UDC 633.1:631.527 DOI: 10.30835/2413-7510.2022.271759

CURRENT STRATEGY OF CEREAL BREEDING

Kyrychenko V.V., Vasko N.I., Leonov O.Yu., Shchypak H.V., Suvorova K.Yu., Morhun O.V.
Plant Production Institute named after V.Ya. Yuriev of NAAS, Ukraine

Basing on results of long-term research (2015–2021), the Plant Production Institute named after V.Ya. Yuriev of NAAS determined the genetic and phenotypic variabilities of cereal genotypes (winter wheat and triticale, spring barley) for useful economic characteristics, adaptability, and grain and flour quality indicators. New breeding material was created; it allows for expansion of new trends in the breeding of these crops; the trends are focused on increasing the physiological value of end-use products: bread, cookies, cakes, flakes, etc. New cereal cultivars have been bred: Haiok, Metelytsia Kharkivska, Pronia, Mavka IR, Mazurok, Tymofii, Pudik, Yelan, Parnas, Yavir, and Shedevr. Grain and flour of these cultivars meets the requirements of the food industries, in particular, baking and confectionery ones. The cultivars have passed state registration and are allowed to be grown at Ukrainian agrarian enterprises.

Keywords:*winter wheat, winter triticale, spring barley, yield, grain quality, fiber, protein, genetic resources, antioxidant activity, phytonutrients, adaptability.*

Introduction. According to epy FAO data[1], the volume of feed grain production in the world in 2022 was expected to be 1,462 million tons, including 680 million tons of wheat. These figures are lower by 5 million tons or by 3.1% than the 2021 figures. The predicted deficit in cereals in the 2022–2023 will reach 0.7% (21 million tons). The current situation at the global grain market is caused by a long drought in Argentina, a drought in several European Union countries, and the war in Ukraine. At different levels of production intensification and various characteristics of climatic zones of cultivation, the variety has always been and remains one of the main factors in increasing grain yields. M.A. Lytvynenko (2006) demonstrated that a 75% increase in grain production depended on the genetic potential of new varieties and hybrids. Nevertheless, the vast majority of farmers only use 45–55% of the genetic potential of cereals (wheat, rye, triticale, barley). The idea of industrial F_1 hybrids based on cytoplasmic or male sterility with a certain restoration of pollen fertility is advancing very slowly. Work on food triticale cultivars and F_1 hybrids is inefficient. Methods of identifying new genotypes with higher contents of phytonutrients, such as phenolic acids, anthocyanins, flavonoids, etc., are insufficiently used.

Scientists' (breeders', geneticists', physiologists') objective is to develop these areas of research, allowing one to boost the biological value of products for healthy human nutrition.

Literature Review and Problem Articulation. Studies of global research centers have proven that cereal yields can be upward regulated via breeding for quantitative traits: plant height, number of fertile shoots, thousand kernel weight, and kernel size, via farming techniques related to mineral fertilizers, protective agents, growth stimulants, chelated fertilizers, anti-stressors, as well as due to irrigation of crops in critical phases of their development [3, 4]. Recently, issues of the plant product quality have become more relevant for the human food security, which is a component of the national security of the state. Basing on the Laws of Ukraine No. 8370-1 dated 12.22.2011 "On Food Security of Ukraine", No. 771/97-BP dated 12.23.1997 "On Basic Principles and Requirements for the Safety and Quality of Food Products",

ISSN 1026-9959. Селекція і насінництво. 2022. Випуск 122.

the Plant Production Institute plans and implements scientific research programs, the primary purposes of which are as follows:

- To study sources and donors of valuable economic features;
- To investigate the yield formation processes and components;
- To study physiology of resistance to biotic and abiotic environmental factors;
- To evaluate product quality;
- To analyze biochemical parameters and, on this basis, to create narrow-specialized varieties and hybrids (for certain use) [5].

Covering this topic, we emphasize that in this article we discuss wheat, triticale and spring barley only, in accordance with the research programs, which have been performed at the Plant Production Institute (PPI) named after V.Ya. Yuriev of NAAS for over 100 years and dealing with grain and product quality parameters [5].

Purpose and Objectives. To analyzes of multi-year studies on wheat, hexaploid triticale and spring barley breeding and to evaluate varieties, hybrids, and breeding material for competitiveness in view of global trends in human nutrition.

Material and Methods. The methods of creating breeding material are inter-cultivar and inter-species hybridization, selection of high-yielding plants from high-yielding populations and hybrids. Winter and spring triticale, bread and durum wheat, rye, and spring barley accessions of different geographical and genetic origins, F_2–F_5 populations, individual plants selected under contrast test conditions were taken as starting material. The end-use product quality (loaf volume, rheological parameters of dough, protein and fiber contents, wet gluten content, gluten deformation index (GDI), sedimentation index, electrophoresis of gliadins and HMW glutenins, identification of material with molecular markers, antioxidant activity, vitamin contents in grain, trace minerals in wheat) was improved by traditional methods [6]. The protein and starch contents in barley grain were measured on an InfraLUM FT-10 M 09495; waxy genotypes were identified by Lugol's iodine staining (as Giuliani described). Kernel vitreousness was determined on a diaphanoscope. Total antioxidant activity (AOA) was assessed by the ability of alcohol extracts to neutralize the DPPH radical (2,2-diphenyl-1-picrylhydrazyl) [7]. The content of phenolic compounds in grain was evaluated with Folin-Ciocalteu reagent [8]. The fat content was measured by modified SV Rushkovsky's method. Methyl esters of fatty acids were prepared and investigated by Peisker's method.

The farming techniques were traditional for the Eastern Forest-Steppe of Ukraine. The seeding rate was 3–4.5 million germinable seeds/ha; the record plot area was 5–15 m^2. Elite triticale plants were selected under contrast conditions of the zone, namely in the Kharkivska, Donetska and Volynska Oblasts. The breeding material was evaluated for yield, grain quality, winter hardiness, resistance to diseases and pests. High-molecular-weight (HMW) glutenin electrophoresis for some accessions was carried out in the Laboratory WIBEX (Poland) [9]. Barley protein digestibility was determined by O. Pokrovsky and I. Ertanov's method [10] in the Laboratory of Medical and Biological Problems of Food Technology at the Chair of Chemistry, Microbiology and Nutrition of Kharkiv State University of Food Technology and Trade.

