by specific biological characteristics (Table 1). They are scientific products of Dobrudzha Agricultural Institute – General Toshevo. The criteria for setting up of a working collection were the included cultivars to be from the varietal list of Republic of Bulgaria, and these cultivars to meet the levels of the quality groups. Data accumulated from the application of laboratory methods to differentiate the resistance to types of abiotic and abiotic stress was used. The experiments were carried out at two locations: Institute of Agriculture – Karnobat (IA) and Dobrudzha Agricultural Institute – General Toshevo (DAI). The regions had specific soil and climatic conditions, and the combination of the meteorological factors during the periods of investigation determined different levels of the risk factors for wheat development (Table 2).

Table 1. Economic traits characterizing the accessions from the working collection

№	Cultivar	Grain quality and technological properties	Date of heading	Frost resistance	Drought tolerance
1	Bozhana	very good	late	***	**
2	Dragana	very good	late	**	***
3	Enola	very good	early	**	***
4	Fani	good	medium late	***	***
5	Goritsa	very good	medium early	***	*
6	Kalina	good	early	*	*
7	Karina	very good	early	*	*
8	Katarzhina	very good	medium late	***	***
9	Kiara	good	medium early	**	***
10	Korona	good	late	**	**
11	Kosara	very good	medium early	*	*
12	Kristalina	very good	medium early	**	***
13	Kristi	very good	medium early	**	**
14	Lazarka	excellent	medium early	***	***
15	Merilin	excellent	medium early	***	**
16	Nikodim	good	medium early	**	***
17	Phelina	excellent	medium late	***	**
18	Rada	very good	medium early	**	***
19	Sladuna	very good	medium late	**	**
20	Zhana	very good	medium late	**	*

*** high; ** sufficient; * satisfactory

Table 2. Differentiation factors by growing season.

Growing season	Differentiation factors
DAI, General Toshevo (42º64" N; 26º98" E; altitude 250 m) Soil type: haplic Chernozem	
2017-2018	Favorable conditions for over-wintering; spring frosts at the beginning of booting stage; formation and setting of the reproductive organs under conditions of severe drought; high rate of yellow and brown rust outbreaks; rainfalls at the beginning of economic maturity stage, the reason for deteriorated physical properties of grain.
2018-2019	Low mean daily air temperatures during November – December and significantly lower rainfalls during the autumn-and-winter period; entering the winter months at an inappropriate stage, a reason for the registered high percent of damage; spring frosts and low radiation temperatures; outbreaks of powdery mildew, yellow and brown rust.
2019-2020	High mean daily and absolute maximum temperatures in the winter months; recurrent frosts at the resuming of spring vegetative growth; extremely insufficient rainfalls from germination to the beginning of wax maturity; intensive rainfalls at wax maturity.
IA, Karnobat (42º41" N; 23º19" E; altitude 174 m) Soil type: leached Pellic Vertisol	
2017-2018	Normal over-wintering, long cool spring, conditions for outbreaks of diseases; high mean daily and maximum air temperatures at the end of the vegetation.
2018-2019	Over-wintering without damages, spring drought, grain formation and grain filling under favorable conditions, outbreak of economically important diseases.
2019-2020	Negative temperatures at the beginning of booting stage; severe drought during the entire vegetative growth season.

The experiment was designed in four replications, the harvest plot area being 10 m^2. The sowing norm was 550 germinating seeds per m^2. The previous crop at DAI was grain pea. At the end of February, fertilization was done with 0.06 $t.ha^{-1}$ active matter of nitrogen. Under the conditions of IA, the previous crop was sunflower, and spring nutrition was done with 0.08 $t.ha^{-1}$ active matter of nitrogen. The following parameters were analyzed: days to heading (DH), number of days (from 1st January); plant height (PH), cm; productive tillers per 1 m^2 (NPT), number; thousand kernel weight (W_{1000}), g; test weight (TW), kg/hl and grain yield (YG) $t.ha^{-1}$. Protein content (PC), %, wet gluten content (WGC), % and W index were determined using NIR analyzer (CropScan 1000B). The experimental data were processes with the help of Microsoft $Excel^{xp}$ and STATISTICA, release 7.0 (StatSoft Inc., 2004).

