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Study of yield and stability by common winter wheat varieties by changing climatic conditions in Sadovo region

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Abstract

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The experiment was conducted on the experimental field of IPGR "K. Malkov", Sadovo in the period 2019-2021. The yield and its stability in fifty-six varieties of common winter wheat were studied. The varietal experiments were carried out according to a block scheme in three repetitions, with the size of the experimental plot of 10 m^2 according to the cultivation technology adopted in IPGR. Yield stability and varietal adaptability were assessed using Shukla (1972), σi^2 and Si^2 stability variants, Wricke ecovalence Wi, Kang (Ysi) phenotypic stability criterion (1993), b_i regression. by Finlay & Wilkinson (1963) and General adaptability by Eberhart & Russell (1966).The results of the study show that the highest average yield was reported for the varieties Kristi, Nikodim and Todora. In twelve genotypes, the trait was exceeded compared to the standard. The genotype factor (40.7%) has the strongest and proven influence on the yield, followed by the growing conditions – enviroment (20.7%). The varieties Petya, Karina, Yoana, Bolyarka and Milena are characterized by the highest yield stability, while the varieties Nikodim and Kiara are characterized by both high and stable yields. The most adaptable to environmental conditions are the varieties Mustang, Enola and Yoana, with the highest overall adaptability are characterized by Kristi, Nikodim and Todora. Nikodim, Kiara, Kristi and Todora, which are characterized by high yield, stable and with a wide adaptability to adverse climatic conditions, are considered to be the most valuable varieties.

Keywords: common winter wheat; climatic conditions; grain yield; suitability; adaptability

Introduction

The common winter wheat is the most important cereal crop grown conventionally or organically in the world, Europe and Bulgaria (Wolfe et al., 2008; Konvalina et al., 2009). It is a raw material for important industries such as food, confectionery and others. The products of low-quality varieties of common winter wheat, straw and waste from the milling industry are used to feed farm animals. Wheat originates from Mala Asia, the Caucasus and the south-eastern part of the Balkan Peninsula. This most important food crop has been cultivated in our lands since prehistoric times – as far back as the Neolithic, Stone-Copper and Bronze Ages. With the spread of wheat in Europe, begins the use of straw for roof insulation, a practice applied in the second half of the XIX century. In Bulgaria, wheat is the main field crop, grown on an area of about 12 million acres. The most favorable conditions for growing wheat are in Dobrudja, followed by the other plain regions of Northern Bulgaria, the districts of Burgas and Plovdiv. As of mid-November, the total area sown with wheat accounted for 991 813 million ha, about 6% below those reported at the same time last year.

In Bulgaria, wheat production in 2020 amounts to 4 711 thousand tons – a decrease of 23.5% compared to 2019, due to unfavorable climatic conditions in the process of culture development, which led to a decrease in average yield (from 23.7%). The sown areas with wheat in 2020 are 1 207 994 ha – by 0.5% more on an annual basis, of which 1 200 175 ha were harvested (www.mzh.government.bg/media/filer_public/2021/12/07/ad_2021.pdf). Based on the reports of the Ministry of Agriculture and Food, 7 088 thousand tons of wheat were harvested and the average yield was 596 kg/da. The production is 54.2% higher than last year, mainly as a result of an increase in average yields (https://www.mzh.government.bg/media/filer_public/2021/08/18/operativen_analiz_2021-08-18.pdf).

The data show a large fluctuation in the yield over the years. Grain yield is a function of the interaction between genotype, environment and genotype$_x$environment (Arain et al., 2001; Hamam et al., 2009; Sial et al., 2007). The stability of the yield of genotypes in a wide range of environments is of great importance for breeders. Thus, studies of the interaction of genotype$_x$environment provide a basis for selecting genotypes that are suitable for general breeding and others for the specific area and under certain environments (Nachit et al., 1992; Ahmed et al., 1996; Peterson et. al., 1997; Yan & Rajcan, 2002; Khan et al., 2007).

The current study includes 56 Bulgarian varieties of common winter wheat, created in IRGR, Sadovo and Dobrudzha Agricultural Institute, General Toshevo and evaluates the so-called phenotypic stability of yield, which is the realization of relatively constant genotypic productivity under different environmental conditions.

Different parameters are known for assessing phenotypic stability (Eberhard & Russell, 1966; Shukla, 1972), but the most reliable method for simultaneous assessment of yield and stability is the Kang parameter (1993) – Ysi. It gives a summary assessment of the yield and stability of its manifestation, which is extremely important in the assessment of varieties by economic value in changing climatic conditions.

