

EREM 82/1

Journal of Environmental Research,
Engineering and Management
Vol. 82 / No. 1 / 2026
pp. 88–99
10.5755/j01.erem.82.1.40939

**Varietal Effects on Winter Wheat Competitiveness
in the Steppe Region of Ukraine**

Received 2025/05

Accepted after revisions 2025/11

<https://doi.org/10.5755/j01.erem.82.1.40939>

Varietal Effects on Winter Wheat Competitiveness in the Steppe Region of Ukraine

**Volodymyr L. Matyukha¹, Yurii I. Tkalich², Oleksandr I. Tsyliuryk², Serhii S. Semenov^{1*},
Oleh O. Didur³, Nina O. Khromykh³, Andriy V. Kokhan⁴, Andreii V. Shepel⁵**

¹ State Institution Institute of Grain Crops of NAAS of Ukraine, Ukraine

² Dnipro State Agrarian and Economic University, Ukraine

³ Oles Honchar Dnipro National University, Ukraine

⁴ Luhansk Taras Shevchenko National University, Ukraine

⁵ Kherson State Agrarian and Economic University, Ukraine

***Corresponding author:** semenmart@gmail.com

Winter wheat competitive ability against weeds in agrophytocenoses is determined, in part, by varietal characteristics, with implications for the grain yield of this globally important crop. Field experiments conducted in 2021–2023 were aimed at evaluating the competitive ability of the newest winter wheat cultivar of Ukrainian selection (Tsarychanka, Koshova, Oleksiyvka, Hratiya Myronivska, Vezha Myronivska, Estafeta Myronivska) in the Steppe arid conditions. Weed abundance and pressure were determined by the dominant species *Sinapis arvensis*, *Fumaria officinalis*, *Raphanus raphanistrum*, and *Thlaspi arvense*, and varied depending on the crop development phase, maturity group of cultivars, and weather conditions. Early-maturing wheat cultivar displayed the highest biometric and structural parameters, such as plant height, leaf surface area, spike length, grain number per spike, and 1000 kernel weight, and were also characterized by the lowest weed air-dry mass in crops. Grain yield varied depending on the growing season conditions, reaching the highest average for all maturity groups in 2022 (7.12 t/ha), which was the highest for early-maturing cultivar in all years of research (6.31 t/ha). Thus, early-maturing cultivar excelled in terms of resistance to weed competition, adaptation to adverse climate conditions, and productivity, and were determined to be the most competitive among the newest cultivar of winter wheat created by Ukrainian breeders.

Keywords: wheat cultivar, weed abundance, competitive ability, grain yield.

Introduction

In modern grain production, crop competition with weeds remains a challenging problem, which can significantly affect the agrophytocenoses productivity, including the winter wheat crops. According to the International Weed Science Society data (Bryson and DeFelice, 2009), annual yield losses due to the impact from weeds ranged from 20% to 40%, depending on the region, climatic conditions and applied protection technologies. In the countries with high-technology agriculture, the main focus is on integrated weed control, while in regions with less developed technology, mechanical weeding is more intense due to limited chemical crop protection (Nath et al., 2022; Md-AKhir et al., 2022; Schnee et al., 2023). In Europe, North and South America, and Australia, a key problem is the evolution of herbicide resistant weeds due to overuse of selective active ingredients. Hence, weeds have developed resistance to several herbicide modes of action, forcing farmers to use integrated strategies including mechanical eradication, crop rotation, mulching, and herbicide tank mixes (Maqsood et al., 2018; Abrell et al., 2024; Zhuolin et al., 2024). In South Asia, China and Africa, the weed spectrum and abundance, caused by weeds' rapid growth and reproduction due to long growing season, not only reduce yields, but also negatively affect ecosystems (Lundgren and Anderson, 2023; Zhang et al., 2024). In the Ukraine, including the northern Steppe, winter wheat crop competition with weeds is associated with the wide distribution of annual and perennial dicotyledonous weeds, such as *Descurainia sophia*, *Capsella bursa-pastoris*, *Cirsium arvense*, as well as cereals, including *Echinochloa crus-galli* and *Apera spica-venti* (Tsyliuryk, 2023). Wheat competitive ability with weeds is often affected by environmental conditions, in particular, insufficient and unstable moisture, which reduces both crop competitive ability and herbicide efficacy (Shevchenko et al., 2023).

In the Steppe of Ukraine, the competitive ability of winter wheat cultivar is an important trait that determines the crop's ability to maintain grain yield potential while competing with wild flora for resources, which often possess higher tolerance to abiotic stress. The effective selection of winter wheat cultivar adapted to the steppe climate and associated abiotic stress can help offset the negative impact of unwanted vegetation (Zubets, 2010; Matyukha, 2012). Varietal characteristics, such

as rapid initial growth, forming the high stalks density, and optimal root architecture for nutrient uptake influences cropping efficiency (Nazarenko et al., 2019; Ghosh et al., 2023). In addition, the use of cultivar adapted to local conditions coupled with modern agronomic and integrated weed management practices is key to addressing the problem of traditional weed control technologies insufficiency (Lacroix et al., 2024; Masson et al., 2024; Namatsheve et al., 2024). The main characteristics that determine the winter wheat varietal competitive ability with weeds are morphological and physiological features (Lozinsky et al., 2020; Holyk et al., 2024). In particular, early canopy closure is a feature of some tall cultivar with a well-developed leaf apparatus, rapidly shading the soil surface and limiting weed germination. This intensive initial growth is also advantageous for the competition for light, moisture and nutrients (Tkalic and Shevchenko, 2020; Topko and Kovalyshyna, 2020).

