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Ecological and Economic Study of Winter Wheat Varieties by Different Geographical Origin

Mykola Sobko[1], Yevheniia Butenko[2*], Gennadiy Davydenko[2], Oleksandr Solarov[2], Viacheslav Pylypenko[2], Viktoriia Makarova[2], Maryna Mikulina[2], Iryna Samoshkina[2], Oleksandr Antonovskyi[3], Volodymyr Poriadynskyi[3]

[1] Institute of Agriculture of Northern East of National Academy of Agrarian Sciences of Ukraine, Parkova St., 3, Sumy region, village Sad, 42343, Ukraine

[2] Sumy National Agrarian University, H. Kondratieva St., 160, Sumy, 40021, Ukraine

[3] Poltava State Agrarian Academy, 1/3, Skovorody St., Poltava, 36003, Ukraine

* Corresponding author's e-mail: evg.butenko2011@ukr.net

ABSTRACT

The results of research on increasing resistance of winter wheat varieties of different geographical origins to adverse weather conditions in the zone of unstable moistening in the North-Eastern Forest Steppe of Ukraine have been summarized. Rational use of agrometeorological resources made it possible to determine optimal terms of work on the elements of cultivation technology, taking into account weather conditions of the current year nd on their basis, to improve adaptive technologies for growing winter wheat varieties. This contributed to increase of yielding capacity, quality of grain and sustainability of agriculture. Such conditions were favorable for winter wheat crops of late sowing periods, the plants of which reached tillering phase on a significant part already in winter period. Yielding capacity of winter wheat by sowing dates (on average by varieties) was: September 1 – 5.72 t ha^{-1}, September 10 – 5.54 t ha^{-1}, September 20 – 5.41 t ha^{-1}, October 1 – 5.45 t ha^{-1}, October 10 – 4.87 t ha^{-1}, October 20 – 5.11 t ha^{-1}, November 1 – 5.06 t ha^{-1}. Kraevyd and Pylypivka were the most productive among winter wheat varieties under conditions of 2020. Their yielding capacity varied between 6.18–6.88 t ha^{-1} and 5.53–6.30 t ha^{-1} depending on sowing dates. The highest level of profitability was provided by Kraevyd variety (120.0–131.2%) at late sowing dates (October 1 – November 1).

Keywords: winter wheat, varieties, sowing terms, adaptability, yielding capacity.

INTRODUCTION

Increase of yielding capacity and improvement of grain quality largely depends on selection of varieties for cultivation. Timely replacement of old grain crop varieties with the new ones will additionally enable producers to grow a high yield of agricultural crops [Keivanrad et al., 2012; Karpenko et al., 2022; Tsyuk et al., 2022].

One of main growing techniques for winter ear crops, especially wheat and barley, is correct choice of sowing dates. Sowing is the first and most responsible period in cultivation of a particular crop, which largely determines the time and completeness of seedling shootings, further growth and development of plants in autumn vegetation season, continuation of hardening phases, frost and winter resistance, resistance to other stress phenomena, diseases, pests, weeds, which are determining factors at the final stage for obtaining high yields of winter crops, especially winter wheat [Dhakal et al., 2020; Yakupoglu et al., 2021; Karbivska et al., 2022a]. According to the results of studies carried out by scientific research institutions of Ukraine, deviation of sowing dates from the optimal ones by 15–20 days leads to a decrease in productivity by 15–45% due to receiving overgrown, thickened or weak

non–tillered plants at the period of ending autumn vegetation. Under unfavorable wintering conditions, such plants may die completely. Taking into account the factors affecting the harvest positively or negatively, it is possible to significantly level effect of meteorological conditions and purposefully use human–controlled factors [Lamandé & Schjønning, 2017; Woźniak 2019; Rieznik et al., 2021].

Today's conditions require cultivation of main grain crop varieties which are most adapted to the conditions of unstable hydrothermal regime, stressful situations, with a weak reaction to regulated and unregulated factors of external environment, high adaptability and wide agro–ecological plasticity, and are able to form a consistently high yield [Paz-Ferreiro & Fu, 2016; Nan et al., 2019; Singh et al., 2019; Novák et al., 2020].

