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ECONOMIC VALUABLE INDICATORS OF WINTER BREAD WHEAT ACCESSIONS WITH DIFFERENT PIGMENTATION OF KERNELS

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The article presents the results of evaluating winter bread wheat varieties and lines with different pigmentation of kernels for economically valuable characteristics and biochemical parameters. Winter bread wheat accessions blue and purple kernels were noticeable for increased levels of the total antioxidant activity and increased contents of polyphenols and anthocyanins. Instead, they were significantly inferior to modern locally bred varieties in terms of yield due to low adaptability to local conditions, which was manifested as reduced winter hardiness, low resistance to diseases, late ripening and tall plants. Involvement of accessions of high biochemical value in hybridization allowed us to obtain material that is better adapted to the conditions of North-Eastern Ukraine, however, further breeding is necessary to create a commercial variety.

Key words: *winter wheat, kernel pigmentation, yield, phenols, anthocyanins, micronutrients*

Introduction. Pigmented grain of cereals, in particular wheat, is attracting more and more attention primarily due to its high antioxidant activity and clinically proven advantages over grain of traditional varieties in terms of significant positive impact on physical health of humans [1]. In addition, high contents of pigments in wheat grain is of direct agronomic importance, as they are associated with plant resistance to environmental stressors and diseases [2]. Since the kernel pigmentation and contents of bioactive substances are controlled by genotype, it is possible to improve the biochemical value of winter wheat grain via breeding [3].

Literature review and problem articulation. Cereals play a key role in human nutrition. Among cereals, the leading position is occupied by wheat, which is used for different purposes, including bread, noodles, cookies, flakes, etc. Wheat is a source of starch, protein, minerals, and dietary fiber, satisfying a significant percentage of daily calorie needs. However, today there is a growing interest in functional bakery products with high contents of biologically active compounds and increased benefits for human health [4], primarily to prevent some chronic diseases [5], such as type 2 diabetes [6], cardiovascular diseases [7], neurodegenerative disorders [8]. High contents of biologically active compounds, which correlate with a high antioxidant activity in pigmented wheat genotypes, may be used as stress-resistant genotypes [9] as well as in the production of functional foods [10]. Hence, recently breeders, grain processors and producers of functional foods have been paying a lot of attention to pigmented wheat (blue, black, violet), which contain more bioactive phytochemical compounds (anthocyanins, polyphenols) [4].

The unusual pigmentation of kernels is attributed to blue aleurone (*Bagenes*), violet pericarp (*Ppgenes*) and yellow endosperm (*Psygenes*), which are determined by the presence of polyphenols, tannins, anthocyanins, and carotenoids, respectively [3]. The color in red-grained wheat is determined by the dominant alleles of 1 to 3 genes: R-A1b (chromosome 3AL), R-B1b (chromosome 3BL), and R-D1b (chromosome 3DL) [11]. Unlike red-grained wheat, white color of kernels is determined by the recessive alleles of these genes, and the white wheat genotype has the following genetic formula: R-A1a, R-B1a, R-D1a. Chromosomal translocations from couch grass cause the appearance of black grain in wheat, which is associated with increased contents of vitamins, valuable minerals (including selenium) in grain and total antioxidant activity [8]. It should be noted that black-grained wheat varieties is now especially popular in China because of higher antioxidant activity of grain compared to red-grained wheat [12]. Violet color of kernels is a highly variable trait (from light-violet to black-violet) [13]. The violet color of the pericarp is controlled by two complementary dominant genes: *Pp1* (chromosome 7B) and *Pp3* (chromosome 2A) [14]. An Austrian blue-grained variety, Skorpion, is another promising donor of a high antioxidant activity due to high contents of anthocyanins in the aleurone layer of caryopses. The blue color of kernels in this variety is determined by 2 genes: *Ba1* (located on chromosome 4BS (4el2) and transferred to the wheat genome from *Thinopyrum ponticum* Podp.) and *Ba2* (located in the long arm of chromosome 4Am and transferred to hexaploid wheat from wild einkorn *Triticum monococcum* L.) [15].

