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ADAPTABILITY AND STABILITY OF NEW SPRING TRITICALE VARIETIES AND LINES

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The article presents results of environmental trials of 13 spring triticale varieties and lines in two environments differing in agro-climatic conditions. The yield stability and valuable economic features were assessed; the best genotypes with several valuable features were identified. A high yield capacity (6.85–7.44 t/ha) and high plasticity (bi 1.34−1.82) were recorded for Darkhliba Kharkivkyi, Svoboda Kharkivska, YATKH 23-19, YATKH 29-19, and YATKH 40-19, indicating their ability to effectively realize the performance potential under favorable conditions. A higher stability in terms of adaptability (general and specific adaptive ability, relative stability) was intrinsic to Svoboda Kharkivska, Kripost Kharkivka, and Opora Kharkivska. These varieties can be recommended for growing under different conditions throughout Ukraine to a wide range of producers. Of the lines, the highest breeding value was registered for YATKH 23-19 and YATKH 40-19. The selected accessions are also valuable material in breeding for yield capacity and adaptability.

***Key words**: spring triticale, yield capacity, adaptability, stability, variety, line*

Introduction. In agricultural production, spring triticale ranks important among cereals. Modern spring triticale varieties give high yields and show good grain quality as well as resistance to bio- and abiotic environmental factors. First of all, the adaptive features of this crop, such as less strict exigencies for forecrops, sowing time and soil type, allow for grain production in areas unsuitable for wheat or barley. High cold tolerance in many cases allows one to plant triticale in late autumn, after the timeframe advisable for winter wheat. In the south of Ukraine, it is possible to sow spring triticale at the earliest possible time during the "February windows", which significantly reduces the negative impact of droughts. Spring triticale is the best option for reseeding winter crops, as the biochemical properties of grain allow harvesting high quality grain, both for fodder and for food [1].

Spring triticale has been bred at the Plant Production Institute named after V.Ya. Yuriev of NAAS (PPI) since the 1970s. During this period, 23 spring triticale varieties were created: with high bread-making scores (Aist Kharkivkyi, Khlibodar Kharkivskyi, Darkhliba Kharkivskyi, Zlit Kharkivskyi), increased resistance to diseases such as septoria tritici blotchand brown leaf rust (Solovey Kharkivskyi, Lebid Kharkivskyi, Husar Kharkivskyi), lodging resistance (Sontsedar Kharkivskyi, Boryviter Kharkivskyi, Opora Kharkivska, Kripost Kharkivska), easy threshing (Volia Kharkivska, Svoboda Kharkivska), etc. Today, the Register of Plant Varieties Suitable for Dissemination in Ukraine includes 17 spring triticale varieties and 11 of them were bred at the PPI [2].

The breeding mainstreams are high and stable yields, good bread-making and mixing scores, high nutritional value of fodder grain, suitability for environmentally friendly production. Given that spring triticale fields cover all natural and climatic zones of Ukraine and that many of them are located in areas with unstable or insufficient wetting, frequent droughts during the spring triticale growing period remain the main factor reducing yields. Therefore, special attention in breeding is paid to creating varieties with increased drought resistance and high adaptability to abiotic environmental factors [3].

Literature review and problem articulation. Environmental trials allowing for quick assessments of genotypes' responses to different environmental conditions are a very effective method of field evaluation of the adaptability of breeding material. This helps to speed up the breeding process due to objective selection of starting material depending on breeding purpose and growing regions. In many countries, where spring triticale is grown, varieties are routinely tested under different agroclimatic conditions with further recommendations for their zoning. This allows farmers to select varieties that would be the most acceptable for certain conditions and end products from a great assortment of varieties and to optimize their territorial distribution.

In Europe, Poland and Germany are the leaders in triticale production. Varieties created in these countries are highly adaptable and essential in the fodder industry [4]. Winter varieties Pizzaro and Subitto proved to be the most suitable for organic farming in Poland [5]. Canadian spring triticale varieties AC Ultima, Bunker, Pronghorn, and Tazata Tyndal turned out to be good for green fodder and silage production in Western Canada, where the bulk of livestock is concentrated [6]. As to grain production in the Canadian prairies, spring variety Brevis is well adapted, as it gives high grain yields, demonstrates increased resistance to diseases and its plants are relatively short [7]. Green mass of spring triticale varieties of Camelot, Pacheco and TRICAL BRAND 118 was shown to be excellent for forage production in California (USA). They are most suitable for growing in the Central Valley of California, SouthCentralCoast and southern Californian deserts [8]. In the arid highlands of northwestern China, CIMMYT's Mexican lines gave much greater yields than a local control accession. In Turkey, 25 spring triticale lines and varieties were studied in three subregions of Southern Anatolia and six breeding genotypes that can be grown in this region were identified [10]. In the North-Eastern Forest-Steppe of Ukraine Boryviter Kharkivskyi, Husar Kharkivskyi and Zlit Kharkivskyi were studied and Husar Kharkivskyi was shown to the best variety in terms of growth, development and yield [11].