The aim of the present study is to test the yield and yield stability of 56 Bulgarian common winter wheat varieties under the conditions of climate change in Sadovo region.

Materials and Methods

The experiment was conducted on the experimental field of IRGR – Sadovo in the period 2019-2021. The yield and its stability in fifty-six common winter wheat varieties, created in IRGR, Sadovo and DAI General Toshevo were studied. Varietal experiments were performed on a block scheme in three replications, with the size of the experimental plot of 10 m^2, and the studied genotypes were compared with the complex standard for the country variety Sadovo 1.

Yield data were processed using analysis of variance (Lidanski, 1988), which assessed the strength of the influence of sources of variation – genotype, environment and their interaction. Yield stability and adaptability of winter wheat varieties were assessed by Shukla (1972), σi^2 and Si^2 stability variants, Wricke ecovalence Wi, Kang phenotypic stability criterion (Ysi) (1993), Finlay & Wilkins b_i regression coefficient (1963), general adaptability GA by Eberhart & Russell (1966). Statistical and mathematical data processing was performed with the software products Microsoft Excel and Stabilitysoft.

Results and Discussion

The reporting period is characterized by significant meteorological differences during the growing season, which is reflected in the realized yields by years. The second year is characterized by the most favorable conditions for the development of wheat from the studied period.

During the first growing year 2018-2019, the average monthly temperatures were higher than the perennial ones, and the precipitation was not evenly distributed (Table 1 and Table 2). There was a delay in the development of wheat before the rain in April. Unfavorable conditions during grain

Table 1. Average temperature sum t °C of months during three vegetation years 2018/2019, 2019/2020, 2020/2021

Years/Months	X	XI	XII	I	II	III	IV	V	VI
2018/2019	14.5	7.7	3.0	2.4	4.7	11.2	12.4	18.3	23.8
2019/2020	14.8	10.7	4.1	2.2	6.1	8.9	11.8	18.2	21.6
2020/2021	15.2	6.7	5.6	3.3	5.9	5.8	10.9	18.5	22.3
Average multi-annual	12.6	6.9	2.1	-4.3	2.4	6.3	12.2	17.5	21.2
Deviation	2.2	1.5	2.1	6.9	3.2	2.3	-0.5	0.8	1.4

Table 2. Sums of month rainfall (mm) during three vegetation years 2018/2019, 2019/2020, 2020/2021

Years/Months	X	XI	XII	I	II	III	IV	V	VI
2018/2019	37.1	75.0	23.8	42.6	20.3	8.5	75.9	17.3	179.2
2019/2020	14.2	80.7	24.9	2.1	49.4	91.5	93.8	40.1	45.9
2020/2021	72.7	6.3	55.7	96.4	32.8	42.5	78.5	32.7	60.4
Average multi-annual	37.4	47.1	49.7	39.3	30.9	39.0	42.9	56.8	58.4
Deviation	3.9	6.9	-14.9	7.7	3.3	8.5	39.8	-26.8	36.8

pouring, expressed in high, excessive temperatures during the second and third ten days of May, insignificant rainfall and the presence of drought contributed to premature ripening of varieties and malnutrition of grain.

The meteorological conditions in the vegetation 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 in late March and early April 1. The average monthly temperatures only in April were lower than the norm by 0.4 °C. In the remaining months from October to March the temperatures are higher. Moisture deficiency was not observed during the important phases of stem extension, heading and grain filling. The rainfall in April and May favored the formation of a higher stem compared to the typical varieties, big grain and high yield the formation. Conditions during the grain filling and ripening phases were favorable. Rainfall during the growing year is more than the norm, but not evenly distributed.

For the vegetation period 2020/2021, a strong influence of agro-climatic conditions on the development of ordinary winter wheat has been established. The precipitation that fell in October was more than 35.3 l above the norm, and the temperatures were close to the norm. Until March, temperatures are higher than normal. In April, the necessary moisture for the spindle phase was available. During hatching, flowering, milk and wax maturity, the precipitation was about 24 l less than the norm, as a result of which smaller and lighter grain is formed. The amount of precipitation for the growing season is above the norm, but they are unevenly distributed. The average monthly temperatures in November, March and April are lower than the norm, with differences of -0.19, -0.49 and -1.3, respectively. The trend of the last 5 years of increasing temperatures in December, January and February is preserved.