Given the importance of pigmented wheat in the diet, a lot of research centers around the world intensively breed wheat with pigmented kernels to biofortify grain of this crop. China is leading in the creation of varieties with violet, black and blue grain, as over 20 black-grained wheat varieties and over 10 blue-grained wheat varieties have been registered there [16]. Breeders in the SlovakRepublic [17] and the CzechRepublic [18] have also made significant progress in this direction: they have bred new promising varieties, using blue-grained Skorpion and violet-grained PS Karkulka. Breeding for these traits has been started in Turkey [19] and Russia [20]. In Ukraine as of 2022, the State Register of Plant Varieties Suitable for Dissemination in Ukraine includes violet-grained variety Chornobrova (Institute of Plant Physiology and Genetics of NAS) and white-grained variety Biliava (Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation ofNAAS) [21].

Foreign wheat accessions with pigmented grain are inferior to varieties with typical (red or white) grain grown in Ukraine in terms yield and other economic indicators [22]. Thus, our study was aimed to evaluate modern varieties and breeding lines of winter bread wheat with different pigmentation of kernels for valuable economic and biochemical characteristics, determining the stability of their expression.

Purpose and objectives. To screen modern varieties and breeding lines of winter bread wheat with different pigmentation of grain for valuable economic and biochemical characteristics, determining the stability of their expression.

Materials and methods. Sixty six breeding accessions from eight European countries were studied. Most varieties and lines had red grain; Biliava and Grekum1197-17 were white-grained; two varieties (Chornobrova and Chornozerna) and line Bluex Red had violet caryopses; and variety Scorpion and lines KM 186/2, Vavilovy 2004-87, Viridiferrugineum 2022-87, and Germakianum 2005-87 had a blue aleurone layer, due to which caryopses were blue-green.

The field experiments were conducted in the breeding crop rotation fields of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2017–2020 in compliance with the methods of qualification examination of plant varieties [23] and Merezhko A.F., Udachyn R.A. et al.' recommendations [24].

Laboratory tests. The total content of phenolic compounds was determined with Folin-Ciocalteu reagent [25] and calculated in micrograms (μg) of gallic acid equivalent per gram of dry matter.

The total antioxidant activity (AOA) was assessed by ability of ethanol extracts to neutralize the DPPH radical, as S. Arabashahi and A. Urooj described [26].

The content of anthocyanins was spectrophotometrically determined [27.]. The light absorption of samples was measured at a wavelength of 530 nm against distilled water. The data were calculated in μg of cyanidino-3-glucoside (Cy 3-glu) equivalent per gram of dry matter.

Trace element contents were determined atomic absorption spectrophotometers AANALYST 400 and Saturn-4 EPAV, after mineralization in accordance with DSTU 7670: 2014 [28], in the certified Laboratory of Instrumental Methods of Soil Science, Standardization and Metrology of the National Research Center Institute of Soil Science and Agrochemistry named after O.N. Sokolovsky.

Data were statistically processed (correlation analysis, analysis of variance and linear constructions of different degrees) in accordance with Ermantraunt E.R., Hoptsii T.I. et al.' guidelines [29] in STATISTICA 6.1, SN BXXR502C631824NET3.

The weather in 2017–2020 differently affected the growth and development of winter wheat plants. As to the beginning of the growing period, August–October 2018 were unfavorable because water deficit: 54.6 mm of precipitation fell, which was more than twice less than the average. In addition, in August–September 2017, only 37.1 mm fell; in 2019 – 26.6 mm, and only October precipitation allowed for full seedlings in the autumn.

The warm conditions in January–February 2018 and 2019 with sufficient snow contributed to the spread of snow mold, which became the main factor in reducing the winter hardiness of some lines. At the end of 2019 – beginning of 2020, no stable above-zero average daily temperatures were observed. Thus, there were no harsh factors for overwintering in the study years to clearly differentiate the test material under natural conditions.

The average daily temperatures increased above 0°C during the second or third 10 days of February, except for 2018, when below-zero temperatures lasted until April, and the winter wheat vegetation renewed in March or April, respectively.

