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Varietal features and sowing dates of wheat winter as factors of increasing the sustainability of agroecosystems

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ABSTRACT

The article presents the results of a three-year study on the effects of sowing dates on the productivity of winter wheat varieties under the conditions of the Northeastern Forest-Steppe zone of Ukraine. The study assessed plant height, productive tillering capacity, number of grains per spike, grain weight per spike, and 1000-grain weight for the Podolianka, Bohdana, Zdobna, Harmonika, and Pylypivka varieties. The first factor analyzed was plant height, which reflects the development of vegetative biomass and is an important indicator of yield formation and lodging resistance. It was established that the Podolianka variety exhibited stability across most parameters under different sowing dates. In contrast, Bohdana was sensitive to optimal sowing times (September 10), at which it reached maximum performance. The Zdobna variety showed variability but achieved peak values at medium-late sowing dates (October 10). Harmonika demonstrated the lowest plant height yet maintained stable tillering and grain weight indicators. The Pylypivka variety stood out for its highest adaptability and stability across all studied parameters, even under late sowing conditions. The study results highlight the importance of considering varietal characteristics and sowing dates to achieve high yield and grain quality, which is critical in introducing new varieties and improving crop management practices.

Keywords: varietal characteristics, yield, adaptability, sustainable agriculture, climate challenges, sustainability of agroecosystems, sowing conditions.

INTRODUCTION

Modern agriculture in Ukraine faces numerous challenges in ensuring food security, primarily related to the invasion of the aggressor country into the state's territory. However, this is not the only factor affecting production volumes; climate change, soil degradation, and the need to reduce the negative impact of intensive technologies on crop cultivation also play a significant role [Litvinov et al., 2020; Datsko et al., 2024; Datsko et al., 2025a]. In this context, winter wheat is one of the key crops of paramount agroecological and economic importance in Ukraine and globally [Voitovyk et al., 2023; Radchenko et al., 2024]. Important factors determining its productivity and adaptive potential are the proper selection of varieties and optimization of sowing dates [Yi et al., 2020; Nazarenko et al., 2023; Kovalenko et al., 2024]. These factors affect yield and grain quality and shape sustainable agroecosystems by ensuring efficient resource use, improving resilience to stress conditions, and reducing anthropogenic pressure [Kvitko et al., 2021; Yakupoglu et al., 2021; Sobko et al., 2022; Dehodiuk et al., 2024]. Research into the interaction between varietal characteristics and sowing dates opens up new opportunities for implementing environmentally friendly cultivation technologies aimed at the balanced development of the agricultural sector [Macholdt et al., 2017; Shtakal et al., 2022; Karbivska et al., 2023; Velimirović et al., 2023; Datsko et al., 2025b]. Many researchers have demonstrated the influence of variety and cultivation technology on winter wheat productivity. In particular, Shakaliy et al. [2021], under the conditions of the Poltava region, established that the crop yield level depends by one-quarter specifically on the variety. According to the research by Fanin & Lytvynenko [2023], significant progress has been recorded in the productivity and performance of modern winter wheat varieties compared to early breeding stages, with current varieties yielding 5.88–6.77 t ha^{-1}, which is 1.32–2.25 times higher than older varieties. Studies by Dutova et al. [2024], Radchenko et al. [2023] on the fields of the Ukrainian Institute for Plant Variety Examination demonstrated the influence of soil and climatic conditions on the productivity and grain quality of new soft winter wheat varieties (Novik, Haimars, Papilon, Obivan, STK21G), with the highest yields observed in the Forest-Steppe zone (8.03–9.14 t ha^{-1}), led by Haimars (8.71 t ha^{-1}) and Obivan (9.14 t ha^{-1}). Research by Demydov et al. [2024], Tsyuk et al. [2022] established that the productivity level of soft winter wheat is primarily determined by sowing dates, weather conditions, and other agronomic practices, with shifting sowing dates from September 25 to October 15 generally reducing yield, except after sunflower and mustard, where the best results were obtained with October 5 sowing. These findings confirm that selecting the appropriate variety, predecessor, and sowing date is a key factor in improving yield and seed quality in winter wheat. Studies by Zheldubovskyi et al. [2024] showed that sowing dates significantly affect plant development and yield formation in the northeastern Forest-Steppe, with early sowing dates (September 10 and October 10–20) providing the best results for plant height (up to 121 cm), productive tillering density (up to 576 stems/m²), grain number per spike (34–38), grain weight per spike (1.58–1.74 g), and 1000-grain weight (45.4–48.5 g). The highest yields were recorded in the varieties Kraievyd (8.02 t ha^{-1}), Pylypivka (6.72 t ha^{-1}), Vyhadka (6.68 t ha^{-1}), and MIP Vyshyvanka (6.54 t ha^{-1}) under October 10 sowing. Late sowing (November 10) significantly reduced yield (average 4.29 t ha^{-1}) and morphological parameters. The results confirm that sowing dates from September 10 to October 20 are recommended to achieve high productivity in the studied zone, considering varietal specifics.

