

## The potential of durum winter wheat cultivars in Ukraine

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**Purpose.** To highlight the durum winter wheat breeding results at the Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation (PBGI – NCSCI) during many years. **Methods.** Multiple both intraspecific and interspecific (with varieties and forms of common wheat) hybridization, including introgressive hybridization to create certain desired genotypes. Evaluation of the created lines and hybrids by a number of biological and economic characteristics, including the resistance to frost (winter hardiness), drought and main diseases, as well as protein content in the grain and its vitreousness. **Results.** There were 6 durum winter wheat cultivars replacement in Ukraine during past 65 years, with the leading role in the assortment belonging to cultivars created at the PBGI – NCSCI. The creation of varieties was focused on the introgression of dwarfism genes and alleles with low photoperiod sensitivity, improving floral fertility, increasing resistance to biotic and abiotic stresses. New cultivars (the sixth cultivars replacement) belong to the varieties of durum winter wheat *leucurum* ('Lainer', 'Shliachetnyi', 'Blyskuchyi', 'Almaznyi', 'Yantarnyi', 'Kryshtalevyi', 'Zolotystyi', 'Marmurovyi', 'Sribliastyi'), *hordeiforme* ('Areal Odeskyi', 'Hranatovyi') and *leucomelan* ('Prestyzhnyi', 'Yaskravyi'). All of them are cultivars of intensive type and universal use which are characterized by high resistance to lodging, drought and the most common diseases and average or above average frost resistance. Their grain has high vitreousness and high or above average protein content. **Conclusions.** Today, in the agricultural production of the steppe and forest-steppe zones of Ukraine, the most common cultivars of hard winter wheat of the fifth cultivars replacement are well established and therefore the most widespread: 'Hardemarin', 'Burshtyn', 'Kontynent', 'Kreiser', 'Linkor' and 'Bosfor'. New varieties (sixth cultivars replacement) are also gradually spreading: 'Areal Odeskyi', 'Liner', 'Prestyzhnyi', 'Shliachetnyi', 'Blyskuchyi', 'Yaskravyi', 'Almaznyi', 'Yantarnyi', 'Kryshtalevyi', 'Hranatovyi', 'Marmurovyi', 'Zolotystyi' and 'Sribliastyi' which belong to the selection of the Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation.

**Keywords:** Durum winter wheat varieties; plant breeding; grain quality; cultivars replacement.

### Introduction

In recent years, global wheat production has reached 700–790 million tons per year. Of this, durum wheat production accounts for 33–37 million tons, or about 5% [1, 2]. In 2022, durum wheat ranked 278th worldwide in sales volume (out of 4,648). The main exporters were Canada, Russia, France, USA, Romania, and Ukraine, which ranks sixth (accounting for 4.39% of global exports) and considers itself the breadbasket of Europe.

Durum wheat and its processed products are a source of protein, essential amino acids, carbo-

hydrates, minerals, and vitamins, all of which are extremely beneficial to humans. When milled, durum wheat does not turn into ordinary flour, but rather into small grains. This is due to the difference in carbohydrate structure between durum wheat and soft wheat. This type of flour is known worldwide as semolina. Semolina crystals contain starch grains combined with protein particles and carotenoid pigments [3]. Semolina from durum wheat, like other types of tetraploid wheat, also has a significant antioxidant enzyme system. In addition to high-quality semolina pasta, couscous production has become widespread in Central Asia and the Mediterranean. Couscous is a staple food of the Middle East. Couscous consists of uniform granules of durum wheat semolina. Durum wheat flour is also used to bake many varieties of local bread, such as lavash, churek, and puri. In some

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countries, a mixture of soft and durum wheat flour is used to make traditional bread, significantly improving its sensory and textural properties as well as its taste [4]. Durum wheat flour is also used to make high-quality croissants, cookies, and other pastries.