The precipitation amount in April–July 2020 exceeded the average, while in 2017, 2018 and 2019 it was significantly lower, but as it was relatively evenly distributed by months, it did not cause significant deterioration of plants. At the same time, in 2019 the average daily air temperature in June was 24.8°C, which significantly accelerated the winter wheat ripening. In general, the vegetation periods in the study years were quite diverse, which allowed us to distinguish both highly productive accessions and stable and adapted to the regional conditions ones.

Results and discussion. Of the studied accessions, variety Slaven turned out to be the most short-season one; Zdobna, Krasa Laniv, Grekum 1197-17, Metalist, Kantata, Kokhanka, Yednist, Sympatiia, Shchedrist Odeska, Borovytsia, MV Nador, MV Pengo, Astra, and Kurs formed ears concurrently with short-season check varieties Smuhlianka and Bunchuk. Accessions Ferugineum 1239, Lucio, Fiorina, Viglanka, Scorpion, BluexRed, KM 186/2, Vavilovy 2004-87, Viridiferrugineum 2022-87, Germakianum 2005-87, Yuzhanka, and Yuka formed ears 4-7 days later than the check variety. That is, the accessions with a pigmented aleurone layer were characterized by late ripening. Under water deficit, late-ripening accessions were not able to reach their potential productivity. In particular, in 2019 the correlation between the 'spring vegetation resumption – earing' period length and yield was significantly negative (r = -0.65); so was the correlation between the 'spring vegetation resumption – earing' period length and the productive stems density (= -0.68), while the correlation between the 'spring vegetation resumption – earing' period length and the plant height was significantly positive (r = 0.47).

In the study years, there were no critical conditions for wheat plant overwintering. However, KM 186/2 and MV Pengo were slightly less winter-hardy than other accessions, but due to mild winters, the differences between them were not significant. MV Lucia, Biliava, and Nebokray were more affected by snow mold (resistance 4-5 points). Podolianka, Pryvitna, Rozkishna, Grekum 1197-17, Zdobna, Sympatiia, and Lucio combined high winter hardiness (8-9 points) and resistance to snow mold (7-8 points).

Of leaf diseases, powdery mildew, leaf blotch and yellow leaf spot affected plants greatly in 2018 (the average resistance in the studied array was 5.9; 5.8 and 6.8 points, respectively). In 2017 and 2019, the prevalence of these diseases was much lower. The average resistance to powdery mildew of > 7.0 points was recorded for Borovytsia, Katrusia Odeska, Talisman, Viglanka, Fiorina, MV Pengo, MV Nador, and Vyd. Koliada, Kalym, MV Pengo, and MV Nador showed resistance to leaf blotch of > 7.0 points. MV Korej, MV Pengo, MV Nador, Viglanka, Krasnopilka, Sotnytsia, Nebokray, Katrusia Odeska, Kantata Odeska showed resistance to yellow leaf spot of > 7.5 points. Accessions with white, violet or blue-green kernels did not have complex resistance to diseases (Table 1).

