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The influences of genotype, environment, and genotype × environment interaction on quality traits in common winter wheat. 1. Sedimentation value and fermentation number

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Abstract: The experiment was carried out on the experimental field of the IPGR "K. Malkov", Sadovo, during the period 2019-2022 (3 vegetation years). Thirty-eight common winter wheat varieties were studied, under the conditions of a control test. The qualitative traits were recorded: sedimentation value (SdV) according to Pumpyansky, and fermentation number - Pelshenke test (FN). The traits stability of the studied materials was assessed using the stability variances σi^2 according to Shukla (1972), the ecovalence Wi according to Wricke (1962), and the phenotypic stability criterion (Ys_i) according to Kang (1993). To determine the stability index, the software product IPCSSVKYSI (Interactive program for calculating Shukla's stability index, developed by Kang and Magari (1995) was used. It was found that the influence of genotype, environment and their interaction was significant for both monitored traits. The influence of genotype was leading for FN, and for SdV the environment had the greatest influence. The remaining factors have a significant influence on both traits. The varieties Kami, Neda, Pchelina and Dragana exhibit high stability of the traits sedimentation value and fermentation number.

Keywords: common winter wheat; quality; sedimentation value; fermentation number; stability

INTRODUCTION

Wheat (*Triticum aestivum*) is cultivated in many parts of the world, which is a result of its wide and ecological plasticity and adaptability. It is one of the main and cheap and accessible sources of protein on a global scale (Bayissa et al., 2023). The wide application of the crop and the growing demand for grain stimulate the continuous development of scientific research and breeding programs (Chamurliyski, 2019; Robles-Zazueta et al., 2024). An important goal in their work is not only to obtain high yields, but also to create varieties of high quality. This requires the development of genetically diverse materials, resistant to different climatic conditions and meeting quality requirements (Galushko and Sokolenko, 2021; Farhad et al., 2023; Han et al., 2025). Achieving high-quality grain is a complex process influenced by genotype, environment, and the complex interaction between them (G × E). Correctly determining of these factors is essential for breeders, to set correct targets for developing wheat varieties with high yield potential, as well as consistent quality characteristics that meet market needs (Gubatov and Delibaltova, 2020; Tsenov et al., 2021; Yue et al., 2022; Han et al., 2025).

A number of scientists have conducted studies on the changes in grain growing conditions, and found that without changes in agronomic management practices and the use of different wheat varieties, projected global wheat production will decrease (Bonfil et al., 2023). According to Liu et al. (2019), a 2.3–10.5% reduction is expected for 1.5–2.0°C warming. Guarin et al. 2019 predict a 12% reduction in wheat production due to climate change. Additional research confirms these trends and highlights the threats posed by increased temperature variability, droughts, and other extreme climate events (Raimondo et al., 2021). To mitigate these risks, it is crucial to assess wheat performance over multiple years and in different locations. These observations, together with the results of other studies (Mahmood et al., 2019; Kheir et al., 2019), indicate the negative effects of global temperature changes on wheat production (Ryumkina et al., 2022; Wang et al., 2024). The stability of weather conditions during critical stages of plant growth and development is of greatest importance for the formation of high grain yield and quality (Rangare et al., 2010). Analysis of the stability of genotypes in different environments (suitable for specific meteorological conditions and locations) is essential for identifying varieties with good adaptability and productivity (Dimitrov et al., 2023; Saeidnia et al., 2023). Through this approach, and proper selection of varieties, it is possible for them to express their genetic potential under a wide range of conditions (Annicchiarico, 2002), and to significantly increase yields and production quality (Mitura et al., 2023; Yue et al., 2025). The understanding the various interactions (G × E interactions) in winter wheat quality traits is critical for breeding and sustainable production (Harisha, et al., 2024).