Based on the above-mentioned research, the topic remains highly relevant but requires further study in the context of new winter wheat varieties. Therefore, this article aims to present data on the effect of sowing dates on the productivity of the studied varieties.

MATERIAL AND METHODS

The research was conducted at the experimental field of the Institute of Agriculture of the North-East of the National Academy of Agrarian Sciences of Ukraine, located in the Sumy region (Ukraine) at geographic coordinates 50°53’22.3”N, 34°42’34.1”E. The experiments were carried out over the period 2022–2024. The soil of the experimental plots was classified as typical deep medium-loamy black soil, with a humus content of 4.3% (according to I.V. Tyurin) and a pH_{KCl} of 6.2. The average nutrient content was nitrogen (by Kornfield) – 128.5mg kg^{-1} of soil; phosphorus and potassium (by Chirikov) – 211.6mg kg^{-1} and 81.1 mg kg^{-1} of soil, respectively.

In 2022, the total precipitation during spring durum wheat growing season amounted to 370 mm, exceeding the long-term average (237 mm) by 133 mm. The monthly precipitation distribution was as follows: April – 107 mm, May – 26 mm, June – 155 mm, and July – 82 mm. In 2023, total precipitation reached 222 mm, 15 mm below the long-term average; monthly distribution: April – 54 mm, May – 17 mm, June – 71 mm, July – 80 mm. In 2024, only 150 mm of precipitation was recorded, 87 mm below the long-term average; monthly distribution: April – 48 mm, May – 34 mm, June – 51 mm, July – 17 mm (Fig. 1).

In 2022, the average daily temperature during the growing season was 16.0 °C, 0.2 °C above the long-term average (15.8 °C); monthly temperatures: April – 8.3 °C, May – 13.3 °C, June – 21.0 °C, July – 21.3 °C. In 2023, the average daily temperature reached 16.6 °C, exceeding the long-term average by 0.8 °C; monthly distribution: April – 9.8 °C, May – 15.5 °C, June – 19.3 °C, July – 21.6 °C. In 2024, the average daily temperature was 19.2 °C, surpassing the long-term average by 3.4 °C; monthly distribution: April – 12.9 °C, May – 16.0 °C, June – 22.4 °C, July – 25.4 °C. Overall, the most favorable years for yield formation were 2022 and 2023, while dry conditions and significant temperature anomalies characterized 2024 during the growing season (Fig. 2).

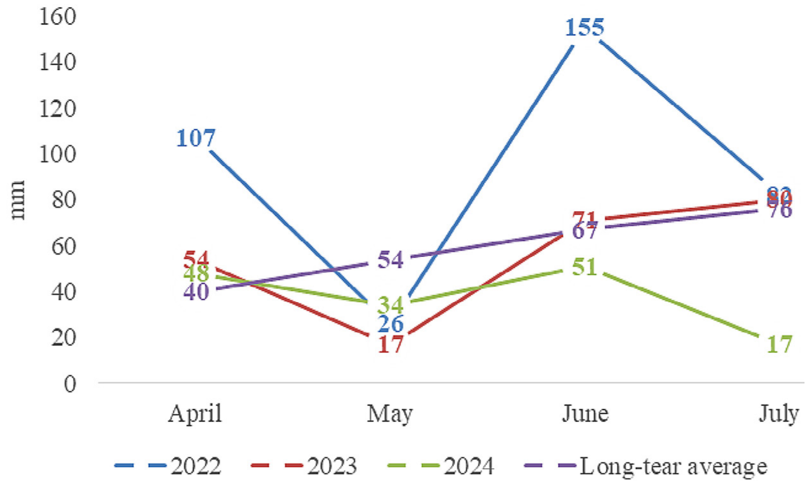

Figure 1. Average precipitation during growing season in 2022–2024, mm

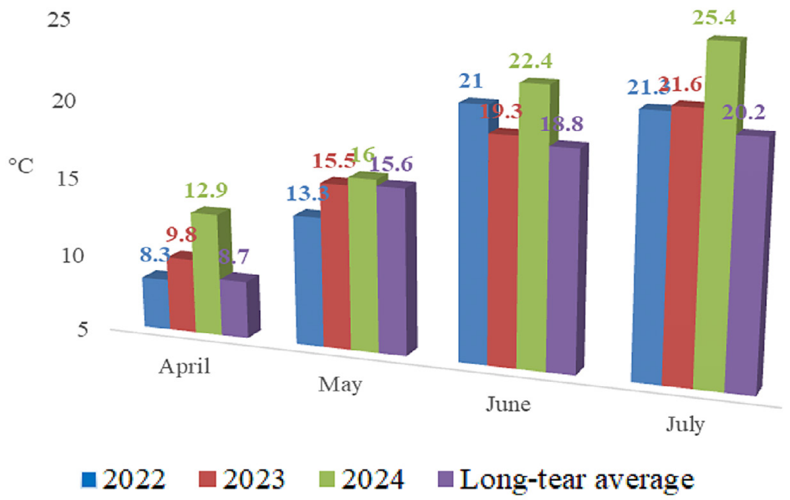

Figure 2. Average temperature during growing season in 2022–2024, mm

The experiment was conducted as a two-factor experiment. Factor A – 5 varieties of winter wheat (Podolyanka, Bohdana, Zdobna, Harmonika, Pylypivka); factor B – sowing dates (September 1, September 10, October 10, October 1, October 10, October 20, November 1, November 10). The replication was four times. The plant density is 450 pcs/m^2. Mathematical processing of primary data and reliability assessment were performed using Microsoft Excel. Descriptive statistical analysis was conducted using Statistica 10.0 (StatSoft Inc., Tulsa, USA).

