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COMPARATIVE EVALUATION OF THE PRODUCTIVITY OF WINTER CROPS (WHEAT [*TRITICUM AESTIVUM L.*], RYE [*SECALE CEREALE L.*], TRITICALE [*TRITICOSECALE WITT.*]) IN THE WESTERN FOREST-STEPPE OF UKRAINE

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Abstract: The aim of the study was to determine the parameters of adaptability of winter crop varieties for cultivation in the western forest-steppe zone of Ukraine (2019–2021). The subject of the study were wheat (*Triticum aestivum L.*) varieties: Vodogray bilotserkivsky, Oberig Myronivsky, Mudrist odeska; rye *(Secale cereale L.):* Knyazhe, Kobza, Kharkivyanka; triticale *(Triticosecale Witt.)*: Markian, Molfar, Obrij myronivsky. The tests were carried out in the field. The area of the experimental plot was 55 m^2, and the placement of varieties was consecutive with three repetitions. The results showed that under the basic cultivation technologies and weather conditions of the growing seasons, the grain productivity of soft wheat varieties varied from 4.88 (Mudrist odeska) to 5.39 t ha^{-1} (Oberig Myronivsky); rye – from 5.55 (Kharkivyanka) to 6.32 t ha^{-1} (Kobza); triticale – from 6.45 (Markian) to 6.74 t ha^{-1} (Obrij myronivsky). The results obtained allow to conclude that ecologically plastic varieties of winter crops in the conditions of the studied soil-climatic zone accumulate a sufficient amount of sugar in the tillering nodes – 25–30%, ensure overwintering of plants – 94–96%, are resistant to the main diseases, which contributes to the production of high-quality seeds to ensure the cultivated area in the region and the efficiency of seed production.

Key words: disease, soft wheat (winter), rye (winter), triticale (winter), weight of 1000 grains, yield.

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Introduction

Climate change and agriculture are two interconnected processes at the global level that affect the temperature regime, rainfall, atmospheric carbon dioxide and ozone concentrations, the emergence of new pests and diseases, and food quality (Deryng et al., 2011). According to the materials of the National Academy of Agrarian Sciences of Ukraine, the boundaries of the country's natural and climatic zones have actually shifted northward by 100–150 km in recent decades (Ivanyuta et al., 2020; Kovalchuk, 2019). These changes affect the grain market of Ukraine, the state of which determines the security of the country, the results of the economic activity of agricultural producers, and, in general, the well-being of the Ukrainian population (Dibrova et al., 2019; Rahman and Babenko, 2020; Kazak and Grishchenko, 2016; Kovaleva, 2015).

A science-based strategy for the development of the grain industry provides ample opportunities for effective control of the volume of grain production – the main resource potential. To support the high competitiveness of national agrarian interests, it is necessary to reliably predict the situation while maintaining the ecological balance. To achieve this, the area under cereals in Ukraine should remain relatively stable – 15–16 million hectares: of which in the steppe – about 7.1, forest-steppe – 5.6, in polissya – 2.3 million hectares. The cultivated area is expected to be distributed as follows: winter wheat – at least 6.0 million ha, winter barley – 1.2, winter rye – 0.3, corn – 5.0, spring barley – 1.5, soybeans – 2.0, millet, sorghum and buckwheat – 0.3 million ha each (Cherchel and Shevchenko, 2020).

Regional manifestations of climate change are reflected in an increase in the sum of effective temperatures and sufficient precipitation in the western forest-steppe zone, which allows the cultivation ofnot only cereals but also niche crops (corn, soybeans, sunflower) (Voloshchuk, 2018; Mazur et al., 2020; Yasnolob et al., 2018; Budyak and Budyak, 2020). These crops are resistant to biotic and abiotic stresses and are characterized by high yield, protein and lysine content in the grain (Petrichenko and Korniychuk, 2018; Yegupova and Romanyuk, 2020; Ryzhuk et al., 2021; Gritsenko, 2020; Wilde et al., 2018).

Litvinenko (2016) argues that the genetic yield potential of modern winter wheat varieties has increased to 8.0–10.2 t ha^{-1} over the past decade, but is realized in production at an average of 2.62 t ha^{-1} (25–30%).