Grain quality is a complex and multi-layered concept that includes a number of chemical, physical and technological traits, the number of which does not decrease despite the development of biotechnology. Therefore, there is a need for more elementary methods for determining quality characteristics that are standardized and can be applied in different phases of the agro-industrial process (Kibkalo et al., 2022). Among the most widely used analytical methods for indirect assessment of baking qualities are sedimentation value and fermentation number. They are influenced by both the genetic potential of the variety (genotype) and the growing conditions (environment). They are key traits in the breeding of stable varieties with high technological quality. These are rapid analytical methods that use minimal amounts of test materials and the ability to predict protein quality and quantity. A number of screening methods have been developed in the early breedingstages, including measuring the sedimentation volume of ground grain and flour in various solutions-dilute lactic acid, 2% glacial acetic acid, sodium dodecyl sulfate SDS solution and dilute lactic acid — as well as the Pelshenke dough ball test, which involves measuring the time it takes for a yeast dough ball made from whole wheat flour to disintegrate in water (Zeleny, 1947; Pelshenke, 1953; Pomeranz, 1965; Pumpyansky, 1971; Orth and O'Brien, 1976; Greenaway, 1977; Axford et al., 1979). Authors such as Bebyakin et al. (2001), Morris et al., (2007), Shabolkina et al. (2012), Kibkalo, (2022) and Aydoğan et al. (2023) emphasize the high methodological robustness and accuracy of sedimentation tests. The Pumpyansky, (1971) and Pelshenke tests (Pelshenke, 1953) were developed based on different approaches, but with a common goal - assessing gluten quality and predicting the baking qualities of wheat. These methods find wide application in the analysis of common winter wheat, where classical sedimentation tests do not always provide sufficient sensitivity. Express methods for the analysis of common winter wheat play an important role in assessing its quality, suitability for processing, and economic value.

The study aimed to analyze the influence of changes in climatic conditions and genotype on the values of sedimentation and fermentation number.

MATERIALS AND METHODS

The field experiment was conducted during the period 2020-2022 (3 vegetations), on an experimental field at the Institute of Plant Genetic Resources „K. Malkov", in the town of Sadovo, south-central Bulgaria. Cultivation technology adopted at the institute was used. Thirty-eight varieties of common winter wheat were included, breeded at the Dubrudzha Agricultural Institute, General Toshevo, obtained during the National Scientific Program "Healthy Foods for a Strong Bioeconomy and Quality of Life". The evaluation of the quality traits was carried out in a technological laboratory of IPGR, Sadovo. To characterize the grain of the studied lines, the following traits were taken into account:

-The Pumpyansky tests (1971) and Pelshenke et al., 1953 were developed based on different approaches, but with a common goal - assessment of gluten quality and prediction of the wheat baking qualities.

-Sedimentation value, cm^3 (SdV) – the Pumpyanskiy method is based on the principle of swelling of the protein fraction in an acidified environment. A 2% solution of ice acetic acid was used (Pumpyanskiy, 1971);- The Sedimentation Value (SdV) (Iced Acetic Acid Test – 2%, (Pumpyanskiy, 1971) test was used to provide information on the protein quality and baking properties of the wheat (Angelova et al., 2020; Galushko & Sokolenko, 2021; Uhr et al., 2023).

-The Fermentation Number (FN) – Pelschenke test was used to assess the fermentation capacity of the wheat, which is important for bread-making quality. The test is based on the retention of CO_2 gases released during dough fermentation. A 10 g sample of grain meal is mixed with a yeast solution (a biological product, representing a concentrated mass of yeast of the Saccharomyces cerevisiae species) in two replicates (Pelshenke et al., 1953). The experiment was carried out under controlled conditions (30^{o}C - water thermostat). The longer the retention time of the sample on the water surface, the better the quality of the gluten (Angelova et al., 2020; Galushko and Sokolenko, 2021; Uhr et al., 2023). The variation of the traits is determined according to Dimova and Marinkov, (1999).