Table 3 presents the results obtained from grain yield for the study period. The data show that the highest average yield of the three years was reported for the varieties Kristi (867.6 kg/da), Nikodim (829.4 kg/da) and Todora (817.2 kg/da), and the lowest values were for the varieties Aglika (558.8 kg/da) and Kalina (530.2 kg/da). Higher yields than the Sadovo 1 standard were observed in twelve varieties. Thirteen genotypes of wheat are characterized by proven differences from the Sadovo 1 standard.

Regarding the yields obtained in the individual years of the study, we can summarize that the most favorable for the development of plants in climatic terms is 2020, where the reported average yield of all studied samples is the highest (748.8 kg/da). The years 2019 and 2021 can be mentioned as less favorable, where the reported average yields are relatively lower, by 635.6 and 670.1 kg/da, respectively. The calculated coefficient of variation shows us that the variation

Table 3. Average yield of winter common wheat for the period 2019-2021

№	Variety	Grain yield, kg/da						
		2019	2020	2021	$\bar{x}$	± D	Sign.	% to standard
1	Sadovo 1 st.	675.5	729.0	771.7	725.4			100
2	Pobeda	525.4	641.6	591.7	586.2	-139.2	--	80.8
3	Bononiya	605.4	630.7	612.6	616.2	-109.2	--	85.0
4	Yoana	635.8	765.6	681.9	694.4	-31.0	n.s.	95.7
5	Sad. beliya 1	625.0	763.6	638.6	675.7	-49.7	n.s.	93.2
6	Mustang	615.3	737.7	637.1	663.4	-62.0	n.s.	91.4
7	Niky	595.6	705.7	648.1	649.8	-75.6	n.s.	89.6
8	Lysil	635.5	818.8	653.3	702.5	-22.9	n.s.	96.8
9	Diamant	615.2	842.0	593.1	683.4	-42.0	n.s.	94.2
10	Murgavets	655.2	807.1	687.0	716.4	-9.0	n.s.	98.8
11	Sadovo 772	595.5	748.9	619.7	654.7	-70.7	n.s.	90.3
12	Sadovo 552	540.3	682.1	550.0	590.8	-134.6	--	81.4
13	Geya 1	675.8	676.3	700.0	684.0	-41.4	n.s.	94.3
14	Guinness	661.2	739.1	685.6	695.3	-30.1	n.s.	95.9
15	Tsarevets	695.2	733.1	734.6	721.0	-4.4	n.s.	99.4
16	KM 135	635.9	834.7	630.6	700.4	-25.0	n.s.	96.6
17	Petya	675.1	783.0	700.9	719.7	-5.7	n.s.	99.2
18	Crystalina	695.2	846.3	691.9	744.5	19.1	n.s.	102.6
19	Nikodim	790.3	866.6	831.4	829.4	104.0	+	114.3

