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Analysis of the varietal composition of soft winter wheat in the context of variety renewal and replacement

Abstract. Weather conditions that have been changing towards extreme values determined the need to carry out variety replacement and renewal of soft winter wheat on a systematic level capable of improving the efficiency of agricultural technologies and ensuring a consistently high level of crop yields. Thus, the aim of the work was to analyse the peculiarities of the formation of the assortment and distribution of soft winter wheat, as well as to select the best varieties in terms of productivity and ecological stability. Field studies were conducted at the State Enterprise Research Farm “Salivinkivske” of the Institute of Bioenergy Crops and Sugar Beet of the NAAS of Ukraine (Kyiv region) during 2020-2024. Indicators of stability and plasticity of grain yield for 36 varieties of soft winter wheat were calculated according to the Eberhart-Russell method. It was established that for full variety replacement or renewal and to achieve a high level of soft winter wheat yield, it is necessary to sow at least 15% of

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areas annually with new varieties or seeds of higher generations. In 2021, this figure in Ukraine stood at 16%; however, in 2022 and 2023, it decreased to 5.2% and 5.5% respectively, which potentially had a negative impact on the overall productivity level of the crop. The varieties 'Lehenda Bilotserkivska', 'MIP Valensiia', 'Optyma Odeska', 'Okhtyrchanka Yuvileina', and 'Analoh', similarly to 'RGT Reform', exhibited high plasticity and were suitable for cultivation using intensive technologies, providing a yield increase of over 3.0 t/ha compared to the long-term average for the Kyiv region (2020-2024) of 4.81 t/ha. When cultivating soft winter wheat using resource-saving technologies, it is advisable to consider varieties such as 'Berehynia Myronivska', 'Vozdvyzhenka', and 'MIP Dniprianka'. These were capable of providing a grain yield increase of over 2.0 t/ha while maintaining productivity under the influence of limiting factors. The practical value of this work lies in the fact that its results can be used by agronomists and seed companies to select effective soft winter wheat varieties and increase yields.

Keywords: assortment; yield; intensive conditions; environmental limiting factor; certified seeds; cultivation areas

INTRODUCTION

Global wheat production volumes are influenced by the area under cultivation, climate change, agricultural technologies and variety selection. The issue of optimising crop cultivation, especially for grain crops, is particularly acute, as climate change factors – such as an increase in arid areas, erosion and loss of soil fertility – are deteriorating the condition of cultivated land and reducing the amount of land suitable for agriculture.

In a global context, climatic factors are believed to account for one-third of the observed fluctuations in wheat yields, although overall global production of this crop is growing by 1.0% annually. At the same time, researchers Y. Li & F. Tao (2022) have proven that climate change is the main limiting factor and even leads to a decrease in winter wheat yields. Winter crops are particularly sensitive to the reduction or absence of the period with temperatures necessary for their vernalisation. In order for winter wheat plants to produce a high yield, air temperatures of 0-1°C must persist for 40-70 days during the autumn-winter period, as noted by J. Bailey-Serres *et al.* (2019) and W. Xiong *et al.* (2021). Researchers also found that from 1979 to 2000, the temperature during the wheat growing season increased by 1°C, which led to a 3-10% decrease in grain yield.

The reduction in sown areas, partly due to the negative impact of climate change, may lead to a further decline in production. To prevent this, environmentally friendly and resource-efficient cultivation technologies should be

introduced and new wheat varieties should be actively introduced into production (Elazab *et al.*, 2021). L. Crespo-Herrera *et al.* (2018) argue that the increase in yield due to genetic factors depends on environmental conditions, and even under unfavourable conditions, it is at least 1.4% per year. In the United States, the increase in yield due to timely variety replacement in 1919-1993 was 0.98% annually; in Brazil in 1949-2009 – 0.92%; in Spain in 1930-2000 – 0.88%, and in Chile – 0.49% in 1965-2019 (del Pozo *et al.*, 2022). All researchers agree that timely variety replacement or renewal is a prerequisite for maintaining high wheat cultivation efficiency.

Three approaches are commonly used to assess the impact of variety replacement or renewal on grain yield: process-based modelling, statistical data, and field experiments, each with its own advantages and limitations (Madhukar *et al.*, 2020). C. Rivera-Amado *et al.* (2020) noted that field experiments are often the most reliable and accessible, but it is difficult to assess the genetic increase in wheat yield based on historical varieties in specific environmental conditions due to the limited number of experiments and varieties used. Thus, it is advisable to consider statistical data as the primary method of analysis, as it effectively reflects the dynamics of yield changes in mass production conditions. It should be noted that among most agricultural crops, winter wheat is relatively simple in terms of seed production: it is based on varietal selection, and high-reproduction varieties, provided that seed

material is carefully selected, are capable of ensuring high productivity without the need for annual renewal (Najafi *et al.*, 2018). However, in a global context, the issue of variety replacement or renewal should be considered at the level of state policy – as a universal indicator of the effectiveness of winter wheat cultivation technologies.