RESULTS AND DISCUSSION

During three years of research, the average plant height and key productivity indicators were studied, including productive tillering density, number of grains per spike, grain weight per spike, and 1000-grain weight. The first factor analysed was plant height, as it indicates the degree of vegetative biomass development, which is directly related to the photosynthetic potential of the crop stand and competitiveness against weeds. It is also an important indicator influencing yield formation and plant lodging resistance.

Figure 3 shows the effect of sowing dates on the height of winter wheat plants across all studied varieties. For the Podolianka variety, plant height remained relatively stable throughout the study, with an average over three years of 89 cm for September 1 sowing, 88 cm for September 10, 87 cm for September 20, 90 cm for October 1, 85 cm for October 10, 89 cm for October 20, and 94 cm for November 1. Data for November 10 could not be obtained, as crop emergence under this sowing date was insufficient to form a

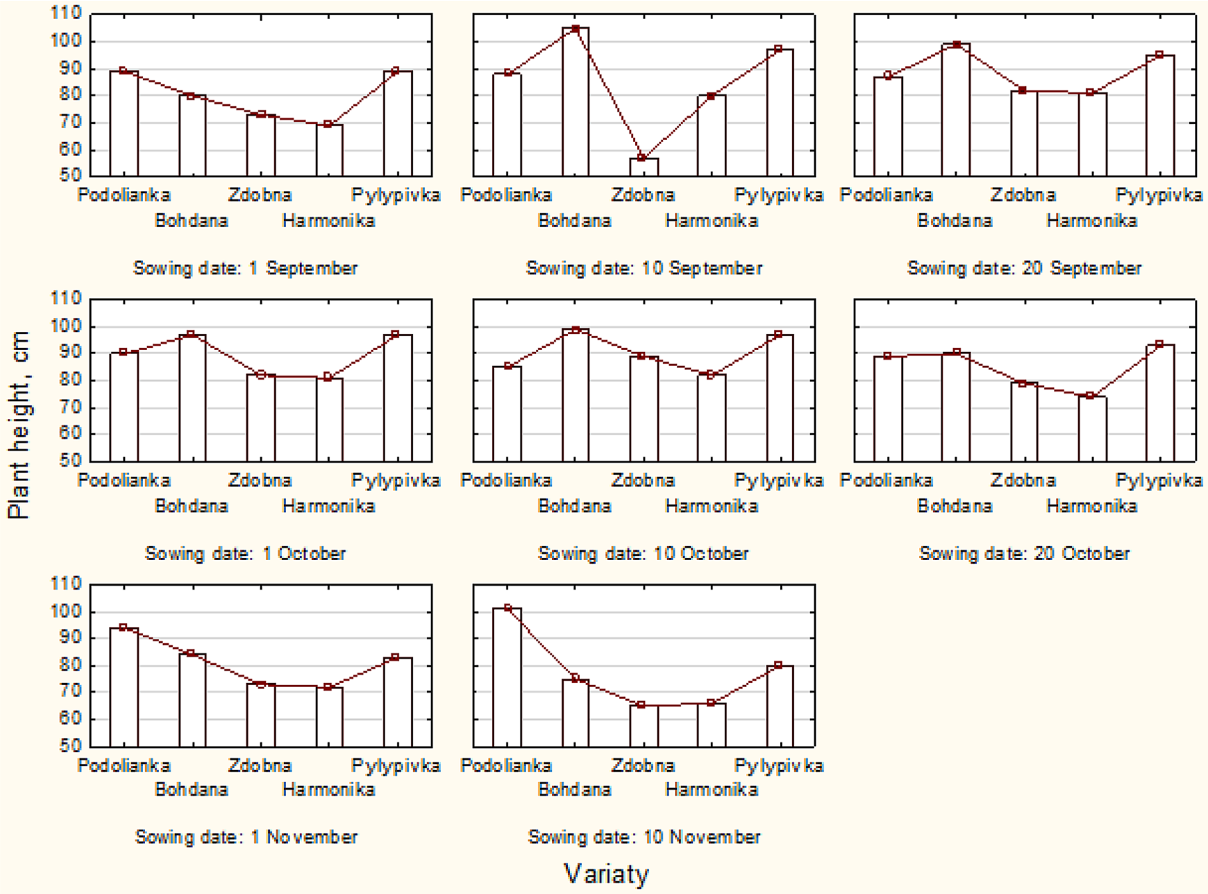

Figure 3. Average heights of the studied winter wheat varieties depending on sowing dates in 2022–2024

productive stand, leading to exclusion from the analysis. The results show no significant differences, indicating good adaptability of the variety to changing sowing dates without substantial height loss, except for the latest sowing.