For many years, the PPI has been using environmental trials for evaluation of breeding material. Annually, the best lines are tested in two natural and climatic zones: in the Eastern Forest-Steppe at the PPI and in the transitional zone from the Southern Forest-Steppe to the Steppe at Ustymivka Experimental Station of Plant Production (UESPP).

Purpose and objectives. The purpose was to evaluate the adaptability and stability of spring triticale varieties and breeding lines for yield and expression of valuable economic characteristics in environmental trials and to identify the best genotypes with a set of valuable features.

Materials and methods. Thirteen spring triticale genotypes were studied in the environmental trials: varieties Darkhliba Kharkivskyi, Dostatok Kharkivskyi, Kripost Kharkivska, Opora Kharkivska, Svoboda Kharkivska, Skarb Kharkivskyi, and Bulat Kharkivskyi as well as lines YATKH 22-19, YATKH 23-19, YATKH 29-19, YATKH 29-19, YATKH -19, YATKH 58-19, and YATKH 153-18.

The study was conducted in two different agroclimatic environments in 2020–2021. Black fallow was predecessor. The experimental plots of 2 m^2 in three replications were arranged in series. The field assessments were carried out in accordance with the requirements for qualification examination of plant varieties [12]. The plant height was measured; the vegetation phase onsets (seedlings, tillering, earing, ripening) were registered; lodging resistance was assessed. Disease-inflicted damage was determined with a 9-point scale as percentage of affected area in accordance with the CMEA's international classification [13]. The adaptability parameters (general adaptability (GA), variance of specific adaptability (SA), relative stability (Sgi), genotype's breeding value (GBV) were determined by A.V. Kilchevskiy and L.V. Khotylyova's method [14]. To determine the significance of differences, we used two-factor analysis of variance, as B.A. Dospekhov described [15].

The PPI's breeding base is located in the Eastern Forest-Steppe of Ukraine (Kharkivska Oblast, Kharkivskyi District). The climate in the study location is temperate continental. The average annual air temperature is 6°C. The summer months are warm enough: the long-term average air temperature in June is 19.1°C, in July - 21.0°C, in August − 19.7°C. The soil is powerful slightly leached chernozem on dust-loamy loess; the humus layer is ≥75 cm thick and contains 5.5–7.3% of humus; this soil has an agronomically valuable granular-lumpy structure, good physical and mechanical properties, and large reserves of available nutrients. Soil solution is weakly acidic (pH = 5.7–6.0).

UESPP is located in the transitional area, from the forest-steppe to the steppe (Poltavska Oblast, Hlobinskyi District). The climate is temperate continental with unstable wetting, cold winters, hot and often dry summers. The average annual air temperature is 8.2°C; the maximum temperature is 38°C (in July). The annual precipitation amount ranges 430 to 480 mm. The soil is medium-loamy powerful chernozem with a humus content of up to 3.84%.

In 2020, the PPI sowed in early April under water deficit. Such conditions delayed in the seedling emergence. At the same time, seedlings were even, with a satisfactory density. In May 2020, the precipitation amount was 108.3 mm, which is by 64.6 mm more than the long-term average (Table 1). This provided the plants with enough water to go through the critical phases of development − stem elongation and earing. Rainfall flurries in July accompanied by strong winds led to partial lodging of plants, which allowed us to differentiate genotypes by lodging resistance.

Table 1

Weather during the spring triticale growing period, 2020–2021

Month	PPI			UESPP		
	2020	2021	Long-term average	2020	2021	Long-term average
			Precipitation amount, mm			
April	13.7	43.7	35.5	11.9	27.0	44.0
May	108.0	51.5	43.7	81.2	64.3	50.0
June	54.2	81.9	63.3	27.7	101.0	57.0
July	106.0	7.0	71.7	31.4	37.8	72.0
			Air temperature, °C			
April	8.8	8.7	9.6	10.8	9.1	8.9
May	13.5	16.1	16.1	14.8	16.7	15.9
June	21.9	20.8	20.2	23.8	21.7	19.5
July	22.8	24.8	21.4	24.0	25.9	21.0

The weather in 2020 at UESPP was periodically dry and waterlogged during the spring triticale vegetation. Spring triticale was sown in sufficiently wet and warmed soil within the third 10 days of March. There was insufficient precipitation in April (11.9 mm or 27% related to the long-term average) coupled with elevated air temperature, which made stems uneven. May was waterlogged (81.2 mm vs. the long-term average of 50 mm). Sufficient wetting contributed to the formation of long multi-flowered ears. *Septoria tritici blotch*was observed on plants under the natural conditions. June, in which had the earing, anthesis and grain filling occurred, was dry and hot. The air temperature was by 4.3°C higher than the long-term average. The precipitation amount was 27 mm, which was by 29.3 mm less than the long-term average.