The aim of the study was to analyse the peculiarities of the formation of the assortment and distribution of soft winter wheat, as well as to assess the level of productivity, ecological stability and economic efficiency of its modern varieties when grown in the forest-steppe zone of Ukraine.

MATERIALS AND METHODS

The research was conducted during 2020–2024 under the conditions of the experimental field of the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences (State Enterprise Research Farm “Salivinkivske”, Bila Tserkva district, Kyiv region). The field component of the study involved the annual cultivation of the following soft winter wheat varieties: ‘Analoh’, ‘Anatoliia’, ‘Berehynia Myronivska’, ‘Vezha Myronivska’, ‘Vodohrai’, ‘Vozdvyzhenka’, ‘Hratsiia Bilotserkivska’, ‘Hratsiia Myronivska’, ‘Estafeta Myronivska’, ‘Zdobna’, ‘Zorepad Bilotserkivskiyi’, ‘Katrusia Odeska’, ‘Kesariia Poliska’, ‘Konka’, ‘Kraievdyd’, ‘Lehenda Bilotserkivska’, ‘Manera Odeska’, ‘Mariia’, ‘MIP Assol’, ‘MIP Valensiia’, ‘MIP Vyshyvanka’, ‘MIP Dniprianka’, ‘Mudrist Odeska’, ‘Nasnaha’, ‘Optyma Odeska’, ‘Oranta Odeska’, ‘Okhtyrchanka Yuvileina’, ‘Poliska 90’, ‘Pryvitna’, ‘RGT Reform’ (France), ‘Romanivna’, ‘Svitankova’, ‘Solovushka’, ‘Spivanka Poliska’, ‘Spriiatlyva’, and ‘Futurum’ (France).

The cultivation technology for soft winter wheat was conventional for the conditions of

the Kyiv region. The area of the primary plots was 35 m², and the experiments were established with three replications. The soil of the experimental field is a deep, medium-loamy chernozem on loess-like loam. The humus content in the arable soil layer was 2.58% (according to Tyurin), alkaline-hydrolysable nitrogen was 176 mg/kg (according to Cornfield), and mobile phosphorus and potassium compounds were 160 and 95 mg/kg respectively (according to Chirikov).

Weather conditions during the research years differed significantly from long-term averages. In particular, March and April 2020 were warm with a slight moisture deficit, while May was cool and excessively wet. In summer, periods of extreme heat prevailed, especially in June and July, coupled with a lack of precipitation, which significantly affected wheat yields both in the region overall and within the experiments. In 2021, spring was cool with unstable precipitation; summer saw hot periods with moisture deficits, which generally negatively impacted wheat growth and development but did not cause a yield decrease compared to the previous year. In 2022, weather conditions were predominantly warm, with particularly significant droughts noted in June and July, leading to substantial plant stress during critical developmental phases. Consequently, wheat yields were the lowest across the entire research period. Conversely, in 2023, spring was moderately wet, and summer featured alternating hot and moderate periods in terms of temperature and moisture supply. Similar weather conditions were observed during the spring-summer vegetation of 2024, which favoured the formation of high yields. The Selyaninov hydrothermal coefficient (HTC) values during the growing periods over the research years are presented in Table 1.

Table 1. HTC for the Kyiv region during the growing season (May–August)

Year	HTC	Characteristics of moisture regime
2020	0.65	Insufficient (arid)
2021	1.15	Sufficient moisture
2022	0.56	Severe drought
2023	1.00	Moderate moisture
2024	0.90	Slight drought / normal

Note: HTC < 0.5 – severe drought; 0.5–0.7 – moderate drought; 0.7–1.0 – slight drought; 1.0–1.3 – sufficient moisture; >1.3 – excessive moisture

Source: compiled by the authors

In general, the weather conditions of the spring-summer growing period in 2020-2024 corresponded to a zone of unstable moisture supply. During this time, periods of drought, instability of precipitation, and high air temperatures were observed, which significantly influenced the course of vegetation. However, it was precisely this variability of conditions that allowed for a more thorough identification of the reactions of soft winter wheat varieties to changes in their cultivation environment. The assessment of the distribution of soft winter wheat varieties was carried out based on data from The Unified State Web Portal of Open Data (n.d.), as well as the results of own research and information from the State Register of Plant Varieties Suitable for Distribution in Ukraine (n.d.).