The northern limit of high-quality durum wheat cultivation practically coincides with the northern border of the steppe zone. This suggests that durum wheat is naturally a steppe crop with increased requirements for solar insolation, low atmospheric precipitation, and relatively high humidity. This is because it originates mainly from the Near East [5]. The main growing areas for facultative and winter durum wheat varieties are concentrated around the Mediterranean, Black, and Caspian Seas. Ukraine can successfully grow various types of durum wheat, but the winter and facultative varieties are most effective at using autumn-winter moisture reserves. Compared to soft wheat, durum wheat is less prone to shattering, more resistant to lodging, less susceptible to diseases and pests, and more resistant to salt stress, especially winter varieties and forms [6]. When grown on fertile soils with proper agricultural techniques, durum wheat produces yields comparable to the best varieties of soft winter wheat.

In Ukraine and worldwide, high-quality durum wheat grain is priced 10–20% higher than soft wheat [7]. Demand for high-quality durum wheat is constantly increasing on the international market, partly because legislation in several countries prohibits pasta production from soft wheat flour. The global market prefers large, high-density, amber-colored grain with a protein content of 13–17%, a specific gravity of at least 790 g/L, and vitreousness greater than 75%. According to Ukrainian legislation, commercial batches of durum wheat may contain no more than 3% soft wheat grain and 2% grey grains (rye, triticale, and barley) [8]. In some European countries, the requirements are more stringent. For instance, if pasta contains more than 2% soft wheat flour, the factory may have its license revoked.

Modern domestic varieties of hard winter wheat, adapted to various growing conditions, can produce grain yields of over 7.5–8.0 tons per hectare (t/ha) with high grain quality indicators in Ukraine's steppe and forest-steppe regions.

*The aim of the work* was to demonstrate the potential of domestic hard winter wheat varieties, especially those developed at the Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation through selective breeding over many years.

## Materials and methods

The main method of breeding is multiple hybridization, followed by careful evaluation of the resulting lines and hybrids for desirable biological and economic traits. Intraspecific and interspecific hybridization were both used with varieties and forms of soft wheat characterized by high winter hardiness. Introgressive hybridization was used to create new varieties and forms with high adaptive properties, such as frost resistance, drought resistance, and resistance to major diseases. The yield, weight of 1,000 grains, and grain quality were determined by weighing them. Resistance to the most common diseases and drought was evaluated using a 10-point scale [9]. Grain protein content was analyzed using an Infromatic 8611 device. Grain vitreousness was calculated as a percentage using the ISO 11051 method.

## Results and discussion

The first varieties of winter durum wheat, 'Michurinka' and 'Novomichurinka', were created by Academician F. H. Kyrychenko at the Plant Breeding and Genetic Institute – National Center of Seed and Cultivar Investigation (PBGI – NCSCI) in 1960 [10]. Through introgressive hybridization, many different forms of hard winter wheat with increased adaptive properties were created, enabling breeding work to begin based on them. The varieties 'Odeska Yantarna' and 'Odeska Yuvileina' resulted from the intraspecific hybridization of hard winter wheat forms, which began to be systematically improved in the early 1970s.

The development of new hard winter wheat sources focused on introgressing dwarfism genes and alleles with low photoperiod sensitivity, improving flower fertility, and increasing resistance to biotic and abiotic stresses. The most winter-hardy and frost-resistant varieties of hard winter wheat were used for hybridization with dwarfing donors: 'Novomichurinka', 'Rubizh', 'Odeska Yuvileina', 'Kharkivska 1', 'Novynka' and others. As a result of long-term breeding efforts, source material was developed that enabled the gradual enhancement of winter durum wheat productivity by 2–2.5 times.

Six variety changes took place in Ukraine during this period (Table 1). Trials of hard winter wheat varieties from different years of regionalization under comparative conditions showed that yield increased by 4.5–5.0 t/ha. This breeding program's development made the creation of the first short-stemmed hard winter wheat varieties in the Soviet Union possible:

'Parus' and 'Koral Odeskyi'. These varieties were included in the Register of Varieties of Ukraine and the Russian Federation in 1983 and 1985, respectively. These varieties increased the productivity of hard winter wheat by 2.3 t/ha compared to the initial regionalized varieties, 'Michurinka' and 'Novomichurinka', and by 1.8 t/ha compared to varieties in production at that time.