Based on the natural and economic conditions of the main zones and the different degrees of specialization of cooperative and farm enterprises, it is advisable to use a wide range of winter crops in the structure of cultivated areas. It is possible to achieve 15–20% higher productivity of the grain field only with a scientifically based varietal policy of each farm, growing three or four varieties of different development types (Gavrilyuk and Kalenich, 2017; Lifenko et al., 2021; Gamayunova and Litovchenko, 2017).

The western forest-steppe covers a number of subzones (forest-steppe, polesia, foothills and mountains) with different soil types characterized by low natural fertility, high acidity, leaching, and large amounts of precipitation during the formation period – grain harvesting. In this zone, selection does not take place in most winter crops, so grain producers buy the seeds of new varieties in the institutions of origin of the central forest-steppe, and even the steppe. Under these conditions, a large number of varieties of foreign selection are found in the industrial crops of the region. The modernization of the seed industry of these economically developed countries (Germany, Italy, France, Poland, Spain, Hungary, Great Britain, Romania, Greece, Portugal), whose companies operate on our territory, allows the production of high-quality seeds, which, due to calibration, encrustation with microelements, etc., underestimate the performance of domestic varieties.

The aim of the study was to determine the parameters of adaptability and productivity of winter crop varieties: soft wheat, rye, triticale for cultivation in the western forest-steppe zone of Ukraine.

Material and Methods

The experiment was laid in the crop rotation of the Department of Seed Growing and Seed Science of the Institute of Agriculture of Carpathian region of National Academy of Agrarian Sciences (NAAS) of Ukraine in 2019–2021 (49°47′07″ N, 23°52'07"E; 314 m a.m.s.l.).

The yield of varieties of three winter crops from different institutions of the owners of Ukraine was tested.

The soil of the experimental plots is a gray forest soil, superficially gleyed, light loamy, characterized by the following indicators: humus content (according to Tyurin) – 1.7%, the amount of absorbed bases – 13.7 meq per 100 g of soil, alkaline available nitrogen (according to Kornfield) – 89.6 mg kg^{-1} of soil, phosphorus and potassium (according to Kirsanov), 69.5 and 68.0 mg kg^{-1} of soil, respectively. Beyond the gradation, such a soil has a very low supply of nitrogen, a medium supply of phosphorus, and a low supply of potassium. The reaction of the soil solution (pH salt – 5.4) is slightly acidic.

The agrotechnology of cultivation is generally accepted for crops in this zone. The predecessor was winter rapeseed. The seeding rates for winter crops were as follows: 5.5 million viable seeds ha^{-1} – wheat, 5.0 million viable seeds ha^{-1} – rye, 4.5 million viable seeds ha^{-1} – triticale. The sowing time was optimal (20–25.09 – rye, triticale; 25.09–01.10 – wheat). Seed protection included Vitavax 200 FF, 3 l t^{-1}; plants – herbicides: roundup, 4.0 l ha^{-1}; granstar, 75% aqueous solution, 0.025 kg ha^{-1}; fungicide: falcon Dou, emulsion concentrate, 0.6 l ha^{-1}. Mineral fertilizers were applied before sowing, and post-fertilization was carried out at the stages BBCH 20-22 and BBCH 30-32. The application rate for wheat and triticale was $N_{120}P_{90}K_{90}$, and for rye – $N_{60}P_{90}K_{90}$. The total area of the sowing plot was 60 m^2 and the accounting area was 50 m^2. The experiment was repeated three times.

The studies were carried out according to the generally accepted methods indicated below.

According to the data from the Lviv hydrogeological and reclamation station, the sum of the temperature regime (°C) and the amount of precipitation (mm) in the fall and winter periods and the duration of fall vegetation and dormancy of plants were determined.

For each variety, the seeding rate (R) was determined according to the following formula:

$$R = \frac{\text{N x W x 100}}{\text{Es}} \tag{1}$$

N – number of millions of germinated seeds per 1 ha;

W – weight of 1000 seeds;

Es– economic suitability of the seed.

Economic suitability of the seed (Es) determined according to the following formula:

$$Es = \frac{\text{seed germination x seed purity}}{100} \tag{2}$$

The germination of seeds was determined using the method of accounting plots based on the following calculations: the beginning of seedlings development (at least 15% of seedlings appeared), mass seedlings (50%), full seedlings (75% or more), the end of the phase – the emergence of the last seedlings and calculated (in percent) as the ratio of the number of seedlings to the total number of similar seeds sown (Izhik, 1976).