Results and Discussion. Over the past 10 years, wheat breeders of the Plant Production Institute named after V.Ya. Yuriev of NAAS, have created 23 bread wheat cultivars, for example Zapashna, Fermerka, Krasa Laniv, Prynada, Haiok, Metelytsia Kharkivska, Pronia, Mazurok, and Mavka IR. Previously created cultivars are known to agricultural producers: Vasylyna, Alians, Dyshonila, Doridna, Rozkishna, Statna, etc. Following the general breeding technology design for winter and spring wheat grain quality, we selected initial sources taking into account international databases and results of our studies, which had been accumulated since 1992 in the National Center for Plant Genetic Resources of Ukraine. High-yielding, winter-hardy, tolerant to overwintering, adapted to the conditions of the Eastern Forest-Steppe accessions bred by us were hybridized with high quality donors. The material obtained at the breeding and selection stages was evaluated, namely: by express methods in F_2 - F_4 generations; by determination of protein content (as dry matter (DM) percentage) and its relationship with the sedimentation index in F_5; by rheological properties of dough in F_6 and subsequent generations; by bread-making scores, characteristics of cookies and electrophoregrams of gliadins and HMW glutenins starting with F_7.

Selections of plants with waxy kernels, plants with soft grains and high-carotenoid genotypes are new directions of assessments in early generations [11]. These are new areas of breeding for wheat grain quality, such as confectionary lines. Kharkiv cultivars and lines were screened for wild-type *pin a* and *pin b* alleles using molecular markers [12]. Due to determining kernel hardness, water absorption capacity of flour and cookie quality parameters, a new soft-grained winter wheat cultivar, Mazurok, was selected from our lines; it has already been included in the State Register of Plant Cultivars Suitable for Dissemination in Ukraine. In 2016-2020, cookies made from Mazurok flour with a water absorption capacity of 54% were 10.1 mm tall and of 87 mm in diameter; the diameter/height ratio was 8.6; the surface score was 8.3 points. The corresponding parameters for the hard-grained cultivar (Pryvablyva) were 63%, 12.2 mm, 80 mm, 6.6, and 3.9 points, respectively [13].

Due to the use of molecular markers, recessive alleles of *Vrn* loci were detected in spring wheat with a high content of carotenoids in grain. Cultivar Omskaya 41 as well as lines Lutescens 516 and Lutescens 540, which have only one dominant *Vrn* allele, were distinguished and hybridized with winter cultivars [14]. Waxy wheat accessions with a low content of amylose, donors of anthocyanin pigmentation of grain and accessions with a blue aleurone layer, which are characterized by high total antioxidant activity, were taken as starting material [15, 16]. Winter wheat accessions in competitive cultivar trials were investigated for seven loci of storage proteins: *Gli-A1*, *Gli-B1, Gli-D1, Gli-A3, Glu-A1, Glu-B1, Glu-D1.* We identified 8 alleles of the *Gli-A1* locus, 7 *Gli-B1,* 5 *Gli-D1,* 4 *Gli-A3,* 5 *Glu-B1,* 3 *Glu-A1*, and 2 *Glu-D1* alleles. Most of the identified alleles are intrinsic to Ukrainian winter wheat cultivars. At the same time, lines with introgressed alleles, markers of wheat-rye translocations 1AL/1RS and 1BL/1RS, were identified. Line Erythrospermum 484-19 has an introgressed allele of the Gli-D1 locus from *Ae. tauschiiat* [17].

The results of long-term research into the technological and bread-making properties of new winter bread wheat cultivars are summarized in Table 1. Of the grain quality parameters, the total bread-making score was most strongly correlated with flour strength and dough elasticity. The test weight and kernel vitreousness did not have significant effects on the bread quality. The most significant negative correlation was found between the total bread-making score and the gluten deformation index (GDI). Correlations with other parameters are better described by polynomials; in particular, medium contents of protein and gluten in grain ensure the best quality of bread, while both low and too high values lead to its decrease [18]. New cultivars, namely Haiok, Pronia, and Mavka, were included in the State Register of Ukraine; they are characterized by high protein content (12.16–12.64% DM) and flour strength (226–245 W) similar to that of check cultivars. They have high tenacity (87–88 mm) and elasticity of dough, with a loaf volume much better than that of check cultivars and the total score of 7.8–8.6 points.

Results of scientific studies in the US captured the interest of business in white-grained wheat cultivars, flour of which is suitable for whole grain food production, and seed coats contain more vitamins. Such raw materials are used to make hearth bread, Mexican tortillas, noodles, etc.

However, farmers have problems with growing such wheat cultivars because of intensive grain germination, especially after rains, if this crop is not harvested on time. Nevertheless, genetic variability makes it possible to create resistant cultivars, so we pay attention to triticale cultivars that are much less prone to this drawback.

Phytochemical compounds, which are contained in seed coats and germs, are valuable ingredients of grain for human health. Phenolic compounds, anthocyanins, quinones, flavonoids, tocopherols and others are beneficial for human health. This research trend is extremely important in cereal breeding. Given the high functional value of the above-listed compounds for the human body and significant variability of wheat and triticale lines and cultivars, there is a real prospect of breeding for improved biological value of grain.

Long-term investigations in different countries (the US, Canada, Poland, Australia, Algeria, France and others) convince us of good adaptability of triticale and profitability of its cultivation. Cultivars bred by scientists in Poland (Lamberto, Pavo, Moderato) and other countries (Mykhas, Dubrava, Mara) can consistently yield more than wheat and rye by 20-30%. This result is achieved not only due to better adaptability, higher yield, but also due to optimized

chemical load on agrocenoses [19]. The breeding of hexaploid triticale is rapidly developing towards increasing the production of better quality grain, overwintering cultivars and preserving adaptive capacities [9, 19]. New food and universal triticale cultivars, namely Amos, Rarytet, Nikanor, Plastun Volynskyi, and Yaroslava, are noticeable for excellent qualities of gluten, dough and bread. These cultivars yield 8.5–11.5 t/ha.

