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CHARACTERISTICS OF SPRING TRITICALE CULTIVARS BRED AT THE YURIEV PLANT PRODUCTION INSTITUTE OF NAAS

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The article presents results of 2019–2021 studies of economic and technological features of 10 spring triticale cultivars bred at the Yuriev Plant Production Institute of NAAS. The grain yield of spring triticale cultivars ranged from 4.07 to 5.00 t/ha. By growing period, the cultivars were medium-ripening (90–94 days); the plant height was 84–108 cm. The test weight was high (717–753 g/L); the thousand kernel weight was 38.1–40.9 g; the protein content was 11.9–13.0%; and the starch content was 58.2–60.1%. The flour strength (W-index) was 68–154; the gluten content was 17.7–22.0%; the GDI was 62–82 units; the dough resilience (P) was 35–69 mm; the dough extensibility (L) was 53–74 mm; and the dough equilibrium (P/L) was 0.6–1.3. The loaf volume was 400–500 mm^3; the total bread-making score was 7.4–8.8 points. There were direct correlations between the total bread-making score and three parameters: loaf volume (r = 0.86), gluten quality (r = 0.51) and dough resilience (r = 0.30).

***Key words**: spring triticale, cultivar, quality, yield, correlation*

Introduction. Triticale is a cereal that has a wide scope of uses: as a food, fodder, and technical crop. Spring triticale is superior to rye, barley, and oat in terms of productivity, feed value, and resistance to biotic and abiotic factors. Currently, in Ukraine, growing attention is paid to the cultivation of triticale as a high-yielding cereal and possibilities of its use to ensure the population's food security [1, 2]. Spring triticale is the best option for overseeding winter crops since the biochemical properties of triticale grain allow harvesting high-quality grain for both fodder and food purposes [3].

The Yuriev Plant Production Institute of NAAS (PPI NAAS) has been breeding spring triticale since the 1970s. To date, 25 cultivars have been bred. As of 2023, the Register of Plant Varieties Suitable for Dissemination in Ukraine includes 17 spring triticale cultivars, 11 of which have been bred by our institute [4].

The breeding mainstreams are high and stable yields, increased adaptability to biotic and abiotic factors of the environment, good bread-making and mixing properties, high nutritional value of grain, and suitability for environmentally friendly farming [5].

Solving tasks of creating bread cereal cultivars adapted to biotic and abiotic factors of the environment, scientists came to the conclusion that it was expedient to combine valuable properties of wheat (high yield capacity, multi-kerneled spike, gluten protein content) and rye (resistance to drought, diseases and adverse conditions of overwintering, ability to more actively assimilate nutrients from soil, multi-spikeleted spike, well-balanced amino acid composition of protein, increased content of vitamins, etc.) in one organism This resulted in the creation of a new crop - triticale [6, 7].

After triticale had been created, studies to evaluate technological properties of its grain and flour as well as bread quality were initiated. Currently, there are new cultivars of spring triticale, which are close in quality to bread wheat, allowing for use them as a valuable cereal [8].

Several studies of biochemical and technological parameters of triticale grain have been conducted in Ukraine and worldwide. The vast majority of scientists proved that both triticale grain and products of its processing were of high biochemical and nutritional value. It should be noted that the studies were carried out on grain and flour from cultivars of various quality. There is convincing evidence that the protein-proteinase complex of bread cultivars makes it possible to bake pure triticale bread or triticale-wheat, triticale-rye, triticale-oat, and other mixed breads in various proportions [9, 10].

There is great interest in triticale in the bakery industry. A number of recipes for making bread and confectionery from triticale flour have been developed. The proposed technologies involve both using triticale flour as an improver and baking pure triticale bread. Scientists believe that triticale flour is quite suitable for making crackers, muffins, waffles, and high-quality cookies [11, 12].

Today, an important challenge for triticale breeders and producers is improvement of the grain quality and its effective use of grain in bakery production and other food industries [13].

A lot of scientific and technological investigations in different countries over the past two decades have opened up ample opportunities for businesses to distribute triticale foods for healthy and tasty people's nutrition. To evaluate and compare morphobiological and technological features of the registered and new spring triticale cultivars bred at the Yuriev Plant Production Institute of NAAS of Ukraine.

Materials and Methods. The variety trials were carried out in accordance with the Methodology of Qualification Examination of Plant Varieties [14]. The seeding rate was 5,000,000 seeds per hectare. At all breeding stages during the vegetation, the lengths of the 'emergence-earing' and 'earing-ripening' periods were recorded; the plant density and evenness were evaluated; resistances to diseases (leaf blotch, brown and leaf rusts) and lodging were assessed; and the plant height was measured. The yield was determined and the grain plumpness and size were assessed [15]. The contents of protein and starch in grain were determined spectrometrically by an express method (on an InfraLIUM infrared analyzer).