According to the method of Fursova et al. (2004), phenological observations of plant development during the growing season were carried out. The heading phase was determined when the inflorescence emerged at least halfway from the axil of the upper leaf, and the flowering phase was determined by the presence of anthers or stigmas. Grain maturity was determined by the organoleptic method 12–15 days after the phase of full flowering of the plants and repeated every three days. Sampling was carried out manually at 5 evenly spaced locations of each experimental plot in three incompatible replicates, then the average value of the indicator was determined. Technical maturity and harvest maturity were determined by the gravimetric drying method, which allows the timing of the onset of these stages to be determined with an accuracy of up to one day. Grain moisture above 20% was determined by oven drying and mathematically converted to the standard value of 14%.

The weight of 1000 seeds (M) was determined by 2 weighings of 500 pieces, and the average weight was calculated with an accuracy of 0.1 g. If the weight of 2 samples differed from the average by more than 0.5%, the third sample was weighed and calculated according to the following formula:

$$M = \frac{M1x(100-h)}{100-Sh} \quad (3)$$

M_1 – mass of 1000 grains, g;

h – grain moisture, %;

Sh – standard grain moisture, 14%.

Total mono- and disaccharide content was determined by photometry using picric acid (Major et al., 2007). Sugars were extracted from samples ground in a mortar and dried in an oven (105°C) with water in a water bath (10 min at 100°C). The concentration of total sugars after acid hydrolysis (3.3% HCl) was determined colorimetrically at 490 nm using a calibration curve constructed using the scale of standard solutions of glucose or hydrolyzed sucrose. The content of dry matter in the plant material was calculated by the weight method.

Overwintering of plants of the varieties was based on the data of fall and spring registration of the state of crops in each replicate in relation to the plants that restored spring vegetation for field germination of seeds (Eshchenko et al., 2014).

The range of variation (R) in the traits of the varieties and weather conditions of the study years was determined by the difference between the maximum and minimum values.

Phytopathological evaluation was performed according to the method of Omelyuta et al. (1986) using the formula:

$$I = \frac{\Sigma(a \cdot в) \cdot 100}{К \cdot В} \quad (4)$$

I – disease development (in %);

Σ (a *x* в) – the sum of the product obtained by multiplying the number of leaves by the corresponding score;

К – total number of counted leaves (healthy and damaged);

В – the highest score on the accounting scale.

The assimilation coefficient (AC) was determined by the method of Peterson et al. (1993) using the following formula:

$$AC = (m2 - m1)(\ln S2 - \ln S1) / (S2 - S1) \quad (5)$$

m_1 i m_2 – dry mass of the harvest sample at the beginning and end of the accounting period, g;

ln S_1 i ln S_2 – natural logarithms of leaf areas for the accounting period;

t – duration of the experiment, days.

Biomass gain (G) per day (g m^2) was determined by the following formula:

$$G = AC \times A/a \quad (6)$$

a – number of plants per 1 m^2 of sowing, pcs.;

A – number of experimental plants, pcs..

Grain yield was determined by threshing with a Sampo-130 combine for each plot and weighing. Processing and summarizing of the experimental results were carried out on the computer using the Microsoft Excel program. According to the method of Ushkarenko et al. (2013), the analysis of variance was carried out according to one- and three-factor types.

Results and Discussion

During the growing seasons of winter cereals, different weather conditions prevailed, which allowed a comprehensive evaluation ofthe adaptive and productive features of the varieties.

Depending on the seeding rates of a crop and variety, plant density per unit area varied within 501.0–511.4 pieces m^2 for winter wheat, for rye – 458.0–460.8, for triticale – 433.6–438.0 pieces m^2 (Table 1). Since the fall vegetation of the plants was longer, the varieties accumulated a sufficient amount of soluble sugars (26.9–27.1%).

Table 1. Changes in growth and sugar content in the tillering nodes of winter cereal plants at the time of fall vegetation termination (2018–2020).