Mathematical data processing - Data analysis- Analysis of variance (Anova) - through the analysis of variance, the influence of the genotype, weather conditions and their interaction on the studied indicators was determined. The stability of breeding material traits was evaluated by the stability variance σi^2 according to Shukla (1972), the equivalence Wi according to Wricke (1962) and the criterion of phenotypic stability (Ws_i) according to Kang (1993). The program product IPCSS-VKYSI (Interactive program for calculating Shukla's stability index, developed by Kang and Magari (1995) was used to determine the stability index.

RESULTS AND DISCUSSION

Climatic characteristics

The average monthly air temperature (Figure 1) and the amount of precipitation (Figure 2) were monitored during the period March – May, in order to characterize the growing season. They are compared with data for a 30-year period (1991-2020), kindly provided by the National Institute of Meteorology and Hydrology, based on a meteorological cell in the area of the IPGR, Sadovo. The conditions are important for the formation of the grain and its traits.

In the first year 2019/2020, the average monthly temperatures during the winter months from December to March were higher than norm. In April, the deviation was negative.

Below-normal precipitation is reported in May and June during flowering, filling, and grain ripening.

In the second growing year 2020/2021, the deviations in the average daily temperature in April and May are negative, as is the observed trend of shifting the colder period to March and April. Below-normal precipitation was recorded in February, March and May. The conditions are again unfavorable during important phases of wheat development.

In the third growing year, negative deviations from the norm are reported in March (–2.7)^{o}C. Precipitation is below norm in February, March and May.

A number of authors establish that sedimentation is an indirect method for evaluating test ma-

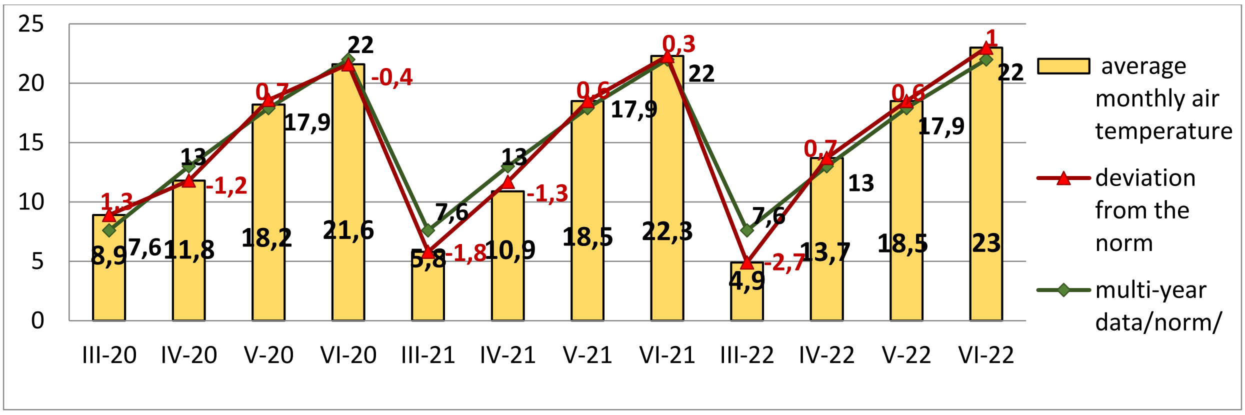

Figure 1. Average monthly air temperature amount for the months of March to June, 2020-2022