RESULTS AND DISCUSSION

There are different opinions as to what is the genetic potential of the winter cereals and if a plateau has been reached. Levels of grain yield above 11 – 12 $t.ha^{-1}$ have been mentioned. In practice, however, often a small part of this potential is realized. The main reason is the long phenological development, which actually encompasses all seasons. The meteorological factors are often with significant deviations from the optimal values.

Thus, the effect of the stress occurs at different stages, with different pressure and different duration (Kazandjiev et al., 2011). The response is specific and may vary from perishing of the plant to full compensation of the negative effect. Genetic and molecular researches on the cereal crops have determined homologous parts of their genome. Similar genetic systems have been identified, which play a key role in their development, including those related to their reaction under stress (Langridge et al., 2006). Such researches allow not only better understanding of the adaptation mechanism of the crops but also differentiating their specificity (Maiti and Satya, 2014). Another major problem is the complex nature of the inheritance of the traits, which imposes the necessity to combine different approaches. A key moment is the conservation of biodiversity, widening of the genetic basis and identification of suitable sources for initial material development. This include phenological development, yield structure, resistance to abiotic stress, resistance to diseases and pests, genotypic specificity of nutrition, stable high level of realization of the qualitative parameters, etc. There are also numerous questions concerning the new European Union Programs on the conservation of biodiversity, the protection of the environment and the limited use of pesticides (Halford et al., 2015). All this implies multidisciplinary approaches for the realization of high efficiency along the breeding – production – user chain. In response to these challenges, the breeding program of DAI offers wheat cultivars with high adaptability potential suitable for regions and productions, which are highly specific (Mihova et al., 2018).

Within this investigation, the differences with regard to yield were statistically significant both between the cultivars (Factor A) and over years (Factor B). The analysis of the variance revealed that the conditions of the environment had a considerable percent in the total variation. The effect of the stress factors was especially high under the conditions of IA-Karnobat, where the mean productivity over years varied from 1.18 to 6.88 $t.ha^{-1}$ (Tables 3 and 4). For both regions, most unfavorable was the last growing season (2019 – 2020). The combination of soil moisture under the critical minimum and the recurrent spring frosts at the beginning of booting stage were the main reasons for the low productivity. The analysis of the data from the weather stations of DAI – General Toshevo showed that during 1953 – 2019, only seven of the years were with lower values, the last two being 2000 – 2001 and 2006 – 2007. The highest yields at both locations were registered during 2018 – 2019. In spite of the drought in the spring months, the comparatively good autumn-and-winter moisture reserves ensured better conditions for accumulation of sufficient biomass, which was decisive for the formation of the yield. The results showed that the new varieties introduced in practice were with high adaptability and good balance between productivity potential and stability under unfavorable growing conditions. For Dobrudzha region, cultivars Rada, Korona, Enola, Kristalina, Kalina, Dragana, Goritsa, Nikodim, Katarzhina, Kiara and Bozhana were with higher yield, averaged for three vegetative growth seasons. In this group, cultivar Enola was with the lowest variation over years; it is no accident that this cultivar is a national standard. Under the conditions of AI – Karnobat, a high mean yield was registered from cultivars Kristi, Rada, Bozhana, Kalina, Katarzhina, Kristalina, Lazarka, Zhana, Sladuna and Pchelina. Some of them (Rada, Kristalina, Kalina, Katarzhina and Bozhana) demonstrated high productivity at both locations. With the exception of Kalina, all cultivars are from the group of medium wheat genotypes with increased strength, which revealed a balance between quality and productivity. An example for a successfully

broken negative correlation between the traits are the cultivars with excellent bread-making properties Lazarka, Merilin and Pchelina, which are from the group of strong wheat genotypes.

Table 3. Grain yield (t.ha^{-1}) and coefficient of variation (CV, %) over years at DAI - G. Toshevo.