Table 3. Continued

20	Todora	785.4	823.9	842.4	817.2	91.8	n.s.	112.7
21	Kosara	615.3	801.0	594.4	670.2	-55.2	n.s.	92.4
22	Merelin	640.2	680.0	679.6	666.6	-58.8	n.s.	91.9
23	Kami	545.0	686.3	563.6	598.3	-127.1	--	82.5
24	Katarzyna	700.2	706.1	714.3	706.9	-18.5	n.s.	97.4
25	Enola	641.2	775.1	719.0	711.8	-13.6	n.s.	98.1
26	Albena	595.7	695.3	692.7	661.2	-64.2	n.s.	91.2
27	Iveta	565.5	554.4	666.4	595.4	-130.0	--	82.1
28	Sladuna	715.3	713.7	770.7	733.2	7.8	n.s.	101.1
29	Bojana	605.8	654.6	667.6	642.7	-82.7	n.s.	88.6
30	Aglika	497.2	598.3	581.0	558.8	-166.6	---	77.0
31	Stoyana	625.9	778.8	664.7	689.8	-35.6	n.s.	95.1
32	Milena	515.2	645.9	550.3	570.5	-154.9	--	78.6
33	Rada	557.2	687.6	562.9	602.6	-122.8	-	83.1
34	Tina	705.2	749.9	704.3	719.8	-5.6	n.s.	99.2
35	Slaveya	725.2	757.4	786.4	756.3	30.9	n.s.	104.3
36	Karat	685.6	781.4	783.0	750.0	24.6	n.s.	103.4
37	Kristi	825.2	983.7	794.0	867.6	142.2	++	119.6
38	Antonovka	625.4	1023.0	652.4	766.9	41.5	n.s.	105.7
39	Karina	593.4	697.1	628.9	639.8	-85.6	n.s.	88.2
40	Korona	625.2	843.3	598.6	689.0	-36.4	n.s.	95.0
41	Neda	630.2	756.1	651.0	679.1	-46.3	n.s.	93.6
42	Bolyarka	605.0	697.7	632.7	645.1	-80.3	n.s.	88.9
43	Zlatitsa	545.2	570.0	728.3	614.5	-110.9	-	84.7
44	Lazarka	658.5	781.4	655.4	698.4	-27.0	n.s.	96.3
45	Demetra	695.2	832.9	683.3	737.1	11.7	n.s.	101.6
46	Lider	615.4	830.1	583.6	676.4	-49.0	n.s.	93.2
47	Goritsa	620.3	792.3	681.4	698.0	-27.4	n.s.	96.2
48	Laska	595.5	693.1	660.4	649.7	-75.7	n.s.	89.6
49	Galateya	525.2	637.1	593.1	585.1	-140.3	--	80.7
50	Kalina	415.3	715.1	460.1	530.2	-195.2	---	73.1
51	Kiara	710.6	791.6	708.4	736.9	11.5	n.s.	101.6
52	Kristal	645.8	778.0	656.1	693.3	-32.1	n.s.	95.6
53	Dragana	705.7	735.3	671.4	704.1	-21.3	n.s.	97.1
54	Pchelina	695.9	737.7	710.7	714.8	-10.6	n.s.	98.5
55	Svilena	689.0	770.4	781.9	747.1	21.7	n.s.	103.0
56	Avenue	703.3	778.0	791.5	757.6	32.2	n.s.	104.4
Mean	635.6	748.0	670.1	684.6				
Minimum	415.3	554.4	460.1	530.2				
Maximum	825.2	1023.0	842.4	867.6				
Stand. deviation	74.3	86.4	76.2					
Coeff. of variation	11.7	11.6	11.4					
Stand. error of mean	9.9	11.5	10.2					
GD 5.0%=94.0								
GD 1.0%=123.8								
GD 0.1%=158.6								

+ -,+ + - -,+ + + - - -, proven at GD 5.0%, GD 1.0% and GD 0.1%; n.s. – unproven of the studied indicator in the individual years is estimated as an average, with values of CV ≥ 10.0%.

Analysis of genotype$_x$interaction is particularly important for the breeding process (Yan & Hunt, 2001). Very often, high yield stability is associated with low levels of manifestation, and vice versa (Tsenov et al., 2004; Atanasova et al., 2010). In our study, the results of the analysis of variance (Table 4) show that the strongest and proven influence on yield has the genotype factor (40.7%), followed by growing conditions (20.7%). The interaction of genotypic factors is less represented with a value of ŋ = 17.1%.

A very important condition for determining the stability and adaptability of genotypes with respect to the trait yield is the presence of a proven interaction between the studied genotypes and the conditions of the environment in which they are grown (Uhr, 2015; Ivanov et al., 2018). The presented data from the analysis of variance show us that there are proven differences both between the studied wheat genotypes and between the different climatic conditions during the studied years. This gives us reason to evaluate the varieties not only in terms of yield, but also in terms of stability depending on the characteristic conditions in the individual years.

To assess the stability of the studied wheat genotypes, the indicators including the variants of stability σi^2 and Si^2 according to Shukla, ecovalence Wi according to Wricke and the stability criterion YSi according to Kang were calculated (Table 5). Varieties showing lower values of σi^2 and Si^2 are considered more stable because they interact less with environmental conditions. In Wricke's ecovalence, the higher the values of the indicator, the more unstable the corresponding genotype is. The obtained results show that the varieties Antonovka, Zlatitsa, Kalina, Iveta and Diamant are characterized as the most unstable and with the highest values according to the stability criteria σi^2, Si^2 and Wi. Their instability is due to large differences in grain yields in different climatic years. Petya, Karina, Yoana, Bolyarka and Milena can be mentioned as varieties with high stability. In these varieties there are no large differences in terms of yield values during the different years of the study.