Variety	Plant density, pcs m^2	Sugar content in tillering nodes, %	Plant height, cm	Absolute dry weight of 100 plants, g	Root system length, cm
Soft wheat (winter)					
Vodogray bilotserkivsky (control)	504.2	26.8	15.0	5.78	5.9
Oberig Myronivsky	511.4	27.3	15.7	6.69	6.3
Mudrist odeska	501.0	26.5	14.8	6.30	5.9
Average	505.5	26.9	15.2	6.26	6.0
$SSD_{0.05}$	5.0	1.0	0.4	0.30	0.5
Rye (winter)					
Knyazhe (control)	460.8	26.6	18.0	8.14	7.9
Kobza	460.6	27.5	17.2	7.89	8.1
Kharkivyanka	458.0	26.8	15.8	7.63	7.4
Average	459.8	27.0	17.0	7.89	7.8
$SSD_{0.05}$	3.0	0.6	1.1	0.25	0.4
Triticale (winter)					
Markian (control)	433.6	27.8	17.3	7.87	7.4
Molfar	438.0	27.1	17.5	8.52	7.8
Obrij myronivsky	433.6	26.3	16.3	8.44	7.3
Average	435.1	27.1	17.0	8.28	7.5
$SSD_{0.05}$	2.0	0.5	0.8	0.28	0.3

The good development of the plants entering winter, the accumulation of a sufficient amount of sugars in the tillering nodes, and the abnormally warm weather conditions during the winter months led to a high percentage of overwintering of plants of all crops. The average indicator for winter wheat was – 96.6%, for rye – 94.9, for triticale – 94.2% (Table 2). This confirms that the varieties of the different ecological types of wheat, rye and triticale are well adapted to the growing conditions of the western forest-steppe zone.

According to the mathematical processing of the data, the influences of the factors were as follows: weather conditions of the year (A) – 39%, crops (B) – 22, varieties (C) – 25, interaction of year and crop (AB) – 3, year and variety (AC) – 4, crop and variety (BC) – 2, year, crop and variety (ABC) – 2, others – 3%.

Table 2. Overwintering of plants of winter crop varieties (2019–2021), %.

Variety	Year			Average	± to control
	2019	2020	2021		
Soft wheat (winter)					
Vodogray bilotserkivsky (control)	96.2	95.0	99.0	96.7	-
Oberig Myronivsky	97.0	95.5	98.8	97.1	0.4
Mudrist odeska	95.8	95.2	97.6	96.2	-0.5
Average	96.3	95.1	98.8	96.6	
Rye (winter)					
Knyazhe (control)	95.4	88.4	99.0	94.3	-
Kobza	96.6	89.1	98.8	94.8	0.5
Kharkivyanka	94.2	87.7	98.7	95.5	-1.2
Average	95.4	88.4	98.8	94.9	
Triticale (winter)					
Markian (control)	94.1	89.2	98.1	93.8	-
Molfar	93.5	90.0	98.8	94.1	0.3
Obrij myronivsky	94.9	90.6	98.5	94.7	0.9
Average	94.2	89.9	98.5	94.2	
Factor:	Impact intensity			$SSD_{0.05}$	
A (year)	0.39			0.93	
B (crop)	0.22			0.72	
C (grade)	0.25			0.72	
Interaction of factors:					
AB	0.03			1.61	
AC	0.04			1.61	
BC	0.02			1.25	
ABC	0.02			2.79	
Other factors	0.03				

An important indicator for determining the likely productivity of varieties is their assessment based on the photosynthetic chlorophyll potential of the leaves. In our experiments, the winter crop varieties formed a well-developed photosynthetic apparatus that was optimal in terms of volume and functional dynamics, which affected the final result – yield.

According to the dynamics of determining the total area of the leaf surface of the plants presented in Table 3, it can be seen that it increased from the second macrostage BBCH 28–29 to the third BBCH 37–39 and was the highest. In winter wheat varieties, this indicator varied from 39.5 thousand m^2 ha^{-1} (Mudrist odeska) to 61.5 thousand m^2 ha^{-1} (Oberig Myronivsky). When rye was sown, the largest leaf area was recorded in the Knyazhe variety (64.8 thousand m^2 ha^{-1}), and in the Molfar triticale variety (70.2 thousand m^2 ha^{-1}). As a result of leaf death in the seventh microstage BBCH 71–75, this indicator decreased in all crops and varieties. The average assimilation coefficient at stages 3–7 BBCH 39–75 was – 10.2 g m^3 of dry matter per day for winter wheat, 12.9 g m^3 for rye, and 14.5 g m^3 of dry matter per day for triticale.