Variety	‘2018	‘2019	‘2020	Average	CV, %
Bozhana	7,94	8,58	6,30	7,61	15,46
Dragana	8,51	8,36	6,90	7,92	11,23
Enola	8,18	8,31	7,65	8,05	4,34
Fani	7,33	8,51	6,73	7,52	12,04
Goritsa	8,52	8,36	6,47	7,78	14,65
Kalina	8,01	8,86	6,98	7,95	11,84
Karina	6,92	6,16	6,29	6,46	6,30
Katarzhina	7,84	9,06	6,11	7,67	19,33
Kiara	7,58	7,84	7,49	7,64	2,38
Korona	7,94	9,11	7,42	8,16	10,61
Kosara	7,56	7,94	6,53	7,34	9,93
Kristalina	8,59	8,84	6,50	7,98	16,11
Kristi	7,18	7,73	7,30	7,40	3,91
Lazarka	8,10	7,72	6,89	7,57	8,17
Merilin	7,75	8,28	6,77	7,60	10,08
Nikodim	7,47	9,14	6,55	7,72	17,01
Phelina	8,22	8,39	6,01	7,54	17,61
Rada	8,25	9,24	7,13	8,21	12,86
Sladuna	7,97	6,73	4,98	6,56	22,90
Zhana	7,78	7,92	6,60	7,43	9,75
Average	7,88	8,25	6,68	7,61	10,82
CV, %	5,70	9,51	9,09	5,90	
Factor A(genotype)$GD_{5\%}$=0.354; $GD_{1\%}$=0.473; $GD_{0.1\%}$=.622					
Factor B (Year) $GD_{5\%}$=1.090; $GD_{1\%}$=1.457; $GD_{0.1\%}$=1.916					

Table 4. Grain yield (t.ha^{-1}) and coefficient of variation (CV, %) over years at IA - Karnobat.

Variety	‘2018	‘2019	‘2020	Average	CV, %
Bozhana	3,85	7,74	1,17	4,25	77,67
Dragana	3,55	6,74	1,25	3,85	71,67
Enola	4,10	5,52	0,69	3,44	72,23
Fani	3,80	6,98	1,01	3,93	76,01
Goritsa	3,65	7,19	1,01	3,95	78,50
Kalina	3,55	7,77	1,33	4,22	77,58
Karina	3,30	5,98	1,01	3,43	72,52
Katarzhina	3,85	7,06	1,58	4,16	66,13
Kiara	3,50	5,65	0,74	3,30	74,66
Korona	3,55	6,15	1,24	3,65	67,36
Kosara	3,60	7,37	0,90	3,96	82,13
Kristalina	4,10	7,05	1,30	4,15	69,28
Kristi	4,30	7,66	1,13	4,36	74,84
Lazarka	4,10	6,99	1,27	4,12	69,42
Merilin	4,10	6,96	1,08	4,05	72,66
Nikodim	3,60	6,65	1,14	3,80	72,70
Phelina	4,20	6,68	1,19	4,02	68,33
Rada	4,10	7,38	1,54	4,34	67,45
Sladuna	3,75	6,78	1,69	4,07	62,86
Zhana	3,62	7,29	1,37	4,09	73,00
Average	3,81	6,88	1,18	3,96	72,07
CV, %	7,45	9,32	21,72	7,64	
Factor A(genotype)$GD_{5\%}$=0.241; $GD_{1\%}$=0.322; $GD_{0.1\%}$=0.424					
Factor B (Year) $GD_{5\%}$=0.744; $GD_{1\%}$=0.994; $GD_{0.1\%}$=1.307					

The comparison of the results by location and year showed that some of the cultivars were with high productivity only during individual vegetative growth seasons, and with higher variation, respectively. In response to the demands of the markets and the climatic changes, a focus of the DAI breeding program is the development of varieties with specific traits. They are primarily directed toward the peculiarities of the phenological development and the structure of yield (Table 5). The average duration of the date to heading from 1st January at both locations was about 130 days, but the variation was within a wider range, 124 – 132 days at DAI and 128 – 133 days at IA. Longest was the period during the second harvest year, when the mean radiation and daily temperatures during booting stage were lowest. The specificity of the genotype was with the highest percent from the total

variation (Table 6). Cultivars Kalina, Enola, Karina and Kiara were with early date to heading. They are especially suitable for growing in regions with comparatively warm spring and risks of dry winds at grain filling stage.