In 2021 at the PPI, spring triticale was sown in wet and sufficiently warmed soil within the third 10 days of April. The weather during the first half of 2021 was favorable for the plant growth and development. Soil water reserves and sufficient wetting during seed germination ensured the uniform and timely emergence of seedlings. Important stages of the plant development, tillering and earing, occurred under uniform rainfall exceeding the long-term average.

Such conditions positively influenced the formation of dense and uniform haulm stand, allowing us to assess genotypes by plant habitus, size and flower number per ear. Seed setting and filling was accompanied by significant drought and high air temperatures, which negatively affected the grain size and plumpness.

In 2021 at UESPP, spring triticale was sown within the second 10 days of April. There was insufficient precipitation in April: 27 mm, which was by 17 mm less than the long-term average. May and June were wet with temperatures close to the long-term averages, which positively affected the plant growth and development, but led to the development of diseases (*Septoria tritici blotch*). July was hot and rainy. The precipitation amount was 37.8 mm, which was 52.5% related to the long-term average. The air temperature was by 4.9°C higher than the long-term average. Such conditions during the seed filling and ripening made seeds smaller.

Thus, the weather in the study years differed in air temperature and rainfall. Particularly contrasting conditions in terms of impact on plants were registered during the earing phase in 2020 and during the seedling and tillering phases in 2021 (UESPP – unfavorable; PPI – favorable). The conditions during the seed filling in 2020 and 2021 were unfavorable at the both locations. This allowed us to assess the yield stability under the influence of environmental conditions.

Results and discussion. On average across to the study years, the spring triticale yields were higher at UESPP (5.56 t/ha) (Table 2).
Under favorable conditions in 2020, the yield was 6.04–7.44 t/ha. Of the varieties, the highest yields were produced by Darkkhliba Kharkivskyi (6.85 t/ha) and Svoboda Kharkivska (6.95 t/ha). Of the lines, high yields were given by YATKH 40-19 (7.44 t/ha), YATKH 29-19 (7.09 t/ha), and YATKH 23-19 (7.04 t/ha). In 2021, at this test site, the yields from the studied accessions ranged 4.60 t/ha to 6.65 t/ha. Of the varieties, the highest yields were produced by Darkkhliba Kharkivskyi (6.65 t/ha) and Svoboda Kharkivska (6.33 t/ha) in the 2nd consecutive year. Of the lines in 2021, YATKH 153-18 (6.10 t/ha) and YATKH 29-19 (6.08 t/ha) stood out.

At the PPI, the average annual yield from the varieties was 5.01 t/ha. In 2020, the greatest yields were produced by Svoboda Kharkivska (5.96 t/ha), Kripost Kharkivska (5.69 t/ha), and Opora Kharkivska (5.67 t/ha). Of the lines, the highest yields were harvested from YATKH 153-18 (5.19 t/ha), YATKH 23-19 (5.54 t/ha), and YATKH 40-19 (5.01 t/ha). In 2021, the yields ranged 4.50 to 5.73 t/ha. Of the varieties, the highest yields were given by Svoboda Kharkivska (5.73 t/ha), Opora Kharkivska (5.45 t/ha), Bulat Kharkivskyi (5.30 t/ha), and Darkhliba Kharkivskyi (5.29 t/ha). Of the lines, the highest yields were harvested from YATKH 23-19 (5.60 t/ha), YATKH 29-19 (5.49 t/ha), and YATKH 40-19 (5.33 t/ha). It is noteworsy that under the PPI conditions Opora Kharkivska, Svoboda Kharkivska, YATKH 23-19, and YATKH 40-19 gave high yield in the both testing years.

On average for 2020–2021, across the two study sites, the highest yields were harvested from varieties Svoboda Kharkivska (6.24 t/ha), Opora Kharkivska (5.84 t/ha), and Kripost Kharkivska (5.66 t/ha) as well as from lines YATKH 40-19 (5.88 t/ha) and YATKH 23-19 (5.83 t/ha).

