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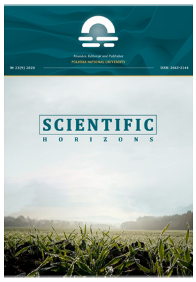

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Yield and quality of winter wheat depending on sowing dates in the Southern Steppe of Ukraine

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Abstract. Changing climatic conditions necessitate continued research to refine sowing dates for new winter wheat varieties and determine the level of their influence on productivity indicators, taking into account the specific weather conditions of the year. Therefore, the study of sowing dates, especially for innovative varieties with

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intensive initial growth, remains a relevant issue. This research aimed to determine and adapt to the conditions of the Southern Steppe of Ukraine the optimal and permissible sowing dates for new winter wheat varieties to achieve the highest possible level of realisation of their genetic potential in terms of yield and grain quality. Field experiments were conducted in 2021-2023 under the conditions of the Odesa Region. The main method used in the experiment was field research, which was supplemented by analytical studies, measurements, calculations, and observations. The harvest was recorded using a continuous threshing method with a SAMPO selection combine. It was established that the highest grain yield of winter wheat over the three-year study was achieved with sowing on 5 October. In 2021-2022, the average yield was 3.60 t/ha, while in 2022/2023, it increased to 3.90 t/ha. The highest yields were recorded for the following winter wheat varieties sown on 5 October (average for 2021-2022): Dovira Odeska – 4.03 t/ha, Katrusia Odeska – 5.16 t/ha, Pokrovska – 4.48 t/ha, Hospodarka Odeska – 4.28 t/ha, and Udacha Odeska – 4.08 t/ha (2022/2023). It was found that the grain quality of winter cereals largely depends on the year's weather conditions, variety, and sowing dates. The best results for these indicators were obtained with sowing on 5 October. However, for all winter wheat varieties, there was a tendency towards an increase in protein and gluten content in the grain when sown on 15 October. Thus, the practical value of this research lies in identifying the adaptability of new-generation winter wheat varieties to unfavourable growing conditions, realising their potential genetic yield, and determining the optimal and permissible sowing dates in the soil and climatic conditions of the Southern Steppe of Ukraine

Keywords: winter cereals; weather conditions; sowing dates; productivity; physical and chemical quality indicators

INTRODUCTION

Modern technology for growing winter cereals requires the development and implementation of new innovative solutions aimed at mitigating the negative impact of environmental factors on plant growth, development, and productivity, especially in light of the increasing challenges posed by climate change. Therefore, the response of promising and new winter wheat varieties to various abiotic conditions must be clarified, and research in this direction holds both scientific and practical interest, highlighting the relevance of this study.

O. Shevchenko (2023) in their studies highlights the threats of the climate crisis for the entire world and, in particular, for Ukraine. The author noted that in Ukraine, changes in climatic conditions are primarily manifested as an increase in average temperature, changes in precipitation, and an intensification of extreme weather events. Climate change can lead to instability in agriculture due to its impact on crop yields, the risks of extreme weather events, infrastructure, and water resources. Research into the impact of climate change on agricultural land use in Ukraine is crucial for developing effective adaptation strategies and implementing new technologies that will allow agriculture in Ukraine to maintain sustainable growth in a changing climate.

J. Dong *et al.* (2020) highlight the significant importance of winter wheat (*Triticum aestivum* L.) globally. It occupies the largest sown areas and has the highest grain production and trade. According to their findings, winter wheat accounts for 20% of human caloric needs and plays a major role in ensuring food security. Therefore, to achieve a significant increase in winter wheat yield, reduce the anthropogenic load, optimise water and resource provision, improve the environmental condition, and reduce production costs, the correct choice of sowing time is crucial.

Timely sowing is an important agronomic practice that ensures proper seed germination, stable seedling establishment, and the formation of the final winter wheat (*Triticum aestivum* L.) yield. However, delays in sowing often occur due to uncontrollable constraints, especially in repeated sowing. Long-term studies by D. Sun *et al.* (2018) have shown that climate change negatively affects winter wheat grain yields. Therefore, scientific adjustment of sowing dates can help mitigate these effects. S. Ma *et al.* (2018) and A. Ren *et al.* (2019) argue that regulating sowing dates allows for the effective utilisation of natural resources and helps prevent factors such as frost, lodging, and premature plant ageing, which can reduce yields. Research by F. Shah *et al.* (2020) found that delaying sowing beyond the optimal time may become a major obstacle to realising the genetic yield potential of winter wheat. In experiments conducted at the Sanyuan Experimental Station (34°36′N, 108°52′E) of Northwest A&F University in Shaanxi province of China, grain yield decreased by 1% for each day of delay beyond the optimal sowing date.

Sowing dates are one of the key factors in winter wheat cultivation technology, particularly in the context of climate change. Selecting optimal sowing dates reduces the risks associated with unstable weather conditions, such as droughts, frosts, or excessive rainfall, and provides plants with the necessary time to develop before the onset of winter. Early sowing dates come with their own risks, such as plant overgrowth, susceptibility to diseases, and reduced frost resistance, while late sowing dates may lead to insufficient plant development and lower yields. The optimal sowing dates should ensure that plants reach the tillering stage before winter without overgrowing, striking the best balance between winter hardiness and maximum yield. This is particularly important in the context of climate change, where weather conditions can be unpredictable. According to O. Vinyukov *et al.* (2021), deviations from the optimal sowing dates for winter wheat can significantly affect several critical aspects of its development, including plant growth, frost and winter hardiness, resistance to adverse environmental factors, plant survival, density of productive stems, and yield reduction. These factors collectively lead to yield decline. Optimal sowing dates offer the best balance between plant development and resilience to adverse conditions, which is crucial for ensuring high yields. Thus, precise selection of sowing dates is a decisive factor in ensuring winter wheat's resilience to winter conditions and optimising its productivity.

The quality of winter wheat grain is of significant importance. L. Guerrini *et al.* (2020) and D. Dilmurodovich *et al.* (2022) note that winter wheat should be characterised by high yield and meet technological quality requirements, particularly in terms of protein content, gluten content, and baking properties, which ensures its suitability for processing and consumption. K. Mitura *et al.* (2023) point out that the suitability of wheat for processing is determined by grain quality indicators, including both physical and chemical properties such as 1,000-grain weight, falling number, protein content, and crude gluten content, which directly affect the quality of the milling process and flour yield. Protein content in the grain also significantly affects the quality of the flour.

Given the analysis presented above, this study aimed to test and adapt innovative technologies for winter wheat production of modern varieties to regional conditions, to maximise the realisation of their genetic potential in terms of grain yield and quality.