The Bohdana variety showed an apparent height increase at optimal sowing dates, with a maximum of 105 cm on September 10, gradually decreasing to 99 cm (September 20), 97 cm (October 1), 99 cm (October 10), 90 cm (October 20), 84 cm (November 1), and 75 cm (November 10). This dynamic indicates a strong dependence of the variety on optimal sowing timing. The Zdobna variety exhibited substantial height fluctuations, from 73 cm (September 1) to a minimum of 57 cm (September 10) and a maximum of 89 cm (October 10). On September 20 and October 1, the height was 82 cm; on October 20, 79 cm; on November 1, 73 cm; and only 65 cm on November 10. This indicates low stability of the trait and sensitivity to agronomic conditions. The Harmonika variety had the lowest plant height among the studied genotypes, ranging from 69 cm (September 1) to 80 cm (September 10), 81 cm (September 20 and October 1), 82 cm (October 10), 74 cm (October 20), 72 cm (November 1), and 66 cm (November 10). Despite low values, this variety showed height stability at late sowing dates. Pylypivka consistently exhibited high plant height: 89 cm (September 1), 97 cm (September 10), 95 cm (September 20), 97 cm (October 1), 97 cm (October 10), 93 cm (October 20), 83 cm (November 1), and 80 cm (November 10). The variety demonstrated good plasticity, maintaining relatively high height even under late sowing conditions.

The productive tillering density for the Podolianka variety ranged from 378 stems/m² (September 1) to 510 stems/m² (October 20), showing a tendency to increase with later sowing dates. The highest values were recorded on October 20 (510 stems/m²) and November 1 (498 stems/m²), indicating the variety's high ability to form a productive stand even under late sowing conditions (Fig. 4). The Bohdana variety showed the highest productive tillering density on September 10 (489 stems/m²) and October 1

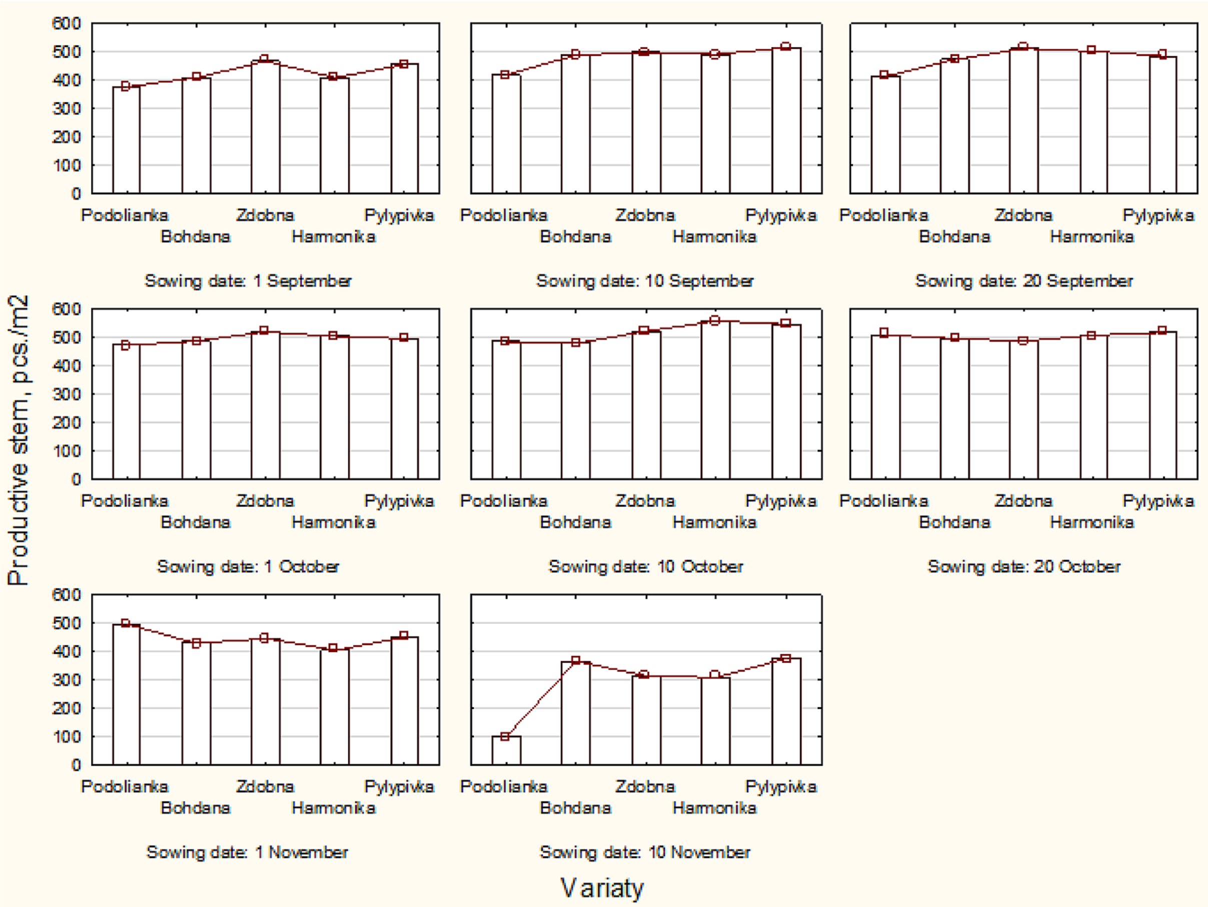

Figure 4. Average indicators of the productive stem of the studied winter wheat varieties depending on the sowing dates for 2022–2024

(488 stems/m²), after which the indicator gradually declined to 367 stems/m² with November 10 sowing. This suggests the variety's dependence on optimal sowing dates.