Yield stability and plasticity were determined using the Eberhart-Russell method, which involves evaluating the crop productivity level through plasticity (b), reflecting the regression to changes in cultivation conditions, and the stability (W) of this reaction (Eberhart & Russell, 1966). The baseline data for the economic analysis of winter wheat cultivation under the conditions of the Kyiv region at 2024 prices were as follows: average yield for the Kyiv region: 4.81 t/ha; wheat sale price: ≈ 7,500 UAH/t; cultivation costs excluding seed costs: ≈20,000 UAH/ha; cost of seeds: elite: 12,000-15,000 UAH/t; 1st reproduction: 9,000-11,000 UAH/t; 2nd-3rd reproduction: 7,000-8,500 UAH/t; weight-based sowing rate of winter wheat: 0.22-0.25 t/ha.

Return on Investment (ROI) was calculated according to the formula:

$$ROI = (\text{Additional Profit} / \text{Investment}) \times 100\%. \quad (1)$$

The research was conducted in accordance with the methods for field experiments and state variety testing of agricultural crops (Ermantraut *et al.*, 2007; Prysiazhniuk *et al.*, 2021). The study was carried out in compliance with the ethical standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1976).

RESULTS AND DISCUSSION

In Ukraine, according to Law of Ukraine No. 411-IV "On Seeds and Planting Material" (2025), there is a Register of Certificates for Seeds and/or Planting Material, which contains information about batches of seeds of a certain variety (The unified state web portal of open data, (n.d.)). The presence of a record of the variety and volume of the seed batch in this register at least confirms the intention to officially sell it as seed material. On the other hand, the presence of an entry for a variety in the State Register of Plant Varieties Suitable for Distribution in Ukraine only indicates the intention to distribute it commercially, but does not confirm the fact of its use. Thus, analysis of the Register of Certificates is the most reliable way to determine the prevalence of modern varieties, including winter wheat (Table 2).

Table 2. Winter wheat varieties included in the 20 most common varieties in terms of area sown with certified high-reproduction seeds

Year of sowing									
2023		2022		2021		2020		2019	
Variety	ha	Variety	ha	Variety	ha	Variety	ha	Variety	ha
'Bohdana'	22,359	'RGT Reform'	19,068	'Bohdana'	51,380	'Bohdana'	39,511	'Podolianka'	5,654
'RGT Reform'	14,167	'KWS Emil'	7,893	'RGT Reform'	31,354	'Podolianka'	29,017	'Zymoiaarka'	4,222
'Mudrist Odeska'	9,776	'Mudrist Odeska'	7,642	'Podolianka'	31,315	'RGT Reform'	23,439	'Balaton'	3,313
'Podolianka'	8,083	'Podolianka'	7,093	'Mudrist Odeska'	26,741	'Mudrist Odeska'	22,841	'Bohdana'	2,793
'KWS Emil'	5,940	'Etana'	6,887	'Katrusia Odeska'	15,589	'Kubus'	21,445	'Matrix'	2,287
'Katrusia Odeska'	5,585	'KWS Jersey'	6,313	'Astarta'	13,759	'Skagen'	17,447	'Mudrist Odeska'	2,088
'Julia'	5,030	'Bohdana'	6,303	'Julia'	13,461	'Colonia'	15,992	'Lyst 25'	1,733
'Shestopalivka'	4,986	'Skagen'	5,233	'Skagen'	13,327	'Tobak'	14,914	'Kubus'	1,704

Table 2, Continued

Year of sowing									
2023		2022		2021		2020		2019	
Variety	ha	Variety	ha	Variety	ha	Variety	ha	Variety	ha
'KWS Jersey'	4,923	'Katrusia Odeska'	4,897	'Tobak'	12,765	'Mescal'	13,780	'Lira Odeska'	1,667
'Lemmy'	4,551	'Matchball'	4,761	'Sofia Kyivska'	12,450	'Julia'	13,767	'Zhytnytsia Odeska'	1,567
'Nordika'	4,547	'Julia'	4,687	'Liha Odeska'	11,050	'Praktik'	12,858	'Nyva Odeska'	1,518
'Matchball'	4,490	'Astarta'	4,408	'Oranta Odeska'	11,045	'Novosmuhlianka'	12,572	'Vanessa'	1,387
'Patras'	4,261	'Lemmy'	4,083	'Shestopalivka'	10,919	'Astarta'	11,648	'Smuhlianka'	1,280
'Asory'	4,187	'Felix'	4,080	'Kubus'	10,692	'Shestopalivka'	11,506	'Julia'	1,260
'Oranta Odeska'	4,065	'KWS Talant'	4,053	'Oktava Odeska'	10,636	'Patras'	11,300	'Nordika'	1,220
'Balitus'	3,760	'Artist'	4,040	'Patras'	10,418	'Lira Odeska'	10,571	'Skagen'	1,193
'Felix'	3,633	'Frisky'	3,573	'Artist'	10,260	'Fermerka'	10,343	'Mulan'	1,153
'Sofia Kyivska'	3,613	'Aspekt'	3,280	'Aspekt'	10,085	'Katrusia Odeska'	10,274	'Slavna'	1,149
'Futurum'	3,467	'LG Keramik'	3,220	'KWS Jersey'	8,899	'Nordika'	10,147	'Novosmuhlianka'	1,093
'Etana'	3,447	'Emblem'	2,967	'Kraievyyd'	8,612	'Pylypivka'	10,065	'Mescal'	1,050