Thus, a wide differentiation of genotypes in response to changing environmental conditions allowed us to select genotypes with high yield capacity, which gave high yields under favorable conditions (YATKH 40-19 and YATKH 29-19) or relatively high mean yields under variable growing conditions (Svoboda Kharkivska, Darkhliba Kharkivskyi, YATKH 40-19). In this case, genotypes can significantly reduce yields in some years under adverse conditions. To reduce risks in grain production, it is important to find adaptable genotypes that can optimally change the intensity of morphogenesis processes in response to changing environmental conditions.

The linear regression coefficient (bi) indicates the response of a variety changes in growing conditions, i.e. characterizes the environmental plasticity of the genotype. The higher the coefficient is (bi> 1), the greater response of the variety to improvement of growing conditions. Such varieties are fastidious about environmental conditions and they maximally fulfill their potentials under favorable conditions only. In the case of bi <1, the variety is less responsive to changes in conditions than the average across the studied sample. It is better to use such varieties in extensive technologies, where they will provide maximum effect at minimum cost. If bi = 1, the yield variations fully correspond to changes in environmental conditions [16].

Table 2

Spring triticale yields, PPI and UESPP, t/ha, 2020–2021

Variety/line	PPI			UESPP			Average for variety/line
	2020	2021	Average across the years	2020	2021	Average across the years	
Bulat Kharkivskyi	4.03	5.30	4.67	6.25	5.98	6.11	5.39
Darkhliba Kharkivskyi	4.84	5.29	5.07	6.85	6.65	6.75	5.91
DostatokKharkivskyi	3.96	5.19	4.58	5.63	5.60	5.61	5.10
KripostKharkivska	5.69	5.07	5.38	5.91	5.98	5.94	5.66
Opora Kharkivska	5.67	5.45	5.56	6.04	6.20	6.12	5.84
Svoboda Kharkivska	5.96	5.73	5.85	6.95	6.33	6.64	6.24
SkarbKharkivskyi	4.34	5.02	4.68	5.50	5.65	5.58	5.13
YATKH153-18	5.19	4.50	4.85	6.50	6.10	6.30	5.57
YATKH22-19	4.27	4.70	4.49	6.44	5.25	5.85	5.17
YATKH23-19	5.54	5.60	5.57	7.04	5.13	6.08	5.83
YATKH29-19	3.84	5.49	4.67	7.09	6.08	6.58	5.63
YATKH40-19	5.01	5.33	5.17	7.44	5.73	6.58	5.88
YATKH58-19	4.50	4.65	4.58	6.17	4.60	5.38	4.98
Average across the genotypes	4.83	5.18	5.01	6.45	5.79	6.12	5.56
LSD_{05}	Genotype						0.39
	Environment						0.22
	Genotype-environment interaction						0.16

YATKH 29-19 (bi = 1.85) and YATKH 40-19 (bi = 1.45) were the most plastic genotypes; their yields exceeded 7.0 t/ha under favorable conditions. Of the varieties, Darkhliba Kharkivskyi was the most plastic one (bi = 1.45), as it produced 6.85 t/ha at UESPP in 2020. The selected accessions have a high yield capacity and are able to maximize it under favorable conditions. They can be used in hybridization to increase yields. At the same time, under adverse environmental conditions, some genotypes may be significantly inferior in terms of yield to others. Therefore, genotypes with high adaptability to growing conditions are of special value to obtain stable yields when grown on poor agricultural lands or in areas with unstable wetting and other adverse factors.

The general adaptability (GA) of a genotype characterizes the average value of a trait in different environments. The strongest GA effects were recorded for varieties Svoboda Kharkivska (67.9), Darkhliba Kharkivskyi (34.5), and Opora Kharkivska (27.9) as well as for lines YATKH 40-19 (31.4) and YATKH 23-19 (26.6) (Table 3). These varieties were the most stable both across the study years and across the environments, producing yields exceeding the average across the experiment.