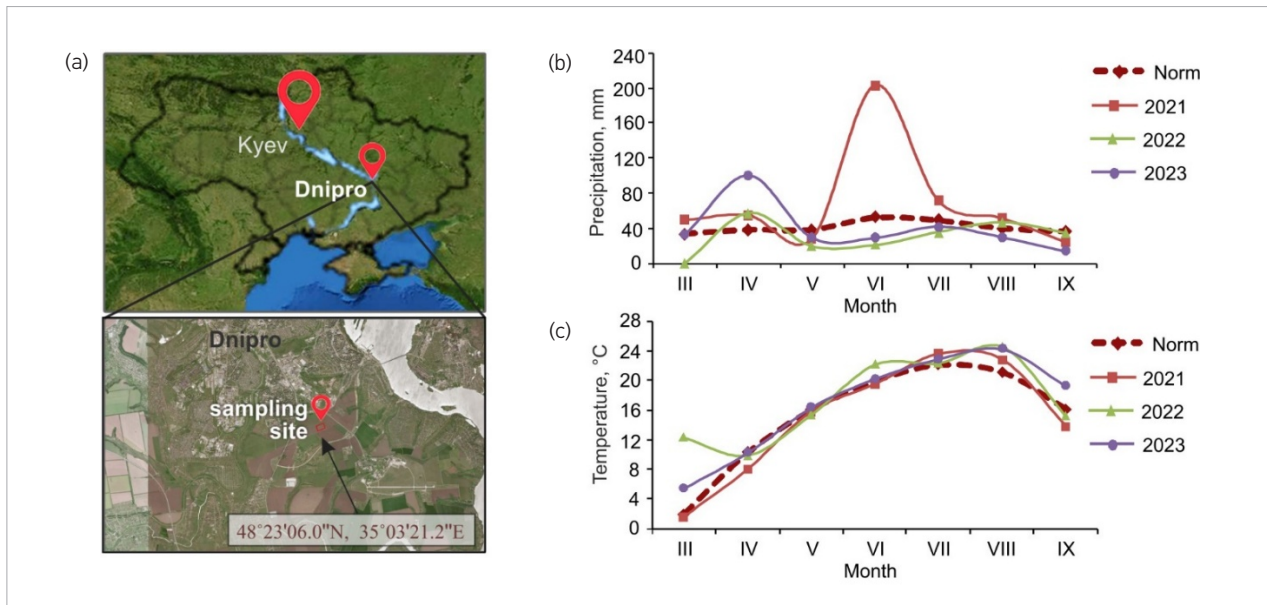
Sustainability metrics such as environmental loading becomes especially important due to agricultural intensification, particularly if certain modes of action or application practices are associated with environmental risks (Krainsiuk et al., 2024). In this sense, the use of wheat cultivar with increased competitive ability enhances ecosystem services (Gong et al., 2016; Sharma et al., 2019). On the contrary, the lack of systematic research on the genetic ability to compete with weeds creates a scientific gap (Olesen et al., 2004; Kaur et al., 2021). Since winter wheat occupies a leading place among grain crops (Kalenska et al., 2019), the study of its sustainability is important both from a scientific perspective and for practical agriculture. This task is strategic for increasing the food security of Ukraine and the world as a whole. The purpose of this work was to assess the prospects of the newest winter wheat cultivar with differential maturity traits created by Ukrainian breeders in terms of competitive ability in agrocenoses.

Methods

Study area

Field experiments were conducted in 2021–2023 in the demonstration range areas of the Institute of Grain Crops of the NAAS of Ukraine, located on the basis of the Dnipro Research Farm (48°23'06.0"N, 35°03'21.2"E), Dnipro city (Fig. 1a).

Fig. 1. Study area (a) location, (b) humidity conditions and (c) temperature regime (in 2021–2023)



The study region was conducted in the Steppe zone, which covers 40% of the total territory of Ukraine (Burykina and Tsurkan, 2020) and is characterized by significant temperature differences between usually hot summers and cold, wet winters (Khromykh et al., 2018). The continental features of the steppe climate are complemented by frequent droughts with dry winds, high air temperatures, low precipitation, and high evaporation (Department of Ecology and Natural Resources of the Dnipropetrovsk Regional State Administration, 2022). Weather conditions in 2021–2023 differed significantly in precipitation (Fig. 1b) and temperature indicators (Fig. 1c) both from the multi-year norm and in different years of research. In 2021, the wheat vegetation recovery period (late March–April) was marked by low air temperatures and a gradual

decrease in precipitation with a transition to drought in late April–early May; in the summer of 2021, heavy precipitation in the form of short-term showers was observed only in the first decade of June. In the spring of 2022 and 2023, the temperature regime and precipitation levels were significantly more favorable than the previous year for active wheat growth, while the summer period was characterized by drought, when precipitation was significantly below the climatic norm, especially in June.

The soil cover in the areas of the demonstration range was represented by ordinary chernozems, medium loamy and low in humus, which contains 3.1–3.2% humus, 0.17–0.19% gross nitrogen, 0.12–0.13% phosphorus, and 2.1–2.2% potassium in the arable layer.

Table 1. Characteristics of winter wheat cultivar used in the field experiments in 2021–2023

Cultivar	Vegetation period, days	Plant height, cm	Definition of variety
Tsarychanka	265–296	92–102	early-maturing, medium height
Koshova	279–296	75–103	early-maturing, medium-sized
Oleksiyvka	278–281	80–88	mid-early, short stature
Hratsiya Myronivska	279–283	78–82	mid-early maturity, low-growing
Vezha Myronivska	273–280	71–84	mid-maturing, low-growing
Estafeta Myronivska	275–284	91–95	mid-maturing, medium-sized

Design of the field experiments

Experimental plots with an area of 40.0 m² (2.0 m × 10.0 m) were arranged in the field in triplicate. Agricultural techniques for growing winter wheat corresponded to general recommendations for the Steppe zone (Lebid' et al., 2008). The main soil cultivation was carried out using a conventional plowing system to a depth of 20–22 cm, followed by leveling and cultivation before sowing. Six winter wheat (*Triticum aestivum* L.) cultivar of Ukrainian selection, registered in (Ahrari razom, 2023), were used in field experiments (Table 1).

Winter wheat was sown in the second half of September, at a seeding rate of 4.5–5.0 million grains/ha. Granular complex fertilizers (ammophoska, nitroammophoska) were applied simultaneously with sowing (in rows) at the rate of P_{10–12}. To nourish plants during the growing season, mineral fertilizers were used in doses of N₆₀P₆₀K₃₀, which were applied during the main tillage of the soil and with subsequent in-crop application of nitrogen fertilizers (N₃₀) at the tillering stage Zadoks 10–19. Harvesting of winter wheat cultivar of different maturity groups was carried out in July–August, using a small-sized combine harvester “Sampo-500”.