In addition to the above, the State Register of Varieties Suitable for Distribution in Ukraine (hereinafter referred to as the "Register of Varieties") includes the varieties 'Delfin', 'Arhona', 'Perlyna Odeska', 'Zolote Runo' and 'Lahuna'. These varieties are characterized by high yields and grain quality, respond well to optimal agricultural conditions and have comprehensive resistance to common diseases.

Table 1

**Yield of durum winter wheat of different variety changes in the comparative variety trial of the PBGI – NCSCI over the past decades**

Variety change	Variety	Cultivation in production	Average grain yield, t/ha	Excess over variety change, t/ha	
				first	previous
I	'Michurinka', 'Novomichurinka'	1960–1970	2.83	–	–
II	'Rubizh', 'Odeska Yuvileina'	1969–1978	3.14	0.31	0.31
III	'Parus', 'Koral Odeskyi'	1979–1995	5.20	2.37	2.06
IV	'Aisberh Odeskyi', 'Delfin', 'Alyi Parus', 'Perlyna Odeska', 'Arhona', 'Zolote Runo', 'Lahuna'	1990–2005	6.27	3.44	1.07
V	'Hardemaryn', 'Burshtyn', 'Tavryda', 'Kontynent', 'Kreiser', 'Linkor', 'Bosfor', 'Havan', 'Akveduk', 'Prozoryi', 'Areal Odeskyi', 'Lainer'	2006–2014	7.15	4.32	0.88
VI	'Shliakhetnyi', 'Blyskuchyi', 'Yaskravyi', 'Prestyzhnyi', 'Koralovyi', 'Nadiinyi', 'Almaznyi', 'Yantarnyi', 'Kryshtalevyi', 'Hranatovyi', 'Marmurovyi', 'Zolotystyi', 'Sribliastyi'	2015–2024	7.63	4.80	0.48

Their productivity increases with various elements of the crop structure [11, 12]. The increased grain yield of these varieties is primarily associated with an increase in biomass (+0.62 kg/m<sup>2</sup>). Despite the decrease in the harvesting index (–3.9%), the number of grains on the main spike (+6.2 grains) and on the other productive spikes of the plant (0.09 grams) increased in the new varieties. As a result, the grain yield of the new varieties increased by 0.06 kg/m<sup>2</sup> compared to the 'Parus' and 'Koral Odeskyi' varieties.

To create frost- and winter-resistant starting material, we hybridized highly winter-resistant varieties of soft winter wheat, as well as our own varieties and forms of hard winter wheat adapted to local conditions. Saturating crosses were carried out on interspecific hybrid F<sub>1</sub> plants with frost- and winter-resistant varieties and forms of hard winter wheat to consolidate the stability of the tetraploid genome and its winter hardiness. After several years of selection, the hybrid material was crossed again with winter-resistant varieties of soft and hard winter wheat from other agro-ecological zones. This process gradually accumulated adaptive indicators and properties in the starting material. The result was the development of the highly adapted varieties of hard winter wheat,

'Aisberh Odeskyi' (1985) and 'Alyi Parus' (1990). These varieties have been used in production in Ukraine's steppe and forest-steppe regions, as well as in other countries, for about 30 years.

It is characteristic that in the varieties of durum winter wheat of the fifth variety change (entered into the Register of Varieties in 2006–2011), the following varieties experienced an increase in grain yield due to an increase in biomass (+0.12 kg/m<sup>2</sup>): 'Hardemaryn', 'Burshtyn', 'Kontynent', 'Kreiser', 'Linkor', 'Bosfor', and 'Havan'. On average, the number of grains per main ear increased by 3.2, the weight per ear by 0.07 g, and the weight per cob by 0.22 g. The harvesting index increased slightly (+1.2), while the weight of 1000 grains decreased by 2.8 g [13].