Table 1

Technological and bread-making properties of grain of the new winter bread wheat cultivars, PPINAAS, 2015 — 2020

Cultivar	Test weight, g/L	Kernel vitreousness, %	Protein content, DM %	Wet gluten content, %	GDI	Dough tenacity (P), mm	Dough extensibility, mm	Flour strength, W	Elasticity index (Ie), %	Loaf volume, cm^3	Total bread-making score, points
Bunchuk, check cultivar	794	55	12.81	23.9	48	87	66	245	59	705	8.3
Podolianka, check cultivar	812	44	12.81	25.8	63	78	80	243	56	660	7.7
Mazurok	778	29	13.29	25	81	38	74	111	52	660	6.9
Mavka	802	51	12.16	23.4	61	89	65	245	57	748	8.6
Pronia	820	53	12.67	23.9	51	87	68	249	58	745	9
Haiok	806	51	12.64	24.6	51	88	60	226	62	692	7.8
Metelytsia Kharkivska	775	44	12.59	24.8	61	73	68	218	62	662	7.8
Vyhadka	803	47	12.62	24.2	57	98	54	250	63	680	8.1
Prynada	813	54	13.87		51	86	78	289	68	710	8.9
Krasa Laniv	801	38	12.74	24.5	49	86	71	258	66	707	8.3
Harmonika	789	52	12.97	26.8	63	72	78	234	58	742	8.3
Patriotka	787	42	12.73	23.2	43	101	69	302	71	702	8.3

Scientists of the Plant Production Institute named after V.Ya. Yuriev of NAAS managed to combine high performance with short stems and excellent bread-making properties in one genome, maintaining complex resistance to biotic and abiotic factors. Genetic sources of triticale from Polish, Slovakian and Romanian research centers potentially give high yields, but they have weak gluten. We investigated a Raryten/KHAD 7 population under contrast conditions and identified constant high-yielding triticale lines with plant heights of 60–130 cm and high technological parameters (Table 2).

Table 2

Morphological and technological features of the triticale cultivars (average for 2016 - 2021)

Cultivar	Plant height, cm	Yield, t/ha	Protein content in grain,DM %	Wet gluten content, %	GDI	Dough tenacity (P), mm	Dough extensibility, mm	Flour strength, W	Loaf volume, cm^3	Total bread-making score, points
Rarytet, check cultivar	132	6.87	15.2	17.4	55	71	74	194	627	9
Podolianka, check cultivar	102	6.02	15	27	63	72	69	207	657	8.8
Amos	129	7.33	15	16.9	58	75	79	203	640	9
Tymofii	92	9.94	15.5	17	54	84	81	210	701	9
Pudik	90	10.14	15.3	20.3	45	81	77	226	727	9
Yelan	94	10.36	14.9	19	50	72	77	229	800	9
$LSD_{0.05}$	12	0.4	0.22	1	13	19	10	9	72	0.6

Correlation analysis of the morphological and technological characteristics of semi-dwarf triticale cultivars and lines showed that the bread quality was significantly correlated with dough stability time and resistance (r=0.69), farinograph quality number (r=0.76), loaf volume (r =0.76) and especially crumb elasticity (r=0.82) and bread porosity (r=0.87). There was no significant correlation between the falling number and the total bread-making score or between the falling number and loaf volume.

The results of research into relationships between bread-making parameters served as a basis for creating new genotypes with specific expression of the gluten protein traits. Further, this was used in the breeding of new competitive triticale cultivars with a desirable plant height (Table 3).

Table 3

Physical properties of dough from grain of the new triticale cultivars (PPI NAAS, average for 2015 - 2022)

Cultivar	Dough parameters					
	Dough development time, min	Resilience, min	Resistance, min	Dough stability time, min	Softening degree, BU	Farinograph quality number
Rarytet, check cultivar	2.65	6.46	9.17	9.1	87	74
Podolianka, check cultivar	2.82	10.2	13.07	15.47	73	85
Tymofii	2.85	10.75	13.6	15.15	81	84
Pudik	2.9	10.5	13.4	13.85	75	86
Yelan	3.2	12.5	15.7	17.2	62	90
Baltiko	1.8	1.5	3.3	5.4	170	32
Stil	2.0	1.2	3.2	4.0	200	39
$LSD_{0.05}$	0.2	2.19	2.41	2.72	28.8	13.1

Environmental trials of the new semi-dwarf triticale cultivars bred by the PPI named after V.Ya. Yuriev of NAAS in Ukraine (Kharkiv, Melitopol), Poland (Rzeszów, Częszów), the US (California, Davic), Australia, Germany demonstrated that they were high-yielding and had good technological properties. New cultivars, namely Pudik, Yelan, according to the fariograph data, were not inferior to valuable and strong wheat, overwintered very well and showed good adaptability in general, including resistance to major diseases of cereals.

The new advantages of triticale over bread wheat in terms of yield capacity, adaptability, grain quality, and biological value are not yet fully used in grain production and processing industry.

Barley is a recognized cereal crop all over the world; it is functional food, i.e. it is able to ensure the healthy functioning of the body, suitable for the production of dietic and baby foods [20–24]. We studied starting material and bred new spring food barley cultivars. In order to provide dietic and baby foods, a breeding program was implemented to cross domestic cultivars, which are well-adapted to the conditions of Eastern Ukraine and resistant to lodging and diseases, with waxy naked accessions [25].

In addition to high performance, a food cultivar is supposed to have high-quality grain, i.e. contain a lot of proteins with high percentages of essential amino acids, which are extremely important for the human body. Naked barley accessions contain significantly more protein than chaffy ones. At the same time, the protein content in waxy chaffy barley lines is higher (12.60–16.80% DM) than in those with wild-type starch (11.2–15.9% DM). However, high protein content is only one indicator of the usefulness for the human body. Protein digestibility is important. We showed that cultivars Parnas and Berkut had highly digestible protein: 69.80–74.20 mg of tyrosine per 1 gram of protein compared to 53.90 mg/g in wheat (Table 4) [25].

Table 4

***In vitro* digestibility of spring barley proteins by human gastrointestinal enzymes, 2018**

Accession (combination)	Amount of soluble products of protein hydrolysis, mg of tyrosine per 1 g of protein		
	Pepsinolysis	Trypsinolysis	Pepsinolysis + Trypsinolysis
Parnas	15.2	54.6	69.8
Berkut (Parnas/Omskiy Golozyornyy 1)	25.5	48.7	74.2
Akhilles	14.05	38.75	52.8
Omskiy Golozyornyy 1	14.3	41.8	56.1
14-105 (Omskiy Golozyornyy 1 /Parnas)	9.05	58.55	67.6
13-802 (Parnas/Omskiy Golozyornyy 1)	14.3	38.6	52.9

Thus, cultivars Parnas and Omskiy Golozyornyy 1 are sources of high protein digestibility by proteolytic enzymes. Kernel hardness, which is determined by endosperm vitreousness is an important technological parameter in barley food industry. Barley cultivars with vitreous grain are used for groats production, while with low vitreousness – for flakes and flour. This trait was established to be variable and the variability of this trait largely depends on genotype. According to our data, the vitreousness of naked and chaffy accessions varied 90% to 100%, and 22% to 51%, respectively. Dry weather during the ripening period contributes to the formation of vitreous grain.