Source: compiled by the authors

In general, there has been a certain renewal of the assortment from year to year, but it cannot be said that Ukrainian varieties are inferior to foreign ones in terms of area. On the contrary, in 2019-2021 and 2023, it was domestic varieties that occupied the leading positions in terms of sown areas. At the same time, 2022 was quite atypical for the agricultural sector of Ukraine, not only because of the war, but also due to the inability to sow part of the areas in the east of the country, where there was traditionally high demand for Ukrainian varieties, as they have the ability to withstand unfavourable growing conditions without a significant reduction in yield.

Analysing the availability of certified winter wheat seeds in general, it should be noted that in 2019, with Ukrainian varieties prevailing by 1.6 times, the areas sown with them were 50% larger than the areas sown with foreign varieties (Fig. 1). Despite the fact that in 2020-2021 the total number of wheat varieties increased, the ratio between domestic and foreign varieties remained 1.0:1.6 in 2020 and 1:2 in 2021. Although the area sown with certified seeds of foreign varieties is growing every year, they only managed to exceed the area of Ukrainian varieties in 2022.

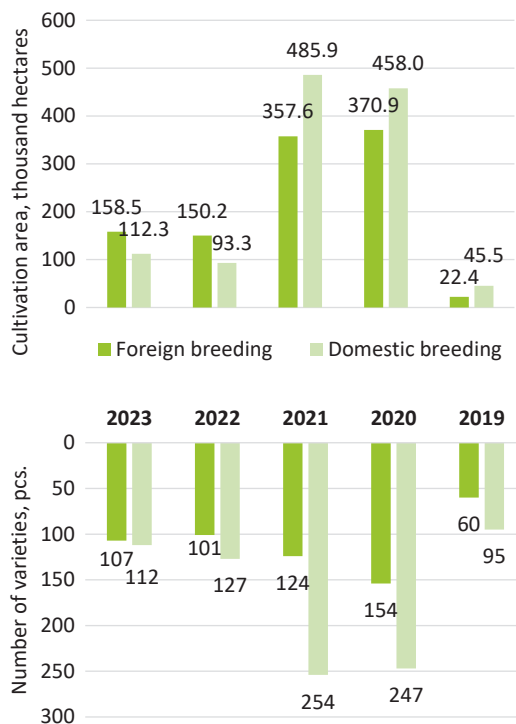


Figure 1. Structure of areas and varieties of high-yielding winter wheat, common in Ukraine

Source: compiled by the authors

At the same time, there is a certain parity in the number of registered varieties, but the area under Ukrainian varieties has decreased. As of 2023, foreign varieties occupied 1.4 times more area. As of 20 September 2025, the State Register of Plant Varieties Suitable for Distribution in Ukraine (n.d.) contains records of 783 varieties of soft winter wheat, but only 219 are

available for purchase. It is advisable to carry out a complete replacement or renewal of winter wheat varieties on the farm every 5-7 years. Since this process is gradual, farms should sow 15-25% of their areas with new varieties each year. In this regard, the demand for certified winter wheat seeds in Ukraine has been determined (Table 3).

Table 3. Areas sown with certified winter wheat seeds in Ukraine

Indicator	Year of sowing				
	2023	2022	2021	2020	2019
Certified seeds available per area, ha	270,748	243,484	843,467	828,885	67,834
Sown area, ha	4,950,422	4,658,400	5,281,500	7,090,200	6,554,500
Seed requirement, ha	4,679,674	4,414,916	4,438,033	6,261,315	6,486,666
Percentage of area sown with high-reproduction seeds	5.5	5.2	16.0	11.7	1.0

Source: compiled by the authors based on The unified state web portal of open data (n.d.)