The bread-making properties of the cultivars were evaluated by several characteristics. Baking and evaluation of bread parameters and technological properties of flour were performed in compliance with the formula and scale for triticale [16–18]. The kernel hardness was determined on a YPD-300D direct-action hardness tester by the method developed in the PPI NAAS [19]; it was measured as the force required to crash a whole kernel and expressed in newtons (N). The accessions were categorized using the scale for bread wheat: hard (> 190 N), semi-hard (161–190 N), medium soft (131–160 N), soft (105–130 N), and very soft (< 104 N).

Ten registered and new spring triticale cultivars were screened for morphobiological and technological features. For comparison, we used the best, registered cultivar, Darkhliba Kharkivskyi, which is the reference for bread-making qualities.

The data were statistically processed by analysis of variance and correlation analysis [20] in Excel 2007.

The field studies were carried out in the breeding crop rotation of the experimental station of the PPI NAAS, which is located 15 kilometers from Kharkiv (eastern forest-steppe of Ukraine). The forecrop was pea.

The soil was thick slightly leached chernozem on silt loamy loess; the humus layer was 75 cm thick; the humus content was 5.5–7.3%; this soil is characterized by an agronomically valuable granular-lumpy structure, good physical and mechanical properties, and large reserves of substances available to plants. The reaction of the soil solution was weakly acidic (pH=5.7–6.0). The soil cover of the experimental fields was homogeneous, which is one of the main conditions for obtaining reliable data. The hydrolytic acidity was 0.76–0.99 mL per 100 g of soil. The climate in the test area is temperate-continental. The average annual air temperature is 6.7°C. The summer months are characterized by rather high air temperature: the average long-term temperature is 19.1, 21.0, and 19.7°C in June, July, and August, respectively [21].

In 2019, spring triticale was sown within the first 10 days of April. In general, the spring and summer of 2019 were hot and dry. The average daily air temperature in April, May, and June was by 1.9, 2.3, and 4.6°C higher than the long-term average, respectively. The average daily temperature in July was 21.4°C, which is close to the long-term average. The precipitation amount in April exceeded the long-term average by 9.0 mm; in May it was similar to the long-term average; and in June and July, it was significantly less than the long-term average (by 48.1 and 32.9 mm, respectively) (Table 1).

Table 1

Weather conditions during the spring triticale growing period, 2019–2021.

Month	2019	2020	2021	Long-term average
Precipitation amount, mm				
April	44.5	13.7	43.7	35.5
May	43.4	108.0	51.5	43.7
June	15.2	54.2	81.9	63.3
July	38.8	106.0	7.0	71.7
Air temperature, °C				
April	11.5	8.8	8.7	9.6
May	18.4	13.5	16.1	16.1
June	24.8	21.9	20.8	20.2
July	21.4	22.8	24.8	21.4

In 2020, triticale was sown in early April on insufficient wetting. Such conditions delayed the emergence of seedlings. In May 2020, 108.3 mm of precipitation fell, which was more than the long-term average by 64.6 mm. This provided the plants with a sufficient amount of water to complete the critical phases of development - stem extension and earing. In July, brief torrential rains with squally winds led to partial lodging of the crops.

In 2021, triticale was sown in the moist and sufficiently warmed soil within the third 10 days of April. The weather in the first half of 2021 was favorable for plant growth and development. A water reserve in the soil and sufficient wetting during the seed germination contributed to the even and timely emergence of seedlings. The important stages of plant development (tillering and earing) occurred on regular precipitation that exceeded the long-term average. Such conditions had a favorable effect on the formation of a thick and uniform plant stand. Grain setting and filling occurred during a significant drought and at high air temperatures, which negatively affected the grain size and plumpness.

Results and Discussion. By growing period, all studied cultivars were medium-ripening. This parameter ranged from 90 days (easily threshed cv. Volia Kharkivska) to 94 days (check cv. Darkhliba Kharkivskyi, cvs. Boryviter Kharkivskyi and Bulat Kharkivskyi) (Table 2).

The plant height of spring triticale cultivars was optimal (98–108 cm). Spring triticale 'Krypost Kharkivska' was the only cultivar with plants 84 cm tall and was classed as low-stemmed triticale.

The mean grain yield of the studied spring triticale cultivars ranged from 4.07 to 5.00 t/ha in 2019–2021. The yield of the check cultivar, Darkhliba Kharkivskyi, was 4.27 t/ha. A new, easily threshed cultivar (Svoboda Kharkivska), which has been tested within the qualification examination since 2022, yielded the most (5.00 t/ha, which was by 0.73 t/ha more than the yield harvested from the check cultivar). New cultivars, Opora Kharkivska and Kripost Kharkivska, which have been tested within the qualification examination since 2021, yielded slightly less: 4.74 t/ha and 4.61 t/ha, respectively, exceeding the check cultivar (Darkhliba Kharkivskyi) by 0.37 t/ha and 0. 24 t/ha, respectively. The lowest yields among the studied spring triticale cultivars were harvested from cvs. Dostatok Kharkivskyi (4.07 t/ha), Skarb Kharkivskyi (4.09 t/ha), and Zlit Kharkivskyi (4.14 t/ha), which were by 0. 13–0.18 t/ha less than the yield harvested from the check cultivar (>$LSD_{0.05}$) (see Table 2).