The creation of barley cultivars suitable for the production of functional foods is impossible without determination of antioxidant activity (AOA), which has a therapeutic and preventive effect on the human body, namely, it contributes to the normal physiological functioning of human systems. We demonstrated the variability and dependence of the antioxidant activity on genotype and growing conditions (Table 5).

Table 5

Antioxidant activity and oil content in spring barley grain (2017 - 2020)

Accession	Variety	Starch	Antioxidant activity, mg/g of chlorogenic acid equivalent	Oil content, %
Parnas, PPI	nutans	Wild-type	2.77	2.7
Yavir, PPI	nudum	Wild-type	2.95	3.08
01/12/54	nutans	*waxy*	2.74	3.75
Shedevt, PPI	rikoteuse	*waxy*	2.59	3.45
CDC Alamo	nudum	*waxy*	3.46	3.04
CDC Candle	nudum	*waxy*	2.96	2.8
Golozyornyy 1	nudum	Wild-type	2.79	2.45

Oil content and its fatty acid composition is an important component of the nutritional value of barley grain. Barley oil contains healthy polyunsaturated omega-3 (linolenic acid). It was reported that the genes determining the *waxy* trait could be linked with genetic determinants increasing the lipid content in barley. Our results are in agreement with other researchers' data as we found that the oil content in *waxy* grain was significantly higher (up to 3.75%) than in grain from accessions with wild-type starch (2.48–2.47%). Of the chaffy cultivars with a high level of linolenic acid (6.09–2.47%), Hatunok, Berkut and Oscar were selected. In order to provide dietic and baby foods, a breeding program was implemented to cross domestic and foreign cultivars, in particular waxy naked accessions with cultivars, which are well-adapted to the conditions of Eastern Ukraine and resistant to lodging and diseases. We created lines with high protein

digestibility (61.75 mg of tyrosine per 1 g of protein), high antioxidant activity (2.02 mg/g of chlorogenic acid equivalent), increased content of polysaturated (omega-3) linolenic acid in oil (6.09%), which is valuable genetic material for spring food barley breeding. We created *waxy* cultivars, namely Shedevr and Amil, which can be used in healthy food production due to their valuable economic characteristics and quality indicators (Table 6). Fiber and minerals, which are not synthesized by the human body, play strategic roles in adequate nutrition. We analyzed chaffy and naked barley cultivars and lines of different origins. The ash content in the investigated barley accessions ranged 2.18% to 3.20% in chaffy barley and 1.60% to 1.83% in naked barley.

Table 6

Characteristics of the *waxy* spring barley cultivars (2017 - 2021)

Cultivar	Trait							
	Yield, t/ha	Protein content, DM %	Starch content, %	Vitreous-ness, %	Oil content, %	Ash content, %	Fiber content, %	Antioxidant activity, mg/g of chlorogenic acid equivalent
Shedevr	5.43	11.13	60.11	43	3.45	3.2	3.65	1.94
Amil	5.38	12.7	60.66	40	3.47	3.21	3.7	2.07

Thus, barley accessions of the genetic diversity from the NCPGRU and the breeders' working collection of the PPI named after V.Ya. Yuriev of NAAS are promising materials for creating new spring barley cultivars suitable for food production, including dietic, baby and prophylactic nutrition.

Conclusions. Our studies in 2015–2021 demonstrated the variability of useful economic characteristics, in particular, grain and flour quality indicators, in winter bread wheat, winter triticale and spring barley.

New breeding material, which is adapted to the conditions of Eastern Forest-Steppe of Ukraine, was created; it is superior to the check cultivars in terms of quantitative and qualitative characteristics.

The new trends in cereal (wheat, triticale, barley) breeding are proposed; they which involve wide using assessments of flour quality, especially protein, starch, dough-forming ability, antioxidant activity, *waxy* determinants, oil, unsaturated fatty acids, phenolic compounds, tyrosine (protein digestibility indicator), etc.

The new cereal cultivars were bred; their grain is suitable for the production of groats, pasta, cookies, high-quality bread, and flakes. These are winter wheat cultivars Haiok, Pronia, Mazurok, and Mavka IR0; winter triticale cultivars Tymofii, Pudik and Yelan; spring barley cultivars Parnas, Berkut, Shedevr, Amil, and Troian. These cultivars have passed the state registration and are approved for growing at Ukrainian agrarian enterprises.

Список використаних джерел

1. Продовольственная и сельскохозяйственная организация объединённых наций. Публикуемая сводка ФАО сводка предложения зерновых и спроса на зерновые. Дата публикации: 02/12/2022**.** https://www.fao.org/worldfoodsituation/csdb.
2. Литвиненко М.А. Створення сортів пшениці м'якої озимої (Triticum aestivum L.), адаптованих до змін клімату на Півдні України. *Збірник наукових праць СГІ-НЦНС*. 2016. Т. 27. С. 36–53. http://nbuv.gov.ua/UJRN/Znpsgi_2016_27_5.
3. Aljarrah M., Oatway L., Lohr S., Capettini F. Breeding Triticale for grain and foregeyild and quality challeuges and future prospects. In: ItineraryAbstracts. 10 h International Triticale Symposium. Lethbridge, July 15–18, 2019. Lethbridge, AB, Canada, 2019.P. 17.