Table 1

Resistance of the wheat accessions to diseases in 2018, score

Accession	Resistance to			
	Snow mold	Powdery mildew	Leaf blotch	Yellow leaf spot
Bunchuk (check variety)	8.0	6.3	6.3	6.3
Fiorina	7.7	7.0	6.0	7.3
KM 186/2	8.3	6.7	6.0	7.3
Lucio	8.7	6.7	6.3	5.0
MV Korej	7.0	6.7	5.7	7.7
MV Lucia	7.0	6.0	5.3	8.0
MV Nador	8.0	6.7	6.7	7.7
MV Pengo	6.3	7.7	7.0	8.0
MvToldi	6.7	6.3	5.3	7.0
Blue x Red	7.0	6.7	4.7	6.0
Podolianka (check variety)	8.0	7.0	5.0	6.0
Scorpion	7.0	5.7	6.0	7.0
Viglanka	6.7	6.3	5.7	7.3
Biliava	6.7	6.0	5.3	5.7
Borovytsia	8.7	6.7	6.0	7.0
Vavilovy 2004-87	7.3	5.7	4.7	6.7
Vyd	8.7	6.3	5.0	6.3
Viridiferrugineum 2022-87	7.7	6.0	6.0	6.7
Germakianum 2005-87	7.3	5.0	5.3	6.0
Zapashna	8.3	5.3	5.7	6.7
Smuhlianka (check variety)	8.7	6.3	6.3	7.0
Kalum	8.0	7.3	7.3	7.7
Katrusia Odeska	8.3	7.0	6.7	8.0
Koliada	7.0	5.7	6.3	7.0
Kantata Odeska	8.0	5.0	6.0	7.7
Krasnopilka	8.0	7.0	6.3	7.3
Doskonala (check variety)	7.3	6.0	6.3	7.0
Nebokray	7.0	5.7	5.7	7.7
Grekum 1197-17	7.7	4.7	5.7	6.3
Pryvitna	8.3	6.0	6.0	7.0
Sotnytsia	7.0	5.7	6.7	7.3
Rozkishna (check variety)	7.7	6.0	5.7	7.0
Talisman	7.3	6.3	5.0	6.3
Chornobrova	7.7	6.0	5.3	5.7
Chornozerna	7.7	5.0	4.7	5.3

The plant height also changed over the years: it was the minimum in 2018 (88 cm on average across the studied accessions), significantly higher (97 cm) in 2017, and maximum (100 cm) in 2019. Of the varieties, Ferugineum 1239 and Kharkivska 63 were the tallest (141 cm and 130 cm, respectively); accessions with atypical pigmentation of kernels were also quite tall: Germakianum 2005-87 (121 cm), Viridiferrugineum 2022-87 (120 cm), BLUE x RED (115 cm), Vavilovy 2004-87 (113 cm), Chornobrova (110 cm), Chornozerna (109 cm). Nebokray, MV Nador, Kalym, and blue-grained KM 186/2 plants were lower than 80 cm. The correlation between the plant height and yield in 2017 was insignificant, while in 2018 and 2019 it was significantly negative ($r=-0.32$ and -0.64, respectively; $p < 0.05$). In general, the relationship between the yield and plant height is best described by a second-degree polynomial function (Fig. 1), where the optimal plant height was 80–100 cm.