The Zdobna variety increased productive tillering from 468 stems/m² (September 1) to a maximum of 523 stems/m² (October 10), which is attributed to its high tillering capacity under medium sowing dates. However, under late sowing (November 10), the indicator sharply decreased to 315 stems/m², reflecting the variety's sensitivity to delayed sowing. The Harmonika variety was characterized by consistently high productive tillering under medium and late sowing dates, reaching a maximum of 559 stems/m² on October 10. The initial level of 410 stems/m² (September 1) gradually increased, although a sharp decline to 310 stems/m² was observed with the latest sowing date (November 10). The Pylypivka variety demonstrated some of the highest productive tillering densities among all studied varieties. Sowing on September 10 resulted in 516 stems/m², October 10 – 548 stems/m², and October 20 – 519 stems/m². Only with November 10 sowing was a noticeable decrease to 376 stems/m², indicating the variety's high plasticity and good capacity to form a productive stand even when sowing dates are shifted.

Figure 5 presents the number of grains per spike averaged over three years. In the Podolianka variety, the number of grains per spike ranged from 28 to 34, with the highest values recorded on October 20 (34 grains) and September 10 (32 grains). Under late sowing conditions (November 1–29 grains), a decrease in this indicator was observed, indicating a specific dependence of the variety on optimal sowing dates for this trait. The Bohdana variety was characterized by consistently high grain numbers per spike, with a maximum of 34 grains (September 1 and 10) and 33 grains maintained across almost all subsequent sowing dates. Only with November 1 and November 10 sowing did the grain number slightly decrease to 32, demonstrating good adaptability of the variety. The Zdobna variety showed stable values ranging from 28 to 32 grains per spike,

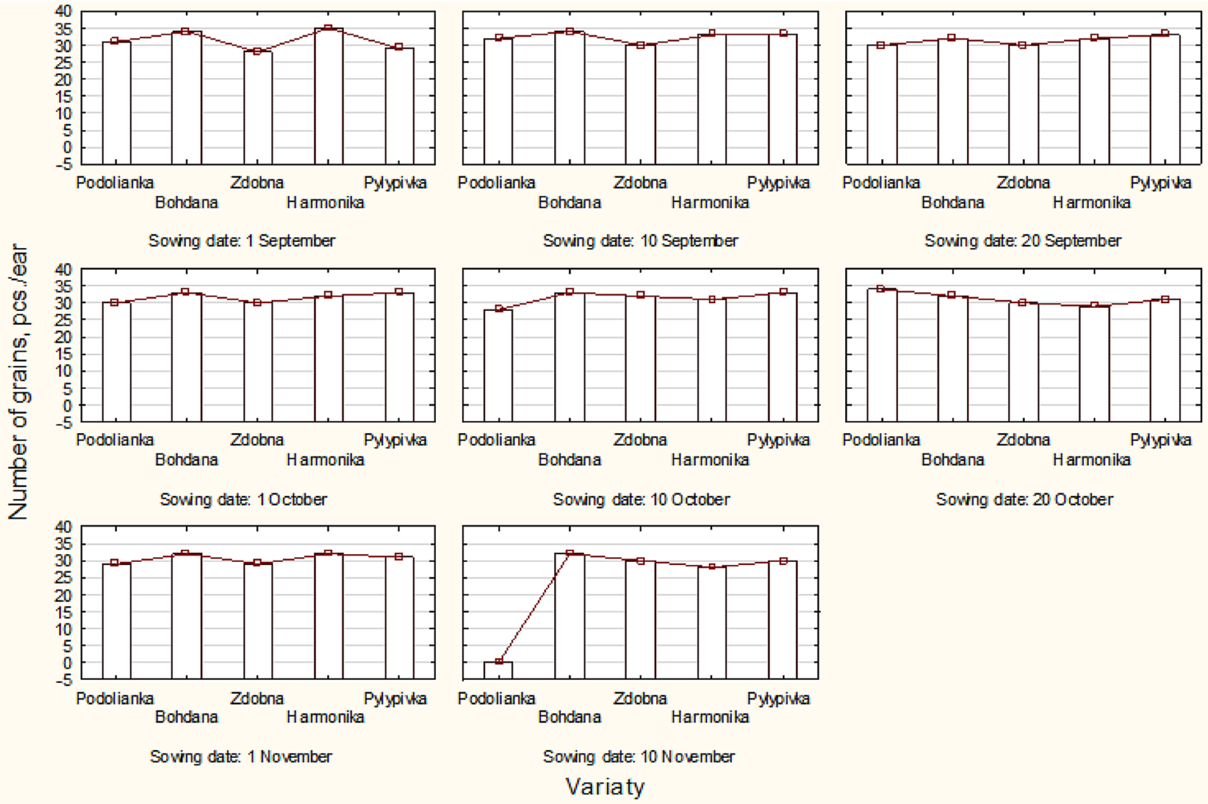

Figure 5. The average number of grains per ear of winter wheat varieties under study will depend on sowing dates from 2022 to 2024