4. Wos H., Brzezinski W. Triticale for food – the guality driver. Springer International *Publishing Switzerland*. 2015. P. 213–232. DOI: https//doi. org/10.1007/978-3-319-22551-7- 11.
5. Методи визначення показників якості рослинної продукції: Методика державного сортовипробування сільськогосподарських культур. Під ред. О.М. Гончара. К.: Алефа. 2000. Вип. 7. С. 6–41.
6. Леонов О.Ю. та ін. Методичні рекомендації з оцінки якості зерна селекційного матеріалу. Харків: ІР НААН, 2011. 26 с.
7. Arabshahi S., Urooj A. Antioxidant properties of various solvent extracts of mulberry Morus indica L. Leaves. *Food Chem*. 2007. V. 102. P. 1233–1240.
8. Maillard M.N., Boivin P., Soum M.H., Berset C. Antioxidant activity of barley and malt: relationship with phenolic content. *Food Science and Technology*. 1996. V. 29(3). P. 238–244. DOI: https//doi. org/10.31 073/agrovisnyk 202203-07.
9. Кириченко В.В., Щипак Г.В., Кобизєва Л.Н., Святченко С.І. Сучасна селекція високоврожайних сортів тритикале з поліпшеною якістю зерна. *Вісник аграрної науки.* К. 2022. №3. С. 52–61. DOI: https//doi. org/10.31 073/agrovisnyk 202203-07.
10. Покровский А.А., Ертанов И.В. Атакуемость белков пищевых продуктов протеолитическими ферментами *in vitro*. *Вопросы питания*. 1965. № 1. С. 38–44.
11. Леонов О.Ю., Усова З.В., Суворова К.Ю., Шелякіна Т.А. Вдосконалена методика визначення вмісту каротиноїдних пігментів у зерні та борошні пшениці м'якої для селекційних досліджень. Харків: Інститут рослинництва ім. В.Я. Юр'єва НААН, 2020. 15 с.
12. Leonov O.Yu., Sharypina Ya.Yu., Usova Z.V., Suvorova K.Yu., Sakhno T.V. Allelic composition of puroindolinium genes and confectionery properties of flour of soft winter wheat samples. *Plant Varieties Studying and Protection*. 2020. V. 16(2). P. 217–225.
13. DOI: https://doi.org/10.21498/2518-1017.16.2.2020.209258.
14. Леонов О.Ю., Усова З.В., Суворова К.Ю. Селекція пшениці озимої кондитерського напряму використання. *Сучасні технології підвищення генетичного потенціалу рослин:* Збірник тез Міжнародної науково-практичної конференції, присвяченої 100-річчю Національної академії аграрних наук України та 110-річчю заснування Інституту рослинництва імені В.Я. Юр'єва НААН (4–5 липня 2018 р.) / Інститут рослинництва ім. В.Я. Юр'єва НААН. Харків, 2018. С. 78–80.
15. Леонов О.Ю., Шарипіна Я.Ю., Усова З.В., Суворова К.Ю., Сахно Т.В. Ідентифікація ліній пшениці ярої за алельним станом генів Vrn для використання в селекції пшениці озимої на вміст каротиноїдів. *Збірник наукових праць "Агробіологія"*. 2020. № 1. С. 88–95. DOI: https://doi.org/10.33245/2310-9270-2020-157-1-88-95.
16. Аліпов В.О., Леонов О.Ю., Поздняков В.В., Анциферова О.В., Падалка О.І. Антиоксидантна активність зразків пшениці мякої ярої. *Іноваційні напрямки розвитку галузі рослинництва*: матеріали міжнародної науково-практичної конференції молодих вчених (7–8 липня 2016 р.)/ Інститут рослинництва ім. В. Я. Юр'єва НААН.- Харків: НТМТ, 2016. С. 20.
17. Leonov O.Yu., Popov Yu.V., Usova Z.V., Pozdniakov V.V., Suvorova K.Yu., Antsyferova O.V., Zuza O.O. Economic valuable indicators of winter bread wheat accessions with different pigmentation of kernels. ISSN 1026-9959. *Селекція і насінництво.* 2022. Вип. 121. P. 28–40. DOI: https://doi.org/10.30835/2413-7510.2022.260993.
18. Усова З.В., Леонов О.Ю., Козуб Н.О., Созінов І.О. Ідентифікація зразків пшениці м'якої озимої харківської селекції за білковими маркерами. Збірник наукових праць. *Фактори експериментальної еволюції організмів.* 2019. Т. 29. С. 52–57.
19. DOI: https://doi.org/10.7124/FEEO.v29.1406/.
17. Леонов О.Ю., Усова З.В., Буряк Л.І., Падалка О.І., Ярош А.В. Мінливість показників якості зерна пшениці м'якої у зв'язку з погодними умовами. *Збірник наукових праць СГІ-НЦНС*. Одеса, 2016. Вип. 27 (67). С. 141–155.
18. Тритикале – материалы международной научно-практической конференции «Роль тритикале в стабилизации и увеличении производства зерна и кормов». Под ред. А.И. Грабовца. Ростов на Дону, 2010.

19. Newman R.K., Newman C.W. Barley for food and health – science technology and products. USA, 2009. 245 p.
20. Dickin E., Steele K., Wright D. Hulless barley for functional food. Project Report. No 472. HGGA. 2010. 48 p.
21. Рибалка О.І., Моргун Б.В, Поліщук С.С. Ячмінь як продукт функціонального харчування. Київ: Логос, 2016. С. 172, 517–574.
22. Meints B., Hayes P.M. Breeding naked barley for food, feed and malt. Plant Breeding Reviews. 2019. V. 43. DOI: https://doi.org/10.1002/9781119616801.ch4.
23. La G., Li M., Zhang G., Ye L. Barley: a protential cereal for producing healthy and functional foods. *Food Quality and Safety.* 2022. V. 6. fyac012. DOI: https://doi.org/10.1093/fqsafe/fyac012.
24. Vasko N.I., Seric M.L., Kozhachenko M.R., Naumov O.G., Vazhenina O.E., Solonechnyi P.M., Sheliakina T.A. Content and biological value of protein in grain of spring barley accessions. *Sel. Nasinn*. 2018. Issue 113. P. 45–55. DOI: https://doi.org/10.30835/2413-7510.2018.134357