Consequently, only in 2021 did producers ensure a sufficient level of variety replacement and renewal for winter wheat, whereas in 2022-2023, this indicator decreased significantly to 5.2-5.5%. According to M. Korkhova & O. Kovalenko (2019), 141 wheat varieties are distributed in Southern Ukraine, of which 32.4% are outdated. This confirms the results obtained regarding the insufficient level of variety replacement and renewal of winter wheat. Global food security challenges require constant improvement of the varietal composition of winter wheat. Research over recent decades convincingly demonstrates that degradation processes on arable lands in various regions of the world, climate change, and the spatial variability of the suitability of soil and climatic conditions for wheat cultivation create additional challenges

for stable grain production (Práválie *et al.*, 2021; Li & Zheng, 2022). At the same time, an analysis of the dynamics of sown areas and production volumes of major cereal crops, particularly wheat, in leading producing countries shows that productivity growth largely depends on the introduction of new varieties, as noted by Y. Wang *et al.* (2019) and A. Zvonar (2020). This emphasises the critical importance of systematic variety replacement and renewal as a strategic tool for adaptation to changing environmental conditions. Thus, special attention should be paid to the field trials of wheat varieties of Ukrainian and foreign breeding conducted under the conditions of the State Enterprise Research Farm “Salivinkivske” of the Institute of Bioenergy Crops and Sugar Beet of the NAAS (Kyiv region) during 2020-2024 (Table 4).

Table 4. Ecological characteristics of wheat varieties grown under the conditions of the State Enterprise Research Farm “Salivinkivske” (average for 2020-2024)

Variety	Ecological characteristics	Yield increase, t/ha
‘Analoh’	low plasticity	1.05
‘Anatoliia’	low plasticity	1.99
‘Berehynia Myronivska’	low plasticity, withstands limiting factors	2.22
‘Vezha Myronivska’	high plasticity, intensive	2.21
‘Vodohrai’	low plasticity	1.86
‘Vozdvyzhenka’	low plasticity, withstands limiting factors	2.25
‘Hratsiia Bilotserkivska’	high plasticity, intensive	2.63
‘Hratsiia Myronivska’	low plasticity, limiting factors	2.18
‘Estafeta Myronivska’	low plasticity	1.25

Table 4, Continued

Variety	Ecological characteristics	Yield increase, t/ha
'Zdobna'	low plasticity	1.54
'Zorepad Bilotserkivskiy'	high plasticity, intensive	2.88
'Katrusia Odeska'	low plasticity	1.82
'Kesariia Poliska'	high plasticity, intensive	2.29
'Konka'	low plasticity	1.78
'Kraievvd'	high plasticity, intensive	2.66
'Lehenda Bilotserkivska'	high plasticity, intensive	3.39
'Manera Odeska'	high plasticity	1.95
'Mariia'	high plasticity, intensive	2.7
'MIP Assol'	low plasticity	2.11
'MIP Valensia'	high plasticity, intensive	3.02
'MIP Vyshyvanka'	low plasticity	1.76
'MIP Dniprianka'	low plasticity, withstands limiting factors	2.55
'Mudrist Odeska'	high plasticity, intensive	2.83
'Nasnaha'	high plasticity	2.09
'Optyma Odeska'	high plasticity, intensive	3.13
'Oranta Odeska'	low plasticity	1.59
'Okhtyrchanka Yuvileina'	high plasticity, intensive	3.34
'Poliska 90'	low plasticity	0.98
'Pryvitna'	high plasticity, intensive	3.14
'RGT Reform'	high plasticity, intensive	3.37
'Romanivna'	low plasticity	1.67
'Svitankova'	low plasticity	1.61
'Solovushka'	low plasticity	1.47
'Spivanka Poliska'	high plasticity, intensive	2.45
'Spriiatlyva'	low plasticity	1.27
'Futurum'	low plasticity	2.09
HIP _{0.05}		0.11

Source: compiled by the authors

The obtained wheat yield data served as the basis for analysing their stability and plasticity, as well as assessing their suitability for intensive cultivation. Furthermore, the average yield of each variety was compared with the long-term average for the Kyiv region, which is 4.81 t/ha. Research conducted by M. Korkhova & O. Kovalenko (2019) in the Kherson, Mykolaiv, and Odesa regions showed that outdated wheat varieties – such as 'Anatoliia', 'Hurt', 'Lira Odeska Blaho', 'Konka', 'Mariia', 'Shestopalivka', and 'Zysk' – remain widespread. This not only underscores the importance of research into new varieties but also indicates an insufficient rate of variety renewal by farmers, which can, among other things, affect average yield levels.