regardless of sowing date. The lowest values were noted on September 1 (28 grains) and November 1 (29 grains), while the highest were recorded on October 10 (32 grains). This response indicates the variety's ability to maintain grain number per spike even under changing agronomic conditions. The Harmonika variety demonstrated stability in grain number, varying from 29 to 35 grains per spike. Maximum values were observed on September 1 (35 grains) and November 10 (32 grains), while the minimum was noted on October 20 (29 grains), highlighting the variety's flexibility regarding sowing dates and its ability to maintain high reproductive potential. The Pylypivka variety exhibited high grain number per spike, ranging from 29 to 33 grains. The highest values were observed with September 10, September 20, October 1, October 10, and November 1 sowing (33 grains). Even under November 10 sowing, the variety maintained 30 grains per spike, indicating good stability of this parameter across different sowing dates.

In the Podolianka variety, the grain weight per spike ranged from 1.0 g (October 1) to 1.28 g (September 10), showing a tendency to decrease with later sowing dates. Relatively high values were observed with September 10 sowing (1.28 g) and September 20 (1.23 g), while on November 1 the value was 1.23 g; no data were available for November 10 (Fig. 6). The Bohdana variety demonstrated consistently high grain weight per spike, with a maximum of 1.53–1.49 g (September 10 and October 10) and gradually decreasing to 1.33 g with November 10 sowing. This indicates the variety's ability to form a full spike even under less favorable conditions.

For the Zdobna variety, the grain weight per spike varied within 1.09–1.30 g at the initial sowing dates, gradually increasing to 1.29 g (October 10) and 1.28 g (October 20). However, with November 10 sowing, the value decreased to 1.25 g, indicating the variety's sensitivity to late sowing. The Harmonika variety showed relatively stable grain weight per spike, with a maximum of 1.44 g (September 20) and 1.36 g (November 1). The lowest values were recorded with September 1 (1.25 g) and November 10 sowing (1.18 g), reflecting moderate dependence on agronomic conditions. In the Pylypivka variety, the grain weight per spike remained at a high