In harsh winter conditions, varieties of durum winter wheat such as 'Aisberh Odeskyi', 'Alyi Parus', 'Akveduk', 'Lahuna', 'Perlyna Odeska', 'Hardemaryn', 'Kreiser', 'Tavryda' and 'Bosfor' demonstrate high frost resistance. This was confirmed by Russian researchers in a comparative test of varieties from different ecological regions [14]. The best frost- and winter-resistant durum winter wheat varieties have a long vernalization requirement and strong photoperiod sensitivity. Meanwhile, varieties with a long vernalization requirement (30–35 days) and medium photo-

period sensitivity produce more stable grain yields of durum winter wheat in southern Ukraine. In the steppe zone, such varieties restore vegetation faster and make better use of spring soil moisture. These varieties include 'Hardemaryn', 'Kreiser', 'Havan', 'Akveduk', 'Prozoryi', 'Areal Odeskyi', 'Blyskuchyi', 'Lainer', 'Prestyzhnyi', 'Shliakhetnyi', 'Yaskravyi', 'Koralovy', 'Nadiinyi', 'Almaznyi', and 'Yantarnyi'.

To successfully introduce durum wheat into production, its productivity must be raised to the level of common soft wheat varieties. A comparative ecological study of modern soft winter wheat varieties from various Ukrainian institutions and a hard winter wheat selection from PBGI – NCSCI shows that new hard winter wheat varieties are not inferior to soft wheat varieties in terms of grain yield. Other researchers have obtained similar results [15, 16]. However, it should be noted that durum wheat is significantly inferior to soft wheat in terms of yield and protein content when grown in northern regions [17], as it has increased requirements for solar insolation, as previously indicated.

Today, in agricultural production in Ukraine's steppe and forest-steppe zones, the most common durum winter wheat varieties in the V variety change are 'Hardemaryn', 'Burshtyn', 'Kontynent', 'Kreiser', 'Linkor', and 'Bosfor'. The 'Havan', 'Akveduk' and 'Prozoryi' varieties show the best results in the forest-steppe and northern steppe regions [13, 18].

The durum winter wheat varieties 'Areal Odeskyi' and 'Lainer' underwent state variety testing from 2014 to 2017. According to the results, they were included in the Register of Varieties in 2016 and 2017, respectively. These varieties are characterized by their high productivity potential and excellent pasta and cereal properties. A study of these varieties during state variety testing (2015–2017) in the Steppe zone revealed high productivity results: 'Areal Odeskyi' – 5.62–8.44 t/ha and 'Lainer' – 5.34–8.08 t/ha. Even better results were obtained in the forest-steppe zone: 7.08–9.66 t/ha for 'Areal Odeskyi' and 7.90–9.83 t/ha for 'Lainer'. The varieties 'Prestyzhnyi' and 'Shliakhetnyi' also demonstrated high productivity. Their grain yield was 5.68–8.25 and 5.14–7.89 t/ha, respectively, in the steppe and 7.53–10.02 and 7.30–10.50 t/ha in the forest-steppe from 2015 to 2017. The varieties 'Blyskuchyi' and 'Yaskravyi', which were studied in state variety testing from 2016 to 2017, also demonstrated high productivity. The variety 'Blyskuchyi' exceeded the conditional standard in Ukraine's steppe and forest-steppe zones by 0.64 t/ha. Its grain yield in the steppe was 5.15–8.52 t/ha, and in the

forest-steppe zone, it reached 7.53–9.82 t/ha. The 'Yaskravyi' variety produced a grain yield of 6.60–9.21 t/ha in the forest-steppe zone and 5.21–8.36 t/ha in the steppe zone.

Since the creation of the first variety of durum winter wheat at PBGI – NCSCI, 53 other varieties have been submitted to state variety testing. According to the test results, these varieties have been included in the Register of Plant Varieties of Ukraine and other countries: Bulgaria (3), Moldova, Romania (2 each), Kazakhstan, Kyrgyzstan, USA, Tajikistan, and Uzbekistan (1 each). The Register of Varieties currently includes 36 varieties of durum winter wheat. Twenty-three of these are selections of the PBGI – NCSCI. Thus, PBGI – NCSCI varieties make up over 64% of the zoned varieties in Ukraine and over 75% of those distributed in production.