Table 5. Mean values (2017-2020) of traits in wheat varieties at DAI - G. Toshevo and IA - Karnobat.

Traits / Origin	DH		PH		NPT		W_{1000}		TW	
	DAI	IA	DAI	IA	DAI	IA	DAI	IA	DAI	IA
Bozhana	130	133	106	91	604	445	44	46	77	77
Dragana	132	131	98	89	557	416	42	44	74	74
Enola	126	129	76	75	624	505	40	44	76	75
Fani	129	130	98	86	628	480	40	46	72	74
Goritsa	130	131	92	81	615	448	36	36	76	76
Kalina	124	129	84	83	644	503	43	44	73	74
Karina	127	129	87	87	653	419	39	43	69	74
Katarzhina	130	130	97	88	628	424	33	40	75	76
Kiara	128	130	96	90	670	480	44	45	75	77
Korona	132	132	94	86	603	456	43	47	74	75
Kosara	129	130	94	86	671	433	36	43	72	75
Kristalina	130	130	95	82	542	465	37	43	76	75
Kristi	131	131	96	92	570	443	41	45	75	76
Lazarka	131	129	96	86	616	483	41	43	77	76
Merilin	132	130	89	82	583	488	39	42	73	75
Nikodim	131	130	97	89	591	555	39	40	74	75
Phelina	130	130	92	84	602	424	38	40	75	75
Rada	131	128	99	92	581	499	41	46	73	74
Sladuna	129	130	97	86	543	385	41	44	75	76
Zhana	131	131	95	90	576	520	41	44	73	73

Table 6. Relative portion of genotype, location and interaction in the total variation of investigated traits.

Traits / Sum of squares, %	DH	PH	NPT	W_{1000}	TW
Genotype (A)	46.8	45.7	9.4	14.9	16.6
Location (B)	17.9	43.9	59.8	51.2	46.8
A x B	19.7	3.0	25.5	24.5	22.9
Residual	15.6	7.4	5.3	9.4	13.7

The predominant part of the cultivars was 85 – 95 cm high. Low mean values were registered in 2019 – 2020, when the rainfalls were far too scarce and the plants were not able to accumulate sufficient biomass. The genotype and the conditions of the region had a similar percent from the total variation, and interaction of the factors was not found. Enola, Karina and Merilin were short-stemmed, and Bozhana was with the highest stem. On the whole, the cultivars of Bulgarian breeding had higher stems in comparison to the varieties of west European breeding. The reason is the use of rather different genes for stem shortening, primarily *Rht* 8 (Panayotov, 2013). The observations showed that these cultivars were

with high resistance to stress, mostly to drought, they headed about 10^{th} – 15^{th} May and on the whole, a negative plietropic effect on yield was not found. An important peculiarity of the new cultivars was the successfully broken correlation between the height of the plant and the resistance to lodging even under intensive growing technology, which included high levels of fertilization.