Table 3

Adaptability of the spring triticale varieties and lines for yield, PPI and UESPP, 2020–2021

Variety/Line	Yield, t/ha min-max	Plasticity (b_i)	General adaptability (GA)	Variance of specific adaptability (SA)	Relative stability of the genotype (Sgi), %	genotype's breeding value (GBV)
Bulat Kharkivskyi	4.03–6.25	1.27	-17.14	97.5	18.1	460
Darkhliba Kharkivskyi	4.84–6.85	1.34	34.49	98.1	16.6	511
DostatokKharkivskyi	3.96–5.63	0.91	-46.89	76.5	15.0	447
KripostKharkivska	5.07–5.98	0.33	9.87	37.4	6.6	536
Opora Kharkivska	5.45–6.20	0.35	27.87	29.6	5.1	560
Svoboda Kharkivska	5.73–6.95	0.70	67.87	50.6	8.1	583
SkarbKharkivskyi	4.34–5.65	0.70	-43.39	56.4	11.0	467
YATKH 153-18	4.50–6.50	1.08	1.12	88.5	15.9	485
YATKH 22-19	4.27–6.44	1.31	-39.76	92.6	17.9	441
YATKH 23-19	5.54–7.04	0.80	26.62	81.8	14.0	516
YATKH 29-19	3.84–7.09	1.82	6.24	135.0	24.0	453
YATKH 40-19	5.01–7.44	1.45	31.37	107.1	18.2	501
YATKH 58-19	4.50–6.17	0.95	-58.26	77.5	15.6	435

The specific adaptability (SA) characterizes the deviation from the GA in each individual environment, so it is an indicator of the genotype's stability. Of the accessions distinguished because of GA, Opora Kharkivska and Svoboda Kharkivska had the lowest SA variances indicating a high stability of their increased yields under different conditions. This was confirmed by genotype's relative stability (Sgi), which characterizes the genotype's ability to maintain a certain phenotype in different environments as a result of regulatory mechanisms. Kripost Kharkivska, Opora Kharkivska, and Svoboda Kharkivska were more stable by this indicator. That is, the yields of these varieties changed to a lesser extent under the influence of environmental conditions. The selected varieties are able to use resources more efficiently and to optimize physiological processes to give yields under unfavorable growing conditions. They are valuable as starting material in breeding for adaptability.

The genotype's breeding value (GBV) characterizes combination of the genotype's stability, plasticity and yield. A high GBV means relatively high adaptability parameters and their optimal combination with increased yields.

The new varieties, Svoboda Kharkivska, Opora Kharkivska, and Kripost Kharkivska, had high GBVs in the experiment. These varieties can be recommended for cultivation under different growing conditions throughout Ukraine to many producers. Of the lines, YATKH 23-19 and YATKH 40-19 had the highest GBVs. They are valuable breeding material for breeding for yield and adaptability.

The plant height of plants ranged from 84 cm to 117 cm across the test years and locations (Table 4). In the both years, plants were by 3–5 cm shorter at UESPP than at the PPI. In general, the plant distribution by height among the genotypes was the same regardless of environmental conditions. Kripost Kharkivska plants were consistently short under different conditions (84-98 cm). On average across the years, the plant height in Opora Kharkivska, Svoboda

Kharkivska, and YATKH 29-19 (108 cm) was below the average. Varieties Darkkhliba Kharkivskyi, and Dostatok Kharkivskyi (111 cm) and lines YATKH 22-19 (113 cm) and YATKH 23-19 (116 cm) had the tallest plants.

Table 4

Expression of the valuable economic features in spring triticale, PPI and UESPP, 2020–2021

Variety/Line	"Seedlings-earing" period, days			Plant height, cm			1000-grain weight, g			Resistance to Septoria tritici blotch (UESPP) септоріозу листя,
	UESPP	PPI	Mean	UESPP	PPI	Mean	UESPP	PPI	Mean	
Bulat Kharkivskyi	59	55	57	107	114	110	37.6	40.9	39.3	6.5
Darkhliba Kharkivskyi	60	57	58	109	114	111	35.9	38.4	37.2	7.0
DostatokKharkivskyi	60	56	58	107	115	111	33.2	38.5	35.9	7.0
KripostKharkivska	62	58	60	84	93	89	39.8	40.6	40.2	7.0
Opora Kharkivska	59	54	56	105	112	108	40.1	39.3	39.7	6.0
Svoboda Kharkivska	60	56	58	108	108	108	36.5	35.6	36.1	6.0
SkarbKharkivskyi	60	56	58	107	111	109	35.5	37.6	36.5	6.5
YATKH 153-18	59	56	57	107	113	110	37.0	38.6	37.8	7.0
YATKH 22-19	58	56	57	113	114	113	37.0	42.8	39.9	7.5
YATKH 23-19	60	56	58	115	117	116	37.0	38.8	37.9	6.5
YATKH 29-19	57	56	56	109	108	108	31.4	34.4	32.9	6.5
YATKH 40-19	58	53	55	110	108	109	35.2	38.3	36.7	7.5
YATKH 58-19	59	57	58	110	117	113	40.5	40.3	40.4	6.5
Average across the genotypes	59	56	57	107	111	109	36.7	38.8	37.7	6.7

The "seedlings-earing" period was strongly positively correlated with the vegetation length and significantly affected the yield; in 2020, it was longer at the both locations. At UESPP, it lasted 64-72 days; at the PPI – 64-68 days. In 2021, the "seedlings-earing" period was 49–53 days at UESPP and 43–47 days at the PPI, depending on the genotype. On average, Opora Kharkivska (56 days), YATKH 40-19 (55 days) and YATKH 29-19 (56 days) had shorter "seedlings-earing" periods. In Kripost Kharkivska, the "seedlings-earing" period was consistently longer under different environmental conditions (60 days).