Table 3. Total leaf area and crop assimilation coefficient (2019–2021).

Variety	Total leaf area, thousand m^2 ha^{-1}			Assimilation coefficient, g m^3 of dry matter per day	
	stages, code BBCH organogenesis				
	2, BBCH 28–29	3, BBCH 37–39	7, BBCH 71–75	2–3, BBCH 29–39	3–7, BBCH 39–75
Soft wheat (winter)					
Vodogray bilotserkivsky (control)	35.7	56.7	21.5	5.7	9.9
Oberig Myronivsky	38.1	61.5	23.7	6.2	10.6
Mudrist odeska	37.1	39.5	22.4	6.0	10.2
Average	37.0	59.2	22.5	6.0	10.2
Rye (winter)					
Knyazhe (control)	43.0	64.8	23.9	7.2	12.8
Kobza	43.7	63.1	25.3	7.9	13.7
Kharkivyanka	41.7	61.9	22.3	7.2	12.1
Average	42.8	63.3	23.8	7.4	12.9
Triticale (winter)					
Markian (control)	45.3	66.2	25.8	9.0	13.7
Molfar	46.7	70.2	28.8	10.2	15.1
Obrij myronivsky	46.1	69.3	27.6	9.9	14.6
Average	46.0	68.6	27.4	9.7	14.5
	Impact intensity		$SSD_{0.05}$	Impact intensity	$SSD_{0.05}$
Factor:					
A (year)	0.82		1.22	0.67	0.30
B (crop)	0.04		0.94	0.20	0.23
C (grade)	0.01		0.94	0.02	0.23
Interaction of factors:					
AB	0,00		2.11	0.01	0.52
AC	0.00		2.11	0.00	0.52
BC	0.00		1.63	0.01	0.40
ABC	0.00		3.65	0.00	0.90
Other factors	0.13			0.10	

Studies by a number of scientists have confirmed a close correlation between the chlorophyll photosynthetic potential of leaves and grain yield, as follows: 2019 – r = 0.99 ± 0.07; 2020 – r = 0.92 ± 0.22; 2021 – r = 0.99 ± 0.05, which is due to differences in the nature of the relationship of these parameters with weather conditions. The deviations of yields determined by the regression level from the actual value ranged from 0.09 to 1.81 t ha^{-1} and averaged about 0.7 t ha^{-1} (Pryadkina and Shadchina, 2010; Vozhegova et al, 2019; Voloshchuk and Glyva, 2014; Wu et al, 2012; Wang et al, 2013).

Under the conditions of sufficient moisture in the western forest-steppe zone, it is very important to select for cultivation varieties resistant to ear diseases due to excessive rainfall during the ripening-harvesting period (June–July). According to the average data obtained, the lowest percentage of ear septoria was found in the winter wheat variety – Oberig Myronivsky (2.9%), winter rye – Knyazhe, Kobza (2.4%), winter triticale – Molfar (1.7%) (Table 4).

Table 4. Spread of ear diseases of grain crops depending on varietal characteristics in macrostage 9 BBCH 92 (full maturity) (2019–2021), %.

Variety	Septoria (*Septoria nodorum Berk.*)		Fusarium (*Fusarium Link.*)	
Soft wheat (winter)				
Vodogray bilotserkivsky (control)	3.3		2.4	
Oberig Myronivsky	2.9		2.1	
Mudrist odeska	3.6		2.7	
Average	3.3		2.4	
Rye (winter)				
Knyazhe (control)	2.2		1.8	
Kobza	2.2		1.8	
Kharkivyanka	2.8		2.0	
Average	2.4		1.9	
Triticale (winter)				
Markian (control)	2.2		2.1	
Molfar	1.7		1.7	
Obrij myronivsky	1.8		1.7	
Average	1.9		1.8	
Factor:	Impact intensity	$SSD_{0.05}$	Impact intensity	$SSD_{0.05}$
A (year)	0.38	0.16	0.52	0.13
B (crop)	0.21	0.12	0.17	0.10
C (grade)	0.12	0.12	0.10	0.10
Interaction of factors:				
AB	0.21	0.27	0.12	0.23
AC	0.02	0.27	0.01	0.23
BC	0.02	0.21	0.02	0.18
ABC	0.02	0.47	0.03	0.40
Other factors	0.01		0.03	

The average percentage of Fusarium spread was 2.4 – soft wheat, 1.9 – rye, 1.8 – triticale. Weather factors had the greatest impact (38 and 52%) on the damage to winter crop varieties, crop – 21 and 17%, variety – 12 and 10, interaction of all factors – 27 and 18, other factors – 1 and 3%.