Table 4. Analysis of variance (ANOVA) for grain yield from common winter wheat

Trait	Sources of variation	SS	df	MS	F exp.	F tab.	ŋ	Sign.
Yield	Genotype	2181138.7	55	39657.1	11.6	1.8	40.7	***
	Environment	1112611.1	2	556305.6	162.4	7.1	20.7	***
	Interaction	919966.6	110	8363.3	2.4	1.6	17.1	***
	Error	1150800.0	336	3425.0			21.5	
	Total	5364516.4	503				100.0	

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

Table 5. Stability parameters for the grain yield of common winter wheat in terms of years

№	Variety	GY, $\bar{x}$	σ^2_i	s^2_i	W_i^2	YS_i	b_i	GA
1	Sadovo 1 st.	725.4	2787.2	2434.9	21800.0	58	0.66	724.7
2	Pobeda	586.2	195.6	256.8	1807.6	61	0.98	585.2
3	Bononiya	616.2	1502.4	863.6	11888.9	82	0.62	615.6
4	Yoana	694.4	22.7	39.7	474.1	30	1.07	693.4
5	Sad. beliya 1	675.7	395.6	355.5	3350.1	54	1.15	674.6
6	Mustang	663.4	62.4	90.0	780.3	45	1.06	662.3
7	Niky	649.8	57.1	100.4	739.1	47	0.97	648.8
8	Lysil	702.5	1646.3	1142.3	12998.5	61	1.35	701.2
9	Diamant	683.4	5867.9	4435.6	45565.6	84	1.60	681.8
10	Murgavets	716.4	396.6	273.4	3358.4	38	1.19	715.2
11	Sadovo 772	654.7	535.5	391.9	4429.9	64	1.20	653.5
12	Sadovo 552	590.8	535.1	474.7	4426.7	74	1.17	589.6
13	Geya 1	684.0	2932.9	1742.4	22923.7	77	0.48	683.5
14	Guinness	695.3	205.0	136.6	1880.1	36	0.85	694.5
15	Tsarevets	721.0	1498.7	964.6	11859.8	49	0.64	720.3
16	KM 135	700.4	3202.1	2404.8	25000.6	70	1.45	699.0
17	Petya	719.7	-24.0	15.4	113.3	17	0.99	718.7

Table 5. Continued

18	Crystalina	744.5	1101.0	969.0	8792.0	39	1.22	743.2
19	Nikodim	829.4	371.0	271.4	3160.5	19	0.82	828.6
20	Todora	817.2	1936.8	1380.1	15240.0	44	0.63	816.6
21	Kosara	670.2	3205.8	2630.3	25029.2	84	1.40	668.8
22	Merelin	666.6	1423.8	918.3	11282.7	70	0.65	665.9
23	Kami	598.3	363.6	307.6	3103.7	65	1.15	597.1
24	Katarzyna	706.9	2443.3	1410.9	19147.4	64	0.52	706.3
25	Enola	711.8	326.0	384.5	2813.5	32	1.06	710.7
26	Albena	661.2	1222.7	1297.1	9731.0	70	0.87	660.4
27	Iveta	595.4	7179.9	5500.5	55686.4	103	0.35	595.1
28	Sladuna	733.2	4057.7	2713.3	31600.7	61	0.44	732.8
29	Bojana	642.7	1651.0	1240.0	13034.8	84	0.67	642.0
30	Aglika	558.8	768.0	824.4	6223.0	81	0.89	557.9
31	Stoyana	689.8	347.4	225.2	2978.8	44	1.19	688.6
32	Milena	570.5	45.9	50.8	653.0	59	1.09	569.4
33	Rada	602.6	395.7	401.2	3350.9	68	1.12	601.5
34	Tina	719.8	851.4	527.4	6866.5	42	0.72	719.1
35	Slaveya	756.3	2365.9	1699.7	18550.2	48	0.59	755.7
36	Karat	750.0	1327.8	1384.2	10542.1	39	0.85	749.1
37	Kristi	867.6	2418.9	2230.5	18958.6	44	1.29	866.3
38	Antonovka	766.9	21627.5	13349.6	167139.6	60	2.35	764.6
39	Karina	639.8	-16.9	14.0	168.5	47	0.96	638.8
40	Korona	689.0	5504.2	4277.2	42759.9	80	1.56	687.5
41	Neda	679.1	105.7	123.6	1114.4	41	1.08	678.0
42	Bolyarka	645.1	38.6	43.4	596.5	47	0.91	644.2
43	Zlatitsa	614.5	11045.9	10331.4	85510.3	102	0.43	614.1
44	Lazarka	698.4	459.6	502.3	3843.8	46	1.09	697.3
45	Demetra	737.1	991.1	969.8	7944.7	38	1.17	736.0
46	Lider	676.4	5576.6	4424.2	43318.6	85	1.55	674.8
47	Goritsa	698.0	656.2	398.6	5360.8	50	1.25	696.7
48	Laska	649.7	373.5	394.2	3179.7	60	0.90	648.8
49	Galateya	585.1	254.5	314.8	2261.7	64	0.96	584.2
50	Kalina	530.2	8599.1	5138.6	66634.5	110	1.87	528.3
51	Kiara	736.9	266.8	269.2	2356.7	23	0.89	736.0
52	Kristal	693.3	339.9	334.9	2920.9	42	1.12	692.2
53	Dragana	704.1	1487.2	1106.9	11771.5	55	0.68	703.4
54	Pchelina	714.8	991.5	577.8	7947.8	47	0.69	714.1
55	Svilena	747.1	1562.3	1514.1	12350.7	45	0.79	746.3
56	Avenue	757.6	1600.4	1488.3	12644.5	43	0.77	756.8