Extended droughts and heat during the seed filling and ripening phases were observed in 2020 and 2021 in the both test sites, which negatively affected the grain size and plumpness. The 1000-grain weight at UESPP was 31.4–40.9 g. The greatest 1000-grain weight was recorded for Kripost Kharkivska (39.8 g) and Opora Kharkivska (40.1 g). At the PPI, the 1000-grain weight ranged 34.4 g to 42.8 g. The highest levels of this trait were noted for varieties Bulat Kharkivskyi (40.9 g) and Kripost Kharkivska (40.6 g) and for lines YATKH 22-19 (42.8 g) and YATKH 58-19 (40.4 g). Kripost Kharkivska (40.2 g) and YATKH 58-19 (40.4 g) had consistently higher 1000-grain weights in different environments and years.

Waterlogged periods in May at UESPP contributed to Septoria-caused lesions on leaves. The genotypes were resistant to this pathogen at the level of 6-7 points in 2020 and at the level of 6-8 points in 2021. On average across the study years, the highest resistance to septoria tritici blotch was recorded for Darkkhliba Kharkivskyi, Dostatok Kharkivskyi, and Kripost Kharkivska (7 points). Of the lines, YATKH 22-19 and YATKH 40-19 were resistant. It was noted that genotypes with longer "seedlings-earing" periods had higher resistance scores.

Thus, the best genotypes combining high yield capacity, good adaptability parameters and valuable economic traits were distinguished.

Svoboda Kharkivska consistently gave a high yield on average across the experiment (6.24 t/ha), showed high levels of general and specific adaptability, and a high genotype's breeding value. This variety is noteworthy for easy threshing and its plants are consistently of medium height (108 cm).

Kripost Kharkivska consistently gave a high yield (5.66 t/ha), showed relative stability and was of genotype's breeding value. Its plants were consistently short under different conditions (84−93 cm); the 1000-grain weight was increased (40.2 g); and the score of resistance to septoria tritici blotch was 7 points; the "seedlings-earing" period was extended (60 days).

Opora Kharkivska gave a stable yield of 5.84 t/ha) and stood out for its general and specific adaptability and genotype's breeding value. Its plants were of medium height (108 cm); its "seedlings-earing" period was shorter (56 days).

Darkkhlib Kharkivskyi showed high plasticity and general adaptability. At UESPP, it produced a high (compared to other varieties) yield (6.75 t/ha) and demonstrated increased resistance to septoria tritici blotch.

As to the lines, the highest breeding value in terms of yield and adaptability was found for YATKH 40-19, YATKH 23-19, and YATKH 29-19.

YATKH 40-19 gave a high yield on average across the experiment (5.88 t/ha). It was highly plastic. Under the favorable conditions (UESPP, 2020), it stood out for the highest yield of 7.44 t/ha. It also demonstrated increased resistance to septoria tritici blotch (7.5 points).

YATKH 23-19 and YATKH 29-19 were highly plastic. Under the favorable conditions, they gave high yields (7.04 and 7.09 t/ha, respectively). YATKH 23-19 also showed high levels of general adaptability and genotype's breeding value. It produced over 5 t/ha regardless of growing conditions.

Conclusions. As a result of the environmental trials, the most valuable genotypes in terms of adaptability, yield and valuable economic characteristics were identified.

High yield capacity (6.85–7.44 t/ha) and high plasticity (bi 1.34–1.82) were noted for varieties Darkkhliba Kharkivskyi and Svoboda Kharkivska and for lines YATKH 19-19, YATKH 29-19, and YATKH 40-19, which indicates their ability to effectively fulfill their performance potentials under favorable conditions.

Svoboda Kharkivska, Kripost Kharkivska, and Opora Kharkivska were found to be the most adaptable to environmental changes varieties. That is, the yields harvested from these varieties fluctuated to a lesser extent under the influence of environmental conditions. At the same time, they optimally combine a high yield capacity and stability, as evidenced by their high genotype's breeding values. They produced over 5 t/ha even under the unfavorable growing conditions. These varieties can be recommended for growing under different conditions throughout Ukraine to many producers. As to the lines, the highest breeding value was observed for YATKH 23-19 and YATKH 40-19. The selected accessions are also valuable material in breeding for yield capacity and adaptability.