Weather conditions during the years of study were extremely challenging, primarily due to a lack of precipitation and high air

temperatures in 2020 and 2022. Under such conditions, the average winter wheat yield in the Kyiv region was 4.28 and 3.84 t/ha, respectively. In contrast, the average yield of the varieties in the trial was 1.34 and 3.54 t/ha higher than the regional average. The studied winter wheat varieties demonstrated high productivity potential over the multi-year period. Specifically, in 21 out of 36 varieties, the yield exceeded the regional average by more than 2 t/ha, and in some cases, by more than 3 t/ha. These include: 'Lehenda Bilotserkivska', 'MIP Valensia', 'Optyma Odeska', 'Okhtyrchanka Yuvileina', and 'RGT Reform' (France). These varieties were distinguished by a high level of plasticity and an intensive type of plant development, indicating their ability to respond positively to improved cultivation technologies with a significant yield increase.

Special attention should be paid to varieties with low plasticity that are capable of withstanding limiting factors and ensuring an excess over the regional average yield of more than 2.0 t/ha. Such varieties include: 'Berehynia Myronivska', 'Vozdvyzhenka', and 'MIP Dniprianka'. They form a consistently high yield even under conditions of limited technological resources, which is particularly relevant in wartime. Unlike intensive varieties, they are less sensitive to increased fertilisation or additional crop care. However, a yield difference of approximately 1.0 t/ha does not always compensate for the costs of additional agricultural measures.

According to Ukrainian scientists V. Vlasenko *et al.* (2008), periodic variety replacement or renewal provides an additional yield increase of 0.5 t/ha or more, provided it is carried out every 5-7 years. Yield stability across different environments is ensured by the ability to compensate for its main components – thousand-kernel weight, number of grains per spike, and the number of spikes per square metre (Tadesse *et*

al., 2019). Yield formation occurs differently depending on environmental conditions, and modern varieties demonstrate different combinations of yield components compared to varieties from the 1950s-2000s (Valvo *et al.*, 2018; Cao *et al.*, 2019). An important issue is also the calculation of the economic efficiency of variety replacement or renewal within an average farm in the Kyiv region with a winter wheat cultivation area of 1,000 ha.

Thus, high-intensity soft winter wheat varieties, such as 'Lehenda Bilotserkivska', 'MIP Valensiia', 'Optyma Odeska', 'Okhtyrchanka Yuvileina', and others, provide an increase of over 3.0 t/ha and a total yield under 2024 conditions at a level of 7.81 t/ha. Conversely, for resource-saving varieties – 'Berehynia Myronivska', 'Vozdvyzhenka', 'MIP Dniprianka' – the yield increase was 2.0 t/ha with a total figure of 6.81 t/ha. This allows for a comparison of soft winter wheat replacement strategies when using varieties with different levels of yield formation intensity (Table 5).

Table 5. Comparative effectiveness of soft winter wheat variety replacement strategies

Indicator	Intensive varieties	Resource-saving varieties	No variety replacement
Additional costs, UAH/ha	7,000	2,400	0
Yield increase, t/ha	3	2	-0.96
Cultivation technology costs, UAH/ha	25,000	22,400	20,000
Sales revenue, UAH/ha	62,480	54,480	30,800
Gross profit, UAH/ha	37,480	32,080	10,800
Additional profit, UAH/ha	24,000	16,000	-7,680
Return on investment (ROI), %	343	667	–

Source: compiled by the authors

When using intensive varieties, costs increase not only due to seeds, but also due to the need for additional fertilisers and the use of more protective and stimulating substances. Such varieties respond very well to optimised growing conditions, which increases their productivity. Resource-saving varieties are capable of producing sufficiently high yields under basic cultivation technology conditions. This makes them more attractive for investment in cases of resource shortages or in small farms where intensive technology cannot always be implemented.

The issue of variety renewal in difficult economic conditions, when farms are often forced to grow only existing varieties, deserves special

attention. In this case, the decline in yield will be cumulative: in the first year or two, it may be almost imperceptible, and the existing "decline" in productivity can be explained by the influence of weather conditions or shortcomings in agricultural technology. At the same time, it is crucial to be aware of the cumulative effect of losses, which manifests itself over a longer period, for example, over a five-year period on an area of 1,000 hectares. For a more informed analysis, it is also advisable to take into account the annual impact of weather factors, based on retrospective data on the yield of soft winter wheat in the Kyiv region. Thus, in 2020, the harvest on the farm's fields was obtained from

third-generation seeds. In subsequent years, there is a gradual increase in the degree of reproduction, which is due to the reuse of the same seed material (Table 6).