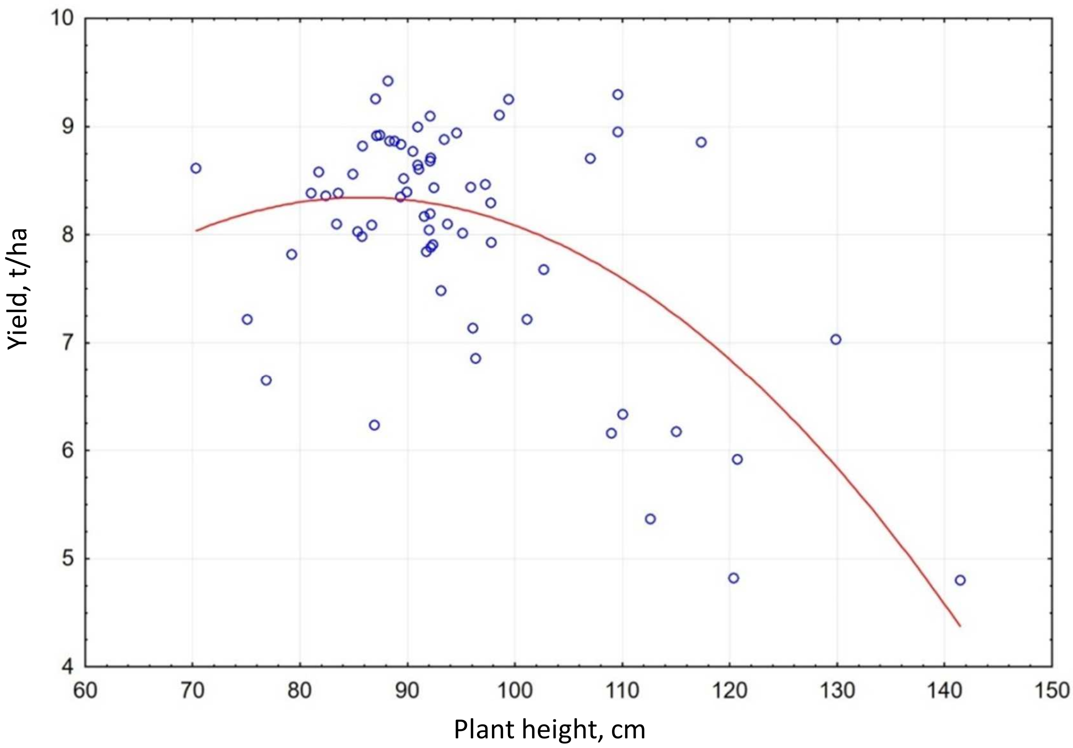

Fig. 1. Second degree polynomial reflecting the relationship between the winter wheat yield and plant height, 2017–2019.

It was the productive stem density that determined the yield level. The correlation between these parameters was significantly ($p < 0.01$) positive every year; the correlation coefficient was 0.62, 0.66, and 0.64 in 2017, 2018, and 2019, respectively, with the three-year average of 0.67. Construction of the second degree polynomials showed that in the study years the ear density was not optimal, after which a decrease in yield would be observed: an increase in all segments of its variability led to a greater or lesser rise in the yield. Amper, Zoloto Ukrainy, Kokhanka, Krasa laniv, Grekum 1197-17, Polianka, Sympatiia, Sotnytsia, Talisman, Viglanka, and MV Pengo had a consistently density of > 7.5 points. The accessions, whose kernels were not red, except for Grekum 1197-17, had a productive stem density of < 6.5 points.

In the end, the yields from the accessions with atypical grain color were also significantly lower (Table 2). On average across the three years, the yield of ≥9 t/ha was produced, in addition to the check varieties (Rozkishna and Doskonala), by Zoloto Ukrainy, Katrusia Odeska, Krasnopilka, Polianka, Pochaina, and Talisman. Of the high-yielding accessions, a stable expression of this trait with a coefficient of variation of below 15% was recorded, in addition to the check varieties, for Ampir, Pryvitna, Smuhlianka, Slaven, Sotnytsia, Spasivka, Tabor, MV Lucia, Nikifor, and Viglanka.

The accessions with atypical grain color were characterized by increased contents of biologically active substances. Thus, the total content of phenols in meal from varieties and lines with blue or violet kernels exceeded 800 µg/g of gallic acid equivalent, while it was 592 µg/g in Biliava and 793 µg/g in the check variety (Zapashna). Of the red-grained accessions, this parameter was also high in MV Nador, Kurs, and Yuzhanka. The content of phenols in bran was even higher: ≥1000 µg/g in Scorpion, Blue x Red, Chornozerna, and Germakianum 2005-87. The anthocyanin content in the red- and white-grained accessions ranged 0.032 to 0.128 (A_{530}-A_{700})/g, while in the blue-grained accessions it ranged within 0.278-0.364 (A_{530}-A_{700})/g and in the violet-grained ones – within 0.544-1.716 ($A_{530} - A_{700}$)/g, with the maximum recorded for Blue x Red.

Table 2

Yields of the best varieties and accessions with atypical grain color by years, t/ha