GY – grain yield (da); σ^2_i – Shukla's stability variance; s^2_i – deviation from redression; W_i^2 – Wricke's ecovalence; YS_i – Kang's rank-sum; b_i – regression coefficient; GA – general adaptability

For a more complete assessment of the individual common winter wheat varieties on the basis of the realized yield, both the size of the yield and its stability in different years must be taken into account. Kang's YSi index provides very good information on the value of genotypes for simultaneous assessment of yield and stability. With this trait, the genotypes are arranged in descending order according to their economic value. In our study, the most priced varieties according to this criteria are Petya, Nikodim and Kiara. They are characterized by high and stable yields during all three years of the study, and in the varieties Nikodim and Kiara the trait is exceeded compared to the standard.

Data on the adaptability of varieties to climatic conditions is given by the regression coefficient b_i. As much higher the value of the coefficient is, as the more sensitive the variety to changes in the environment is. According to Pour-Aboughadareh et al., (2019) if b_i does not significantly differ from 1, then the genotype is adapted to all environments. A $b_i > 1$ indicates genotypes with higher sensitivity to environmental change and greater specificity of adaptability to high yielding environments, whereas a $b_i < 1$ describes a measure of greater resistance to environmental change, thereby increasing the specificity of adaptability to low yielding environments. In our study, the most adaptive varieties are Mustang, Enola and Yoana. Lin & Binns (1988) point out that genotypes with a regression coefficient $b_i < 0.70$ do not meet better growing conditions or have above-average stability, when b_i is 0.70 to 1.30 they have medium stability, and with $b_i > 1.30$ they have high responsiveness to better growing conditions or have lower than average stability. For example, in our study, the Antonovka variety achieved the highest average yield in 2019, when the climatic conditions for wheat development were the best. Therefore, the variety is characterized by high responsiveness to favorable environmental conditions. Iveta, Zlatitsa and Sladuna varieties are characterized by very high stability but low responsiveness to climatic conditions.

Another trait determining the adaptability of varieties to environmental conditions is the general adaptability (GA-General adaptability), representing the difference between the average yield and the regression coefficient b_i. The obtained results show that the highest total adaptability is characterized by the varieties Kristi, Nikodim and Todora, and the lowest total adaptability was reported in Kalina and Aglika. According to Vulchinkov & Vulchinkova (2007), the use of this method is quite limited due to the presence of more complex evaluation parameters.

Conclusion

The highest average yield during the study period was realized by the varieties Kristi, Nikodim and Todora. Twelve genotypes of wheat exceeded the trait compared to the Sadovo 1 standard.

The genotype factor has a primary influence on the variation of the yield trait.

Petya, Karina, Yoana, Bolyarka and Milen varieties showed the highest yield stability during the study period, while Nikodim and Kiara were characterized by both high and stable yields.

The most adaptable to environmental conditions are the varieties Mustang, Enola and Yoana, and the highest overall adaptability are Nikodim and Todora.

The highest valuable are the genotypes Nikodim, Kiara, Kristi and Todora, which are characterized by high yield, stable and with a wide adaptability to adverse climatic conditions. They can be used as sources of starting material in breeding programs to create new varieties of common winter wheat.

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