References

1. Food and Agriculture Organization of the United Nations. FAO's published summary of cereal supply and demand. Publication date: 12.02.2022 Available from: https://www.fao.org/worldfoodsituation/csdb.
2. Litvinenko MA. Created varieties of winter wheat (*Triticum aestivum* L.), adapted to climate change in Ukraine. Zbirnyk Naukovykh Prats SHI-NTsNS. 2016; 27: 36–53.
3. Aljarrah M, Oatway L, Lohr S, Capettini F. Breeding Triticale for grain and foregeyild and quality challenges and future prospects. In: Itinerary Abstracts. 10 h International Triticale Symposium. Lethbridge, July 15–18, 2019. Lethbridge, AB, Canada, 2019.P. 17.
4. Wos H, Brzezinski W. Triticale for food – the quality driver. Springer International Publishing Switzerland, 2015. P. 213–232. DOI: https//doi. org/10.1007/978-3-319-22551-7- 11.
5. Methods of determination of plant productquality parameters: Methodology of the state trials of agricultural cropcultivars. Ed. by OM Honchar K.: Alefa, 2000; 7: 6–41.
6. Leonov OYu et al. Methodological recommendations for evaluation of grain quality of breeding material. Kharkiv: IR NAAN, 2011.
7. Arabshahi S, Urooj A. Antioxidant properties of various solvent extracts of mulberry Morus indica L. Leaves. Food Chem. 2007; 102: 1233–1240.
8. Maillard MN, Boivin P, Soum MH, Berset C. Antioxidant activity of barley and malt: relationship with phenolic content. Food Science and Technology. 1996; 29(3): 238–244. DOI: https//doi. org/10.31 073/agrovisnyk 202203-07.
9. Kyrychenko VV, Shchypak HV, Kobyzeva LN, Sviatchenko SI. State-of-art breeding of high-yielding triticale varieties with improved grain quality. Visnyk Ahrarnoi Nauky. K. 2022; 3: 52–61. DOI: https//doi. org/10.31 073/agrovisnyk 202203-07.
10. Pokrovskiy AA, Yertanov IV. Digestibility of food proteins by proteolytic enzymes *in vitro*. Voprosy Pitaniya. 1965; 1: 38–44.
11. Leonov OYu, Usova ZV, Suvorova KYu, Sheliakina TA. Improved method for determining the content of carotenoid pigments in bread wheat grain and flour for breeding studies. Kharkiv: PlantProduction Institute named after V.Ya. Yuriev of NAAS, 2020. 15 p.
12. Leonov OYu, Sharypina YaYu, Usova ZV, Suvorova KYu, Sakhno TV. Allelic composition of puroindolinium genes and confection eryproperties of flour of winter bread wheat samples. Plant Varieties Studying and Protection. 2020; 16(2): 217–225. DOI: https://doi.org/10.21498/2518-1017.16.2.2020.209258.
13. Leonov OYu, Usova ZV, Suvorova KYu. Winter confectionary wheat breeding. Current technologies for increasing the genetic potential of plants: Abstract book of the International Scientific and Practical Conference dedicated to the 100th anniversary of the National Academy of Agrarian Sciences of Ukraine and the 110th anniversary of the Plant Production Institute named after V.Ya. Yuriev of NAAS (July 4–5, 2018) / Plant Production Institute

named after V.Ya. Yuriev of NAAS. Kharkiv, 2018. P. 78–80.
14. Leonov OYu, Sharypina YYu, Usova ZV, Suvorova KYu, Sakhno TV. Identification of spring wheat lines by allels the Vrn genes for high-carotenoid winter wheat breeding. Collection of scientific papers "Ahrobiolohiia", 2020; 1: 88–95. DOI: https://doi.org/10.33245/2310-9270-2020-157-1-88-95.
15. Alipov VO, Leonov OYu, Pozdniakov VV, Antsyferova OV, Padalka OI. Antioxidant activity of spring bread wheat accessions. Innovative Trends in PlantProduction: Abstracts of the International Scientific and Practical Conference of Young Scientists (July 7–8, 2016)/ PlantProduction Institute named after V.Ya. Yuriev ofNAAS. Kharkiv: NTMT, 2016. P. 20.
16. Leonov OYu, Popov YuV, Usova ZV, Pozdniakov VV, Suvorova KYu, Antsyferova OV, Zuza OO. Economic valuable indicators of winter bread wheat accessions with different pigmentation of kernels. ISSN 1026-9959. Sel. Nasinn. 2022; 121: 28–40. DOI: https://doi.org/10.30835/2413-7510.2022.260993.
17. Usova ZV, Leonov OYu, Kozub NO, Sozinov IO. Identification of winter bread wheat accessions of Kharkiv breeding by protein markers. Collection of scientific papers. Faktory Eksperymentalnoi Evoliutsii Orhanizmiv. 2019; 29: 52–57. DOI: https://doi.org/10.7124/FEEO.v29.1406/.
18. Leonov OYu, Usova ZV, Buriak LI, Padalka OI, Yarosh AV. Variability of bread wheat grain quality parameters in relation to weather conditions. Zbirnyk Naukovykh Prats SHI-NTsNS. 2016; 27 (67): 141–155.
19. Triticale – Abstracts of the International Scientific and Practical Conference "The Role of Triticale in Stabilizing and Increasing Grain and Fodder Production". Ed. by A.I. Grabovets. Rostov-on-Don, 2010.
20. Newman RK, Newman CW. Barley for food and health – science technology and products. USA, 2009. 245 p.
21. Dickin E, Steele K, Wright D. Hulless barley for functional food. Project Report No 472. HGGA. 2010. 48 p.
22. Rybalka OI, Morhun BV, Polishchuk SS. Barley as a product of functional nutrition. Kyiv: Logos, 2016. P. 172, 517–574.
23. Meints B, Hayes PM. Breeding naked barley for food, feed and malt. Plant Breeding Reviews. 2019; 43. DOI: https://doi.org/10.1002/9781119616801.ch4.
24. La G, Li M, Zhang G, Ye L. Barley: a protential cereal for producing healthy and functional foods. Food Quality and Safety. 2022; 6: fyac012. DOI: https://doi.org/10.1093/fqsafe/fyac012.
25. Vasko NI, Serik ML, Kozhachenko MR, Naumov OG, Vazhenina OE, Solonechnyi PM, Sheliakina TA. Content and biological value of protein in grain of spring barley accessions. Sel. Nasinn. 2018; 113: 45–55. DOI: https://doi.org/10.30835/2413-7510.2018.134357.

CURRENT STRATEGY OF CEREAL BREEDING

Kyrychenko V.V., Vasko N.I., Leonov O.Yu., Shchypak H.V., Suvorova K.Yu., Morhun O.V.
Plant Production Institute named after V.Ya. Yuriev of NAAS, Ukraine

Purpose and Objectives. To analyzes of multi-year studies on wheat, hexaploid triticale and spring barley breeding and to evaluate cultivars, hybrids, and breeding material for competitiveness in view of global trends in human nutrition.