Table 6. Potential losses of yield and gross profit in the absence of soft winter wheat variety renewal

Year (reproduction)	Average annual yield, t/ha*	Losses, %	Purchase price, UAH/t	Losses from crop failure, UAH/ha
2020 (III)	4.28	5	5,500	1,177
2021 (IV)	5.06	8	6,850	2,773
2022 (V)	3.84	12	5,250	2,419
2023 (VI)	5.37	15	7,150	5,759
2024 (VII)	5.50	20	8,000	8,800
Total per 1,000 ha				20,928,405

Note: * – according to State Statistics Committee data for Kyiv region

Source: compiled by the authors

The projected decrease in yield when using soft winter wheat seeds of III-IV reproduction in farming is 5 and 8% (0.21 and 0.40 t/ha), respectively, which at first glance does not seem critical. However, over two years, the total losses amount to 3,950 UAH/ha, which is 1,550 UAH/ha more than the cost of timely seed renewal. In the case of variety replacement (using elite or first reproduction seeds), the yield potential is maintained at the average level of the farm in years with similar climatic conditions. In a five-year perspective, failure to renew varieties leads to total losses of UAH 20,928,405, which is

a significant economic indicator. In the conditions of the Kyiv region, one of the key criteria for the correct selection of soft winter wheat varieties is their ability to grow and develop effectively in conditions of low rainfall and high air temperatures. It has been established that the relationship between the hydrothermal coefficient (HTC) and wheat yield in the years of research has a strong positive correlation ($r=0.825$). This indicates that the level of moisture supply during critical periods of crop vegetation is the main limiting factor in the formation of its productivity (Fig. 2).

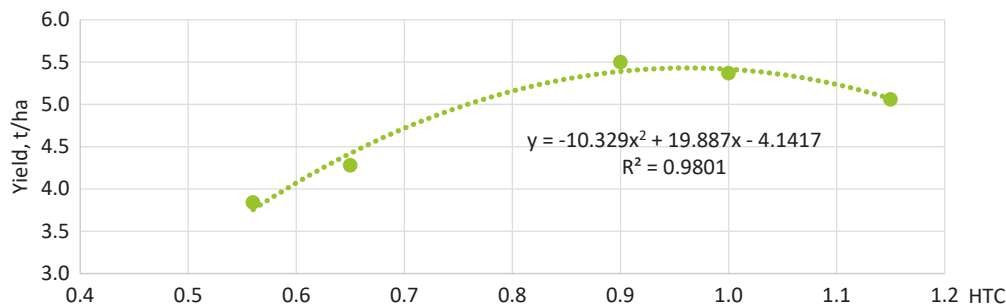


Figure 2. Dependence of soft winter wheat yield on HTC during the growing season

Source: compiled by the authors

Improvements in wheat through breeding and the timely introduction of new varieties ensure stable yield increases, as confirmed by a large-scale study of international breeding programmes by W. Tadesse *et al.* (2019). Modern approaches to variety evaluation based on a comprehensive analysis of soil, climatic and physiological parameters and their contribution

to yield formation (Elazab *et al.*, 2021), as well as on the application of technologies (Araus *et al.*, 2018). These scientific achievements justify the need to model the processes of updating the varietal composition as an effective mechanism for increasing wheat productivity and ensuring food security in the context of global climate change and growing anthropogenic pressure on

agroecosystems. Based on the modelling results, the forecast indicators for soft winter wheat yield have been determined and requirements for varieties have been formulated (Table 7).

Table 7. Forecast yield indicators for soft winter wheat and requirements for varieties depending on HTC

Level of HTC	Estimated yield, t/ha	Recommended types of varieties
0.5-0.6 (drought)	3.2-4.1	Drought-resistant, resource-efficient
0.7-0.9 (mild drought)	4.7-5.4	Versatile, adaptable
0.9-1.1 (optimum)	5.4-5.2	Intensive, high-yielding
>1.2 (excessive moisture)	<4.8	Resistant to lodging

Source: compiled by the authors

As shown in Table 7, intensive varieties can achieve maximum productivity only under optimal HTC values (0.9-1.1). At the same time, due to current climate change in the Kyiv region, such moisture conditions are relatively rare. An additional complication in the selection of winter wheat varieties is the need to predict the conditions of the growing season for the following year in the autumn. Taking into account climate change and the increasing frequency of extreme weather events, it is advisable to recommend the following variety structure within the farm: 30% of the area should be sown with varieties that can withstand limiting factors, primarily drought-resistant ones (ensuring yield formation at HTC <0.7); 40% of the area should be sown with universal, highly plastic varieties (characterised by stable yields at a HTC of 0.7-1.0); 30% of the area should be sown with intensive varieties (achieving maximum productivity at a HTC >1.0).