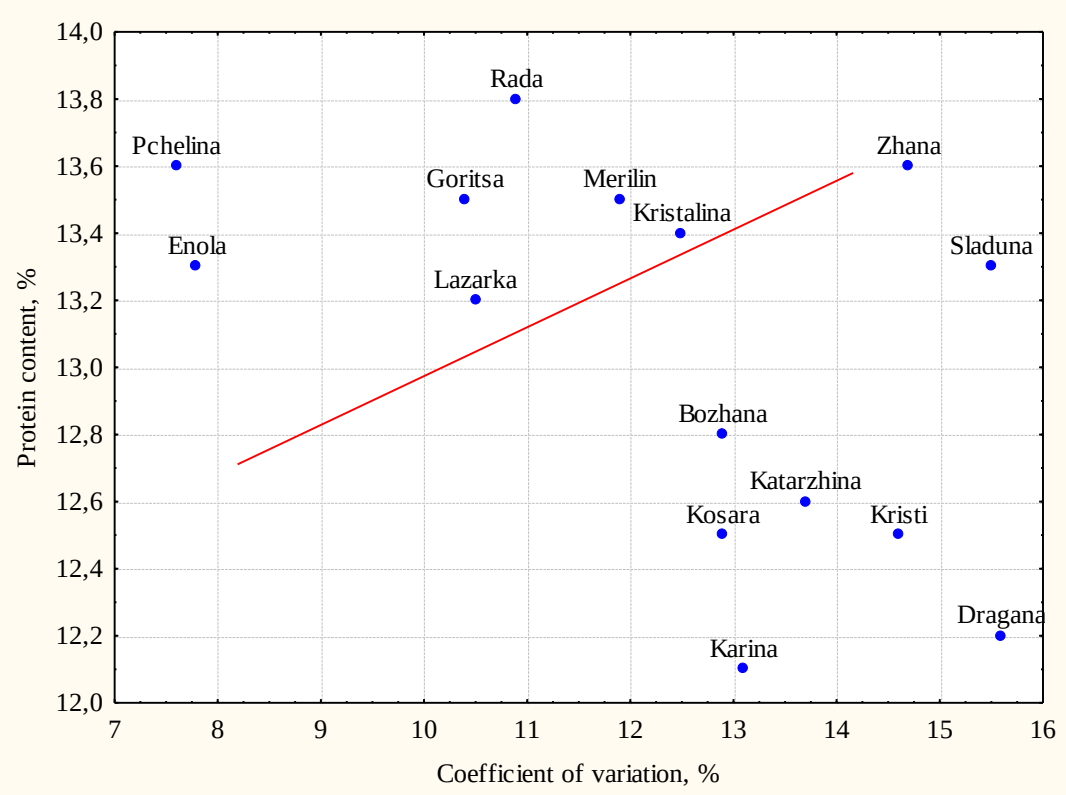
Another peculiarity was the low number of productive tillers at the expense of very good number of grains in spike and seed set, which, to a certain degree, was again related to the used *Rht* genes. The average coefficient of tillering under the conditions of DAI was 1.25, and at IA it was 0.85. The variance analysis demonstrated that there were no significant differences between the cultivars at the expense of a statistically significant effect of the region's conditions. The interaction of the factors was also high, which was an indication of a variety-specific reaction. Under the conditions of DAI, the variation over years was low, the average value of the group being from 575 to 620 tillers per 1 m^2.

The correct interpretation of such a result requires careful analysis of the conditions over phenological phases. During 2017 – 2018, the plants entered into the winter months with up to 2-3 tillers already formed, and the conditions were favorable for over-wintering without damages. In the next year, the over-wintering occurred at an inappropriate phase. At a later stage, the autumn-and-winter moisture reserves, although low, in combination with low mean daily temperatures, elongated the period to the beginning of the booting stage and the plants managed to compensate for the lack of tillering in the autumn months. The last harvest year was rather untypical. The high mean daily temperatures provoked development and in practice there was no autumn-and-winter dormancy. The comparatively good appearance of the crops was misleading. There was a cumulative effect of several stress factors. With the elongation of the photoperiod, the plants rather quickly entered the booting stage, but within several days minimal temperatures in the range from -1 to -4.5 ^{o} C were registered. Different degrees of damage were observed. A more serious challenge was the long-lasting drought, which caused loss of tillers. At a later stage, complete sterility of the formed spikes was further observed. Under the conditions of IA, the number of productive tillers varied within 419 – 491, being lowest during the last harvest year. Under such stress conditions, highest yields were registered from the cultivars with tillering coefficient around 1, the rainfalls at the beginning of wax maturity being decisive.