MATERIALS AND METHODS

Weather conditions during the research years. Odesa Region is located in the southwestern part of Ukraine, in the steppe zone, which is characterised by a warm climate, a relatively mild winter with little snow, hot summers, and frequent dry winds. The average annual temperature is 9.0-11.0°C. The average annual precipitation is 491 mm, with about 70% falling during the warm period. The amount of precipitation varies from year to year, ranging from 263 mm to 766 mm. Weather conditions during the research years were typical for the region but varied significantly from year to year in terms of temperature regime, amount of precipitation, and its uneven distribution throughout the growing season, soil moisture reserves in the meter layer, and the presence of dry winds, which have already reached threatening levels and met the criteria for hazardous phenomena. These factors collectively influence plant growth, development, and the formation of winter wheat yield and grain quality throughout the growing season.

Hydrothermal regime indicators such as air temperature and precipitation were analysed based on data from the Odesa State Agricultural Experimental Station of the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine. Throughout all years of the study, an elevated temperature regime was observed during the growing season, exceeding the long-term average (Table 1), which confirms the ongoing climate change towards warming. Particularly high temperatures were observed in the 2022/2023 agricultural year. In this year, the average annual temperature exceeded the long-term average by 4.3°C.

***Table 1**. Average monthly air temperature during the research years compared to the long-term average, °C*

Month	Average air temperature for the month			Long-term average
	Year of research			
	2020/2021	2021/2022	2022/2023	
September	20.7	16.1	19.6	16.6
October	16.2	10.7	16.1	10.9
November	6.0	6.5	9.8	4.4
December	4.1	2.7	6.3	1.4
January	-2.5	1.1	0.8	-3.1
February	5.1	3.8	3.0	-2.8
March	4.1	3.2	7.6	2.6
April	8.6	10.9	11.2	9.8
May	15.7	16.0	18.4	15.8
June	20.1	22.3	25.1	19.4
Average for the growing season	9.8	9.3	11.8	7.5

***Source:** data from the meteorological station of the Odesa SAES, compiled and processed by the group of authors*

The winter temperature regime did not cause the death of winter wheat plants. During this period, the air temperature was higher than the long-term average. The presence of soil moisture before sowing and in autumn, when winter wheat plants are in their growing phase, is a crucial factor in obtaining high yields. However, in recent years, after sowing winter crops in the Odesa Region, a prolonged period of high temperatures and lack of precipitation has often been observed (Table 2).

***Table 2**. Amount of precipitation over the years of research compared to the long-term average, mm*

Month	Amount of precipitation per month			Long-term average
	Year of research			
	2020/2021	2021/2022	2022/2023	
September	31.0	18.0	45.0	31.8
October	7.5	26.0	18.5	23.1
November	32.0	28.0	37.0	41.8
December	34.0	50.1	47.5	32.0
January	24.0	10.8	19.0	25.0
February	39.8	5.0	6.0	22.0
March	41.0	12.0	36.0	32.1
April	84.0	8.1	85.5	33.3
May	77.2	26.0	45.0	36.6
June	62.6	28.0	32.0	55.0
Average for the growing season	434.1	211.0	375.5	332.7

***Source:** data from the meteorological station of the Odesa SAES, compiled and processed by the group of authors*

In terms of the complex hydrothermal conditions, the 2021/2022 agricultural year was the most unfavourable for the growth, development, grain filling, and yield formation of winter wheat. During the spring-summer period, when generative organs were laid, and grain was formed and matured, there was a severe moisture deficit. The autumn of 2020/2021 and 2022/2023 agricultural years was characterised by insufficient moisture supply and elevated temperatures, which affected the growth and development of winter wheat plants. The winter period was warm, without pronounced contrasts and with uneven precipitation distribution. The spring period was characterised by abundant rains, which significantly replenished soil moisture reserves, positively influencing plant growth and development. In these years, the total amount of precipitation exceeded the long-term average by 101.4 mm (130.5% of the total) and 42.8 mm (112.9% of the total), respectively. The experimental field where the research was conducted is located on typical zonal soils – southern, non-leached, heavy loamy chernozems. The humus horizon is 50-55 cm thick, with a humus content of 3.71%. The arable layer of the soil (25 cm) has the following agrochemical characteristics: content of easily hydrolysable nitrogen – 113-138 mg/kg of soil, mobile phosphorus (according to Chirikov) – 114-131 mg/kg of soil, exchangeable potassium (according to Chirikov) – 161-184 mg/kg of soil (high and high levels of provision), sum of exchangeable bases – 300-341 mg/kg of soil, nitrification capacity according to Kravkov – 11.4 mg/kg. The soil pH in water is 7.8. In the experiment, 18 promising soft winter wheat varieties (Tables 3 and 4) developed by the Plant Breeding & Genetics Institute – National Centre of Seeds and Cultivar Investigation were used in different years.

***Table 3**. Experimental design (2021-2022)*

Variety	Year of registration	Sowing dates		
		25 September	5 October	15 October
		Plot No.		
Zhytnytsia Odeska (soft)	2016	1	11	21
Lira Odeska (soft)	2013	2	12	22
Mudrist Odeska (soft)	2015	3	13	23
Kantata Odeska(soft)	2016	4	14	24
Oranta Odeska (soft)	2017	5	15	25
Nasnaha (soft)	2015	6	16	26
Perepilka (soft)	2016	7	17	27
Knopa (soft)	2014	8	18	28
Shliakhetnyi (hard)	2017	9	19	29
Blyskuchyi (hard)	2018	10	20	30

***Source:** developed by the group of authors*

***Table 4**. Experimental design (2023)*

Variety	Year of registration	Sowing date		
		25 September	5 October	15 October
		Plot No.		
Katrusia Odeska (soft)	2016	1	11	21
Mudrist Odeska (soft)	2015	2	12	22
Fortetsia (soft)	2019	3	13	23
Udacha Odeska (soft)	2021	4	14	24
Hospodarka Odeska (soft)	2022	5	15	25
Oranta Odeska (soft)	2017	6	16	26
Peremoha Odeska (soft)	2018	7	17	27
Pokrovska (soft)	2014	8	18	28
Vyhoda Odeska (soft)	2021	9	19	29
Dovira Odeska (soft)	2020	10	20	30

***Source:** developed by the group of authors*

The experiment was replicated three times, with a total plot area of 12 m^2 and a recorded area of 10 m^2. The experiments were laid out using a randomised complete block design. Wheat was sown in all experiments from 25 September to 15 October at a seeding rate of 4.5 million viable seeds per hectare, with a sowing depth of 6-7 cm.