Data collection

Experimental plant material (10 randomly selected winter wheat plants in each variant) was collected at physiological maturity to characterize plant height, leaf surface area, spike length, grain number in spikes, and 1000 kernel weight. Leaf surface area of wheat plants was calculated according to (Chanda and Singh, 2002; Racz et al., 2021) using the formula: $S = k \times L \times W$, where S is the leaf area, L is the leaf length, W is the maximum leaf width, k is the shape coefficient that takes into account the leaf width unevenness (for wheat plants, $k = 0.75$). The spike length was determined by measuring from the spike base to its top, excluding the awns. To assess the grain number per spike, the total grain number in each spike was counted in all rows. The 1000 kernel weight was determined by weighing a sample of 1000 grains, previously cleaned of impurities and dried to a moisture of 14%, carried out in at least three repetitions for each variant. Weed quantitative and species composition was recorded before herbicide application and before harvesting, when all weed plants were pulled out and dried to determine their air-dry aboveground biomass. The determination of the yield of winter wheat cultivar was carried out when

the grain of each variety reached full ripeness and the grain moisture content was corrected to 14%.

Statistical processing

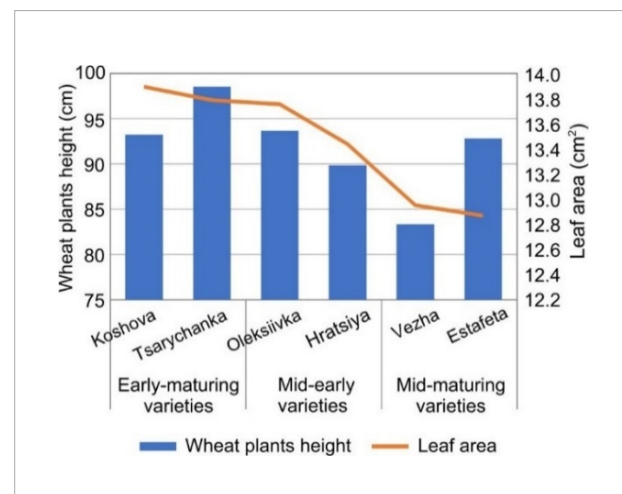
In the course of statistical processing of the obtained data, descriptive statistics were calculated (mean X and standard deviation SD), followed by analysis of variance and a multiple comparison method (Tukey's HSD test). The difference in means was considered statistically significant at $P < 0.05$. Tukey's HSD (Honestly Significant Difference) test was performed, subsequent to an analysis of variance (One-Way ANOVA), using the Statgraphics Centurion 19 (Version 19.5.01) package. If the ANOVA procedure revealed no significant differences between intergroup and intragroup variances, no further multiple comparisons were carried out. However, if the P-value of the F-test was below 0.05, the second stage was initiated – pairwise comparisons of sample means.

Results and Discussion

Observations of the new winter wheat cultivar of Ukrainian selection in the field experiments during 2021–2023 period revealed variations in morphometric indicators of wheat plants from different maturity groups, including plant height and leaf surface area (Fig. 2).

The tallest wheat plant height was in early-maturing cultivar, which corresponds to the characteristics provided by the originators. The height of the mid-early

Fig. 2. Development data of winter wheat cultivar in field studies (averaged for 2021–2023)



cultivar, Oleksiyvka and Hratsiya, exceeded the varietal standards (on average by 11%), and the mid-maturing cultivar Estafeta and Vezha met the varietal standards. The largest leaf surface area was formed by early-maturing Tsarychanka variety ($13.8 \pm 1.5 \text{ cm}^2$), which was almost 9% higher than the smallest indicator of plants of the mid-maturing Vezha variety.

The morphometric parameters characterizing the success of ear formation in winter wheat plants were also

most significant in early-ripening cultivar, according to averaged data for 2021–2023 (Table 2). One-Way ANOVA of the specified morphometric parameters yielded a P-value for the F-test of less than 0.05, indicating a statistically significant difference among the means of the analyzed pairs of the corresponding parameters. The results of the subsequent Tukey's test revealed specific features of the yield structure traits and the advantages of the winter wheat cultivars.

Table 2. Biometric and structural indicators of wheat cultivar in earing – full ripeness phase ($\bar{x} \pm SD$)

Winter wheat variety	Wheat maturity group	Spike length, cm	Grain number per spike, pcs	1000 grain weight, g
Tsarychanka	early-maturing	8.9 ± 0.4^a	34.0 ± 2.0^a	42.3 ± 2.7^a
Koshova	early-maturing	8.7 ± 0.5^a	32.2 ± 2.3^b	40.8 ± 3.2^a
Oleksiyvka	mid-early	8.6 ± 0.5^a	30.1 ± 2.2^c	39.1 ± 2.0^b
Hratsiya	mid-early	8.4 ± 0.4^a	29.5 ± 2.2^c	38.2 ± 2.4^b
Vezha	mid-maturing	8.2 ± 0.6^a	32.0 ± 2.2^b	38.8 ± 1.8^b
Estafeta	mid-maturing	8.0 ± 0.5^b	31.7 ± 2.0^b	38.1 ± 2.2^b

Note. Different letters in a column indicate a significant difference in means by Tukey's test ($P \leq 0.05$).

The above set of wheat plants characteristics of different maturity groups reflects the initial growth rate, the ability to form a high stalks density and suppress weeds through shading, as well as to the effective use of resources, which ultimately determines the competitive stability of winter wheat in the agrocenoses. It is obvious that the large leaf surface area in early-maturing wheat cultivar contributed to more intensive photosynthesis, which enhanced the development of yield components. As a result, in the phase of earing – full ripeness, the early-maturing cultivar reliably exceeded the mid-early and mid-maturing winter wheat cultivar, according to all biometric and structural characteristics. As to the spike length and 1000 grains weight, the early-maturing cultivar were the most ahead of the mid-maturing cultivar (by 8.4% more on average), while the number of grains per spike was the greatest advantage compared to the mid-early cultivar (up to 10.7%).

In general, the stability of winter wheat agrocenoses can be assessed by their ability to maintain high productivity, structure and functionality under the influence of adverse factors, including climate and weather conditions, as well as competition from a wide range of weed plants. The same indicators are given by other researchers to characterize the agrocenoses resistance

to destabilizing factors, which ensures high crop stability (Yanev, 2022; Johansson et al., 2023).