The thousand kernel weight ranged from 38.1 to 40.9 g in the investigated spring triticale cultivars. Cvs. Bulat Kharkivskyi, Boryviter Kharkivskyi, and Kripost Kharkivska had the greatest thousand kernel weight: 40.9, 40.9, and 40.2 g, respectively, which was by 1.8–2.5 g higher than that in the check cultivar (Darkhliba Kharkivskyi). The smallest value of this parameter was recorded for cv. Svoboda Kharkivska (38.1 g). The thousand kernel weight in the check cultivar (Darkhliba Kharkivskyi) was 38.4 g.

Table 2

Economic and technological features of the spring triticale cultivars (mean for 2019–2021)

Cultivar	Growing period, days	Plant height, cm	Yield, t/ha	Thousand kernel weight, g	Test weight, g/L	Vitreousness, %	Kernel hard-ness, N	Protein content in grain, %	Starch content in grain, %
Darkhliba Kharkivskyi (check cultivar)	94	105	4.27	38.4	744	43	118	12.9	58.6
Boryviter Kharkivskyi	94	108	4.28	40.9	745	43	121	13.0	58.2
Volia Kharkivska	90	107	4.23	39.1	729	34	106	12.8	58.7
Zlit Kharkivskyi	91	103	4.14	38.8	753	41	98	12.1	60.1
Bulat Kharkivskyi	94	105	4.40	40.9	751	47	98	12.4	60.0
Dostatok Kharkivskyi	93	106	4.07	38.6	727	45	101	11.9	60.0
Skarb Kharkivskyi	93	103	4.09	39.2	722	31	92	12.0	59.2
Kripost Kharkivska	92	84	4.61	40.2	717	49	90	12.0	58.5
Opora Kharkivska	91	100	4.74	39.3	739	42	105	12.6	58.7
Svoboda Kharkivska	92	98	5.00	38.1	734	38	109	12.4	58.9
$LSD_{0.05}$	2	5	0.12	0.8	7	4	7	0.2	0.3

The test weight in the spring triticale cultivars was high and varied ranged from 717 g/L to 753 g/L, depending on the cultivar. Cvs. Zlit Kharkivskyi (753 g/L) and Bulat Kharkivskyi (751 g/L) had the highest test weights. In cv. Boryviter Kharkivskyi, the test weight was similar to that in cv. Darkhliba Kharkivskyi (check cultivar) (745 g/L). The other cultivars (Kripost Kharkivska, Skarb Kharkivskyi, Dostatok Kharkivskyi, Volia Kharkivska, Svoboda Kharkivska, and Opora Kharkivska) had lower test weights compared to the check cultivar (717 - 739 g/L).

The vitreousness in the spring triticale cultivars was medium, ranging from 31% to 49%. This parameter was higher in cvs. Kripost Kharkivska Bulat Kharkivskyi (49% and 47%, respectively). The lowest vitreousness was detected in cvs. Skarb Kharkivskyi (31%) and Volia Kharkivska (34%).

By kernel hardness, the spring triticale cultivars were divided into two groups: soft (104–132 N) (50%) and very soft (< 104 N) (50%). The soft group included cvs. Boryviter Kharkivskyi (121 N), Darkhliba Kharkivskyi (118 N), Svoboda Kharkivska (109 N), Volia Kharkivska (106 N), and Opora Kharkivska (105 N); cvs. Dostatok Kharkivskyi (101 N), Zlit Kharkivskyi (98 N), Bulat Kharkivskyi (98 N), Skarb Kharkivskyi (92 N), and Kripost Kharkivska (90 N) were referred to the very soft group (see Table 2).

The nutritional value of all cereals is determined by the total contents of protein and starch in grain [22]. The protein content in grain of the investigated spring triticale cultivars ranged from 11.9% to 13.0%. The protein contents in grain of cvs. Boryviter Kharkivskyi (13.0%) and Volia Kharkivska (12.8%) were similar to that in the check cultivar (Darkhliba Kharkivskyi) ($LSD_{0.05}$ was 0.2%). The other cultivars had lower protein contents in grain.

We identified spring triticale cultivars, in which the starch content in grain was higher than in the check cultivar (Darkhliba Kharkivskyi): Zlit Kharkivskyi (60.1%), Dostatok Kharkivskyi (60.1%), Bulat Kharkivskyi (60%), Skarb Kharkivskyi (59.2%), and Svoboda Kharkivska (58.9%). In cvs. Opora Kharkivska (58.7%), Volia Kharkivska (58.7%), and Kripost Kharkivska (58.5%), this parameter was similar to that in the check cultivar ($LSD_{0.05}$ within 0.3%). Cv. Boryviter Kharkivskyi had the lowest starch content in grain (58.2%) or by 0.4% less compared to the check cultivar (Darkhliba Kharkivskyi).

The gluten content in flour and gluten quality are crucial for the technological properties of spring triticale. All studied cultivars contained less gluten (18.3–22.0% than bread wheat 'Kharkivska 30' (27.5%) (Table 3).