Accessions	Year			2018-2019 average	2017-2019 average	CV, %
	2017	2018	2019			
BLUE x RED	6.71	5.05	6.77	5.91	6.17	15.8
KM 186/2	–	5.42	9.02	7.22	–	–
Scorpion	5.88	6.46	8.23	7.35	6.86	17.9
Bunchuk (check variety)	8.24	7.24	10.20	8.72	8.56	17.6
Doskonala (check variety)	9.78	7.48	10.63	9.06	9.30	17.5
Podolianka (check variety)	9.67	7.00	6.37	6.68	7.68	22.8
Rozkishna (check variety)	8.98	7.51	10.83	9.17	9.11	18.3
Smuhlianka (check variety)	8.80	7.98	9.98	8.98	8.92	11.2
Ahra	10.21	6.86	9.50	8.18	8.86	20.0
Biliava	6.29	6.21	8.92	7.56	7.14	21.6
Vavilovy 2004-87	–	4.26	6.48	5.37	–	–
Vyd	9.33	7.03	9.96	8.49	8.77	17.6
Viridiferrugineum 2022-87	–	4.26	5.39	4.82	–	–
Germakianum 2005-87	–	5.22	6.62	5.92	–	–
Grekum 1197-17	8.87	7.31	10.66	8.98	8.94	18.7
Zoloto Ukrainy	10.56	6.96	10.76	8.86	9.42	22.7
Kalancha	8.93	7.06	10.61	8.84	8.87	20.0
Katrusia Odeska	7.73	7.46	10.63	9.04	8.61	20.5
Koliada	10.36	7.04	9.36	8.20	8.92	19.1
Kokhanka	9.25	6.53	10.36	8.44	8.71	22.6
Krasnopilka	9.22	7.39	10.69	9.04	9.10	18.2
Obriad	9.23	7.16	10.21	8.69	8.87	17.6
Polianka	10.15	7.07	9.77	8.42	9.00	18.7
Pochaina	10.08	7.28	10.40	8.84	9.25	18.5
Pryvitna	7.95	8.17	10.00	9.08	8.71	12.9
Slaven	8.79	8.03	9.82	8.93	8.88	10.1
Sontutsia	8.83	7.98	10.04	9.01	8.95	11.6
Spasivka	8.91	7.79	9.77	8.78	8.82	11.2
Talisman	11.42	7.11	9.24	8.18	9.26	23.3
Chornobrova	4.67	6.14	8.19	7.17	6.34	27.9
Chornozerna	5.05	5.98	7.47	6.72	6.16	19.8
Yuzhanka	9.88	6.97	9.67	8.32	8.84	18.4
$LSD_{05\ variety}$	–	1.28	1.85	1.13	–	–
$LSD_{05\ year}$	–	–	–	0.20	–	–
$LSD_{05\ interaction}$	–	–	–	1.59	–	–

There were no significant differences in the contents of trace minerals in grain of the studied accessions (Table 3). The maximum content of zinc was found in Viridiferrugineum 2022-87, and Germakianum 2005-87; the maximum content of iron – in Amper, MV Korej, Viridiferrugineum 2022-87, and Germakianum 2005-87; the maximum content of copper – in Antonivka and Biliava.

Table 3

The contents of trace minerals in the differently pigmented winter bread wheat kernels, harvested in 2017

Accession	Trace mineral content, mg/kg		
	Zn	Fe	Cu
MV Korej	19.7	44.4	3.6
Blue x Red	22.7	36.0	2.9
Scorpion	21.1	34.7	3.0
Amper	21.9	42.3	2.5
Antonivka	13.8	35.6	5.0
Biliava	23.4	35.5	4.0
Vavilovy 2004-87	24.2	35.8	1.7
Viridiferrugineum 2022-87	29.1	48.8	2.5
Germakianum 2005-87	33.1	43.5	3.2
Zapashna (check variety)	15.7	33.1	3.6
Zdobna	16.3	34.0	3.5
Kalancha	21.8	31.6	2.2
Kalym	21.1	29.8	3.0
Krasa Laniv	22.2	29.3	2.4
Grekum 1197-17	23.8	36.1	3.0
Pryvitna	19.0	35.4	3.0
Sotnytsia	22.4	38.1	1.4
Chornobrova	17.8	34.6	2.6
Chornozerna	23.3	38.5	1.7
Shchedrist Odeska	20.8	33.0	1.1

The total antioxidant activity of the studied wheat varieties and lines differed over the study years. It was the highest in 2017, amounting to 524 µg/g of chlorogenic acid equivalent; in 2018, 2019, and 2020, the average values were significantly lower – 419, 418, and 405 µg/g, respectively. The blue- and violet-grained accessions were superior to the white- and red-grained ones in terms of the total antioxidant activity (Table 4); however, due to the yearly fluctuations, the differences were only significant in some cases.