For the winter wheat following short fallow, surface tillage was performed using a disc harrow and cultivators with arrow-shaped tines. Harvesting was carried out using a direct combine harvester in the full maturity phase. The yield of winter wheat was determined by weighing and then adjusting to a standard moisture content of 14% and purity of 100%. The combine harvester thresher was switched off after harvesting each plot when all the grain had been completely transferred to the bag. Bags of grain were weighed, and samples were taken to determine the 1000-grain weight, hectolitre weight, protein content, and gluten content. The grain yield was weighed to an accuracy of 0.1 kg. The protein content in winter wheat grain was determined by infrared spectroscopy using a Spektran-119M device (DSTU 4117-2007, 2007). To determine the 1000-grain weight, DSTU 4138-2002 (2002) was used. The hectolitre weight of the grain was determined using a hectolitre meter (DSTU 10840-2019, 2020). The quantity and quality of gluten in the wheat grain were determined according to DSTU ISO 21415-1:2009 (2011).

Statistical processing of the research results was carried out using generally accepted methods in the field of crop science (Ermantraut *et al.,* 2007; Ushkarenko *et al.,* 2008). To analyse the results, mathematical and statistical methods were used, including analysis of variance, correlation analysis, and regression analysis, as well as logical-theoretical approaches to interpreting the obtained data. During the study, the authors also used their previous findings (Pochkolina *et al.,* 2023).

RESULTS AND DISCUSSION

Yield of winter wheat under different sowing dates. Research shows that sowing dates undoubtedly affect the yield level of winter wheat. Over three years, only three winter wheat varieties were studied (Table 5).

***Table 5**. Grain yield of winter wheat varieties depending on sowing dates, t/ha (average 2021-2023)*

Variety (A)	Sowing date (B)			Average
	25 September	5 October	15 October	
Fortetsia	2.92	3.21	3.25	3.13
Pokrovska	3.15	3.87	2.93	3.32
Dovira Odeska	3.72	3.99	3.71	3.81
Average	3.26	3.69	3.30	3.42
%, before sowing on 25 September	100.0	113.2	101.2	
$LSD_{0.95}$, t/ha	**A**-0.09; B-0.09			

***Source:** developed by the group of authors based on the conducted research*

Analysis of the research results shows that the highest yield – 3.69 t/ha – was obtained with the second sowing date (5 October). With sowing on 25 September and 15 October, almost the same yield was harvested, and the difference in yield was insignificant. On average over 3 years, the highest yield was formed with sowing on 5 October for the variety Dovira Odeska – 3.99 t/ha. With sowing on 25 September, the grain yield of winter wheat was 13.2% lower and with sowing on 15 October – 11.8% lower compared to sowing on 5 October. The averaged data on the yield of 10 winter wheat varieties for 2021-2022 shows that the optimal weather conditions for plant growth and development, for grain formation, were formed with sowing on 5 October for winter wheat (Table 6).

Table 6*. Grain yield of winter wheat varieties depending on sowing dates, t/ha (average 2021-2022)*

Variety (A)	Sowing date (B)			Average
	25 September	5 October	15 October	
Zhytnytsia Odeska	3.66	3.68	3.46	3.60
Lira Odeska	2.82	3.33	3.15	3.10
Fortetsia	2.83	3.28	3.24	3.12
Palitra	3.65	3.80	3.57	3.67
Liha Odeska	3.10	3.65	2.97	3.24
Nasnaha	3.31	3.50	3.21	3.34
Veteran	3.08	3.24	2.84	3.05
Pokrovska	3.04	3.57	2.68	3.10
Storytsia	3.79	3.90	3.47	3.72
Dovira Odeska	3.84	4.03	3.78	3.88
Average	3.31	3.60	3.24	3.38
%, before sowing on 25 September	100.0	110.9	97.0	
$LSD_{0.95}$, t/ha	**A**-0.08; B-0.08			

Source: *developed by the group of authors based on the conducted research*

With a sowing date of 5 October, the highest average yield of 3.60 t/ha was obtained across the 10 varieties studied. This represents a 10.9% increase compared to the first sowing date (25 September) and a 1% increase compared to the third sowing date. Earlier and later sowing dates (25 September and 15 October) can be considered acceptable. The difference in yields obtained with sowing on 25 September (3.31 t/ha) and 15 October (3.24 t/ha) is insignificant, meaning that the yield for these sowing dates is the same. The highest yield was formed with sowing on 5 October for the following varieties: Dovira Odeska (4.03 t/ha), Storytsia (3.90 t/ha), Palitra (3.80 t/ha), and Zhytnytsia Odeska (3.68 t/ha). The lowest yield was formed in the wheat variety Veteran (3.24 t/ha). The research shows that different winter wheat varieties, registered at different times and requiring different vernalisation and photoperiod conditions, respond differently to the same abiotic conditions within each sowing date.

Table 7*. Grain yield of winter wheat varieties depending on sowing dates, t/ha (2022)*

Variety (A)	Sowing date (B)			Average
	25 September	5 October	15 October	
Katrusia Odeska	4.73	5.16	4.58	4.82
Mudrist Odeska	3.29	3.28	3.26	3.28
Fortetsia	3.10	3.09	3.26	3.15
Udacha Odeska	3.67	4.08	3.88	3.88
Hospodarka Odeska	3.89	4.28	3.90	4.2
Oranta Odeska	3.62	3.81	3.72	3.72
Peremoha Odeska	3.39	3.69	3.67	3.58
Pokrovska	3.37	4.48	3.43	3.76
Vyhoda Odeska	2.84	3.16	2.76	9.2
Dovira Odeska	3.50	3.92	3.58	3.67
Average	3.54	3.90	3.60	3.68
%, before sowing on 25 September	100.0	110.2	101.7	
$LSD_{0.95}$, t/ha	**A**-0.09; B-0.09			

Source: *developed by the group of authors based on the conducted research*

The data in the table indicate that the highest yield of 3.90 t/ha was also achieved with the second sowing date (5 October). The difference in yield between the sowing dates of 15 October and 5 October across the ten varieties is 0.30 t. Compared to the sowing on 25 September, the increase in yield is 0.36 t. The difference in yield between the sowing dates of 25 September and 15 October was not 2% compared to the 25 September sowing, but was higher by 8.3% compared to the 15 October sowing, as mathematically demonstrated. The yield differences among certain varieties averaged across all sowing dates are not significant (Oranta Odeska – 3.72 t/ha and Pokrovska – 3.76 t/ha; Oranta Odeska – 3.72 t/ha and Dovira Odeska – 3.67 t/ha). The highest yields on 5 October were produced by the following varieties: Katrusia Odeska (5.16 t/ha), Pokrovska (4.48 t/ha), Hospodarka Odeska (4.28 t/ha), and Udacha Odeska (4.08 t/ha). The minimum yield was recorded for the wheat variety Fortetsia at 3.09 t/ha.