The new generation of varieties is being introduced into production at a rapid pace. These include 'Areal Odeskyi', 'Lainer', 'Prestyzhnyi', 'Shliakhetnyi', 'Blyskuchyi', 'Yaskravyi', 'Almaznyi', 'Yantarnyi', 'Kryshtalevyi', 'Hranatovy', 'Marmurovy', 'Zolotystyi' and 'Sribliastyi', which were selected by the PBGI – NCSCI. Their characteristics are given in Table 2.

All of these varieties are intensive types. They are recommended for cultivation after black steaming in the steppe zone or after crops that provide sufficient moisture and mineral nutrients, such as perennial grasses, grain legumes, vegetables, and melons. The percentage of vitreous grain varies by variety and is also influenced by weather conditions before and during harvest. These varieties differ in terms of weight per 1,000 grains (43.1–50.6 g), gluten deformation index (90–100 units), and grain density (797–819 g/L). There are also differences in protein content (13.0–15.4%) and resistance to powdery mildew, brown rust, and stem rust. It should be noted that all of these varieties are versatile thanks to their appropriate quality, such as protein content and vitreousness. They can be used to produce cereals, pasta, and various baked goods. Additionally, the average yields (5.7–9.8 t/ha), including those obtained at state variety testing stations, are generally not achieved under maximum agricultural conditions typical of European cultivation.

## Conclusions

Throughout the breeding program at PBGI – NCSCI, six changes occurred in the winter durum wheat varietal. Through long-term breeding work involving introgressive hybridization methods, genotypes were saturated with the necessary genes. This created material that in-

Table 2

## Characteristics of new varieties of durum winter wheat included in the State Register of Plant Varieties of Ukraine

Variety, variant	Plant height cm	Resistance to							Grain yield (average), t/ha	Grain quality					Weight of 1000 grains, g
		lodging	wintering	drought	most common diseases, points					Content, %		GDI in units	Grain nature, g/l	Vitreousness, %	
					smut fungy	powdery mildew	brown and stem rust	pyrenophora		dry protein	fiber				
'Areal Odeskyi', <i>hordeiforme</i>	90–105	high	average	high	8–9	7–9	5–7	6–7	6.28	13.9–15.9	28.0–30.7	90	798–835	93	45.8–48.4
'Lainer', <i>leucurum</i>	85–95		average			7–9	7–9		5.74	14.4–16.3	33.7–36.9	95	800–818	95	42.5–43.6
'Shliakhetniyi', <i>leucurum</i>	95–105		average			8–9	6–8		6.9–9.8	14.8–15.5	27.7–31.9	95	792–806	93	43.5–47.3
'Blyskuchyi', <i>leucurum</i>	95–105		average			5–7	5–7		6.8–8.8	13.1–14.7	27.4–31.3	95	798–800	93	43.6–48.7
'Prestyzhnyi', <i>leucomelan</i>	85–95		average			8–9	5–7		8.2–9.7	13.6–14.9	27.3–30.1	99	796–802	95	45.1–48.5
'Yaskravyi', <i>leucomelan</i>	95–105		average			8–9	6–8		7.6–8.4	14.8–16.0	29.7–34.4	97	798–816	95	49.8–55.3
'Koralovyi', <i>hordeiforme</i>	80–90		average			7–8	7–8		6.59	14.2–15.0	30.1–35.3	90	775–801	92	43.1–47.4
'Nadiinyi', <i>hordeiforme</i>	90–95		average			6–8	6–8		6.99	13.0–14.7	29.6–31.3	90	786–811	93	42.0–44.9
'Almaznyi', <i>leucurum</i>	100–110		average			5–7	5–7		6.80	13.3–14.2	29.7–32.5	95	798–836	94	43.6–44.9
'Yantarnyi', <i>leucurum</i>	90–105		average			6–8	6–8		6.87	13.0–15.6	28.3–30.1	90	786–808	90	42.2–44.0
'Kryshtalevyi', <i>leucurum</i>	85–95		average			7–9	7–9		5.74	14.4–16.3	34.7–35.9	95	800–818	95	42.5–43.6
'Hranatovyi', <i>hordeiforme</i>	100–105		average			7–9	5–7		7.25	13.9–15.9	28.0–30.7	90	798–835	93	39.1–43.4
'Zolotystyi', <i>leucurum</i>	90–105		average			5–7	6–8		6.87	13.6–14.4	28.3–30.1	90	786–808	95	47.5–45.1
'Marmurovyi', <i>leucurum</i>	90–105		average			6–8	6–8		6.70	13.3–14.7	27.1–29.8	95	781–803	92	43.0–44.5
'Sriblyastyi', <i>leucurum</i>	90–105		average			6–8	6–8		7.93	14.0–15.2	28.2–30.1	94	783–807	91	43.0–44.5