To assess the influence of weather factors on the studied wheat cultivar crops, it should be taken into account that in the Steppe conditions, the critical growth period of winter wheat occurs in May–June. During the field experiments in 2021–2023, the specified period was characterized by extremely uneven precipitation, which created differential plant development and crop formation responses of the wheat cultivar from different maturity groups. In particular, early-maturing cultivar had time to effectively complete the critical growth period in June under more favorable conditions, before the onset of a long drought, and achieve high biometric and structural characteristics. On the contrary, mid-early and mid-maturing cultivar, due to a longer growing season, were affected by high temperatures and drought in July, which partially caused their lower yield. That is, the highest biometric and structural indicators of early-maturing winter wheat cultivar indicate better adaptation to changing and unfavorable climate conditions of the Steppe zone (Slafer et al., 2023).

Weed influence on the growth, development and yield of winter wheat is realized through their competition

Table 3. Weed abundance in winter wheat treatments collected at three different phenological phases (average for 2021–2023, $\bar{x} \pm SD$)

Wheat maturity group	Number of weed plants, pcs./m ²			Air-dry mass of weeds, g/m ²
	Tillering phase	Earing phase (exit into the tube)	Harvest phase	
Early-maturing	5.13 ± 0.49 ^a	0.53 ± 0.04 ^b	0.13 ± 0.03 ^c	1.79 ± 0.12 ^a
Mid-early	3.73 ± 0.59 ^a	0.08 ± 0.01 ^b	0.02 ± 0.01 ^c	3.54 ± 0.14 ^b
Mid-maturing	3.33 ± 0.63 ^a	0.23 ± 0.02 ^b	0.05 ± 0.01 ^c	4.44 ± 0.27 ^c

Note. Different letters in a row for number of weeds and in a column for air-dry mass indicate a significant difference in means by Tukey's test ($P \leq 0.05$).

for vital resources (water, light, minerals) in the agrocenoses. According to the results of field experiments, the main weeds that dominated the crops of all wheat cultivar were field mustard (*Sinapis arvensis* L.), common fumitory (*Fumaria officinalis* L.), wild radish (*Raphanus raphanistrum* L.), and field pennycress (*Thlaspi arvense* L.), which were mostly in the lower tier. The total number of weed plants of all mentioned species, averaged for the years 2021–2023, changed significantly during the growing season of each winter wheat variety, and also varied depending on the variety maturity group (Table 3). A one-way ANOVA of weed abundance in winter wheat crops at different growth stages (for each ripening group) yielded an F-test P-value of less than 0.05, indicating a statistically significant difference in mean weed abundance and mass values. The results of the Tukey test revealed that weed abundance effectively decreased as the plants progressed from the tillering phase to the earing phase.

In the winter wheat tillering phase (in April), weed abundance in the early-maturing cultivar exceeded the numbers in the mid-early and mid-maturing cultivar (by 1.5 and 1.4 times, respectively). However, earlier onset of growth in spring translated to earlier canopy closure, which was sufficient to effectively shade weeds and reduce their competitiveness. In the phase of earing-emergence into the tube (in May–June), the weed number in the crops of all wheat cultivar decreased sharply (by 46 times in mid-early cultivar), remaining the largest in early-maturing cultivar. The tendency towards a decrease in the weed number persisted until the end of the growing season, so before crop harvesting (in July–August) weediness was minimal in winter wheat crops of all maturity groups. The weeds remained did not pose a threat to the crop because they were completely shaded by the well-developed wheat plants, which eliminated the need for herbicides.

According to results of the field experiments in 2021–2023, the wheat variety's ability for crop growth and vigor under favorable climatic conditions ensured the culture superiority over weeds at all development stages, which made it possible to minimize crop losses and reduce the need for chemical plant protection. Similar conclusions were drawn (Matyukha and Tklich, 2008) regarding the possibility of reducing the herbicide load on wheat crops through the use of cultivar with highly competitive ability. Our finding coincides with data published by (Beres et al, 2010) regarding the dependence of the competitive ability of agrocenoses on the optimal number of crop plants per unit area, which contributes to the formation of a favorable microclimate that limits the development of weeds.

As for the air-dry mass of weeds, the largest was found in crops of mid-maturing cultivar, which exceeded the indicators for early-maturing and mid-early cultivar by 2.5 and 1.3 times, respectively. Therefore, the early-maturing wheat cultivar had the lowest weed mass at the end of the growing season, which indicates poor weed plant development, when compared with their high number. This pattern is associated with a shorter vegetation period of early-maturing cultivar, which ensured faster initial growth and, as a result, denser optical coverage of the soil surface and more effective shading of weeds, which led to a decrease in their biomass. On the contrary, the largest air-dry weed mass in crops of mid-maturing cultivar can be explained by the wheat plant later growth, which led to less soil surface shading and provided an opportunity for the weed seedlings emergence and more successful development. Similar data were reported by Drews et al. (2009) about the weaker weed plants growth in crops of mid-maturing winter wheat cultivars that were characterized by almost horizontal leaf inclination and higher leaf area index.

Our findings regarding the higher competitiveness of winter wheat cultivar, which are characterized by an intensive type of initial development, coincide with the data of other authors. In particular, Korkhova et al. (2023) reported that mid-maturing Podolyanka and mid-early Smuglyanka wheat cultivar capable of intensive growth due to their morpho-physiological characteristics, effectively suppressed weeds in crops. In contrast, wheat cultivar with shorter plant height or slower initial growth are less competitive in weedy agrocenoses (Ramesh et al., 2017; Dhakar et al., 2022). The patterns we found are also confirmed by the results of field experiments conducted in Germany (North Rhine-Westphalia), which aimed to evaluate the effectiveness of several mid-maturing winter wheat cultivar with different shading capabilities in suppressing weeds under organic farming conditions (Drews et al., 2009). According to these authors, the more competitive cultivars Astron and Pegassos, in which weed growth was lower, had greater plant height, leaf ground cover area and light absorption compared to the less competitive cultivar Greif.