Table 3

Technological properties of flour and bread quality of the spring triticale cultivars (mean for 2019–2021)

Cultivar	Gluten		Flour strength (W-index)	Dough			Bread	
	Content in flour, %	GDI, units		Resilience (P), mm	Exrencibility (L), mm	Equilibrium (P/L)	Loaf volume, mm^3	Total bread-making score, points
Darkhliba Kharkivskyi (check cultivar)	18.3	82	154	69	55	1.3	487	8.8
Boryviter Kharkivskyi	18.5	80	100	50	60	0.9	460	8.3
Volia Kharkivska	22.0	82	98	44	64	0.7	457	8.5
Zlit Kharkivskyi	20.3	80	115	46	74	0.6	437	8.2
Bulat Kharkivskyi	20.0	73	118	49	70	0.7	400	7.4
Dostatok Kharkivskyi	19.8	73	112	66	54	1.2	473	8.2
Skarb Kharkivskyi	16.8	62	109	54	66	0.8	470	8.2
Kripost Kharkivska	17.7	75	92	52	53	1.0	500	8.6
Opora Kharkivska	18.0	72	95	54	63	0.9	410	7.8
Svoboda Kharkivska	19.2	70	68	35	55	0.6	427	8.0
Bread wheat 'Kharkivska 30'	27.5	75	183	68	88	0.7	600	8.5
$LSD_{0.05}$	1.1	4	18	7	5	0.2	24	0.3

It was established that, when the gluten content in flour was increased content, its quality more often corresponded to a worse group. Cv. Volia Kharkivska had the highest gluten content in flour (22.0%), but the gluten deformation index (GDI) was 82 units (satisfactorily weak gluten), which meant quality group II. Cvs. Zlit Kharkivskyi, Bulat Kharkivskyi, and Dostatok Kharkivskyi contained less gluten (20.3. 20.0, and 19.8%, respectively) with GDI of 80 (quality group II, satisfactorily weak gluten), 73 and 73 units (quality group I, good gluten), respectively. In the new cultivars, Skarb Kharkivskyi, Kripost Kharkivska, Opora Kharkivska, and Svoboda Kharkivska, the gluten content ranged from 16.8% to 19.2% and the gluten quality corresponded to group I (good gluten). In cvs. Boryviter Kharkivskyi and Darkhliba Kharkivskyi, the gluten content was 18.5% and 18.3%, respectively and their gluten was in quality group II (satisfactorily weak).

Alveographic determination of the physical properties of dough showed that the spring triticale cultivars differed in flour strength. This parameter ranged from 68 to 154 among the studied cultivars. The highest flour strength was recorded for the check cultivar (Darkhliba Kharkivskyi, 154). Cvs. Zlit Kharkivskyi, Bulat Kharkivskyi, and Dostatok Kharkivskyi had flour strength of 109–118. Cvs. Kripost Kharkivska, Opora Kharkivska, Volia Kharkivska, and Boryviter Kharkivskyi had flour strength of 92–100. The lowest value of this parameter was noted in cv. Svoboda Kharkivska (68) (see Table 3).

Dough resilience (P) is the maximum pressure that is created inside the dough at the moment of its mechanical destruction when it is inflated in the shape of a bubble; resilience characterizes the resistance that the gluten in the yeast dough offers during fermentation and rising. Dough extensibility (L) is the diameter of the dough bubble when it is broken; it is an inverse characteristic to resilience. Dough equilibrium (P/L) is one of the most important indicators that determine the bread-making qualities of spring triticale cultivars. In terms of resilience and extensibility, the studied spring triticale cultivars were diverse. The resilience in the spring triticale cultivars ranged from 35 mm to 69 mm; the extensibility was from 53 to 74 mm. The highest P/L ratio was recorded for the check cultivar (Darkhliba Kharkivskyi (P/L=1.3; P = 69 mm; L = 55 mm). Cvs. Dostatok Kharkivskyi and Kripost Kharkivska had P/L of 1.2 (P = 66 mm; L = 54 mm) and 1.0 (P = 52 mm; L = 53 mm), respectively. P/L was at the lowest level in cvs. Volia Kharkivska, Bulat Kharkivskyi, Zlit Kharkivskyi, and Svoboda Kharkivska (0.6–0.7).

The loaf volume in the spring triticale cultivars under investigation ranged from 400 mm^3 to 500 mm^3. The best volume was recorded for cvs. Krypost Kharkivska (500 mm^3), Darkhliba Kharkivskiy (reference for the bread-making qualities; 487 mm^3), Dostatok Kharkivskyi (473 mm^3), and Skarb Kharkivskyi (470 mm^3). This parameter was lower in cvs. Boryviter Kharkivskyi and Volia Kharkivska: 460 and 457 mm^3, respectively. The smallest loaf volume was noted in cvs. Bulat Kharkivskyi (400 mm^3) and Opora Kharkivska (410 mm^3).