Список використаних джерел

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АДАПТИВНІСТЬ ТА СТАБІЛЬНІСТЬ НОВИХ СОРТІВ І ЛІНІЙ ЯРОГО ТРИТИКАЛЕ

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Мета і задачі дослідження. Мета досліджень – оцінити адаптивну здатність та стабільність сортів та селекційних ліній тритикале ярого за врожайністю та проявом цінних господарських ознак в екологічному випробуванні та виділити кращі комплексно цінні генотипи.

Матеріали та методи. Вивчали 13 генотипів (2020–2021 рр.) тритикале ярого у двох різних агрокліматичних середовищах (східний Лісостеп – ІР та перехідний ареал від Лісостепу до Степу – УДСР). Дослідні ділянки площею 2 м^2 у триразовому повторенні розміщували методом послідовних повторень. Польові оцінки проводили за методикою кваліфікаційної експертизи сортів рослин. Параметри адаптивності визначали за методикою А.В. Кільчевского, Л.В. Хотильової.

Обговорення результатів. Оцінено стабільність формування врожайності та цінних господарських ознак та виділено кращі комплексно цінні генотипи. Високий потенціал урожайності (6,85–7,44 т/га) та високу пластичність (bi 1,34–1,82) мали Дархліба харківський, Свобода харківська, ЯТХ 23-19, ЯТХ 29-19 та ЯТХ 40-19, що свідчить про ефективність їх вирощування у сприятливих умовах. Найбільш адаптованими до змін умов середовища є сорти Свобода харківська, Кріпость харківська та Опора харківська. Ці сорти можна рекомендувати для вирощування в різних умовах на всій території України.

Сорт Свобода харківська мав високу врожайність у середньому по досліду (6,24 т/га) та високі рівні загальної та специфічної адаптивної здатності, а також високу селекційну цінність генотипу. Сорт характеризується легким обмолотом, має стабільно середню висоту рослин (108 см).

Сорт Кріпость харківська мав стабільно високу врожайність (5,66 т/га), проявляв відносну стабільність та селекційну цінність генотипу. Стабільно за різних умов є короткостеблим (84–93 см) з підвищеною масою 1000 зерен (40,2 г) та стійкістю до септоріозу листя (7 балів), має більш тривалий період сходи-колосіння (60 діб).

Сорт Опора харківська мав стабільну врожайність (5,84 т/га) та виділився за загальною та специфічною адаптивною здатністю, селекційною цінністю генотипу. Характерною для нього є середньорослість (108 см) та менш тривалий період сходи-колосіння (56 діб).

Сорт Дархліба харківський проявив високу пластичність та загальну адаптивну здатність. В умовах УДСР він формував високий, порівняно з іншими сортами, рівень врожайності (6,75 т/га) та підвищену стійкість проти септоріозу листя. Серед ліній вищу селекційну цінність за врожайністю та адаптивністю мають ЯТХ 40-19, ЯТХ 23-19 та ЯТХ 29-19.

Лінія ЯТХ 40-19 мала високу врожайність у середньому по досліду (5,88 т/га), характеризувалася високою пластичністю. За сприятливих умов (УДСР, 2020 р.) мала найвищу врожайність – 7,44 т/га. Вона має підвищену стійкість до септоріозу листя (7,5 балів). Лінії ЯТХ 23-19 та ЯТХ 29-19 мали високий рівень пластичності. За сприятливих умов вони формували високу врожайність (відповідно 7,04 та 7,09 т/га). При цьому лінія ЯТХ 23-19 також проявила високі рівні загальної адаптивної здатності та селекційної цінності генотипу. За усіх умов вирощування вона формувала врожайність понад 5 т/га.

Висновки. В результаті екологічного випробування виділено найбільш цінні генотипи за параметрами адаптивності, урожайності та цінними господарськими ознаками. Високий потенціал урожайності (6,85–7,44 т/га) та високу пластичність (bi 1,34 – 1,82) мали Дархліба харківський, Свобода харківська, ЯТХ 23-19, ЯТХ 29-19 та ЯТХ 40-19. Найбільш адаптованими до змін умов середовища є сорти Свобода харківська, Кріпость харківська та Опора харківська. При цьому вони оптимально поєднують високий рівень врожайності та стабільність, тому можуть бути рекомендуваними для вирощування в різних умовах на всій території України. Серед ліній вищу селекційну цінність мали ЯТХ 23-19 та ЯТХ 40-19. Виділені зразки є також цінним матеріалом для селекції на врожайність та адаптивність.