World-known cultivar of winter wheat are usually characterized by high yield potential, adaptability to various soil and climatic conditions, and stability of development even under adverse weather conditions. However, their ability to form stable agrocenoses may vary depending on varietal characteristics and the level of resistance to competition with weeds. For example, RGT cultivar Reform, Skagen, Julia, Tobak, and Kubus with a powerful leaf surface, high initial growth rate and the ability to bush, suppressed better the weeds creating unfavorable conditions for their development (Harker and O'Donovan, 2013; Jabran et al., 2017). Competition between crops and weeds increases significantly under high temperatures and moisture deficit, therefore, in the Steppe

conditions insufficient adaptability of foreign cultivar is often observed weakening their competitiveness in agrocenoses and reduces productivity, as established by Kalenska et al. (2019). That is, competitive resistance to weeds must be determined through a comprehensive assessment of variety characteristics, although this topic is not always considered in detail in the methodological approaches used for such studies. So, the results of this three-year field experiment allow us to characterize early-maturing and mid-early winter wheat cultivar of Ukrainian selection as more competitive due to the early start of vegetation, more rapid plant growth in the first phases of development, as well as due to improved absorption of nutrients in the competition with weeds.

On-farm winter wheat grain yield attainment that corresponds to the genetic potential of each variety is largely determined by agronomic and climatic factors. Regarding the influence of weather conditions, the tillering phase (April), phase of earing-emergence into the tube (May) and grain ripening (June), which are critical for the yield of winter wheat, should be taken into account. In 2021–2023, we can note the key role of elevated air temperatures and uneven distribution of precipitation during the winter wheat vegetation, especially in June. Such conditions caused abiotic stress in winter wheat, which had a negative impact on grain formation and final yield, and led to significant variability of indicators both by research years and maturity groups (Table 4). One-Way Analysis of Variance (ANOVA) on the yield of winter wheat cultivar across individual years revealed an F-test P-value of less than 0.05, indicating a statistically significant difference in the mean yield of the wheat cultivar over the years. Tukey's test results confirmed this during pairwise comparisons. No statistical difference was found for the three-year generalized yield, and the F-test P-value was > 0.05 (by One-Way ANOVA).

Table 4. Grain yield performance of winter wheat cultivar grown in the Steppe region of Ukraine, t/ha ($\bar{x} \pm SD$)

Winter wheat variety	2021	2022	2023	Average (2021–2023)
Tsarychanka	4.51 ± 0.16 ^a	7.41 ± 0.27 ^b	7.10 ± 0.29 ^b	6.34 ± 1.59 ^a
Koshova	4.40 ± 0.19 ^a	7.30 ± 0.32 ^b	7.21 ± 0.28 ^b	6.30 ± 1.65 ^a
Oleksiyvka	4.02 ± 0.15 ^a	7.01 ± 0.28 ^b	5.60 ± 0.21 ^c	5.54 ± 1.50 ^a
Hratsiya	4.31 ± 0.20 ^a	6.90 ± 0.27 ^b	7.21 ± 0.26 ^b	6.14 ± 1.59 ^a
Vezha	4.11 ± 0.16 ^a	7.20 ± 0.31 ^b	7.01 ± 0.28 ^b	6.11 ± 1.73 ^a
Estafeta	4.10 ± 0.17 ^a	6.90 ± 0.26 ^b	7.10 ± 0.25 ^b	6.03 ± 1.68 ^a

Note. Different letters in the row for individual years and in the column for the average yield over 2021–2023 indicate a significant difference in values (by Tukey's test, $P \leq 0.05$).

In all research years, early-maturing winter wheat cultivar received more favorable conditions for the crop formation and ripening, since their growing season ended in June. Mid-early and mid-maturing cultivar, which required a longer growing season, were affected by high temperatures and drought during grain ripening, which negatively affected their productivity. The obtained results are consistent with previously established (Matyukha et al., 2023) key impact of relative air humidity in the milk ripeness phase on the mid-maturing Podolyanka variety productivity. Similar data from other authors (Woźniak, 2019; Kudria et al., 2021) regarding the variability of winter wheat yield in different research years confirm the significant influence of the weather conditions of each growing season on the realizing the genetic potential of cultivar.

Our findings parallel the results of research conducted in the Steppe zone of Ukraine (Kalenska et al., 2019), which show that taking into account the Steppe complex climatic factors, the optimal selection of adapted wheat cultivar and a rational approach to agricultural technology make it possible to significantly reduce the crop competition from weeds and improve the competitive ability of agrocenoses. Such measures will help not only to reduce the weed pressure, but also to increase the wheat yield due to more efficient use of resources. Ensuring the viability of winter wheat production systems is one of the key elements of sustainable agriculture in the Steppe of Ukraine. In this sense, the vegetation and productivity features of new early-maturing, mid-early and mid-maturing winter wheat cultivar revealed in field experiments will serve to develop successful strategies for the creation of productive and sustainable agrocenoses.

Although the average yield of winter wheat in Ukraine is still significantly lower than in Western European countries, this does not necessarily indicate a lower genetic potential of Ukrainian breeding. The cultivars *Hratsiia Myronivska* and *Estafeta Myronivska* demonstrate high winter hardiness and drought tolerance, which are critically important for Steppe conditions, whereas European cultivars such as *Evklid* (France) or *Urbanus* (Austria), despite their high yield potential, often show insufficient adaptability to Ukrainian soil and climatic conditions, as confirmed by previous studies (Berdnikova and Kucherak, 2021). Thus, the newest Ukrainian cultivars provide better yield stability and greater competitive resilience under conditions of limited resources and abiotic stress.

Our research is of particular importance as it focuses on two critical global challenges of modern agriculture: food security and sustainable farming under climate change.

First, the study provides valuable data on adaptation to stress conditions, which is a global issue due to increasing temperatures and droughts becoming typical for many regions worldwide. The results demonstrate how cultivars bred to survive the harsh conditions of the Ukrainian Steppe with high drought tolerance can serve as valuable genetic material in international breeding programs. The conclusions regarding the phenotypic response of different maturity groups, particularly early-ripening cultivars, to abiotic stress directly contribute to the development of resilience strategies in other countries with continental climates (e.g., parts of Central and Eastern Europe, Asia, and North America).

Second, the study has a direct impact on sustainable weed management strategies. Given the global trend toward reducing the use of chemical crop protection products, research focusing on cultivar competitiveness as an environmentally friendly alternative to herbicides is becoming increasingly relevant. The observed pattern showing that early-ripening Ukrainian cultivars with better biometric indicators (such as plant height and leaf area) suppress weeds more effectively provides practical recommendations for the international community regarding Integrated Weed Management, helping optimize cultivar selection and reduce the chemical load on the environment.

Thus, Ukrainian breeding, as examined in this study, serves as an important model example of utilizing genetic resources to ensure yield stability and environmental sustainability under global change conditions.