The total bread-making scores of the spring triticale cultivars were quite high and amounted to 7.4–8.8 points. The reference for the bread-making qualities, Darkhliba Kharkivskyi, had the highest total bread-making score of 8.8 points. This parameter was the lowest in cvs. Bulat Kharkivskyi (7.4 points) and Opora Kharkivska (7.8 points). The other cultivars (Svoboda Kharkivska, Skarb Kharkivskyi, Dostatok Kharkivskyi, Zlit Kharkivskyi, Boryviter Kharkivskyi, Volia Kharkivska, and Kripost Kharkivska) had the total bread-making scores of 8.0–8.6 points (see Table 3).

Analysis of correlation coefficients showed that the spring triticale plant height was negatively correlated with yield (r = –0.68) and thousand kernel weight (r = –0.30) in 2019–2021. At the same time, the plant height was moderately and positively correlated (r = 0.30–0.50) with GDI, crude gluten content in flour, protein content in grain, dough resilience and extensibility, flour strength, and kernel hardness (Table 4).

The grain yield was moderately correlated with thousand kernel weight (r = 0.55). As to the other parameters, the correlations between them and yield were negative. In particular, there was a strong negative correlation between yield and flour strength (r = –0.64) and between yield and dough resilience (r = –0.51). There was a negative correlation between yield and starch content in grain (r = –0.39), between yield and loaf volume (r = –0.38), and between yield and dough extensibility (r = –0.34).

There was an inverse correlation between thousand kernel weight and kernel hardness and between thousand kernel weight and plant height (r = –0.46 and –0.30, respectively). However, the correlations between thousand kernel weight and dough extensibility and between thousand kernel weight and flour strength were direct and weak (r = 0.30).

Kernel vitreousness was moderately correlated with GDI (r = 0.37), dough resilience (r = 0.32), and crude gluten content in flour (r = 0.30).

There were moderate or strong correlations between protein content in grain and quality parameters and economic characteristics (r = 0.39–0.85). For example, protein content in grain was strongly correlated with kernel hardness (r = 0.85). There was a moderate correlation between protein content in grain and plant height (r = 0.39), between protein content and test weight (r = 0.43), and between protein content and GDI (r = 0.54). There was a negative correlation between protein content and starch content in grain (r = –0.64).

The starch content in grain had significant negative correlations with protein content in grain (r = –0.64), kernel hardness (r = –0.47), total bread-making score (r = –0.46), yield (r = – 0.39), and loaf volume (r = –0.31). There was a direct correlation between starch content in grain and dough extensibility (r = 0.46), between starch content and gluten content in flour (r = 0.46), and between starch content and test weight (r = 0.30) (Table 4).

Table 4

Correlations between the grain flour, dough, and bread quality parameters and economic characteristics of the spring triticale cultivars (mean for 2019–2021)

Sequential number	Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Plant height, cm	1														
2	Yield, t/ha	-0.68	1													
3	Thousand kernel weight, g	-0.30	0.55	1												
4	Test weight, g/L				1											
5	Vitreousness, %					1										
6	Protein content, %	0.39			0.43		1									
7	Starch content, %		-0.39		0.30		-0.64	1								
8	Gluten content, %	0.41			0.31	0.30		0.36	1							
9	GDI, units	0.31			0.40	0.37	0.54		0.53	1						
10	Dough resilience, mm	0.30	-0.51			0.32			-0.32		1					
11	Dough extensibility, mm	0.41	-0.34	0.30	0.54			0.46			-0.32	1				
12	Flour strength (W-index)	0.50	-0.64	0.30	0.39					0.33	0.76		1			
13	Loaf volume, mm^3		-0.38		-0.59			-0.31	-0.30		0.50	-0.57		1		
14	Total bread-making score, points				-0.35			-0.46		0.51	0.30	-0.47		0.86	1	
15	Kernel hardness, N	0.45		-0.46	0.45		0.85	-0.47		0.49						1

There were direct or inverse correlations between gluten content in flour and seven parameters. Thus, there was a close correlation between gluten content and gluten quality (r = 0.53). There was a moderate direct correlation between gluten content in flour and plant height (r = 0.41), between gluten content in flour and starch content in grain (r = 0.36), between gluten content and test weight (r = 0.31), and between gluten content and vitreousness (r = 0.30). Gluten content was negatively correlated with dough resilience (r = –0.32) and loaf volume (r = –0.30).

The gluten quality had only positive direct correlations with eight economic characteristics and quality parameters: plant height, flour strength, vitreousness, test weight, kernel hardness, total bread-making score, gluten content in flour, and protein content in grain (the correlation coefficients increased in order of listing from 0.30 to 0.54).

Dough resilience had eight significant direct or inverse correlations with different features. Thus, there was a direct correlation between dough resilience and flour strength (r = 0.76), between dough resilience and loaf volume (r = 0.50), between dough resilience and kernel vitreousness (r = 0.32), between dough resilience and total bread-making score (r = 0.30), and between dough resilience and plant height (r = 0.30). There were negative correlations in three cases: between dough resilience and yield (r = –0.51), between dough resilience and gluten content in flour (r = –0.32), and between dough resilience and dough extensibility (r = –0.32).