Among scientists, there are conflicting conclusions regarding sowing dates. V. Tkachuk and T. Timoshchuk (2020) demonstrated that under the conditions of Polissia, the maximum yield of winter wheat (3.56 t/ha) was achieved when sown on 10 September. In contrast, sowing on 10 October resulted in a decrease in grain yield by 1.02 t/ha. According to S. Shakaliy *et al.* (2020), in the Poltava region, the highest yield (5.36 t/ha) was provided by the variety Bohemiia when sown on 20 September, and the variety Kosovytsia yielded 5.29 t/ha when sown on 30 September, due to differing levels of weather conditions and sowing dates. Furthermore, the sowing dates influenced both the total and productive number of stems, with the highest figures observed in the experimental varieties sown on 30 September, while the lowest were recorded for sowing on 10 September.

According to the research conducted by S. Yaroshenko (2020) in the northern subzone of the Steppe, shifting sowing dates both earlier (5 September) and later (10 October) resulted in an average decrease in winter wheat yield by 0.36 t/ha and 0.56 t/ha, respectively. In analysing the impact of sowing dates, H. Chuhrii (2021) emphasises that despite the varying duration of autumn vegetation, the highest yields were achieved by plants sown on the same date – 25 September. For instance, in the unfavourable year of 2016, the average yield across three varieties was 35.8 centner/ha, while in another unfavourable year, 2020, it was 34.1 centner/ha. In contrast, the favourable year of 2018 yielded an average of 45.8 centner/ha, and 44.3 centner/ha in 2019, which was also favourable. V. Petrychenko *et al.* (2021), who conducted experiments at the "AgroExpressService" farm in the Mlyniv District of the Rivne Region, noted that the highest yields (9.22 t/ha and 9.43 t/ha) for the winter wheat variety Kubus were achieved with sowing on 30 September. High yield figures were also observed when sowing occurred between 20 September and 10 October. When sowing is delayed until November-December, yields of 7–8 t/ha can still be obtained. These findings are corroborated by data presented in the studies of other researchers, indicating their reliability and consistency with existing scientific principles.

A. Krivenko and S. Pochkolina (2021) concluded from their experiments that the highest yields were obtained from sowing on 5 October for all varieties of winter wheat under study. In this case, the yield was 15.5% higher compared to sowing on 25 September, 19.1% higher than on 15 October, and 27.5% higher than on 25 October. Based on the results of their research, I. Pravdziva *et al.* (2020) established a general trend of decreasing yield with the shift of sowing dates from 26 September to 16 October. However, regarding the number of genotypes for specific predecessors, the optimal sowing date was identified as 5 October following green manure fallow for the varieties Trudivnytsia Myronivska, MIP Assol, and MIP Dniprianka, after mustard for Vezha Myronivska, after sunflower for MIP Fortuna, and after maize for both MIP Fortuna and Podolianka. Using the GGE biplot, it was established that the second sowing date after a green manure predecessor was closest to the "ideal environment" for realising the yield level of most genotypes.

J. Liu *et al.* (2023) from the Hebei Gucheng Agricultural Meteorology National Observation and Research Station in Baoding, Hebei Province (China), state that to ensure high and sustainable yields of winter wheat, the optimal sowing period varied from 1 to 10 October. V. Kyrylenko *et al.* (2023) conducted experiments at the V.M. Remeslo Myronivka Institute of Wheat of the NAAS of Ukraine from 2018/19 to 2020/21. The results indicated that the variety MIP Yuvileina produced the highest yield for the first sowing date (5.52 t/ha and 6.24 t/ha after preceding sunflower and soybean, respectively), while the variety MIP Fortuna yielded the highest for the second sowing date (5.46 t/ha after preceding soybean). The average yield of winter wheat varieties was higher when sown on 25 September and after the soybean predecessor. The maximum yield (5.52 t/ha and 6.24 t/ha) for sowing on 25 September was produced by the variety MIP Yuvileina after sunflower and soybean predecessors, respectively, while for sowing on 5 October, MIP Fortuna achieved 5.46 t/ha after the soybean predecessor. The factors that had the most significant impact on the yield of winter wheat were the growing conditions of the year and the predecessor, contributing 67.8% and 20.9% respectively. The factors "variety" and "sowing date" had contributions of 3.5% and 3.0% respectively.

Therefore, to determine the level of adaptability of new-generation winter wheat varieties to adverse growing conditions and to approach their potential genetic yield, it is necessary to know the optimal and permissible sowing dates, which determine the formation of the highest grain yield of winter wheat in the spring-summer period. Sowing dates also have a certain influence on the physical characteristics of winter wheat grain. Research data shows that the hectolitre weight of most winter wheat varieties exceeded the 1st class standard of Ukraine (775 g/L) for soft winter wheat (Table 8).

***Table 8**. Hectolitre weight of winter wheat, g/L (average for 2021-2022)*

Variety	Sowing date			Average
	25 September	5 October	15 October	
Zhytnytsia Odeska	781.0	783.0	772.0	778.6
Lira Odeska	778.0	787.0	785.0	783.3
Fortetsia	769.0	778.0	775.0	774.0
Palitra	779.0	785.0	789.0	784.3
Liha Odeska	775.0	778.0	770.0	774.3
Nasnaha	767.0	772.0	761.0	766.6
Veteran	771.0	776.0	761.0	769.3
Pokrovska	760.0	766.0	768.0	764.6
Storytsia	776.0	785.0	770.0	777.0
Dovira Odeska	785.0	792.0	781.0	786.0
Average	774.1	780.2	773.2	775.8

***Source:** developed by the group of authors based on the conducted research*

According to the presented data, on average over two years, the highest hectolitre weight was observed in the following varieties: Dovira Odeska – 786.0 g/L; Liha Odeska – 784.3 g/L; and Lira Odeska – 783.3 g/L. On average, a higher hectolitre weight was recorded for the sowing date of 5 October (780.2 g/L), followed by the sowing date of 25 September (774.1 g/L). The lowest value of hectolitre weight was observed with the late sowing date of 15 October (773.2 g/L). Sowing dates in 2023 showed a variable influence on the hectolitre weight of winter wheat (Table 9).