Depending on the genetic potential of the variety, its ecological plasticity that allows it to respond positively to the natural and climatic conditions of the study area and the basic cultivation technology used by most small enterprises and farms, we obtained different grain yields over the years (Table 5). It was the highest (5.42 t ha^{-1}) for soft (winter) wheat in 2019, and the lowest (4.98 t ha^{-1}) in 2021. It was most favorable for rye (winter) and triticale (winter) in 2020. The range of phenotypic variability for common wheat was 0.44–0.71 t ha^{-1}, for rye – 0.67–2.22 t ha^{-1}, for triticale – 1.27–1.37 t ha^{-1}.

Table 5. Grain yield of winter crop varieties (2019–2021).

Variety	Grain yield, t ha^{-1}						% to the maximum
	maximum over the test years	in experiments			average	R (max-min)	
		2018	2020	2021			
Soft wheat (winter)							
Vodogray bilotserkivsky (control)	10.0	5.65	5.48	4.98	5.37	0.67	53.7
Oberig Myronivsky	9.5	5.50	5.56	5.12	5.39	0.44	56.7
Mudrist odeska	11.5	5.10	5.13	4.42	4.88	0.71	42.4
Average	10.3	5.42	5.39	4.84	5.22	0.58	50.7
Rye (winter)							
Knyazhe (control)	7.6	5.15	6.35	5.88	5.79	1.20	76.2
Kobza	9.8	5.25	7.47	6.24	6.32	2.22	64.5
Kharkivyanka	7.5	5.06	5.85	5.73	5.55	0.67	74.0
Average	7.6	5.15	6.55	5.95	5.88	1.36	77.4
Triticale (winter)							
Markian (control)	10.0	5.63	7.00	6.71	6.45	1.37	64.5
Molfar	10.0	5.85	7.12	6.85	6.61	1.27	66.1
Obrij myronivsky	9.7	5.96	7.32	6.95	6.74	1.36	69.5
Average	9.9	5.81	7.15	6.84	6.60	1.34	66.7
Factor:	Impact intensity					$SSD_{0.05}$	
A (year)	0.43					0.17	
B (crop)	0.22					0.15	
C (grade)	0.16					0.15	
Interaction of factors:							
AB	0.07					0.29	
AC	0.04					0.29	
BC	0.04					0.23	
ABC	0.03					0.49	
Other factors	0.01						

Comparing the yield actually obtained by the studied winter crop varieties with the maximum productivity in the test years, we determined the level of implementation in the conditions of the studied soil-climatic zone. Thus, for soft wheat, it was 42.4% for the Mudrist odeska variety – 56.7 t ha^{-1} Oberig Myronivsky; for rye – 64.5 (Kobza) – 76.2 t ha^{-1} (Knyazhe), and for triticale – 64.5 (Markiyan) – 69.5 t ha^{-1} (Obrij myronivsky), which indicates the still completely unused genetic potential.

The influence of weather factors on the grain productivity of winter crop varieties was 44.0%, crops – 22.0, varieties – 16, their interaction – 18.0, the rest – 1.0%.

The massive spread of the phenomenon of enzimomycotic depletion of grain (EMDG) has attracted renewed attention in recent years, especially in the western forest-steppe and Polissya. The disease is more prevalent in those years when there is excessive rainfall, frequent fog formation, and air temperatures above 30 °C during the waxy and full ripening of the grain. Drop moisture penetrates into the middle of the grain, causes the hydrolysis of carbohydrates, increases the osmotic pressure in the grain cells and enhances water endosmosis. As a result of the increasing hydrostatic pressure, microscopic ruptures form in the cell walls and grain shells. These gaps produce a sugary liquid on the surface of the grain, which is washed off by raindrops on the spikelet scales and the upper parts of the stem. Fungi of the genera *Alternaria* and *Cladosporium* colonize these secretions, enhancing the development of black germ and olive mold. Enzymomycotic depletion of the grain causes a reduction in wheat yield by 20–30% or more (Vorobyova, 2016).