Dough extensibility had eight relationships with quality parameters and economic characteristics. Of them, there were four direct moderate or strong correlations: with test weight (r = 0.54), starch content in grain (r = 0.46), plant height (r = 0.41), and thousand kernel weight (r = 0.30). Dough extensibility was inversely correlated with loaf volume (r = –0.57), total bread-making score (r = –0.47), yield (r = –0.34), and dough resilience (r = –0.32).

Flour strength was moderately correlated with plant height (r = 0.50), test weight (r = 0.39), GDI (r = 0.33), and thousand kernel weight (r = 0.30). There was a strong correlation between flour strength and dough resilience (r = 0.76). There was an inverse correlation between flour strength and yield (r = –0.64).

There was a moderate direct correlation between loaf volume and dough resilience (r = 0.50). Other parameters (test weight, dough extensibility, yield, starch content in grain, gluten content in flour) were negatively correlated with loaf volume (r = –0.59, –0.57, –0.38, –0, 31 and –0.30, respectively).

Three parameters had direct correlations with the total bread-making score: loaf volume (r = 0.86), gluten quality (r = 0.51), and dough resilience (r = 0.30). There was a negative correlation between total bread-making score and dough extensibility (r = –0.47), between total bread-making score and starch content in grain (r = –0.46), and between total bread-making score and test weight (r = –0.35).

Kernel hardness had moderate or strong direct correlations with four parameters: protein content in grain (r = 0.85), gluten quality (r = 0.49), test weight (r = 0.45), and plant height (r = 0.45). Kernel hardness was moderately and inversely correlated with starch content in grain (r = –0.47) and thousand kernel weight (r = –0.46).

Conclusions. The 2019–2021 studies showed that the grain yields of the spring triticale cultivars ranged from 4.07 to 5.00 t/ha. By growing period, the cultivars were medium-ripening (90–94 days). The plant height ranged from 84 to 108 cm.

Analysis of the technological quality of spring triticale showed that the studied cultivars had dense grain (test weight = 717–753 g/L); the thousand kernel weight was 38.1–40.9 g; the protein content in grain was 11.9–13.0%; and the starch content was 58.2–60.1%. In our studies, the spring triticale cultivars had flour strength (W-index) of 68–154, dough resilience (P) of 35–69 mm, dough extensibility (L) of 53–74 mm, and dough equilibrium (P/L) of 0.6–1.3. The volumes of loaves baked from flour of these triticale cultivars were 400-500 mm^3, with the total bread-making scores of 7.4-8.8 points. Flour from the triticale cultivars contained 17.7–22.0% of gluten with GDI of 62–82 units.

Correlation analysis showed that three parameters had direct correlations with total bread-making score: loaf volume (r = 0.86), gluten quality (r = 0.51), and dough resilience (r = 0.30).

The following parameters were negatively correlated with total bread-making score: dough extensibility (r = –0.47), starch content in grain (r = –0.46), and test weight (r = –0.35).

Grain yield was moderately correlated with thousand kernel weight (r = 0.55). The other parameters were negatively correlated with yield. In particular, there was a strong negative correlation between yield and flour strength (r = –0.64) and between yield and dough resilience (r = –0.51). There was a negative correlation between yield and starch content in grain (r = –0.39), between yield and loaf volume (r = –0.38), and between yield and dough extensibility (r = –0.34).

The results obtained give reasons to claim breeding aimed at improving bread-making qualities of spring triticale can be effective and, provided certain technological characteristics, it is possible to make nutritious bread of high quality.

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CHARACTERISTICS OF SPRING TRITICALE CULTIVARS BRED AT THE YURIEV PLANT PRODUCTION INSTITUTE OF NAAS

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Purpose. The purpose of 2019-2021 studies was **t**o evaluate and compare morphobiological and technological features of the registered and new spring triticale cultivars bred at the Yuriev Plant Production Institute of NAAS of Ukraine.

Materials and Methods. Ten registered and new spring triticale cultivars were screened for economic characteristics and technological properties. The field evaluations were carried out in accordance with methods of qualification examination of plant varieties. The laboratory tests included determination of the technological properties of grain, flour, and bread.

Results and Discussion. By growing period, all cultivars were medium-ripening (from 90 days in cv. Volia Kharkivska) to 94 days (in cvs. Darkhliba Kharkivskyi (check cultivar), Boryviter Kharkivskyi, and Bulat Kharkivskyi).

The plant height in the spring triticale cultivars was optimal (98–108 cm). Spring triticale 'Krypost Kharkivska' was the only cultivar with a plant height of 84 cm (low-stemmed triticale).

The yield ranged from 4.07 to 5.00 t/ha. Cv. Svoboda Kharkivska yielded the most (5.00 t/ha or by 0.73 t/ha more than the check cultivar). Cvs. Opora Kharkivska and Kripost Kharkivska yielded 4.74 and 4.61 t/ha, respectively, or by 0.37 and 0.24 t/ha more, than the check cultivar (Darkhliba Kharkivskyi), respectively.