***Table 9**. Winter wheat grain hectolitre weight depending on sowing dates, g/L (2023)*

Variety	Sowing date			Average
	25 September	5 October	15 October	
Katrusia Odeska	760.9	766.4	769.2	765.2
Mudrist Odeska	795.0	808.2	788.0	797.1
Fortetsia	787.0	783.7	791.5	787.4
Udacha Odeska	775.2	764.7	770.7	770.2
Hospodarka Odeska	776.0	780.0	786.5	780.8
Oranta Odeska	808.0	783.3	782.2	791.2
Peremoha Odeska	790.7	804.2	797.0	797.3
Pokrovska	796.7	798.2	804.7	799.9
Vyhoda Odeska	779.0	783.0	784.2	782.1
Dovira Odeska	768.2	802.0	778.5	782.9
Average	783.7	787.4	785.3	785.5
%, before sowing on 25 September	100.0	100.5	100.2	-

***Source:** developed by the group of authors based on the conducted research*

Research data indicates that the hectolitre weight of most winter wheat varieties exceeded the 1st class standard. Only a few varieties, such as Katrusia Odeska (765.2 g/L) and Udacha Odeska (770.2 g/L), had a hectolitre weight that corresponded to the 2nd class of the national standard. On average, a higher hectolitre weight was recorded for the sowing date of 5 October (787.4 g/L). The lowest hectolitre weight was observed with the first sowing date, namely 25 September (783.7 g/L). In terms of varieties, on average, the highest hectolitre weight was observed in the following varieties: Pokrovska – 799.9 g/L, Peremoha Odeska – 797.3 g/L, and Mudrist Odeska – 797.1 g/L.

Sowing dates had a varied impact on the hectoliter weight of different winter wheat varieties. For instance, varieties such as Mudrist Odeska (808.2 g/L), Peremoha Odeska (804.2 g/L), and Dovira Odeska (802.0 g/L) exhibited the highest hectolitre weight when sown on 5 October. Conversely, varieties such as Katrusia Odeska (769.2 g/L), Fortetsia (791.5 g/L), and Hospodarka Odeska (786.5 g/L), as well as Pokrovska (804.7 g/L), showed the highest hectolitre weight when sown on 15 October. The varieties Udacha Odeska (775.2 g/L) and Oranta Odeska (808.0 g/L) had the highest hectolitre weight with the first sowing date (25 September). A similar pattern was observed for the 1,000-grain weight (Table 10).

Table 10. 1,000-grain weight of winter wheat seeds, g (average for 2021-2022)

Variety	Sowing date			Average
	25 September	5 October	15 October	
Zhytnytsia Odeska	41.0	42.7	41.1	41.6
Lira Odeska	40.6	41.9	40.8	41.1
Fortetsia	40.5	42.3	40.8	41.2
Palitra	39.2	39.7	39.4	39.4
Liha Odeska	36.0	36.8	34.4	35.7
Nasnaha	37.9	38.5	37.8	38.0
Veteran	39.9	39.8	38.1	39.2
Pokrovska	38.9	40.4	38.9	39.4
Storytsia	40.7	41.9	40.1	40.9
Dovira Odeska	42.0	42.9	41.1	42.0
Average	39.6	40.6	39.2	39.8
%, before sowing on 25 September	100.0	102.3	98.8	-

Source: *developed by the group of authors based on the conducted research*

On average over two years across 10 winter wheat varieties, the highest 1,000-grain weight (40.6 g) was achieved with a sowing date of 5 October. This represented a 2.3% increase compared to the first sowing date (25 September) and a 3.6% increase compared to the third sowing date (15 October). With a sowing date of 5 October, the following varieties produced the highest average 1,000-grain weight over two years: Dovira Odeska (42.9 g), Zhytnytsia Odeska (42.7 g), and Fortetsia (42.3 g). For the sowing date of 25 September, the highest 1,000-grain weight was observed in the varieties Dovira Odeska (42.0 g) and Zhytnytsia Odeska (41.0 g). On average, the varieties Dovira Odeska (42.0 g), Zhytnytsia Odeska (41.6 g), and Lira Odeska (41.1 g) had the largest grain size. A similar pattern was observed for the 1,000-grain weight in 2023 (Table 11).

Table 11. 1,000-grain weight of winter wheat seeds depending on sowing dates, g (2023)

Variety	Sowing date			Average
	25 September	5 October	15 October	
Katrusia Odeska	45.1	46.6	47.1	46.3
Mudrist Odeska	40.7	46.4	41.4	42.8
Fortetsia	45.0	45.8	45.1	45.3
Udacha Odeska	41.9	41.2	42.9	42.0
Hospodarka Odeska	42.3	43.3	40.8	42.1
Oranta Odeska	40.7	42.4	40.4	41.2
Peremoha Odeska	40.6	40.0	40.3	40.3
Pokrovska	41.9	41.9	41.5	41.8
Vyhoda Odeska	40.1	40.8	38.4	39.8
Dovira Odeska	41.3	42.0	40.7	41.3
Average	42.0	43.0	41.9	42.3
%, before sowing on 25 September	100.0	102.6	99.8	-

Source: *developed by the group of authors based on the conducted research*

On average across 10 winter wheat varieties, the highest 1,000-grain weight (43.0 g) was achieved with a sowing date of October 5th. The 1,000-grain weight for both the first (25 September) and third (15 October) sowing dates was almost identical at 42.0 g and 41.9 g, respectively. With a sowing date of 5 October, the varieties Mudrist Odeska (46.4 g), Hospodarka Odeska (43.3 g), and Oranta Odeska (42.4 g) produced the highest 1,000-grain weight. The varieties Katrusia Odeska (47.1 g) and Udacha Odeska (42.9 g) achieved their highest 1,000-grain weight with a sowing date of 15 October. For nearly all sowing dates, the varieties Fortetsia (45.0 g, 45.8 g, and 45.1 g, respectively), Peremoha Odeska (40.6 g, 40.0 g, and 40.3 g, respectively), and Pokrovska (41.9 g, 41.9 g, and 41.5 g, respectively) had similar 1,000-grain weight values. On average, the varieties Katrusia Odeska (46.3 g) and Fortetsia (45.3 g) had the largest grain size. Results from the two-year agrochemical analysis (2021-2023) indicate that sowing dates have a significant impact on the quality of winter wheat grain (Table 12).

***Table 12**. Quality of winter wheat grain depending on sowing dates*

Sowing date	Protein content (% of dry matter) over years			Crude gluten content (%) over years		
	2021	2022	2023	2021	2022	2023
25 September	11.9	11.5	11.4	24.5	19.0	19.8
5 October	12.2	11.9	11.5	25.9	19.3	19.5
15 October	12.6	12.4	11.6	27.6	19.7	19.9
Average	12.2	11.9	11.6	26.0	19.3	19.7

***Source:** developed by the group of authors based on the conducted research*

Throughout all the years of study, a trend towards increased protein (12.6%, 12.4%, and 12.6%, respectively) and gluten content (27.6%, 19.7%, and 19.9%, respectively) was observed for the sowing date of 15 October. The lowest protein content (11.9%, 11.5%, and 11.4%, respectively) was recorded for the sowing date of 25 September. In terms of gluten, the lowest levels in 2021 and 2022 were noted for the sowing date of 25 September (24.5% and 19.0%), while in 2023, the lowest level was recorded for the sowing date of 5 October (19.8%). The highest protein content (12.6%) and gluten content (26.0%) were observed in 2021, whereas the lowest levels occurred in 2023 for protein content (11.6%) and in 2022 for gluten content (19.3%). It should be noted that over the three years of the study, with the first (25 September) and second (5 October) sowing dates, the winter wheat grain met the 3rd class of the national standard in terms of protein and gluten content. Only in 2021, with the third sowing date (15 October), did the winter wheat grain meet the 2nd class standard. The grain quality in 2022 and 2023 with a sowing date of 15 October met the 3rd class standard in terms of protein and gluten content. Regarding varieties, sowing dates had a varied impact on grain quality (Fig. 1).