The effect of the studied factors on 1000 kernel weight was similar to the effect on the number of productive tillers. Significant differences between the cultivars were not found. The environmental conditions and the interaction of the factors had higher percent in the total variation. A high absolute weight of grain was read in the first harvest year, when the number of productive tillers was low. In a sense, the compensatory mechanisms between the components of yield were confirmed, which was the main reason for the ecological stability and plasticity of the wheat plant. The values at DAI varied within 38.45 – 47.90 g, and at IA within 42.90 – 56.90 g. The outbreak of economically important diseases such as leaf and yellow rust was the reason for the rapid defoliation of the plants during 2018 – 2019. The deteriorated grain filling was directly related to its lower absolute weight. The rainfalls at the end of the vegetative growth of the plants in harvest year 2020 allowed for good nutrition of the grain at DAI without observing great deviations in comparison to the long-term data. Under the conditions of AI, however, the grain was with low weight, an average of 36.2 g.

Within the working collection, the

variation of test weight was low. At DAI, the values were similar over years, from 73.77 kg/hl in 2020 to 75.79 kg/hl in 2018. Cultivars Bozhana, Lazarka, Goritsa, Enola, Katarzhina, Kristalina, Pchelina and Sladuna were with a low level of the trait. These results were confirmed at the second location, too, the variation over years being within a wider range, from 71.62 kg/hl in 2020 to 80.65 kg/hl in 2019.

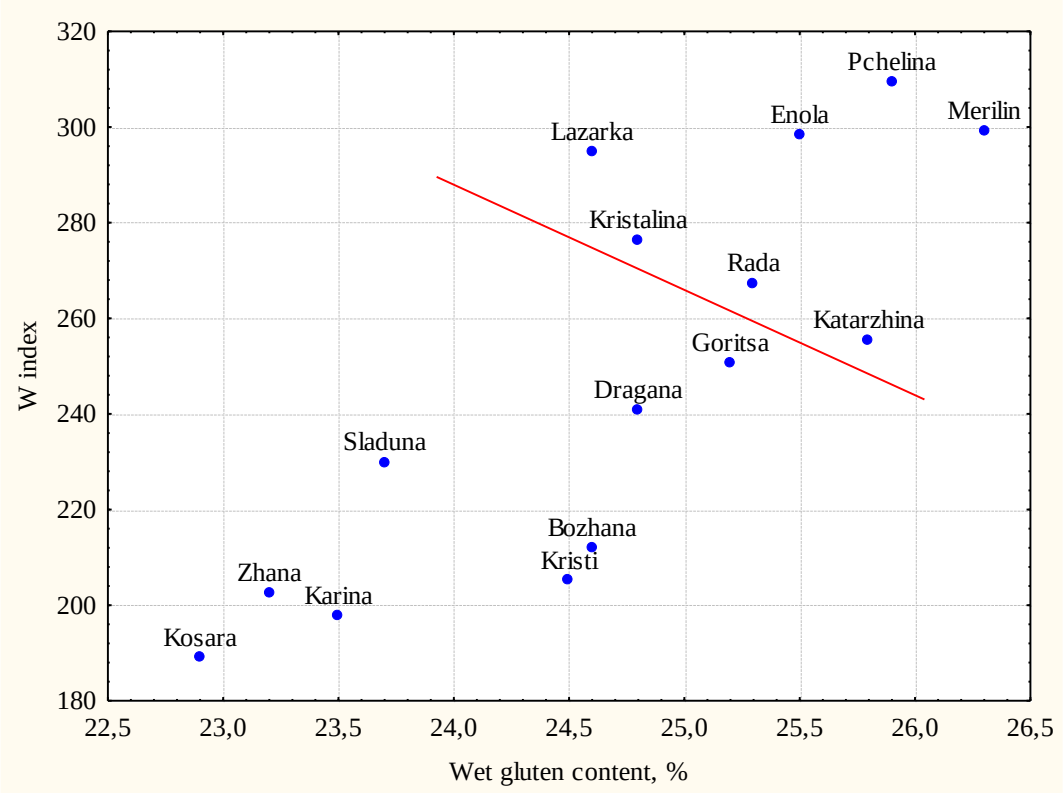


Factor A (genotype) $GD_{5\%}$=0.200; $GD_{1\%}$=0.273; $GD_{0.1\%}$=0.370
Factor B (location) $GD_{5\%}$=0.870; $GD_{1\%}$=1.190; $GD_{0.1\%}$=1.614.