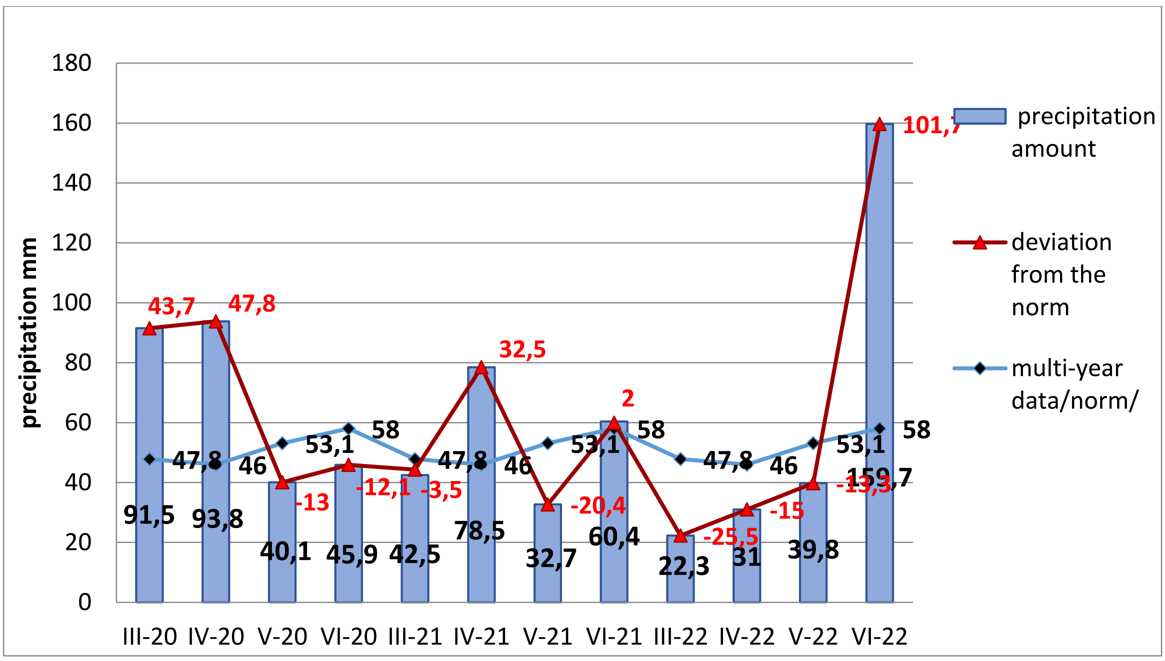

Figure 2. Precipitation amount for the months of March to June, 2020 – 2022

terials, the expression of which can predict gluten strength and baking properties of wheat. Based on the principle of protein swelling, it gives us an idea of its presence in the flour, and therefore in the grain (Campbell et al., 1987; Kruger and Hatcher, 1995; Hruskova and Famera, 2003). This trait is highly hereditary (Pshenichnaya and Dorokhov, 2017; Galushko and Sokolenko, 2021; Harisha et al., 2024; Kibkalo, 2022).

Our research shows that the maximum (63 cm^3), minimum (21 cm^3) and average (41.4 cm^3) values were lowest in the 2020 harvest year, which was characterized by a cooler and wetter spring (Table 1). The settling index is directly related to protein formation (quantity and quality), making it sensitive to conditions before and during grain filling. In 2021 were the best results obtained (Table 1). During flowering and grain filling, the development conditions were close to optimal. The optimal temperature range for wheat grain filling is 20–22°C (Farooq et al., 2011), combined with the warm and dry weather in June, which led to the formation and accumulation of quality protein. The increase in temperature caused by

Table 1. Variational analysis of the traits sedimentation value and fermentation number