Of the red-grained varieties and lines, the AOA in Bunchuk, Metelytsia Kharkivska, Ferugineum 1239, CH – SO 114, Fiorina, Nikifor, and Sanaby was by ≥7% higher than the average value. The AOA in Sympatiia, MV Korej, Mv Toldi, and Astra was by ≤ 10% lower than the average value.

Of the lines created in 2019–2020, lines with a blue aleurone layer (Viridilutescens P5419 (Ahra / KM 186/2); AOA = 488.6 µg/g; yield = 657.3 g/m^2), with violet kernels (Uralikum P6719 (Chornobrova / Ustyvytsia); AOA = 457.4 µg/g; yield = 610.7 g/m^2) and with cream-colored endosperm (L244-1 (Volgouralskaya // Donetska 48 / ID477); AOA = 444.8 µg/g; yield = 683.6 g/m^2) were distinguished because of a high AOA.

Several breeding lines were derived from the selected sources of high antioxidant activity, phenols, and anthocyanins; the lines are being tested in preliminary and competitive variety trials and were included in a working collection of the National Center for Plant Genetic Resources of Ukraine (Request for issuance of "Registration Certificate for the Trait Collection of the Plant Gene Pool in Ukraine" No 000452 dated 10.27.2020).

Table 4

Total antioxidant activity in the winter bread wheat accessions with differently pigmented kernels

Accession	AOA, µg/g of chlorogenic acid equivalent, 2017–2018	Standard deviation	AOA, µg/g of chlorogenic acid equivalent, 2017–2020	Standard deviation
KM 186/2	569	107.6	514	91.1
BLUE x RED	680	161.7	581	151.0
Scorpion	573	70.6	509	87.3
Krasa Laniv	450	102.6	418	70.7
Pryvitna	426	108.5	415	64.0
Rozkishna (check variety)	416	125.8	410	76.5
Chornobrova	487	138.2	456	89.8
Chornozerna	487	111.5	448	79.2
Biliava	491	28.9	–	–
Vavilovy 2004-87	527	70.1	–	–
Viridiferrugineum 2022-87	590	94.6	–	–
Germakianum 2005-87	516	200.0	–	–
Smuhlianka	456	21.8	–	–
Zapashna	452	63.5	–	–
Zdobna	490	51.9	–	–
Podolianka	485	58.2	–	–
Katrusia Odeska	486	67.4	–	–
Doskonala	488	35.2	–	–

Conclusions. The winter bread wheat accessions with blue (Scorpion, KM 186/2, Vavilovy 2004-87, Viridiferrugineum 2022-87, and Germakianum 2005-87) and violet (Chornobrova, Chornozerna, and Blue x Red) kernels were noticeable for a high antioxidant activity as well as for high contents of polyphenols and anthocyanins; Viridiferrugineum 2022-87 and Hermacianum 2005-87 additionally had increased contents of zinc and iron. These accessions were significantly inferior to the common modern locally-bred varieties in terms of yield due to low adaptability to the local conditions, which was manifested as lowered winter hardiness, weak resistance to diseases, late ripening, and tall plants, resulting in a reduced productive stem density and performance. Involvement of accessions with high biological value in hybridization allowed us to obtain lines that are better adapted to the conditions of North-Eastern Ukraine (Viridilutescens P5419, Uralikum P6719, and L244-1); however, further breeding is required to create a commercial variety.

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ЦІННІ ГОСПОДАРСЬКІ ПОКАЗНИКИ ЗРАЗКІВ ПШЕНИЦІ М’ЯКОЇ ОЗИМОЇ З РІЗНИМ ЗАБАРВЛЕННЯМ ЗЕРНА

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Мета і задачі дослідження. Провести скринінг сучасних сортів та селекційних ліній пшениці м’якої озимої з різним забарвленням зернівки за цінними господарськими та біохімічними ознаками, визначити стабільність їх прояву.