Figure 1. Protein content and variation coefficient of wheat cultivars from groups A and B.

Improvement of quality has always been a priority in the breeding program of DAI. Among the strong wheat genotypes included in the national varietal list, which are characterized by excellent technological and bread-making properties, 35 % are scientific products of DAI (EAVTFISC, 2020). Although there are no preferential prices for quality, the vision of the team is introduction of cultivars allowing for production without using enhancers. Cultivars Lazarka, Merilin and Pchelina have high and stable level of the qualitative parameters. Due to these properties, after a three-year testing in the Republic of Turkey, they are already included in varietal list of this country as well. The importance of protein content for the technological properties of wheat is direct and indirect. The environmental conditions are determining for the level of the trait, significant genotype x environment interactions being reported quite often. When comparing the investigated cultivars, which cover the criteria for strong wheat (Group A) and medium wheat with increased strength (Group B), the average protein content was within the range 12.6-13.8 % (Fig. 1). Lower values (11.9-13.4 %) and lower variation were determined at DAI. Under the conditions of IA, the protein content was with 15 % higher in harvest years 2018 and

2020, reaching 15.58 % in the latter year. The main reason for this was the deteriorated filling of grain, which remained malnourished and shriveled.



W index: Factor A (genotype) $GD_{5\%}$=12.039; $GD_{1\%}$=16.475; $GD_{0.1\%}$=22.351
Factor B (location) $GD_{5\%}$=52.479; $GD_{1\%}$=71.813; $GD_{0.1\%}$=97.424.
Wet gluten content: Factor A (genotype) $GD_{5\%}$=0.492; $GD_{1\%}$=0.673; $GD_{0.1\%}$=0.914
Factor B (location) $GD_{5\%}$=2.145; $GD_{1\%}$=2.935; $GD_{0.1\%}$=3.982.

Figure 2. W index and wet gluten content of wheat cultivars from groups A and B.

When qualifying wheat, one of the most important parameters for the grain processing and baking business is the wet gluten content. It possesses unique physical and chemical properties; for the production of bread and baking products not only its quantity but also its quality is important. Parameter W is being used in the recent years, which varies within a wide range and is dependent mainly on the content of wet gluten. The W index is an indicator of the strength of the flour, and is commonly used by professional bakers. Under the specific technology of conducting the field experiments at the two locations, the cultivars from group A Pchelina and Merilin were with expectedly high level of the traits (Fig. 2). The values determined for Lazarka were lower but less variable. Cultivars Enola, Kristalina, Rada and Katarzhina were from the group of the medium genotypes with increased strength, with higher level of wet gluten and W index. The comparison by years showed that under the conditions of IA the mean level of the qualitative parameters was higher, the predominant part of the cultivars maintaining their stability under changeable environment.

CONCLUSIONS

The major abiotic risk factors identified during the period of investigation (‘2018, ‘2019 and ‘2020) were different levels of

drought and recurrent frosts after the resuming of vegetative growth in the spring months. Most unfavorable was 2010-2020, when multiple types of stress had a cumulative effect. Higher mean productivity was realized under the conditions of DAI. At the second location, significant variation was observed both by years and within the working collection.

The cultivars with high mean yield at both locations were Rada, Kristalina, Kalina, Katarzhina and Bozhana. The correlation between productivity and quality was successfully broken in cultivars Lazarka, Pchelina and Merilin, which belong to the group of strong wheat genotypes. The analysis of variance showed that the conditions of the environment had a significant percent in the total variation of grain yield, the number of productive tillers, 1000 grain weight and test weight. Concerning these traits, a genotype x environment interaction was also determined. Under this specific technology of conducting the field experiments, the cultivars from group A Pchelina and Merilin expectedly were with high levels of wet gluten content and W index. The values determined for Lazarka were lower but less variable. In the group of medium genotypes with increased strength, Enola, Kristalina and Rada are worth mentioning.

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