According to the research of Pogorila et al. (2019), seeds affected by Alternaria are physiologically underdeveloped. They have low germination vigor and similarity. Plants grown from such seeds lag behind in growth and development, resulting in lower yields. Grain flour with a "black germ" has a dark color and poor baking properties.

An important task for the producers of grain products is to prevent or minimize shortfalls and losses in the crop and its quality.

This problem is especially aggravated when the harvesting of winter grain crops is delayed up to 12 days after the onset of full grain maturity due to the lack of harvesting equipment.

In our experiments, the weight of 1000 grains of winter wheat at the stage of full maturity varied from 42.7 g for the variety of the ecological steppe type Mudrist odeska to 44.5 g for the forest-steppe variety Oberig Myronivsky (Table 6). On the 4th day after the onset of full maturity in these varieties, this indicator decreased by 3.3 and 2.5% for these varieties, – by 5.0 and 3.7% g on the eighth day, and by 6.8 and 5.3% on the twelfth day. Compared to wheat, winter rye varieties are characterized by higher average weight loss per 1000 grains – 5.0–10.3%.

Table 6. Weight loss of 1000 grains of winter crop varieties after full maturity (2019–2021).

Variety	Full maturity		Grain weight loss per day, g %		
	g	± to control	4	8	12
Soft wheat (winter)					
Vodogray bilotserkivsky (control)	43.5	-	1.0/3.0	1.9/4.4	2.6/6.0
Oberig Myronivsky	44.5	1.0	1.1/2.5	1.6/3.7	2.3/5.3
Mudrist odeska	42.7	-0.8	1.6/3.3	2.2/5.0	2.9/6.8
Average	43.6		1.2/2.9	1.9/4.4	2.6/6.0
Rye (winter)					
Knyazhe (control)	35.4	-	1.7/4.8	2.6/7.4	3.6/10.3
Kobza	36.4	1.0	1.7/4.6	2.3/6.5	3.3/9.3
Kharkivyanka	34.0	-1.4	1.9/5.6	2.8/8.3	3.8/11.2
Average	35.3		1.8/5.0	2.6/7.4	3.6/10.3
Triticale (winter)					
Markian (control)	44.0	-	1.4/3.3	2.2/5.0	3.0/6.9
Molfar	45.6	1.6	1.4/3.1	2.1/4.6	2.3/6.4
Obrij myronivsky	45.7	1.7	1.4/3.1	2.0/4.4	2.9/6.4
Average	45.1		1.4/3.2	2.1/4.7	2.7/6.6
Factor:	Impact intensity		$SSD_{0.05}$		
A (year)	0.45		0.24		
B (crop)	0.18		0.19		
C (grade)	0.15		0.19		
Interaction of factors:					
AB	0.06		0.42		
AC	0.04		0.42		
BC	0.07		0.32		
ABC	0.03		0.72		
Other factors	0.02				

The data of the analysis confirm that the years of research had the greatest impact on the phenomenon of enzymomycotic depletion of grain - 45%; the plant - 18% and the variety - 15%, to a lesser extent.

Climate change puts additional pressure on agricultural producers, especially the most vulnerable smallholder farms not only in Ukraine, but worldwide (Mavromatis, 2015; Iizumi et al., 2018; Hochman et al., 2017; Gupta et al., 2017; Donatti et al., 2019).

To solve the problem of food security in any country, much attention is paid to the use of new varieties that provide higher gross yields by 20–50%. Research by Chinese scientists confirms that the yield potential depends on a variety adapted to an environment with unlimited nutrients, water, effective control of pests and diseases, and exploits the yield potential of rice by more than 80%. Breeders consider it a priority to reduce the yield gap between corn and wheat through new varieties (Fan et al., 2012).