№	Variety	Sedimentation value, cm³						Fermentation number, min					
		2020	2021	2022	$\bar{x}$	+-D	Sign.	2020	2021	2022	$\bar{x}$	+-D	Sign.
1	Enola – st.	45	86	78	69.7			105	154	183	147.3		
2	Kristalina	40	80	60	60.0	-9.7	---	44	116	89	83.0	-64.3	---
3	Nikodim	29	51	54	44.7	-25.0	---	53	137	153	114.3	-33.0	---
4	Todora	32	52	58	47.3	-22.3	---	59	67	81	69.0	-78.3	---
5	Bozhana	43	55	55	51.0	-18.7	---	81	158	226	155.0	7.7	+++
6	Aglika	42	74	62	59.3	-10.3	---	81	172	203	152.0	4.7	+
7	Stojana	40	66	52	52.7	-17.0	---	146	123	155	141.3	-6.0	--
8	Milena	49	86	61	65.3	-4.3	---	74	84	117	91.7	-55.7	---
9	Rada	45	69	65	59.7	-10.0	---	54	155	167	125.3	-22.0	---
10	Tina	50	89	74	71.0	1.3	n.s.	152	190	230	190.7	43.3	+++
11	Slaveja	44	80	68	64.0	-5.7	---	88	192	90	123.3	-24.0	---
12	Karat	21	35	39	31.7	-38.0	---	48	41	51	46.7	-100.7	---
13	Kristi	31	70	50	50.3	-19.3	---	90	114	110	104.7	-42.7	---
14	Antonovka	40	62	45	49.0	-20.7	---	102	115	219	145.3	-2.0	-
15	Karina	34	46	37	39.0	-30.7	---	80	154	96	110.0	-37.3	---
16	Korona	39	65	51	51.7	-18.0	---	73	55	55	61.0	-86.3	---
17	Neda	44	77	58	59.7	-10.0	---	82	125	138	115.0	-32.3	---
18	Boljarka	43	80	50	57.7	-12.0	---	131	140	101	124.0	-23.3	---
19	Zlatitsa	38	62	49	49.7	-20.0	---	40	56	77	57.7	-89.7	---
20	Lazarka	39	86	55	60.0	-9.7	---	106	206	250	187.3	40.0	+++
21	Demetra	45	85	55	61.7	-8.0	---	107	166	77	116.7	-30.7	---
22	Lider	35	75	59	56.3	-13.3	---	94	84	149	109.0	-38.3	---
23	Goritsa	42	90	81	71.0	1.3	n.s.	78	108	201	129.0	-18.3	---
24	Kosara	35	43	67	48.3	-21.3	---	77	135	149	120.3	-27.0	---
25	Laska	50	77	82	69.7	0.0	n.s.	40	188	116	114.7	-32.7	---
26	Merilin	55	75	89	73.0	3.3	+++	76	232	188	165.3	18.0	+++
27	Galateja	55	71	77	67.7	-2.0	-	77	112	99	96.0	-51.3	---
28	Kami	33	67	53	51.0	-18.7	---	70	107	130	102.3	-45.0	---
29	Kalina	34	74	54	54.0	-5.3	---	116	129	172	139.0	-13.0	---
30	Katarzhina	32	60	46	46.0	-23.7	---	137	147	165	149.7	2.3	
31	Kiara	48	60	73	60.3	-9.3	---	105	131	133	123.0	-24.3	---
32	Kristal	37	45	42	41.3	-28.3	---	97	98	101	98.6	-48.8	---
33	Albena	46	77	71	64.7	-5.0	---	71	176	147	131.2	-16.1	---
34	Dragana	45	80	68	64.3	-5.3	---	138	191	198	175.7	28.3	+++
35	Iveta	49	86	71	68.7	-1.0	n.s.	124	179	168	157.0	9.7	+++
36	Pchelina	63	95	92	83.3	13.7	+++	141	217	192	183.3	36.0	+++
37	Sladuna	46	80	78	68.0	-1.7	-	44	191	144	126.2	-21.1	---
38	Svilena	34	45	51	43.3	-26.3	---	40	39	40	39.7	-107.7	---
Minimum		21	35	37	31.7			40	39	40	39.7		
Maximum		63	95	92	83.3			152	232	250	190.7		
Mean		41.4	69.9	61.3	57.5			87.4	136.4	141.1	121.6		
Std. Error		1.3	2.4	2.2	1.8			5.2	8.0	8.7	6.0		
Std. Deviation		8.2	15.1	13.7	11.0			32.0	49.2	53.5	37.3		
CV,%		19.8	21.6	22.3	19.1			36.7	36.1	37.9	30.7		
GD 5%=1.90; GD 1%=2.50; GD 0.1%=3.21								GD 5%=4.22; GD1%=5.57; GD0.1%=7.14					

+ -,+ + - -,+ + + - - -, significant at GD 5.0%, GD 1.0% and GD 0.1%; n.s. – non significant

global warming has a particularly strong impact on wheat quality (Zhao et al., 2022). With climate change, maintaining grain quality has become substantially importance. Temperature indirectly affects it by formation grain size, starch and protein content, and the balance between these components (Liu et al., 2024; Han et al., 2025).