Material and Methods. Triticale, winter and spring bread wheat, and spring barley accessions of different geographical and genetic origins, F_2–F_5 populations, individual plants selected under contrast test conditions were taken as starting material. The farming techniques were traditional for the Eastern Forest-Steppe of Ukraine. Elite triticale plants were selected under contrast conditions of the zone, namely in the Kharkivska, Donetska and Volynska Oblasts. The breeding material was evaluated for yield, grain quality, winter hardiness, resistance to diseases and pests. Iinter-cultivar and inter-species hybridization was applied. The loaf

volume, rheological parameters of dough, protein and fiber contents, sedimentation index, electrophoresis of gliadins and HMW glutenins, antioxidant activity, vitamin contents, and trace minerals were measured by traditional methods. The protein and starch contents in barley grain were measured on an InfraLUM FT-10 M 09495; *waxy*-genotypes were identified by Lugol's iodine staining (as Giuliani described). Kernel vitreousness was determined on a diaphanoscope. The total antioxidant activity (AOA) was assessed by the ability of alcohol extracts to neutralize the DPPH radical (2,2-diphenyl-1-picrylhydrazyl). The content of phenolic compounds in grain was evaluated with Folin-Ciocalteu reagent. The fat content was measured by modified SV Rushkovsky's method. Methyl esters of fatty acids were prepared and investigated by Peisker's method. High-molecular-weight (HMW) glutenin electrophoresis for some accessions was carried out in the Laboratory WIBEX (Poland). Barley protein digestibility was determined by O. Pokrovsky and I. Ertanov's method in the Laboratory of Medical and Biological Problems of Food Technology at the Chair of Chemistry, Microbiology and Nutrition of Kharkiv State University of Food Technology and Trade.

Results and Discussion. The diversity of genetic sources from the starting material of wheat, triticale, and spring barley was described. The prospects of creating lines and cultivars of these crops with good quality grain, flour, dough, and cookies in the Eastern Forest-Steppe of Ukraine with significant changes in the temperature during the plant ontogenesis were proven.In the winter wheat breeding for grain quality, special attention was paid to crossing high-yielding and adapted to overwintering in the Eastern Forest-Steppe accessions bred by us with donors of good quality. It is necessary to evaluate the breeding material of bread wheat: express methods in F_2–F_4 generations to determine the protein content and its correlation with the sedimentation index in F_5, rheological properties of dough in F_6 and subsequent generations, comprehensive assessment of bread-making qualities, characterization of cookies, gliadin and glutenin electrophoresis, starting with F_7. Due to determining kernel hardness, water absorption capacity of flour and cookie quality parameters, a new soft-grained winter wheat cultivar, Mazurok, was selected from our lines; cookies made from Mazurok flour with a water absorption capacity of 54% had the surface score was 8.3 points. By using molecular markers, cultivars Omskaya 41 as well as lines Lutescens 516 and Lutescens 540 with high content of carotenoids and only one dominant *Vrn* allele were identified. It was proven that the medium contents of protein and gluten in grain ensured the best quality of bread, while both low and too high values led to a decline in its quality.In the triticale breeding, it was found that the triticale bread quality was significantly influenced by dough stability time and resistance (r=0.69), farinograph quality number (r=0.76), loaf volume (r =0.76) and especially crumb elasticity (r=0.82) and bread porosity (r=0.87). There was no significant effect of the falling number on the loaf volume and the total score. To create high-yielding semi-dwarf triticale cultivars, accessions of the Western European ecotype are crossed with the best lines (bred by us in the Eastern Forest-Steppe) and tested under contrasting conditions.In the barley breeding, it is necessary to determine not only the protein amount in grain, but also its digestibility. We showed that cultivars Parnas and Berkut had highly digestible protein: 69.80 - 74.20 mg of tyrosine per 1 gram of protein compared to 53.90 mg/g in wheat. Kernel hardness, which is determined by endosperm vitreousness, is an important technological parameter. The vitreousness of naked and chaffy accessions varied 90% to 100%, and 22% to 51%, respectively. Dry weather during the ripening period contributes to the formation of vitreous grain. The variability and dependence of the antioxidant activity, contents of mineral compounds and oil both on genotype and growing conditions were established. In order to provide dietic and baby foods, a breeding program was implemented to cross domestic and foreign cultivars, in particular *waxy* naked accessions with cultivars, which are well-adapted to the conditions of Eastern Ukraine.

Conclusions. Our studies in 2015–2021 demonstrated the variability of useful economic characteristics, in particular, grain and flour quality indicators, in winter bread wheat, winter triticale and spring barley.New breeding material, which is adapted to the Eastern Forest-Steppe of Ukraine, was created; it not inferior to the check cultivars: winter bread cultivars Haiok, Pronia, Mazurok, and Mavka; winter triticale cultivars Tymofii, Pudik, and Yelan;

spring barley cultivars Parnas, Berkut, and Shedevr, which have passed the State registration procedure and are approved for growing at agrarian enterprises of Ukraine.The new trends in cereal (wheat, triticale, barley) breeding are proposed; they involve an extended program of testing products for healthy nutrition, using assessments of flour quality, especially protein, starch, dough-forming ability, antioxidant activity, *waxy* determinants, oil, unsaturated fatty acids, phenolic compounds, tyrosine (protein digestibility indicator), etc.

Key words: *winter wheat, winter triticale, spring barley, yield, grain quality, fiber, protein, genetic resources, antioxidant activity, phytonutrients, adaptability.*

СУЧАСНА СТРАТЕГІЯ СЕЛЕКЦІЇ ЗЕРНОВИХ КУЛЬТУР

Кириченко В.В., Васько Н.І., Леонов О.Ю., Щипак Г.В., Суворова К.Ю., Моргун О.В.
Інститут рослинництва імені В.Я. Юр'єва НААН, Україна

Мета і задачі дослідження. Провести аналіз багаторічних досліджень із селекції пшениці, гексаплоїдних тритикале, ячменю ярого та оцінити сорти, гібриди, селекційний матеріал на конкурентоспроможність з огляду на світові тенденції харчування людини.