creased the productivity potential of winter durum wheat significantly and gradually while ensuring high plant resistance to biotic and abiotic stress factors.

The most common varieties of hard winter wheat in Ukraine's steppe and forest-steppe zones today are 'Hardemaryn', 'Burshtyn', 'Kontynent', 'Kreiser', 'Linkor' and 'Bosfor'. The 'Havan', 'Akveduk' and 'Prozoryi' varieties perform better in the forest-steppe and northern regions of the steppe zone. New generation varieties (the VI variety change) are being rapidly introduced into production: 'Areal Odeskyi', 'Lainer', 'Prestyzhnyi', 'Shliakhetnyi', 'Blyskuchyi', 'Yaskravyi', 'Almaznyi', 'Yantarnyi', 'Kryshtalevyi', 'Hranatovyi', 'Marmurovyi', 'Zolotystyi' and 'Sribliastyi' which were selected by the PBGI – NCSCI.

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**Мета.** Висвітлити результати багаторічних досліджень із селекції твердої озимої пшениці в Селекційно-генетичному інституті – Національному центрі насіннєзнавства та сортівивчення (СГІ – НЦНС). **Методи.** Багаторазова внутрішньовидова та міжвидова (з сортами та формами пшениці м'якої) гібридизація, зокрема й інтрогресивна гібридизація для створення бажаних генотипів. Оцінювання одержаних ліній та гібридів за низкою біологічних і господарських ознак (зимо- та посухостійкістю, стійкістю проти основних хвороб, умістом білка в зерні та його склоподібністю). **Результати.** Протягом останніх 65 років в Україні відбулося шість сортозмін твердої озимої пшениці, а провідна роль у сортименті завжди належала сортам селекції СГІ – НЦНС. Їхнє створення було сконцентровано на інтрогресії генів карликовості та алелів із низькою фотоперіодичною чутливістю, поліпшенні квіткової фертильності, підвищенні стійкості проти біотичних та абіотичних стресів. Нові сорти (VI сортозміни) є різновидами пшениці твердої озимої *leucurum* ('Лайнер', 'Шляхетний', 'Блискучий', 'Алмазний', 'Янтарний',

'Кришталевий', 'Золотистий', 'Мармуровий', 'Сріблястий'), *hordeiforme* ('Ареал одеський', 'Гранатовий') та *leucomelan* ('Престижний', 'Яскравий'). Всі вони належать до інтенсивного типу, характеризуються універсальністю використання, високою стійкістю проти вилягання, посухи та найбільш поширених хвороб і середньою або вищою за середню морозостійкістю. Їхнє зерно має високу склоподібність і високий або вище за середній уміст протеїну. **Висновки.** Сорти пшениці твердої озимої V сортозміни 'Гардемарин', 'Бурштин', 'Континент', 'Крейсер', 'Лінкор' та 'Босфор' добре зарекомендували себе в сільськогосподарському виробництві Степу та Лісостепу України, а тому нині є найпоширенішими у цих ґрунтово-кліматичних зонах. Поступово набувають розповсюдження й нові сорти VI сортозміни 'Ареал одеський', 'Лайнер', 'Престижний', 'Шляхетний', 'Блискучий', 'Яскравий', 'Алмазний', 'Янтарний', 'Кришталевий', 'Гранатовий', 'Мармуровий', 'Золотистий' і 'Сріблястий', виведені в СГІ – НЦНС.

**Ключові слова:** сорти пшениці твердої озимої; селекція; якість зерна; сортозміна.

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