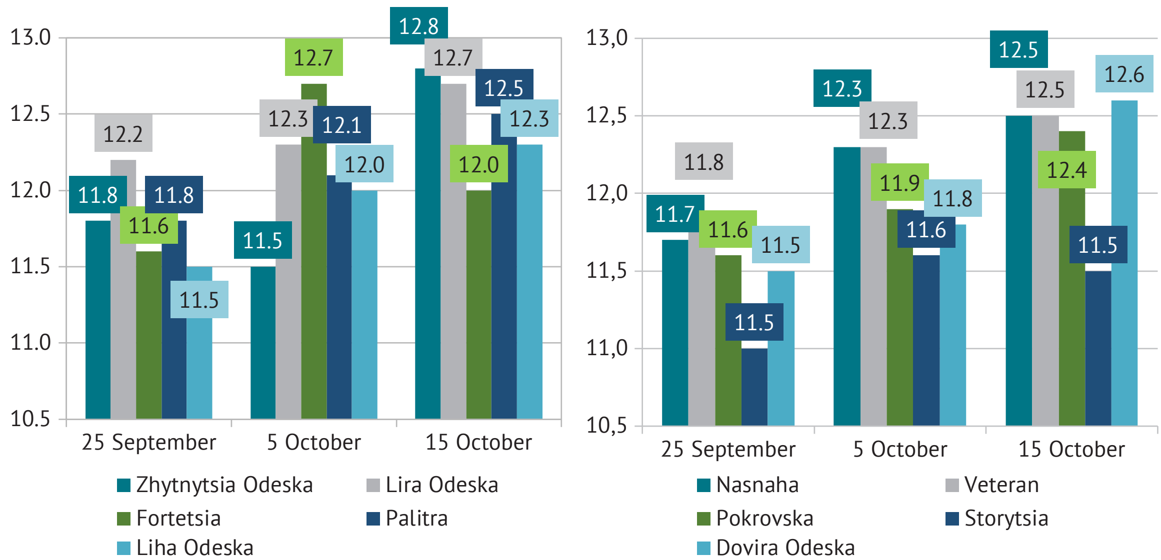

***Figure 1**. Protein content in winter wheat varieties depending on sowing dates (average for 2021-2022)*
***Source:** developed by the group of authors based on the conducted research*

Varieties such as Zhytnytsia Odeska (12.8%), Lira Odeska (12.7%), Palitra (12.5%), Nasnaha (12.5%), Veteran (12.5%), and Dovira Odeska (12.6%) exhibited the highest protein content when sown on 15 October, with their grain quality meeting the requirements of the 2nd class national standard. All varieties sown on 25 September and 5 October produced grain with protein content corresponding to the 3rd class. Varieties like Fortetsia (12.7%) and Storytsia (11.6%) produced the highest protein content when sown on 5 October. The results of the chemical analysis indicate that sowing dates in the 2022/2023 agricultural year had a negligible impact on the quality of winter wheat grain (Fig. 2). However, a general trend was observed: the higher the grain yield, the lower the protein content (assuming equal nutrient supplies). The variety Katrusia Odeska produced grain with a protein content of 10.4%, meeting the requirements of the 4th class according to the national standard when sown on the second date (5 October). For the remaining varieties, the protein content of the grain, regardless of the sowing date, corresponded to the 3rd class of the national standard.

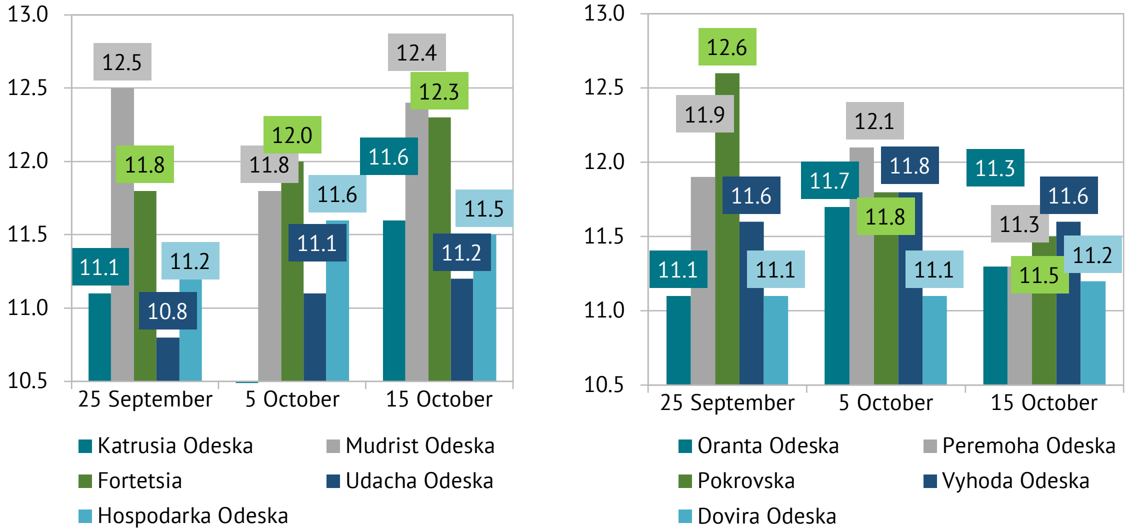

Figure 2*. Protein content in winter wheat varieties depending on sowing dates (2023)*
Source: *developed by the group of authors based on the conducted research*

On average across all sowing dates, the varieties Mudrist Odeska (12.2%) and Fortetsia (12.0%) produced the highest protein content. However, the pattern for gluten content is somewhat different (Fig. 3).