The thousand kernel weight varied from 38.1 to 40.9 g. The highest weight of one thousand kernels was registered for cvs. Bulat Kharkivskyi, Boryviter Kharkivskyi, and Kripost Kharkivska (40.9, 40.9, and 40.2 g, respectively, or by 1.8–2.5 g more than that in the check cultivar (Darkhliba Kharkivskyi).

The test weight in the spring triticale cultivars was high: from 717 to 753 g/L. Cvs. Zlit Kharkivskyi (753 g/L) and Bulat Kharkivskyi (751 g/L) had the highest test weights. In cv. Boryviter Kharkivskyi, this parameter (745 g/L) was similar to that in the check cultivar (Darkhliba Kharkivskyi).

The kernel vitreousness of the spring triticale cultivars was moderate, ranging from 31 to 49%. Cvs. Krypost Kharkivska and Bulat Kharkivskyi had the highest values of this parameter (49 and 47%, respectively).

By kernel hardness, cvs. Boryviter Kharkivskyi (121 N), Darkhliba Kharkivskyi (118 N), Svoboda Kharkivska (109 N), Volia Kharkivska (106 N), and Opora Kharkivska (105 N) were classed as soft; cvs. Dostatok Kharkivskyi (101 N), Zlit Kharkivskyi (98 N), Bulat Kharkivskyi (98 N), Skarb Kharkivskyi (92 N), and Kripost Kharkivska (90 N) - as very soft.

The protein content in cvs. Boryviter Kharkivskyi (13.0%) and Volia Kharkivska (12.8%) was similar to that in Darkhliba Kharkivskyi (check cultivar). We identified cultivars in which the starch content in grain was higher than that in the check cultivar (Darkhliba Kharkivskyi): Zlit Kharkivskyi (60.1%), Dostatok Kharkivskyi (60.0%), Bulat Kharkivskyi (60.0%), Skarb Kharkivskyi (59.2 %), and Svobods Kharkivska (58.9%).

Cv. Volia Kharkivska had the highest gluten content in flour (22.0%), with GDI of 82 units (quality group II). Cvs. Zlit Kharkivskyi, Bulat Kharkivskyi, and Dostatok Kharkivskyi had lower gluten contents (20.3, 20.0 and 19.8%, respectively) with GDI of 80 units (quality group II), 73 and 73 units (quality group I), respectively.

The flour strength (W-index) varied from 68 to 154. The check cultivar (Darkhliba Kharkivkyi) had the strongest flour (154). In cvs. Zlit Kharkivskyi, Bulat Kharkivskyi, and Dostatok Kharkivskyi, the flour strength was 109–118; in cvs. Kripost Kharkivska, Opora Kharkivska, Volia Kharkivska, and Boryviter Kharkivskyi, the flour strength was 92–100.

The dough resilience (P) in the spring triticale cultivars ranged from 35 to 69 mm; the dough extensibility (L) - from 53 to 74 mm. The highest ratioo P/L was registered for cv. Darkhliba Kharkivskyi (1.3). Cvs. Dostatok Kharkivskyi and Kripost Kharkivska had P/L of 1.2 and 1.0, respectively.

The loaf volume in the spring triticale cultivars ranged from 400 to 500 mm^3. The best loaf volume was achieved with cvs. Krypost Kharkivska (500 mm^3), Darkhliba Kharkivskyi (reference; 487 mm^3), Dostatok Kharkivskyi (473 mm^3), and Skarb Kharkivskyi (470 mm^3).

The total bread-making score of the spring triticale cultivars was 7.4–8.8 points. Cv. Darkhliba Kharkivskyi (reference) had the highest total bread-making score of 8.8 points. The lowest bread-making scores were noted in cvs. Bulat Kharkivskyi (7.4 points) and Opora Kharkivska (7.8 points).

Correlation analysis showed that three parameters had direct correlations with total bread-making score: loaf volume (r = 0.86), gluten quality (r = 0.51), and dough resilience (r = 0.30). There was a negative correlation between total bread-making score and dough extensibility (r = –0.47), between total bread-making score and starch content in grain (r = –0.46), and between total bread-making score and test weight (r = –0.35).

Grain yield was moderately correlated with thousand kernel weight (r = 0.55). The correlations between yield and the other parameters were negative. In particular, there was a strong negative correlation between yield and flour strength (r = –0.64) and between yield and dough resilience (r = –0.51). There was a negative correlation between yield and starch content in grain (r = –0.39), between yield and loaf volume (r = –0.38), and between yield and dough extensibility (r = –0.34).

Key words*: spring triticale, cultivar, quality, yield, correlation*

ХАРАКТЕРИСТИКА СОРТІВ ТРИТИКАЛЕ ЯРОГО СЕЛЕКЦІЇ ІНСТИТУТУ РОСЛИННИЦТВА ІМЕНІ В.Я. ЮР'ЄВА НААН

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Мета дослідження. Метою досліджень 2019–2021 рр. було оцінити та порівняти господарські та технологічні особливості зареєстрованих та нових сортів тритикале ярого селекції Інституту рослинництва імені В.Я. Юр'єва НААН України.