Матеріал та методи. Вихідний матеріал: зразки тритикале, пшениці м'якої озимої та ярої, ячменю ярого різних за географічним та генетичним походженням, популяції F_2– F_5, окремі рослини відібрані у контрастних умовах випробувань. Технологія вирощування є загальноприйнятою для східної частини Лісостепу України. Добір елітних рослин тритикале здійснювали у контрастних умовах зони та локацій, а саме Харківська, Донецька та Волинська області. Оцінку селекційного матеріалу проводили на врожайність, якість зерна, стійкість до перезимівлі, хвороб і шкідників. Використана внутрішньосортова та видова гібридизація. Об'єм хліба, реологічні параметри тіста, вміст білка та клітковини, індекс седиментації, електрофорез гліадинів та глютенинів, ідентифікація матеріалу за молекулярними маркерами, антиоксидантна активність, вміст вітамінів у зерні, а також мікроелементів у пшениці) проводили загальноприйнятими методами. Вміст білка та крохмалю в зерні ячменю проводили на "ІнфраЛЮМФТ-10 М 09495", w*axy*-генотипи ідентифікували методом фарбування йодним розчином Люголя (за Джуліані). Склоподібність зерна визначали на діафаноскопі. Загальну антиоксидантну активність (АОА) оцінювали за здатністю спиртових екстрактів нейтралізувати радикал DPPH* (2/2 – dipheny 1-1 – picrylhydrazy). Вміст фенольних сполук у зерні вивчено з використанням реактиву Folin-Ciocalten. Вміст жиру знежиреного залишку за модифікованою методикою С.В. Рушковського. Метилові ефіри жирних кислот та їх визначення проводили за методикою Пейскера. Електрофорез глютенинів окремих зразків здійснювали в лабораторії Wibex (Польща). Перетравлюваність білка ячменю визначали у лабораторії медико-біологічних проблем технології харчових продуктів на кафедрі хімії, мікробіології та харчування ХДУХіТ на основі методики О. Покровського та І. Ертанова

Обговорення результатів. Установлено різноманіття генетичних джерел серед вихідного матеріалу пшениці, тритикале, ячменю ярого. Доведено перспективність створення ліній та сортів цих культур з якісними показниками зерна, борошна, тіста, печива в умовах Східної частини Лісостепу України при суттєвих змінах температурного режиму у процесі онтогенезу рослин.В селекції пшениці озимої на якість зерна особливу увагу приділяли схрещуванню високопродуктивних, адаптованих до умов перезимівлі східної частини Лісостепу зразків власної селекції із донорами параметрів якості. Оцінку селекційного матеріалу пшениці м'якої необхідно проводити: експрес методи у генераціях F_2–F_4 для визначення вмісту білка та зв'язок з показником седиментації у F_5, реологічні властивості тіста у F_6 та наступних поколіннях, загальну оцінку хлібопекарських якостей, характеристику печива, електрофоретичні формули гліадину

та глютеніну, починаючи з F_7. Шляхом визначення твердості зерна, водопоглинальної здатності борошна, а також параметрів якості печива зі створених нами ліній виділено новий м'якозерний сорт пшениці озимої Мазурок із оцінкою поверхні печива 8,3 бали за водопоглинальної здатності борошна 54%. При застосуванні молекулярних маркерів виділено сорти Омская 41 та лінії Лютесценс 516, Лютесценс 540 з високим вмістом каротиноїдів, що мають лише один домінантний алель *Vrn.* Доведено, що вміст білка та клейковини в зерні при середніх значеннях забезпечують найкращу якість хліба, а як низькі, так і надмірно високі значення призводять до її зниження.В селекції тритикале з'ясовано, що на якість хліба із борошна тритикале істотно впливають стійкість та опірність тіста (r=0,69), загальна валометрична оцінка (r=0,76), об'єм хліба (r=0,76) і особливо еластичність м'якуша (r=0,82) та пористість хліба (r=0,87). Істотного впливу числа падіння на об'єм хліба і загальну оцінку не відмічено. Для створення високоврожайних короткостеблових сортів тритикале використовуються схрещування зразків західноєвропейського екотипу із кращими лініями власної селекції (умови східного Лісостепу) за умов випробування у контрастних умовах.В селекції ячменю необхідним є визначення не тільки кількості білку в зерні, а також рівень його перетравлюваності та засвоюваності, у сортів Парнас та Беркут визначено вміст тирозину 69,80–74,20 мг на 1 грам білка при 53,90 мг/г у пшениці. Важливим технологічним показником при виготовлені продуктів харчування з ячменю є твердість зерна, яка визначається склоподібністю ендосперму, у голозерних зразків варіює від 90 до 100%, плівчатих від 22 до 51%. Доведено, що посушлива погода у період дозрівання сприяє утворенню склоподібного зерна ячменю. Встановлено варіабельність та залежність рівня антиоксидантної активності, вмісту мінеральних сполук та олії від генотипу та умов вирощування. Для забезпечення продуктами дитячого та дієтичного харчування виконано програму селекції де передбачено схрещування сортів вітчизняної та зарубіжної селекції – джерела *waxy* голозерного типу, із сортами високоадаптованими до умов східної частини України.

Висновки. За результатами власних досліджень, проведених за 2015–2021 роки встановлено мінливість генотипів пшениці м'якої озимої, тритикале озимого та ячменю ярого за корисними господарськими ознаками, зокрема за якісними показниками зерна та борошна.Створено новий селекційний матеріал, який адаптований до умов східної частини Лісостепу України, що не поступаються сортам-стандартам, а саме озимої м'якої пшениці – Гайок, Проня, Мазурок, Мавка , тритикале озимого – Тимофій, Пудік, Єлань, ячменю ярого – Парнас, Беркут, Шедевр, що пройшли Державну реєстрацію та допущені до вирощування в агропідприємствах України.Пропонуються нові напрями селекції зернових культур (пшениця, тритикале, ячмінь) з використанням широкої програми тестування продукції для здорового харчування, які передбачають широке використання оцінок за якістю борошна, а особливо, білка, крохмалю, тістоутворюючої здатності, антиоксидантної активності, наявності детермінантів *waxy,* високого вмісту олії, ненасичених жирних кислот, фенольних сполук, тирозину (показника перетравлюваності), тощо.

Ключові слова: *пшениця озима, тритикале озиме, ячмінь ярий, урожайність, якість зерна, клітковина, білок, генетичні ресурси, антиоксидантна активність, адаптивність.*