The fluctuations in the sedimentation values in our study are large, for example, in the first year they range from 21 cm^3 for the Karat variety to 63 cm3 for Pchelina. In the second year, the values are lowest for Karat - 35 cm^3, and highest for variety Pchelina – 95 cm^3. For 2022, similar results to the previous year were obtained (Table 1).

The trait variation (CV, %) is strong, both by year and for the three-year study period. This is a result of the diversity of genotypes participating in the study. The results obtained are similar to our previous studies (Uhr et al., 2020; Angelova et al., 2020; Angelova et al., 2023).

Statistically positively significant against the standard are the genotypes Pchelina and Merelin (GD0.1%), with an un significant difference are four of the varieties (Iveta, Laska, Gorica and Tina), the remaining varieties have a significant negative difference.

The values of the trait (Pelshenke et al., 1953) together with those of the sedimentation number give a clearer idea of the interdependence between the quality and quantity of gluten. The data from our study show that all materials have proven differences from the standard. The average values for the period are in a wide range from 39.7 min for Svilena to 190.7 min for Tina. The values obtained for 2020 confirm the results of the sedimentation test, the accumulated amount of protein is of low quality, and only 13 of the varieties were reported to be over 100 minutes (Table 1). Environmental conditions in 2021 also had a favorable impact on this test, which confirmed the accumulation of a large amount of quality protein. As with the SdV and the FN, the results for 2022 are similar to the previous year's results. The variation in this trait is also strong. A significant positive difference compared to the standard is found in seven varieties (GD 0.1%). During the study period, the best results were obtained in the varieties Pchelina and Merelin. The lowest were obtained in Karat, Svilena, and Zlatitsa (Table 1). In our previous study of the traits SdV and FN, similar results were obtained. (Uhr et al., 2023). The data from the study show that all studied varieties have proven differences in the fermentation number compared to the standard at the 0.1% level. For the years of testing.

Variance analysis /Anova/ for sedimentation value and fermantion number

Understanding G × E interactions in winter wheat quality traits is of particular importance for breeding and sustainable production. It supports the selection of stable varieties with high quality, facilitates adaptation to climate change, and plays an important role in agronomic decision-making. Analysis of the genotype × environment interaction in recent years has been indispensable in efforts to objectively assess any variety of traits and crops (Gubatov & Delibaltova (2020). The results of the analysis of variance show a significant influence of year, genotype, and their interaction. Most of the phenotypic variation in trait sedimentation value was due to environment (47.5%), followed by genotype, which accounts for 39% of the total variation. The genotype x environment interaction is weaker – 13.1% (Table 2). By fermentation number, the influence of genotype is leading 51.3%, followed by the interaction genotype × environment, which accounts for 26.3% of the total variation. The influence of environment is less prevalent 22.3% (Table 2). The results obtained are similar to our previous studies, in which the leading factor in FN is also the genotype (Uhr et al., 2023), as well as the significant influence of all studied factors (Angelova et al., 2020; Uhr et al., 2023). The variation that occurs as a result of changing climatic conditions and the interaction of the genotype with the environment is an important assessment of the grain qualities, which is confirmed by research by scientists from different countries (Stoeva, 2012; Kaya and Sahin, 2015; Bornhofen et al., 2017; Wang et al., 2018; Gubatov and Delibaltova, 2020; Öztürk and Korkut, 2020; Ben Mariem et al., 2021; Tsenov et al., 2022; Shahid et al., 2024). In a study by