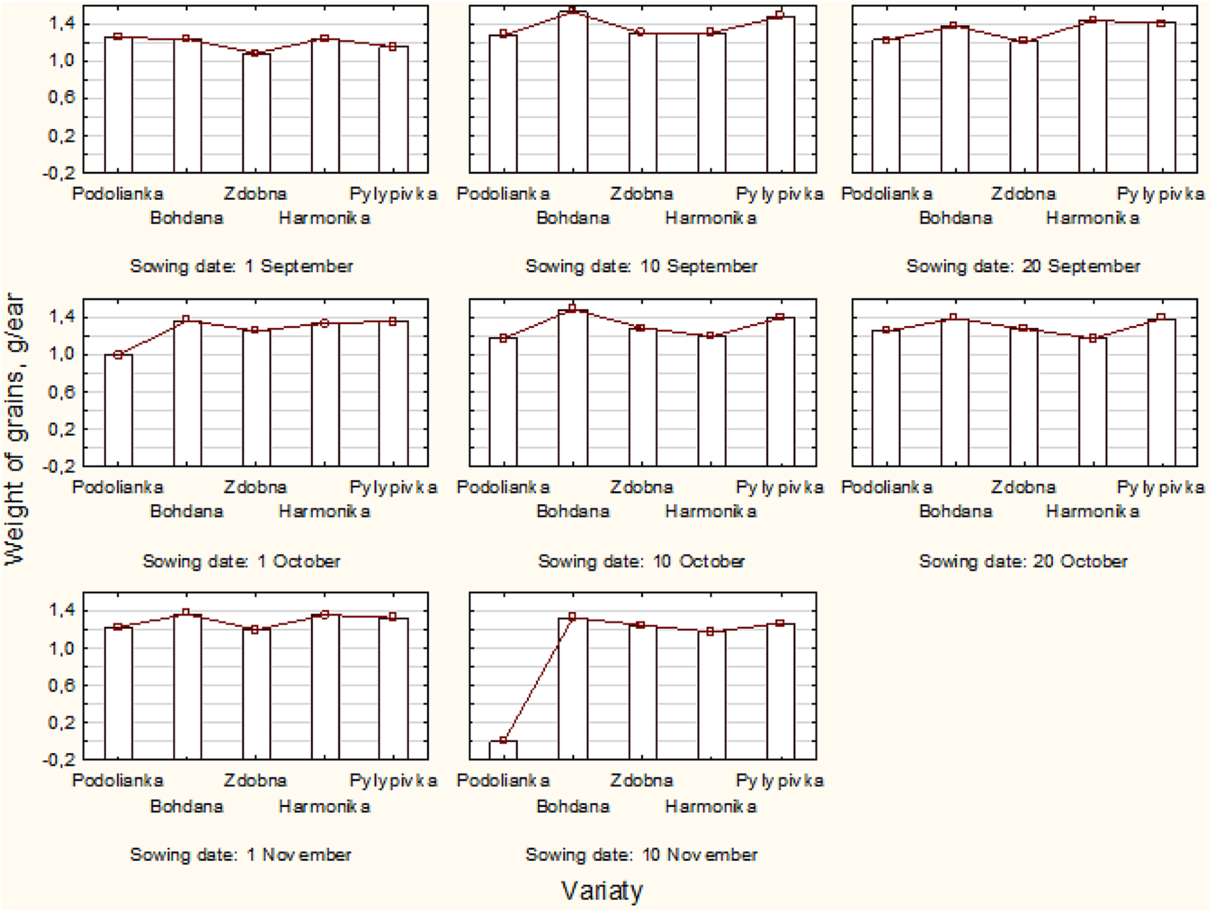

Figure 6. The average weight of grains per ear of winter wheat varieties under study will depend on sowing dates from 2022 to 2024

level across all sowing dates, ranging from 1.16 g (September 1) to 1.48 g (September 10) and 1.4 g (October 10), with only minimal reductions under late sowing (1.27–1.33 g). This highlights the variety's good compensatory capacity and stability in reproductive performance.

In the Podolyanka variety, the thousand kernel weight showed minor variation depending on the sowing dates, ranging from 37.1 g (October 20) to 42.0 g (November 1). The highest values were recorded at both early and late sowing dates (40.8 g on September 1; 42.0 g on November 1), indicating relative stability of this trait (Fig. 7). The Bohdana variety exhibited a clear positive response to optimal sowing periods: the highest thousand kernel weight (45.4 g) was observed with sowing on September 10, gradually decreasing to 41.4 g with late sowing on November 10. This highlights the importance of adhering to agronomic sowing timelines to ensure high grain quality. The Zdobna variety was characterized by increased thousand kernel weight at mid-sowing dates – 42.9 g (September 10), and 42.3–42.8 g (September 20 – October 1), followed by a gradual decline under late sowing conditions – 41.7 g (November 10). The variety demonstrated good adaptability, although with a tendency toward reduced grain quality under delayed sowing. The Harmonika variety exhibited lower thousand kernel weight values than other varieties: from 35.6 g (September 1) to a maximum of 43.2 g (November 1). A noticeable increase in this indicator was observed at mid-late sowing dates, indicating a compensatory response to late sowing. In the Pylypivka variety, the thousand kernel weight remained consistently high across all sowing periods: from 39.9–44.8 g in September to 44.6–42.7 g in October–November. Even with the latest sowing date (November 10), the value remained relatively high (42.3 g), emphasizing the high stability of this variety concerning this trait.

Overall, the analysis of the obtained results allows for the generalization and conclusion that the Podolyanka variety demonstrated good adaptability to sowing dates across most studied traits.