Conclusions

We sought to fill a critical knowledge gap for winter wheat production systems in the Steppe region of Ukraine by conducting a comprehensive assessment of competitiveness of the new winter wheat cultivar of different maturity groups in agrocenoses. The relationship between varietal morphological and physiological winter wheat features and the competitive ability with respect to the most common weeds (*Sinapis arvensis* L., *Fumaria officinalis* L., *Raphanus raphanistrum* L. and *Thlaspi arvense* L.) was established. Weed abundance and mass of the crops of all winter wheat

cultivar significantly decreased during the growing season, while the lowest air-dry mass of weeds was in early-maturing cultivar. In addition, winter wheat early-maturing cultivar had the higher biometric and structural indicators, including the plant height, leaf surface area, grain number per spike, and weight of 1000 grains, as well as the highest yield in all years of research, which indicates their better adaptation to unstable climatic conditions and highly competitive stability. The obtained results make it possible to scientifically justify the selection of new winter wheat cultivar, which are able to provide optimal suppression of weeds and create prerequisites for stable production of high grain yields.

Future research should focus on identifying the physiological mechanisms of competitiveness at the biochemical and molecular levels, as well as on evaluating the long-term effects of competitive cultivars on weed

population dynamics and soil biological activity under different farming systems.

Acknowledgements

The authors are grateful to the staff of the Research Laboratory of Terrestrial Ecology, Forest Soil Science, and Land Reclamation of the Biology Research Institute at Oles Honchar Dnipro National University for their assistance in conducting the research and interpreting the obtained results.

Funding

The work was carried out as part of the applied scientific research "Scientific justification of the integrated protection system for winter wheat and corn against diseases and pests in the Steppe Zone" (2021–2025, state registration number 0121U107708), with financial support of the National Academy of Agrarian Sciences of Ukraine.

References

- Ahrari razom [Agrarians Together] (2023) Perelik sortiv pshenytsia ozyma, pshenytsia miaka [List of cultivars of winter wheat, soft wheat]. Available at: <https://agrarii-razom.com.ua/list-culture-varieties?culture=1404&plant=376&page=3> (accessed 17 March 2025) (*in Ukrainian*).
- Abrell T., Naudin K., Bianchi F., Aragao D., Tittonell P., and Corbeels M. (2024) Shifting cultivation in decline: An analysis of soil fertility and weed pressure in intensified cropping systems in Eastern Amazon. *Agriculture, Ecosystems & Environment* 360: 108793. Available at: <https://doi.org/10.1016/j.agee.2023.108793>
- Berdnikova O.G., Kucherak E.M. (2021) Research on the productivity of the varietal composition of winter wheat under the conditions of the Southern Steppe of Ukraine. *Tavrian Scientific Herald* (118): 15–21. Available at: <https://doi.org/10.32851/2226-0099.2021.118.3>
- Beres B. L., Harker K. N., Clayton G. W., Blackshaw R. E., Graf R. J. (2010) Weed competitive ability of spring and winter cereals in the Northern Great Plains. *Weed Technology* 24(2): 108–116. Available at: <https://doi.org/10.1614/WT-D-09-00036.1>
- Bryson C.T., and DeFelice, M.S. (Eds.) (2009) *Weeds of the South*. The University of Georgia Press, Athens. 480 p.
- Burykina S.I., and Tsurkan O.I. (2020) Tendentsiyi suchasnoyi zminy ahroklimatychnoyi sytuatsiyi na terytoriyi stepovoyi chornozemnoyi zony pivdnya Ukrainy [Trends of modern changes in the agro-climatic situation on the territory of the steppe Chernozem zone of the South of Ukraine]. *Taurida Scientific Herald. Series: Rural Sciences* 111: 29–43. Available at: <https://doi.org/10.32851/2226-0099.2020.111.4> (*in Ukrainian*).
- Chanda S.V., and Singh Y.D. (2002) Estimation of leaf area in wheat using linear measurements. *Plant Breeding And Seed Science* 46(2): 75–79.
- Dhakar R., Sehgal V.K., Chakraborty D., Sahoo R.N., Mukherjee J., Ines A.V.M., Kumar S.N., Shirsath P.B., and Roy S.B. (2022) Field scale spatial wheat yield forecasting system under limited field data availability by integrating crop simulation model with weather forecast and satellite remote sensing. *Agricultural Systems* 195: 103299. Available at: <https://doi.org/10.1016/j.agsy.2021.103299>
- Draws S., Neuhoff D., and Köpke U. (2009) Weed suppression ability of three winter wheat cultivar at different row spacing under organic farming conditions. *Weed Research* 49(5): 526–533. Available at: <https://doi.org/10.1111/j.1365-3180.2009.00720.x>
- Department of Ecology and Natural Resources of the Dnipropetrovsk Regional State Administration (2022) *Ekolohichnyy pasport Dnipropetrovskoyi oblasti za 2021 rik* [Ecological Passport of the Dnipropetrovsk Region for 2021]. Available at: <https://adm.dp.gov.ua/storage/app/media/Pro%20oblast/EkoloHiia/Rehionalna%20dopovid%20ta%20Ekolohichniy%20pasport/2021.pdf> (accessed 17 March 2025) (*in Ukrainian*).
- Ghosh S., Das T.K., Nath C.P., Bhatia A., Biswas D.R., Bandyopadhyay K.K., Yeasin Md., and Raj R. (2023) Weed seedbank, above-ground weed community and crop yields under conventional and conservation agriculture practices in maize–wheat–