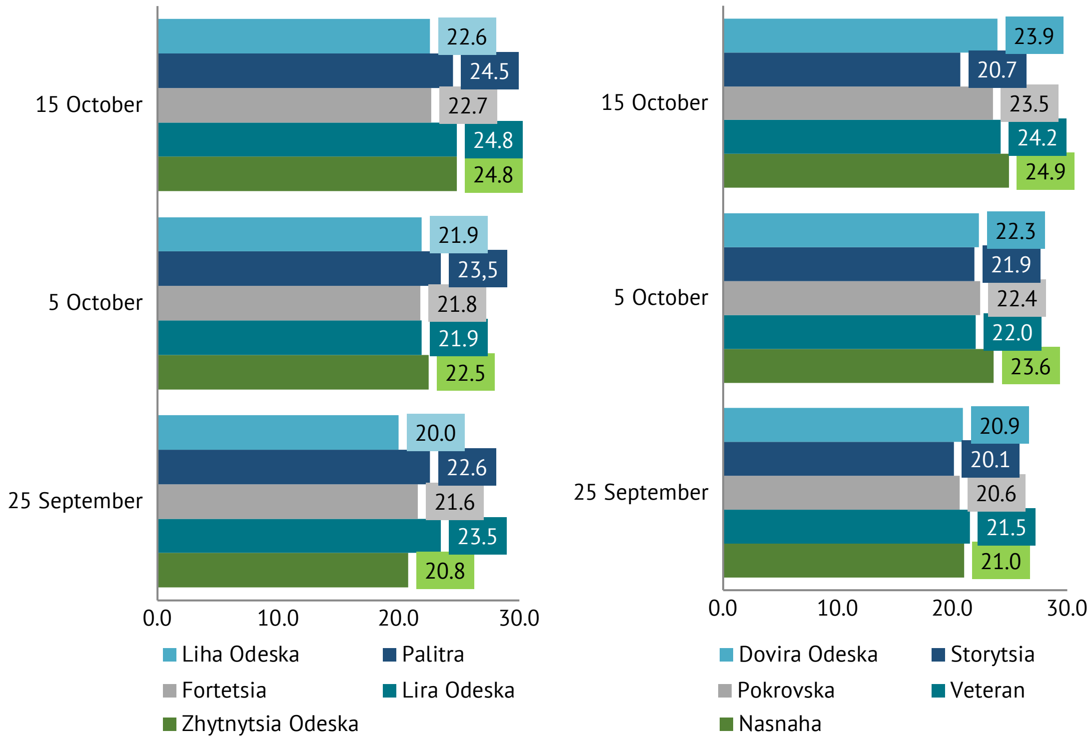

Figure 3*. Gluten content in winter wheat varieties depending on sowing dates (average for 2021-2022)*
Source: *developed by the group of authors based on the conducted research*

On average over 2021-2022, almost all winter wheat varieties, except Storytsia, accumulated the highest amount of gluten with a sowing date of 15 October, with the content in most varieties meeting the requirements of the 2nd class. With a sowing date of 5 October, all varieties showed a decrease in gluten content, with the amount corresponding to the 3rd class, except for the varieties Palitra and Nasnaha, where the gluten content of the grain met the 2nd class. With a sowing date of 25 September, the grain quality in terms of gluten content met the 3rd class for almost all varieties (except Lira Odeska, which met the 2nd class). In 2023, a decrease in gluten content was observed in the grain of all studied winter wheat varieties (Fig. 4).

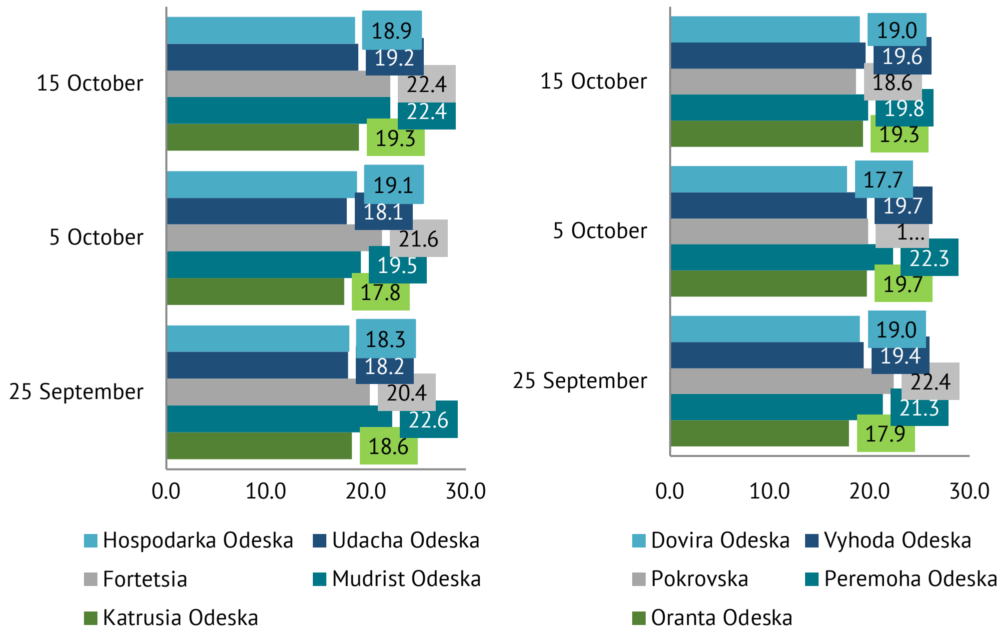

***Figure 4**. Gluten content in winter wheat varieties depending on sowing dates (2023)*
***Source:** developed by the group of authors based on the conducted research*

In terms of gluten content in the grain, all varieties, regardless of sowing date, met the requirements of the 3rd class. Only a few varieties (Katrusia Odeska and Dovira Odeska) when sown on 5 October, and Oranta odeska when sown on 25 September, produced grain with gluten content meeting the requirements of the 4th class. O. Vinyukov *et al.* (2021), based on their research, emphasised that, regardless of the variety, plants sown earliest exhibited the best biometric indicators. It was found that as the sowing dates were shifted towards later periods, the grain number per spike decreased, while the 1,000-grain weight increased.

K. Lachutta and R. Jankowski (2024) in their experiments conducted in Bałcyny (53°35′46.4″ N, 19°51′19.5″ E, NE Poland) determined the impact of different sowing dates on the technological quality of winter wheat grain (*Triticum aestivum* L.). The experimental variables were the sowing date (early: 6 September 2018, 5 September 2019, and 3 September 2020; delayed by 14 days: 1720 September; and delayed by 28 days: 1-4 October). A 14- and 28-day delay in sowing contributed to an increase in the total protein content of the grain (by 1% and 2%, respectively). Furthermore, a 28-day delay in sowing led to an increase in the moisture content of gluten in the grain (+0.5-0.6%) and an improvement in the quality of the protein complex in the Zeleny sedimentation test (+1.5%).