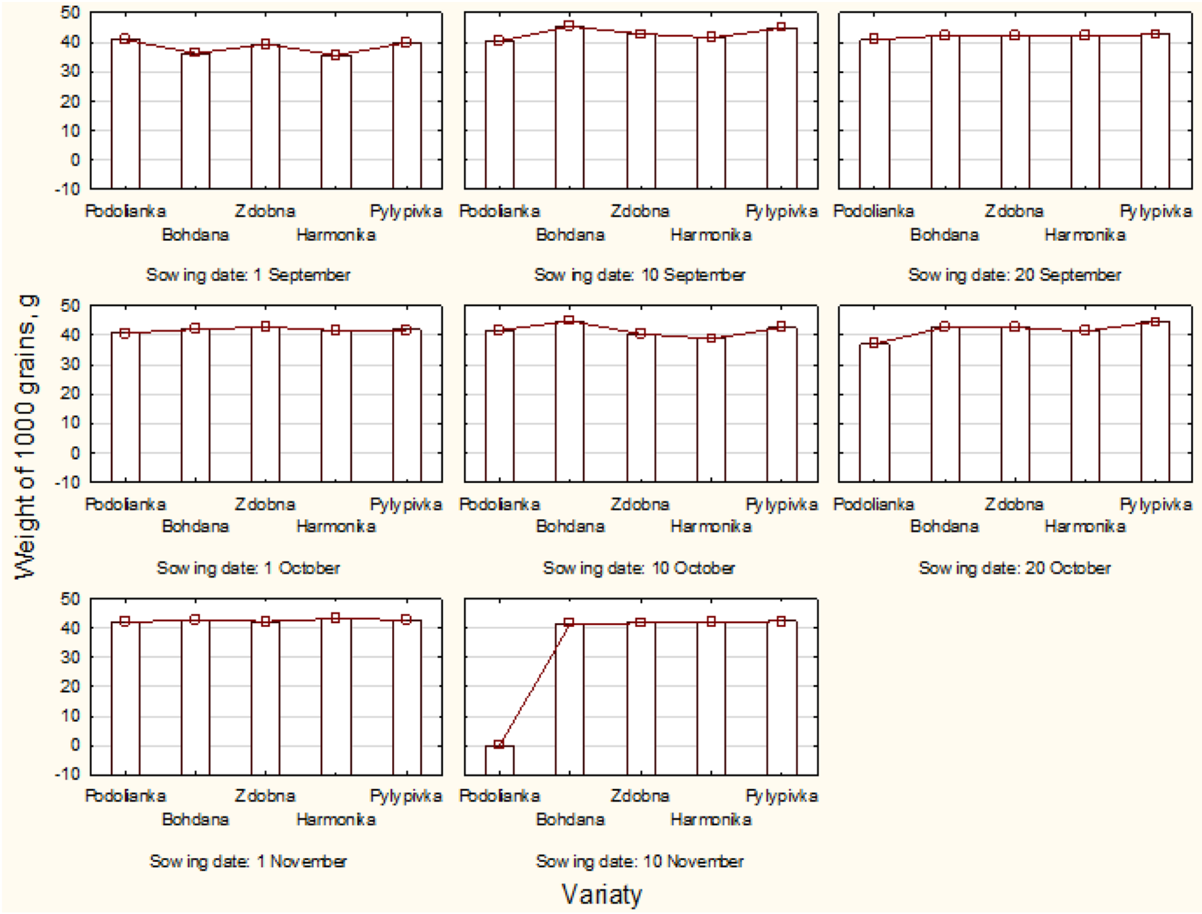

Figure 7. Average weight of 1000 grains of the studied winter wheat varieties depending on the sowing dates for 2022–2024

Despite moderate fluctuations in plant height, productive tillering, and the number of grains per spike, the variety maintained stable values for grain weight and thousand-kernel weight. This indicates its ability to form yield even under late sowing conditions (up to November 1), although data for November 10 were excluded due to elimination. Particularly notable is the stability of the thousand kernel weight, which remained high regardless of sowing time, and the increase in productive tillering at later sowing dates.

The Bohdana variety exhibited a clear dependence of productivity on the optimal sowing date, particularly on September 10. The highest values for plant height, productive tillering, grain weight per spike, and thousand kernel weight were recorded during this period. All parameters gradually declined afterward, especially at the latest sowing date (November 10), indicating limited plasticity and the necessity of adhering to optimal agrotechnical dates to realize its yield potential.

The Zdobna variety showed instability of parameters across different sowing dates. Plant height and productive tillering varied significantly, with minimum values on September 10 and maximums on October 10. The number of grains per spike remained stable, while the thousand kernel weight peaked at mid-late sowing dates and gradually decreased with late sowing. This suggests that Zdobna performs best when sown in September to early October, while late sowing negatively affects its productivity indicators.

The lowest plant height characterized Harmonika but demonstrated high stability in productive tillering, number of grains per spike, and thousand kernel weight. Maximum values for productive tillering and grain weight per spike were observed at mid-late sowing dates, indicating the variety's ability to partially compensate for limited vegetative development through forming reproductive organs. Even under late sowing conditions, Harmonika maintained satisfactory traits, making it suitable for delayed sowing periods.

The Pylypivka variety showed the highest stability across all studied parameters among the varieties. Plant height, productive tillering, number of grains per spike, grain weight, and thousand kernel weight remained high even with sowing shifted to November. This indicates exceptionally high plasticity and adaptability, making it a universal variety suitable for a wide agrotechnical range.

Such studies remain highly relevant, as crop breeding continues, and new varieties require evaluating sowing date effects to optimize their cultivation techniques. Similar experiments were conducted by Yarchuk & Melnyk [2018] under Steppe conditions, where it was established that optimal or even late sowing dates – specifically from September 17 to 24 – are most suitable under adverse overwintering conditions. Findings by Krivenko et al. [2019], also conducted in the Steppe zone of Ukraine, indicate that the optimal sowing date for varieties such as Zhytnytsia Odeska, Mudrist Odeska, and Oranta Odeska was October 5. Melnyk et al. [2013] recommend an optimal sowing period from September 10 to 20 for varieties such as Rozkishna, Podolyanka, and Sonechko in the Forest-Steppe zone. Research in the Right-Bank Forest-Steppe, conducted by Ulich [2018], also confirms that the most optimal sowing date is around September 30 and highly depends on the cultivated variety.

CONCLUSIONS

Based on the results of a three-year study, it was established that sowing dates significantly influence the productivity of winter wheat, depending on varietal characteristics. The Podolyanka and Pylypivka varieties demonstrated high stability and adaptability to different sowing dates, maintaining high productivity indicators even under late sowing conditions. In contrast, the Bohdana and Zdobna varieties showed greater dependence on optimal sowing dates (primarily mid-September to early October), which ensured the best performance across all evaluated parameters.

The results highlight the importance of considering both the variety and the sowing date to achieve maximum grain yield and quality. Specifically, the optimal sowing window for most varieties is between September 10 and October 10, while for highly plastic varieties, the sowing period can be extended into November without significant productivity losses.

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