According to Ceglara et al. (2019), the gaps in the yield of grain crops range from 10 to 70% in the world, being small in many countries of North-Western Europe and large in Eastern and South-Western Europe. They are lower for rainfed and irrigated corn than for wheat and barley. The potential for increasing grain production is in Eastern Europe, half of which is in Ukraine, Romania and Poland.

Conclusion

With the basic growing technology and favorable weather conditions, winter crop varieties had optimal development at the end of the fall vegetation, and accumulated a sufficient amount of sugars in the tillering nodes (26.9–27.1%), which contributed to a high percentage of overwintering (96.6 – soft wheat [winter], 94.9 – sowing rye [winter], 94.2 – triticale [winter]). The largest total leaf surface area in the third macrostage BBCH 37–39 was formed by varieties: soft winter wheat – Oberig myronivsky (61.5 thousand m^2 ha^{-1}), rye – Knyazhe (64.8 thousand m^2 ha^{-1}), triticale – Molfar (70.2 thousand m^2 ha^{-1}). The average degree of spread of ear diseases was as follows: soft winter wheat – 3.3% (septoria), 2.4% (fusarium); rye – 2.4 and 1.9%, respectively, winter triticale – 1.9 and 1.8%, respectively. The grain yield of soft winter wheat varieties ranged from 4.88 (Mudrist odeska) to 5.39 t ha^{-1} (Oberig myronivsky); rye – 5.55 (Kharkivyanka) – 6.32 t ha^{-1} (Kobza); triticale – 6.45 (Markiyan) – 6.74 t ha^{-1} (Obrij myronivsky). Grain productivity of soft winter wheat varieties varied from 4.88 t ha^{-1} (Mudrist odeska) to 5.39 t ha^{-1} (Oberig myronivsky); rye – from 5.55 t ha^{-1} (Kharkovyanka) – to 6.32 t ha^{-1} (Kobza); triticale – from 6.45 t ha^{-1} (Markiyan) – to 6.74 t ha^{-1} (Obrij myronivsky). When overstaying grain “on the root” for 12 days, the average weight loss of 1000 grains for varieties of soft wheat (winter) was – 6.0%, for triticale (winter) – 6.6%, and for rye (winter) – 10.5%.

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KOMPARATIVNA OCENA PRODUKTIVNOSTI OZIMIH USEVA (PŠENICA [*TRITICUM AESTIVUM L.*], RAŽ [*SECALE CEREALE L.*], TRITIKALE [*TRITICOSECALE WITT.*]) U ZAPADNOJ ŠUMO-STEPI UKRAJINE

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R e z i m e

Cilj rada je bio da se odrede parametri prilagodljivosti sorti ozimih kultura za gajenje u zapadnoj šumo-stepskoj zoni Ukrajine (2019–2021). Predmet istraživanja bile su sorte pšenice (*Triticum aestivum L.*): Vodogray bilotserkivsky, Oberig Myronivsky, Mudrist odeska; raži (*Secale sereale L.*): Knyazhe, Kobza, Kharkivyanka; i tritikalea (*Triticosecale Witt.*): Markian, Molfar, Obrij myronivsky. Ispitivanja su obavljena u uslovima poljskog ogleda. Površina ogledne parcele iznosila je 55 m^2, a ogled je bio postavljen u tri ponavljanja. Rezultati su pokazali da je u skladu sa osnovnim tehnologijama gajenja i vremenskim uslovima tokom vegetacionog perioda, produktivnost sorti meke pšenice varirala od 4,88 (Mudrist odeska) do 5,39 t ha^{-1} (Oberig Myronivsky); raži – od 5,55 (Kharkivyanka) do 6,32 t ha^{-1} (Kobza); i tritikalea – od 6,45 (Markian) do 6,74 t ha^{-1} (Obrij myronivsky). Dobijeni rezultati dovode do zaključka da ekološki plastične sorte ozimih useva u uslovima proučavane zemljišno-klimatske zone akumuliraju dovoljnu količinu šećera u čvorovima bokorenja - 25–30%, osiguravaju prezimljavanje biljaka - 94–96%, otporne su na glavne bolesti, što doprinosi proizvodnji visokokvalitetnog semena za snabdevanje obradivih površina u regionu i efikasnost semenske proizvodnje.

Ključne reči: bolest, ozima meka pšenica, ozima raž, ozimi tritikale, masa 1000 zrna, prinos.

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