Матеріали та методи. Вихідний матеріал – 66 зразків пшениці озимої, серед яких: два білозерні зразки, три – з фіолетовим забарвленням зернівки, шість мали блакитнозабарвлений алейроновий шар, зернівки інших зразків мали червоне забарвлення. Польові досліди проведено у 2017–2020 рр. за методикою кваліфікаційної експертизи сортів рослин. Визначали загальний вміст фенольних сполук, загальну антиоксидантну активність, вміст антоціанів та мікроелементів. Статистичний обробіток даних складався з описової статистики, кореляційного, дисперсійного аналізів.

Обговорення результатів. Зразки із забарвленим алейроновим шаром виколошувалися на 4–7 діб пізніше за стандарт та не відзначалися стійкістю проти хвороб. Висоту рослин понад 109 см мали зразки Феругінеум 1239, Харківська 63, Гермакианум 2005-87, Виридиферругинеум 2022-87, BLUExRED, Вавилови 2004-87, Чорноброва, Чорнозерна. Визначальним для врожайності показником стала густота продуктивного стеблостою, яка була меншою за 6,5 балів у зразків з нетиповим забарвленням зернівки. Виділено зразки з урожайністю понад 9 т/га серед червонoземних сортів, переважно української селекції. Зразки з блакитним та фіолетовим забарвленням зернівки характеризувались істотно нижчою врожайністю, але відзначались високими загальним вмістом фенолів у шроті (понад 800 мкг/г за еквівалентом галової кислоти), вмістом антоціанів, загальною антиоксидантною активністю (понад 500 мкг/г за еквівалентом хлорогенової кислоти).

Висновки. Зразки з нетиповим забарвленням зернівки відрізняються підвищеним вмістом біологічно активних речовин, але суттєво поступаються комерційним сортам за врожайністю через низьку адаптованість до місцевих умов. Залучення їх до гібридизації дозволило отримати пристосований до умов України матеріал, але для створення комерційного сорту необхідна подальша селекційна робота.

Ключові слова: *пшениця озима, забарвлення зернівки, урожайність, фенол, антоціан, мікроелементи*

ECONOMIC VALUABLE INDICATORS OF WINTER BREAD WHEAT ACCESSIONS WITH DIFFERENT PIGMENTATION OF KERNELS

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Purpose and objectives. To screen modern varieties and breeding lines of winter bread wheat with different pigmentation of grain for valuable economic and biochemical characteristics, determining the stability of their expression.

Materials and methods. Sixty-six winter wheat accessions, including 2 white-grained accessions, 3 accessions with violet kernels, 6 accessions with a blue aleurone layer (the other accessions were red-grained), were studied. The field experiments were conducted in 2017–2020 in compliance with the methods of qualification examination of plant varieties. The total content of phenolic compounds, total antioxidant activity, as well as contents of anthocyanins and micronutrients were determined. Descriptive statistics, correlation, and analysis of variance were used to statistically process the data obtained.

Results and discussion. The accessions with a pigmented aleurone layer formed ears 4–7 days later than the check variety and were not resistant to diseases. Plants were taller than 109 cm in Ferugineum 1239, Kharkivska 63, Germakianum 2005-87, Viridiferrugineum 2022-87, BLUExRED, Vavilovy 2004-87, Chornobrova, and Chornozerna. It was the productive stem density (which was less than 6.5 points in the accessions with atypical grain color) that determined the yield level. The accessions yielding over 9 t/ha were selected of the red-grained varieties; most of them had been bred in Ukraine. The accessions with blue and violet kernels gave significantly lower yields, but they were characterized by high total content of phenols in meal (over 800 μg/g of gallic acid equivalent), high content of anthocyanins, and high total antioxidant activity (over 500 μg/g of chlorogenic equivalent).

Conclusions. The accessions with atypical grain color were noticeable for high contents of biologically active substances, but they were significantly inferior to the commercial varieties in terms of yield due to low adaptability to the local conditions. By involving them in hybridization, we obtained material adapted to the conditions of Ukraine; however, further breeding is needed to create a commercial variety.

Key words: *winter wheat, kernel pigmentation, yield, phenols, anthocyanins, micronutrients*