- mungbean rotation. *Weed Research* 63(4): 270-281. Available at: <https://doi.org/10.1111/wre.12589>
- Gong Y., Baylis K., Kozak R., and Bull G. (2016) Farmers' risk preferences and pesticide use decisions: Evidence from field experiments in China. *Agricultural Economics* 47(4): 411-421. Available at: <https://doi.org/10.1111/agec.12240>
- Harker K.N., and O'Donovan J.T. (2013) Recent weed control, weed management, and integrated weed management. *Weed Technology* 27(1): 1-11. Available at: <https://doi.org/10.1614/WT-D-12-00109.1>
- Holyk L., Shtakal M., Levchenko O., and Drukovska N. (2024) Yield of modern winter wheat varieties under different physical and geographical conditions. *Agriculture and Plant Sciences: Theory and Practice* 3: 96-106. Available at: <https://doi.org/10.54651/agri.2024.03.10>
- Jabran K., Mahmood K., Melander B., Bajwa A.A., and Kudsk P. (2017) Weed dynamics and management in wheat. *Advances in Agronomy* 145: 97-166. Available at: <https://doi.org/10.1016/bs.agron.2017.05.002>
- Johansson E., Muneer F., and Prade T. (2023) Plant breeding to mitigate climate change-present status and opportunities with an assessment of winter wheat cultivation in Northern Europe as an example. *Sustainability* 15(16): 12349. Available at: <https://doi.org/10.3390/su151612349>
- Kalenska S., Novytska N., Kalenskyi V., Kovalenko R., Yeremenko O., Tascheva J., Honchar L. (2019) Management by formation of winter wheat resistant agrocenoses in the Forrest-Steppe of Ukraine. In: Abstract Proceeding of the 1st International Wheat Congress, Saskatoon, Canada, 22-26 July 2019. Available at: <https://wheatvivo.org/display/iwc-abstract-2019-018599> (accessed 11 February 2025).
- Kaur P., Sachan S., and Sharma A. (2021) Weed competitive ability in wheat: a peek through in its functional significance, present status and future prospects. *Physiology and Molecular Biology of Plants* 27(10): 2165-2179. Available at: <https://doi.org/10.1007/s12298-021-01079-y>
- Khromykh N., Lykholat Y., Shupranova L., Kabar A., Didur O., Lykholat T., and Kulbachko Y. (2018) Interspecific differences of antioxidant ability of introduced *Chaenomeles* species with respect to adaptation to the steppe zone conditions. *Bio-systems Diversity* 26(2): 132-138. Available at: <https://doi.org/10.15421/011821>
- Korkhova M., Smirnova I., Panfilova A., and Mykolaichuk V. (2023) Influence of varietal characteristics of winter wheat and weather conditions on lodging resistance and productivity. *Scientific Horizons* 26(12): 42-53. DOI: 10.48077/scihor12.2023.42.
- Krainiuk O., Buts Y., Barbashyn V., Nikitchenko O., and Pakki M. (2024) Technogenic and ecological hazards of using chemical plant protection products (on the example of copper-containing preparations). *Visnyk of V.N. Karazin Kharkiv National University, series Geology. Geography. Ecology* 60: 354-365. Available at: <https://doi.org/10.26565/2410-7360-2024-60-26>
- Kudria N., Kudria S., and Dehtiarova Z. (2021) Influence of precursors on biometric indicators and yield of winter wheat in different agrobiocenoses. *Scientific Papers. Series A. Agronomy* LXIV(1): 430-436. Available at: <https://repo.btu.kharkov.ua/handle/123456789/46155>
- Lacroix C., Vandenberghe C., Monty A., and Dumont B. (2024) Effect of long-term tillage and residue managements on weed flora and its impact on winter wheat development. *Agriculture, Ecosystems & Environment* 366: 108937. Available at: <https://doi.org/10.1016/j.agee.2024.108937>
- Lebid' E.M., Tsykov V.S., Matyukha L.P., and Shevchenko M.S. (2008) *Metodyka provedennia polovykh doslidiv po vyznachenniu zaburianenosti ta efektyvnosti zasobiv yii kontroliuvannia v ahrofitotsenozakh* [Methodology for conducting field experiments to determine weediness and the effectiveness of means of its control in agrophytocenoses]. Institute of Grain Crops of NAAS of Ukraine, Dnipropetrovsk (in Ukrainian).
- Lozinsky M., Ustinova H., and Obrazhii S. (2020) *Uspadkuvannia i formotvorennia za kilkistiu koloskiv vid hibrizatsii riznykh za tryvalistiu vechetatsiinoho periodu sortiv pshenytsi* [Wheat cultivar from hybridization of different vegetation duration: inheritance and formation by number of ears]. Bulletin of Sumy National Agrarian University. The Series: Agronomy and Biology 42(4): 9-16. Available at: <https://doi.org/10.32782/agro-bio.2020.4.2> (in Ukrainian)
- Lundgren J.G., and Anderson R.L. (2023) Suppression of weed communities by granivores over time in an agroecosystem. *Ecosphere* 14(8): e4641. Available at: <https://doi.org/10.1002/ecs2.4641>
- Maqsood Q., Abbas R.N., Khaliq A., and Zahir Z.A. (2018) Weed seed bank dynamics: weed seed bank modulation through tillage and weed management. *Planta Daninha* 36: e018166706. Available at: <https://doi.org/10.1590/s0100-83582018360100083>
- Masson S., Rueda-Ayala V., Bragazza L., Cordeau S., Munier-Jolain N., Wirth J. (2024) Reducing tillage and herbicide use intensity while limiting weed-related wheat yield loss. *European Journal of Agronomy* 160: 127284. Available at: <https://doi.org/10.1016/j.eja.2024.127284>
- Matyukha V.L., Tkalych Y.I. (2008) *Zakhyst ozymoi pshenytsi vid burianiv z urakhuvanniam enerhetychnoho balansu ahrofitotsenoziv* [Protection of winter wheat from weeds, considering the energy balance of agrocenoses]. Bulletin of the Institute of Grain Crops of the UAAS 35: 22-27 (in Ukrainian).
- Matyukha V.L. (2012) *Ekonomichniy porih shkodochynnosti burianiv. Metodyky vyznachennia ta zasoby zakhystu posiviv pshenytsi ozymoi* [As for methods of weeds harmful economical thresholds determination and means of winter wheat crop protection]. Quarantine and Plant Protection 1: 1-3 (in Ukrainian).