V. Spanic *et al.* (2023) concluded that, due to significant average differences for all winter wheat genotypes with the third sowing date (14 November 2022), the grain had a higher protein and crude gluten content. The lowest content of technological quality traits was observed with the second sowing date (4 November 2022). The second sowing date, compared to the first (13 October 2022), had advantages in terms of 1,000-grain weight (22.5%), protein content (1.2%), and crude gluten content (2.1%). However, it should be noted that the authors did not analyse the stability of these factors in the context of changing weather conditions, such as cultivation practices, weed infestation, and soil fertility levels, which is crucial for a comprehensive assessment of the impact of these factors on grain quality and yield. Nevertheless, from the perspective of developing agronomic science, both positive, negative, and complex results often have contradictory and debatable aspects, but despite this, they complement and deepen knowledge, contributing to the development of more substantiated elements of crop production technology, taking into account many factors such as climate change, varietal characteristics, and soil type and condition.

CONCLUSIONS

Multi-year experimental data on determining the optimal sowing dates for winter wheat indicate a trend towards later sowing, primarily due to changing weather conditions with warmer autumn temperatures and the use of varieties with a shorter vernalisation requirement. Over three years of research, the highest yields of winter wheat were obtained when sown on 5 October for most of the varieties studied: in 2021-2022, the average yield was 3.60 t/ha, which was 10.9% higher than the result of sowing on 25 September and 11.1% higher than the result of sowing on 15 October; in the 2022/2023 agricultural year, the yield was 3.90 t/ha, which is 10.2% more compared to sowing on 25 September and 8.3% compared to sowing on 15 October. The highest yields when sown on 5 October (on average for 2021-2022) were obtained by the following winter wheat varieties: Dovira Odeska (4.03 t/ha), Storytsia (3.90 t/ha), Palitra (3.80 t/ha), Katrusia Odeska (5.16 t/ha), Pokrovska (4.48 t/ha), Hospodarka Odeska (4.28 t/ha), and Udacha Odeska (4.08 t/ha) in the 2022/2023 agricultural year.

On average, the highest hectolitre weight of winter wheat was recorded with sowing on 5 October: in 2021-2022, the hectolitre weight averaged 792.0 g/L; in the 2022/2023 agricultural year, it was 787.4 g/L. The highest hectolitre weight on average was recorded for the following varieties: in 2021-2022: Dovira Odeska (786.0 g/L), Zhytnytsia Odeska (778.6 g/L), Storytsia (777.0 g/L); in the 2022/2023 agricultural year: Pokrovska (799.9 g/L), Peremoha Odeska (797.3 g/L), Mudrist Odeska (797.1 g/L). On average for 10 winter wheat varieties, the highest 1,000-kernel weight was obtained with sowing on October 5th: in 2021-2022, the 1,000-grain weight was 40.6 g; in the 2022/2023 agricultural year, it was 43.0 g. The highest 1,000-grain weight with sowing on 5 October was recorded for the following varieties: in 2021-2022: Dovira Odeska (42.9 g), Zhytnytsia Odeska (42.7 g), Fortetsia (42.3 g); in 2022/2023: Katrusia Odeska (46.6 g), Mudrist Odeska (46.4 g), Fortetsia (45.8 g).

Results of the agrochemical analysis of winter wheat grain show that in 2021-2022: most varieties produced 3rd class grain; the highest protein content (12.4%) and gluten content (23.7%) on average over two years was observed with the late sowing date (15 October). Zhytnytsia Odeska (12.8% protein and 24.8% gluten), Lira Odeska (12.7% protein and 24.8% gluten), Nasnaha (12.5% protein and 24.9% gluten), Veteran (12.5% protein and 24.2% gluten), Palitra (12.5% protein and 24.5% gluten), and Dovira Odeska (12.6% protein and 23.9% gluten) had the best indicators for protein and gluten content when sown on 15 October and met the requirements of the 2nd class standard. In the 2022/2023 agricultural year: the protein and gluten content in winter wheat grain was lower compared to previous years; most varieties produced 3rd class grain; the highest protein content (11.6%) and gluten content (19.9%) on average was observed with the late sowing date (15 October).

The data presented above confirms that there is no universal sowing date. This issue must be addressed on a case-by-case basis, taking into account a whole range of factors: weather conditions, the specific response of different varieties to sowing dates, predecessors, the availability of prepared areas for sowing, soil moisture reserves in the sowing layer, the availability of effective protection measures, the technical level of farms, and so on. Such an approach underlines the importance of a flexible and scientifically sound approach to agricultural practices, especially in the context of climate change.

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None.

CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Урожайність та якість пшениці озимої залежно від строків сівби в умовах південного степу України

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Анотація. Зміна кліматичних умов спонукають до продовження досліджень щодо уточнення строків посіву для нових сортів пшениці озимої та визначення рівня їх впливу на показники продуктивності з урахуванням особливостей погодних умов року. Тому, вивчення строків сівби, особливо сортів-інновацій з інтенсивним стартовим ростом, було і залишається актуальним питанням. Мета досліджень – визначення та адаптація до умов Південного Степу України оптимальних та допустимих строків сівби озимої пшениці нових сортів для досягнення максимально можливого рівня реалізації їх генетичного потенціалу з урожайності і якості зерна. Експериментальні досліди проводили у 2021–2023 роках в умовах Одеської області. Основний метод, який застосовувався у досліді – польовий, який доповнювався аналітичними дослідженнями, вимірами, підрахунками і спостереженнями. Облік врожаю проводився методом суцільного обмолоту за допомогою селекційного комбайну SAMPO. Встановлено, що найвищу урожайність зерна пшениці озимої за три роки досліджень одержано при сівбі 5 жовтня. У 2021-2022 роках – урожайність у середньому становила 3.60 т/га, а у 2022/2023 с.-г. році – 3.90 т/га. Виявлено, що найвищий врожай сформували (середнє за 2021-2022 рр.) при сівбі 5 жовтня такі сорти пшениці озимої: Довіра одеська – 4.03 т/га і Катруся одеська – 5.16 т/га; Покровська – 4.48 т/га, Господарка одеська – 4.28 т/га, Удача одеська – 4.08 т/га (2022/2023 с.-г. р.). Встановлено, що якість зерна озимих зернових значною мірою залежить від погодних умов року, сорту і строків сівби. Найкращі результати за цими показниками були отримані при сівбі 5 жовтня. Але, за всіма сортами пшениці озимої спостерігається тенденція до збільшення білка й клейковини в зерні при строку сівби 15 жовтня. Таким чином, практична цінність дослідження полягає у виявленні рівня адаптивності до несприятливих умов вирощування сортів нового покоління пшениці озимої та реалізації їх потенційно-генетичної урожайності а також визначення оптимальних та допустимих строків їх сівби в грунтово-кліматичних умовах Південного Степу України

Ключові слова: озимі зернові культури; погодні умови; терміни сівби; продуктивність; фізичні і хімічні показники якості