Research by S. Lavrenko & N. Lavrenko (2022) has proven that in order to ensure sustainable production of high-quality grain in farms, it is necessary to carry out variety changes and renewal. The introduction of new and promising varieties with increased productivity, quality, and adaptability to external environmental conditions is an important element of agricultural technology. The researchers also claim that in most cases, 2-4 different varieties are sown in production, which is in line with the results on the need to diversify the risks of wheat cultivation not only in terms of the number of varieties but also their response to growing conditions and elements of agricultural technology.

CONCLUSIONS

It has been researched that the State Register of Plant Varieties Suitable for Distribution in Ukraine contains 783 varieties of soft winter wheat, of which only 28% are available on the market. For full variety replacement or renewal and to achieve a high level of soft winter wheat yield, it is necessary to sow at least 15% of areas annually with new varieties or seeds of higher generations. In 2021, this figure in Ukraine stood at 16%; however, in 2022 and 2023, it decreased to 5.2% and 5.5% respectively, which could potentially have a negative impact on the overall productivity level of the crop. The varieties 'Lehenda Bilotserkivska', 'MIP Valensiia', 'Optyma Odeska', 'Okhtyrchanka Yuvileina', and 'Analoh', similarly to 'RGT Reform', exhibit high plasticity and are suitable for cultivation using intensive technologies, providing a yield increase of over 3.0 t/ha compared to the long-term average for the Kyiv region (2020-2024) of 4.81 t/ha.

When cultivating soft winter wheat using resource-saving technologies, it is advisable to consider varieties such as 'Berehynia Myronivska', 'Vozdvyzhenka', and 'MIP Dniprianka'. These are capable of providing a grain yield increase of over 2.0 t/ha while maintaining productivity under the influence of limiting factors. The highest economic efficiency was noted in resource-saving varieties (ROI – 667%). At the same time, the absence of variety replacement or renewal leads to annual losses at a level of 7,680 UAH/ha. The optimal strategy for winter wheat cultivation under the conditions of farms in the Kyiv region is a

combination of different variety groups, namely: 30% of areas for varieties capable of withstanding the impact of limiting factors, 40% of areas for universal highly plastic varieties, and 30% of areas for intensive varieties. Such an approach ensures both production resilience to stress conditions and the maximum realisation of productivity potential. Further research should evaluate the possibilities of growing new varieties of soft winter wheat in different soil and climatic zones of Ukraine to improve

the variety replacement system and increase the adaptive potential of the crop.

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Аналіз сортового складу пшениці м'якої озимої в контексті сортооновлення та сортозаміни

Анотація. Погодні умови, що змінюються в бік екстремальних значень, визначають потребу здійснювати сортозаміну і сортооновлення пшениці м'якої озимої на систематичному рівні, здатному поліпшити ефективність агротехнологій вирощування та забезпечити стабільно високий рівень урожайності культури. Тому метою роботи було проаналізувати особливості формування сортименту та поширення пшениці м'якої озимої, а також підібрати кращі сорти за продуктивністю та екологічною стабільністю. Польові дослідження проводили в умовах ДП ДГ «Саливківське» Інституту біоенергетичних культур і цукрових буряків НААН України (Київська обл.) упродовж 2020-2024 рр. Показники стабільності та пластичності врожайності зерна 36 сортів пшениці м'якої озимої розраховували за методикою Ебергарда-Рассела. Встановлено, що для повноцінної сортозаміни чи сортооновлення та досягнення високого рівня врожайності пшениці м'якої озимої необхідно щорічно засівати щонайменше на 15 % площ новими сортами або насінням вищих репродукцій. У 2021 році цей показник в Україні становив 16 %, однак у 2022 та 2023 роках знизився до 5,2 і 5,5 % відповідно, що потенційно негативно вплинуло на загальний рівень продуктивності культури. Сорти 'Легенда білоцерківська', 'МІП Валенсія', 'Оптіма одеська', 'Охтирчанка ювілейна', 'Аналог', аналогічно 'РЖТ Реформ' мали високу пластичність і були придатні до вирощування за інтенсивних технологій, забезпечуючи приріст урожайності понад 3,0 т/га порівняно із середнім багаторічним показником по Київській області (2020-2024 рр.) – 4,81 т/га. За вирощування пшениці м'якої озимої з використанням ресурсоощадних технологій доцільно звернути увагу на такі сорти, як 'Берегиня миронівська', 'Воздвиженка' та 'МІП Дніпрянка'. Вони були здатні забезпечити приріст урожайності зерна понад 2,0 т/га, зберігаючи продуктивність за умов впливу обмежувальних чинників. Практична цінність роботи полягає в тому, що її результати можуть використовувати агрономи та насінневі компанії для підбору ефективних сортів пшениці м'якої озимої та підвищення врожайності

Ключові слова: сортимент; урожайність; інтенсивні умови; ліміт факторів середовища; сертифіковане насіння; площі вирощування