- Matyukha V.L., Semenov S.S., Yaroshenko S.S., Didur O.O., Khromykh N.O., and Lykholat Y.V. (2023) Assessment of agrocenosis factors impact on winter wheat yield and grain quality in the Northern Steppe Zone of Ukraine. *Journal of Environmental Research, Engineering and Management* 79(4): 39-44. Available at: <https://doi.org/10.5755/j01.erem.79.4.33482>
- Md-AKhir A.H.B., Isa N., and Mispan M.S. (2022) Natural distribution of weed seedbank in different land activities due to abandoned land reclamation for agriculture. *Applied Ecology and Environmental Research* 20(3): 2597-2607. Available at: https://doi.org/10.15666/aeer/2003_25972607
- Namatsheve T., Cardinael R., Chikowo R., Corbeels M., Ruge J.T., Mabasa S., and Ripoche A. (2024) Do intercropping and mineral nitrogen fertilizer affect weed community structures in low-input maize-based cropping systems? *Crop Protection* 176: 106486. Available at: <https://doi.org/10.1016/j.cropro.2023.106486>
- Nath C.P., Hazra K.K., Kumar N., Singh S.S., Praharaj C.S., Singh U., Singh N.P., and Nandan R. (2022) Impact of crop rotation with chemical and organic fertilization on weed seed density, species diversity, and community structure after 13 years. *Crop Protection* 153: 105860. Available at: <https://doi.org/10.1016/j.cropro.2021.105860>
- Nazarenko M., Khromykh N., Matyukha V., Lykholat Y., Bezus R., Alexeeva A., Lykholat T., and Shupranova L. (2019) Chemical plant protection agents change the yield structure and the grain quality of winter wheat (*Triticum aestivum* L.). *Bulletin of the Transilvania University of Braşov, Series II: Forestry, Wood Industry, Agricultural Food Engineering* 12(2): 97-106. Available at: <https://doi.org/10.31926/but.fwiafe.2019.12.61.2.8>
- Olesen J.E., Hansen P.K., Berntsen J., and Christensen S. (2004) Simulation of above-ground suppression of competing species and competition tolerance in winter wheat varieties. *Field Crops Research* 89(2-3): 263-280. Available at: <https://doi.org/10.1016/j.fcr.2004.02.005>
- Racz I., Kadar R., Vtča S., Bora F.D., Hiriscău D., Varadi A., and Berindean I. (2021) Relationship between leaf area surface, chlorophyll concentration and yield components in spring wheat. *Life Science and Sustainable Development* 2(2): 1-5. Available at: <https://doi.org/10.58509/lssd.v2i2.122>
- Ramesh K., Matloob A., Aslam F., Florentine S.K., and Chauhan B.S. (2017) Weeds in a changing climate: Vulnerabilities, consequences, and implications for future weed management. *Frontiers in Plant Science* 8: 95. Available at: <https://doi.org/10.3389/fpls.2017.00095>
- Schnee L., Sutcliffe L.M.E., Leuschner C., and Donath T.W. (2023) Weed seed banks in intensive farmland and the influence of tillage, field position, and sown flower strips. *Land* 12(4): 926. Available at: <https://doi.org/10.3390/land12040926>
- Sharma A., Kumar V., Shahzad B., Tanveer M., Sidhu G.P.S., Handa N., Kohli S.K., Yadav P., Bali A.S., Parihar R.D., Dar O.I., Singh K., Jasrotia S., Bakshi P., Ramakrishnan M., Kumar S., Bhardwaj R., and Thukral A.K. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences* 1: 446. Available at: <https://doi.org/10.1007/s42452-019-1485-1>
- Shevchenko M.S., Mytsyk A.A., Shevchenko S.M., Pozniak V.V., and Tkalic Y.I. (2023) Optimization of the phytotoxic effect of herbicide mixtures in winter wheat crops of agrocenoses of the steppe ecotype. *Agrology* 5(3): 87-91. Available at: <https://doi.org/10.32819/021113>
- Slafer G. A., Savin R., Sadras V. O. (2023) Wheat yield is not causally related to the duration of the growing season. *European Journal of Agronomy* 148: 126885. Available at: <https://doi.org/10.1016/j.eja.2023.126885>
- Tkalic Y., and Shevchenko S. (2020) Osoblyvosti zakhystu posiviv pshenytsi vid burianiv sivozmini pislia soniashnyku [Features of the protection of winter wheat crops from weed rotation after sunflower]. *Quarantine and Plant Protection* 2-3: 45-49. Available at: <https://doi.org/10.36495/2312-0614.2020.2-3.45-49> (in Ukrainian).
- Topko R.I., and Kovalyshyna H.M. (2022) Otsinka sortiv ta perspektyvnykh linii pshenytsi ozymoï myronivskoi selektsii za pokaznykamy yakosti zerna [Evaluation of winter wheat varieties and promising lines of Myronovka's institute breeding in terms of grain quality]. *Plant Varieties Studying and Protection* 18(3): 193-200. Available at: <https://doi.org/10.21498/2518-1017.18.3.2022.269000>
- Tslyliuryk O.I. (2023) Suchasni systemy mulchualnoho obrobitku gruntu v Pivnichnomu Stepu: monografiya [Modern mulching tillage systems in the Northern Steppe: monograph]. Oldi-Plyus, Odesa 344 p. (in Ukrainian).
- Woźniak A. (2019) Effect of crop rotation and cereal monoculture on the yield and quality of winter wheat grain and on crop infestation with weeds and soil properties. *International Journal of Plant Production* 13(3): 177-182. Available at: <https://doi.org/10.1007/s42106-019-00044-w>
- Yanev M. (2022) Herbicidal weed control in winter wheat (*Triticum aestivum* L.). *Scientific Papers. Series A. Agronomy LXV(1)*: 613-624. Available at: https://agronomyjournal.usamv.ro/pdf/2022/issue_1/Art88.pdf
- Zhang J., Zhao J., Sun J., He Y., Xie Y., Liang Q., Jing J., Tao Y., Yu P., Jia C., and Zhao E. (2024) Herbigation combined with plastic film mulching to control weeds in maize (*Zea*

mays L.) fields in the Hexi Corridor region, Northwest China. *Crop Protection* 176: 106485. Available at: <https://doi.org/10.1016/j.cropro.2023.106485>

Zhuolin L., Dashuai W., Qing Y., Minghu Z., Xiaohu Wu., and Xiaoguang Liu. (2024) Winter wheat weed detection based on deep learning models. *Computers and Electronics in Agricul-*

ture 227(1): 109448 Available at: <https://doi.org/10.1016/j.compag.2024.109448>

Zubets M.V. (2010) *Naukovi osnovy ahropromysloвого vyrobnytstva v zoni Stepu Ukrainy* [Scientific foundations of agro-industrial production in the Steppe zone of Ukraine]. *Ahrarna nauka, Kyiv*. 844 p. (*in Ukrainian*).



This article is an Open Access article distributed under the terms and conditions of the Creative Commons Attribution 4.0 (CC BY 4.0) License (<http://creativecommons.org/licenses/by/4.0/>).