Tsenov et al. (2023), it was found that significant changes in quality parameters (including sedimentation number) are primarily due to the influence of "location" conditions, the effects of which largely determine the "genotype x environment" interaction. All studied traits related to various aspects of quality are influenced by the conditions of the „environment", the „genotype" and the interaction between them, which is expressed in various combinations of effects. Mut et al., (2010) found that changes in the sedimentation index are equally dependent on "genotype" and "conditions". A number of researchers have obtained results from studies on sedimentation traits during different periods (Grausgruber et al., 2000; Atanasova et al., 2009; Tsenov et al., 2023), they found that the influence of the environment is significant, followed by the influence of the interaction between (genotype × environment), and the effects of the genotype are reliable, but relatively weaker. Cases, in which there is no interaction between "genotype" and "environment", have also been reported (Rakszegi et al., 2016; Nehe et al., 2019). Nehe et al., (2019) did not report the interaction between "genotype" and "environment" for seven indices (including the sedimentation index), which is rarely observed. This does not give grounds to assume that all three factors are important elements of qualitative variation and should be systematically studied and used.

Traits stability

The use of stability analysis is essential for identifying genotypes that perform well in different environments, as well as those suitable for specific conditions and locations. It uses various methods, including parametric and non-parametric approaches, to assess genotype stability under changing environmental conditions (Vaezi et al., 2019; Yue et al., 2025). The signicant influence of the factors genotype, environment and their interaction on the sedimentation and fermentation numbers does not provide grounds to determine their stability in all genotypes. Table 3 presents the stability parameters σi^2 and W_i^2. Varieties showing lower values are considered more stable, because they interact less with environmental conditions. With significantly high values of either of the two parameters - σi^2 or W_i^2, genotypes are considered unstable.

In our study, the varieties with the greatest stability of the sedimentation number indicator are Aglika, Albena, Rada, Kami, Dragana and Katarzyna. In them, the value of the trait is at a relatively constant level and no major differences are observed over the years of testing. Kosara, Lazarka, Marilyn, Chiara and Gorica can be defined as unstable. Their interaction with the environment is large, and there is a wide variation in the values of the trait for the studied period (Table 3).

Table 2. Anova - influence of sources of variation

Treits	Source of Variation	SS	df	MS	F	F crit	η,%	Sign.
SdV	Envirpmental A	48839.4	2	24419.7	17508.5	3.0	47.5	***
	Genotype B	40097.3	37	1083.7	777.0	1.5	39.0	***
	Interaction/ A x B	13460.6	74	181.9	130.4	1.3	13.1	***
	Within	318.0	228	1.4			0.3	
	Total	102715.3	341				100	
FN	Envirpmental A	201470.9	2	100735.4	14629.1	3.0	22.3	***
	Genotype B	463303.7	37	12521.7	1818.4	1.5	51.3	***
	Interaction/ A x B	237422.4	74	3208.4	465.9	1.3	26.3	***
	Within	1570.0	228	6.9			0.2	
	Total	903767.1	341				100	

*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 (%), *** - significant at α = 0.001;*