Матеріали та методи. Матеріалом досліджень були 10 зареєстрованих та нових сортів тритикале ярого, які було оцінено за господарськими особливостями та технологічними властивостями. Польові оцінки проводили за методикою кваліфікаційної експертизи сортів рослин. Лабораторні дослідження включали оцінку технологічних властивостей зерна, борошна та хліба за рядом ознак.

Результати та обговорення. За вегетаційним періодом усі сорти належать до групи середньостиглих (від 90 діб (сорт Воля харківська) до 94 діб (еталон Дархліба харківський, Боривітер харківський та Булат харківський).

Висота рослин сортів тритикале ярого – оптимальна (98–108 см). Лише сорт тритикале ярого Кріпость харківська мав висоту 84 см (низькостеблові тритикале).

Урожайність варіювала від 4,07 до 5,00 т/га. Найбільшу врожайність мав сорт Свобода харківська – 5,00 т/га, що перевищує еталон на 0,73 т/га. Сорти Опора харківська та Кріпость харківська мали врожайність 4,74 та 4,61 т/га відповідно, що перевищує еталон Дархліба харківський на 0,37 та 0,24 т/га відповідно.

Маса 1000 зерен становила від 38,1 до 40,9 г. Найбільшу масу 1000 зерен мали сорти Булат харківський, Боривітер харківський та Кріпость харківська – 40,9, 40,9 та 40,2 г відповідно, що перевищувало еталон Дархліба харківський на 1,8–2,5 г.

Натура зерна сортів тритикале ярого була високою – від 717 до 753 г/л. Найбільшу натуру зерна мали Зліт харківський (753 г/л) та Булат харківський (751 г/л). Даний показник у сорту Боривітер харківський був на рівні еталону Дархліба харківський і становив 745 г/л.

Склоподібність сортів тритикале ярого була середньою (від 31 до 49 %). Найбільшим даний показник був у сорту Кріпость харківська та сорту Булат харківський – 49 і 47 % відповідно.

За твердістю зерна до групи м'якозерні було віднесено Боривітер харківський (121 Н), Дархліба харківський (118 Н), Свобода харківська (109 Н), Воля харківська (106 Н) та

Опора харківська (105 Н); до дуже м'якозерних – Достаток харківський (101 Н), Зліт харківський та Булат харківський (по 98 Н відповідно), Скарб харківський (92 Н) та Кріпость харківська (90 Н).

Вміст білка на рівні еталону Дархліба харківський мали Боривітер харківський (13,0 %) та Воля харківська (12,8 %). Виявлено сорти, в яких вміст крохмалю в зерні більший, ніж у еталону Дархліба харківський – Зліт харківський (60,1 %), Достаток харківський (60,0 %), Булат харківський (60,0 %), Скарб харківський (59,2 %), Свобода харківська (58,9 %).

Найбільший вміст клейковини у борошні мав сорт Воля харківська – 22,0 %, ІДК – 82 од. (ІІ група якості). Нижчий вміст клейковини мали сорти Зліт харківський, Булат харківський та Достаток харківський – 20,3, 20,0 та 19,8 % відповідно, ІДК – 80 од. (ІІ група якості), 73 та 73 од. відповідно (І група якості).

Сила борошна варіювала від 68 до 154 о.а. Найбільшою вона була у еталону Дархліба харківський – 154 о.а.; Зліт харківський, Булат харківський та Достаток харківський – 109–118 о.а., Кріпость харківська, Опора харківська, Воля харківська та Боривітер харківський – 92–100 о.а.

Пружність сортів (Р) тритикале ярого становила від 35 до 69 мм, розтяжність (L) – від 53 до 74 мм. Найбільшим співвідношення P/L було у еталону Дархліба харківський – 1,3. Сорти Достаток харківський та Кріпость харківська мали збалансованість 1,2 та 1,0 відповідно.

Об'ємний вихід хліба тритикале ярого становив від 400 до 500 мл. Кращий об'єм хліба був у сортів Кріпость харківська, еталону Дархліба харківський, Достаток харківський та Скарб харківський.

Загальна хлібопекарська оцінка тритикале ярого становила 7,4–8,8 балів. Еталон Дархліба харківський мав найвищий рівень загальної хлібопекарської оцінки – 8,8 балів. Найменшим даний показник був у сортів Булат харківський (7,4 балів) та Опора харківська (7,8 балів).

Загальна хлібопекарська оцінка позитивно корелювала з показниками об'єму хліба ($r = 0,86$), якості клейковини ($r = 0,51$) та пружності тіста ($r = 0,30$). Встановлено зворотні кореляції між загальною хлібопекарською оцінкою та показниками розтяжності тіста ($r = –0,47$), вмісту крохмалю в зерні ($r = –0,46$) та натури зерна ($r = –0,35$).

Урожайність зерна мала тісну середню кореляцію з масою 1000 зерен ($r = 0,55$). Водночас показник врожайності перебував у зворотній кореляції з силою борошна ($r = –0,64$) та пружністю тіста ($r = –0,51$).

Ключові слова: *тритикале яре, сорт, якість, урожайність, кореляція.*