Ключові слова:*тритикале яре, врожайність, адаптивність, стабільність, сорт, лінія*

ADAPTABILITY AND STABILITY OF NEW SPRING TRITICALE VARIETIES AND LINES

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Purpose and objectives. The purpose was to evaluate the adaptability and stability of spring triticale varieties and breeding lines for yield and expression of valuable economic characteristics in environmental trials and to identify the best genotypes with a set of valuable features.

Materials and methods. We studied 13 spring triticale genotypes (2020–2021) in two different agroclimatic environments (Eastern Forest-Steppe [PPI] and transitional zone from forest-steppe to steppe [UESPP]). The experimental plots of 2 m^2 in three replications were arranged in series. The field assessments were performed in accordance with methods of qualification examination of plant varieties. The adaptability parameters were determined by AV Kilchevskiy and PV Khotylyova's method.

Results and discussion. The yield stability and valuable economic characteristics were assessed and the best genotypes with a set of valuable features were identified. A high yield capacity (6.85–7.44 t/ha) and high plasticity (bi 1.34−1.82) were intrinsic to Darkkhliba Kharkivskyi, Svoboda Kharkivska, YATKH 23-19, YATKH 29-19, and YATKH 40-19,

which indicates their ability to effectively fulfill their performance potentials under favorable conditions. Svoboda Kharkivska, Kripost Kharkiv, and Opora Kharkivska were found to be the most adaptable to environmental changes varieties. These varieties can be recommended for cultivation under different growing conditions throughout Ukraine to a wide range of producers.

Svoboda Kharkivska consistently gave a high yield on average across the experiment (6.24 t/ha), showed high levels of general and specific adaptability, and a high genotype's breeding value. This variety is noteworthy for easy threshing and its plants are consistently of medium height (108 cm).

Kripost Kharkivska consistently gave a high yield (5.66 t/ha), showed relative stability and was of genotype's breeding value. Its plants were consistently short under different conditions (84−93 cm); the 1000-grain weight was increased (40.2 g); and the score of resistance to septoria tritici blotch was 7 points; the "seedlings-earing" period was extended (60 days).

Opora Kharkivska gave a stable yield of 5.84 t/ha) and stood out for its general and specific adaptability and genotype's breeding value. Its plants were of medium height (108 cm); its "seedlings-earing" period was shorter (56 days).

Darkhlib Kharkivskyi showed high plasticity and general adaptability. At UESPP, it produced a high (compared to other varieties) yield (6.75 t/ha) and demonstrated increased resistance to septoria tritici blotch.As to the lines, the highest breeding value in terms of yield and adaptability was found for YATKH 40-19, YATKH 23-19, and YATKH 29-19.

YATKH 40-19 gave a high yield on average across the experiment (5.88 t/ha). It was highly plastic. Under the favorable conditions (UESPP, 2020), it stood out for the highest yield of 7.44 t/ha. It also demonstrated increased resistance to septoria tritici blotch (7.5 points).YATKH 23-19 and YATKH 29-19 were highly plastic. Under the favorable conditions, they gave high yields (7.04 and 7.09 t/ha, respectively). YATKH 23-19 also showed high levels of general adaptability and genotype's breeding value. It produced over 5 t/ha regardless of growing conditions.

Conclusions. As a result of the environmental trials, the most valuable genotypes in terms of adaptability, yield and valuable economic characteristics were identified.

High yield capacity (6.85–7.44 t/ha) and high plasticity (bi 1.34–1.82) were noted for varieties Darkkhliba Kharkivskyi and Svoboda Kharkivska and for lines YATKH 19-19, YATKH 29-19, and YATKH 40-19.Svoboda Kharkivska, Kripost Kharkivska, and Opora Kharkivska were found to be the most adaptable to environmental changes varieties. That is, the yields harvested from these varieties fluctuated to a lesser extent under the influence of environmental conditions. At the same time, they optimally combine a high yield capacity and stability, as evidenced by their high genotype's breeding values. They produced over 5 t/ha even under the unfavorable growing conditions. These varieties can be recommended for growing under different conditions throughout Ukraine to many producers. As to the lines, the highest breeding value was observed for YATKH 23-19 and YATKH 40-19. The selected accessions are also valuable material in breeding for yield capacity and adaptability.

Keywords: *spring triticale, yield capacity, adaptability, stability, variety, line*