Table 3. Stability parameters

№	Variety	Sedimentation value				Fermentation number			
		$\bar{x}$	σ^2_i	W_i^2	KR (Ws_i)	$\bar{x}$	σ^2_i	W_i^2	KR (Ws_i)
1	Enola – st.	69.7	55.7	108.8	27	147.3	179.0	395.5	16
2	Kristalina	60.0	44.4	87.4	36	83.0	252.3	534.4	42
3	Nikodim	44.7	33.9	67.4	49	114.3	586.0	1166.7	43
4	Todora	47.3	54.9	107.3	53	69.0	458.1	924.4	50
5	Bozhana	51.0	70.4	136.6	54	155.0	2282.2	4380.5	39
6	Aglika	59.3	2.5	7.9	21	152.0	1224.2	2375.9	33
7	Stojana	52.7	15.7	33.0	33	141.3	1365.6	2643.7	39
8	Milena	65.3	69.5	134.9	37	91.7	399.8	813.8	47
9	Rada	59.7	5.6	13.8	21	125.3	1074.6	2092.3	41
10	Tina	71.0	27.8	55.8	17	190.7	316.0	655.0	14
11	Slaveja	64.0	13.1	28.0	20	123.3	2971.7	5687.0	56
12	Karat	31.7	63.9	124.3	63	46.7	979.0	1911.3	59
13	Kristi	50.3	40.7	80.3	46	104.7	292.9	611.2	40
14	Antonovka	49.0	57.6	112.3	54	145.3	2641.6	5061.4	45
15	Karina	39.0	96.9	186.8	67	110.0	1019.6	1988.2	49
16	Korona	51.7	15.7	33.0	25	61.0	1667.8	3216.3	63
17	Neda	59.7	27.2	54.7	13	115.0	-10.0	37.3	25
18	Boljarka	57.7	121.2	232.8	54	124.0	1818.3	3501.5	47
19	Zlatitsa	49.7	19.4	40.0	40	57.7	258.1	545.4	47
20	Lazarka	60.0	149.5	286.5	37	187.3	2135.9	4103.3	32
21	Demetra	61.7	119.6	229.8	46	116.7	2761.3	5288.3	57
22	Lider	56.3	34.1	67.7	38	109.0	1224.7	2376.8	53
23	Goritsa	71.0	128.9	247.5	34	129.0	2253.7	4326.4	46
24	Kosara	48.3	284.7	542.7	69	120.3	59.1	168.2	25
25	Laska	69.7	56.7	110.7	23	114.7	2814.5	5389.1	60
26	Merilin	73.0	135.5	260.0	38	165.3	2998.3	5737.4	43
27	Galateja	67.7	64.1	124.6	35	96.0	235.9	503.3	39
28	Kami	51.0	8.8	19.8	4	102.3	62.2	174.1	34
29	Kalina	54.0	44.4	87.4	23	139.0	458.6	925.2	30
30	Katarzhina	46.0	9.8	21.7	39	149.7	385.5	786.7	23
31	Kiara	60.3	132.8	254.8	50	123.0	180.6	398.5	27
32	Kristal	41.3	117.2	225.3	67	98.6	810.3	1591.7	50
33	Albena	64.7	5.1	12.8	13	131.2	808.3	1587.8	33
34	Dragana	64.3	9.4	21.0	17	175.7	-18.9	20.5	5
35	Iveta	68.7	18.9	39.1	17	157.0	36.0	124.4	9
36	Pchelina	83.3	20.3	41.7	13	183.3	254.0	537.6	13
37	Sladuna	68.0	36.8	72.8	25	126.2	2505.8	4804.1	49
38	Svilena	43.3	91.3	176.1	64	39.7	919.4	1798.3	59

σ^2_i – Shukla's stability variance; W_i^2 – Wricke's ecovalence; KR – Kang's rank-sum;

Very useful information about the value of genotypes is provided by Kang's KR (Ws_i) indicator for simultaneous assessment of quality traits and their stability, as the indicator is based on the reliability of the differences between different values and the variance of the interaction with the environment. The value of this criterion is that using non-parametric methods and statistical evidence of differences, we obtain a generalized assessment, arranging the genotypes in descending order according to their economic value. Based on this criterion, we can indicate the most valuable varieties Kami, Neda, Albena and Pchelina. They are characterized by a high value and simultaneous stability of the studied trait.

The varieties Dragana, Neda, Iveta and Kosara exhibit high stability of trait the fermentation number, while the genotypes Korona, Laska, Karat and Svilena are considered unstable and have a wide variation in the values of the indicator. According to Kang's criterion, Dragana, Iveta and Pchelina and Tina have high economic value.

CONCLUSIONS

The varieties Pchelina and Merelin have significant the highest values for the trait sedimentation value. For the fermentation number, the varieties Dragana, Iveta, Pchelina, Bojana, Tina, Zlatitsa and Merelin have shown high results.

The influence of environmental conditions, genotype and their interaction is statistically proven in the monitored traits. In the sedimentation value, the influence of the year is the strongest, followed by the genotype and the interaction genotype x environment. In the fermentation number, the influence of the genotype is leading, followed by the influence of the genotype x environment interaction and the environment.

The varieties Kami, Neda, Pchelina and Dragana show high stability of traits the sedimentation value and fermentation number.

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