The primary tasks of scientists and researchers are rational use of agrometeorological resources, determination of optimal terms for carrying out work on the elements of growing technology, taking into account weather conditions of current year, and on their basis, improvement of adaptive technologies for growing grain crops under conditions of unstable moisture zone. This will contribute to increase of productivity, the gross harvest of grain, sustainability of agriculture and restoration of soil fertility [Karpenko et al., 2020; Tanchyk et al., 2021; Karbivska et al., 2022b].

MATERIAL AND METHODS

The research was conducted in the grain-row crop rotation of Cultivation Department at the Institute of Agriculture of the Northern East, National Academy of Agrarian Sciences of Ukraine during 2019–2020.

The research soil is typical deep, low–humus, slightly leached coarse-grained, medium-loamy black soil with the following agrochemical indices of arable layer (at the time of experiment): pH of salt extract – 5.8–6.3; the amount of absorbed bases – 31.2–41.7 mg–eq; P_2O_5 and K_2O according to Chirikov – 14.8 and 11.0 mg per 100 g of soil, humus according to Tiurin – 4.2%, nitrate nitrogen – 1.12–2.35 mg, ammonia – 0.05–0.29 mg, easily hydrolyzed nitrogen – 8.4–10.9 mg per 100 g of soil.

The end of summer 2019 (August) was very dry. Only 4.5 mm of precipitation fell during the month at an average monthly air temperature of 21.5 °C, and in the first and second decades of September – 8.9 mm of precipitation. Reserves of productive moisture, both in the sowing and arable horizon, were unsatisfactory. They were not sufficient to obtain seedlings of winter crops. However, in the 3rd decade of September, fell 34.4 mm of precipitation, which in total amounted to 87% per month of the average long-term norm, and ensured the shootings of winter crops. In October and November, respectively, 30.1 and 30.7 mm fell, which was 68.4 and 68.2% of the long–term average index. In December, only 20.2 mm of precipitation fell (44% of the long–term norm).

There was no precipitation in the first and second decades of January. However, in the third decade, fell 56.2 mm of precipitation in the form of rain and wet snow, which exceeded average long–term norm for the month of January by 15.2 mm. At that time, there was no freezing of the soil, and the air temperature was mostly positive, which contributed to replenishment of soil moisture reserves. In February, was received 39.0 mm of precipitation, which is 111.4% of the average long–term index. Its main amount fell in the third decade of the month (27.8 mm). In the absence of soil freezing and positive temperatures, these precipitations replenished moisture reserves in the soil.

Temperature regime of the autumn period was higher than the long-term index. Thus, September was warmer comparing to long–term data by 2.1 °C, October – 3.5 °C, November – 2.8 °C. Meteorological termination of autumn plant vegetation in 2019, or transition to lower average daily air temperature, due to decrease to +5 °C, took place on November 15.

December was warm with average monthly temperature of 1.4 °C, with a long-term average of – 3.8 °C. Average monthly temperature in January was – 0.5 °C, which is 5.6 °C higher than the average long–term norm. There was no snow cover in December–January, with the exception of a few days at the end of January, when snow fell and melted under the influence of positive temperatures. Due to the fact that air temperature was positive in December–January, sometimes with slight frosts, there was almost no freezing of the soil. February was also warm, but frosty weather prevailed in the first decade. Thus, the average decadal air temperature by decades was – 2.7; +0.8 and 1.2 °C, which is higher than the long-term index by 3.6; 6.5 and 5.3 °C, respectively.

During the month, the average air temperature was – 3.0 °C.

The average daily air temperature went up through 0 °C on the third of April 2020 and indicated that the winter period had ended and spring had begun. Snow cover disappeared completely on March 7, 2020. Winter crops began to grow and vegetation renovated on March 4, 2020, when average daily air temperature exceeded +5 °C. In March, temperature regime was 5.4 °C. 15 mm of precipitation fell – 39% of the long-term index (38 mm).

In April, average daily air temperature was 7.8 °C, which is 0.9 °C less than the long–term index of 8.7 °C. 12 mm of precipitation fell – 30% of the long–term index of 40 mm. There were frosts from minus 10 °C to 0 °C on the soil surface. May was moderately warm. The average daily air temperature was 13.5 °C, which is by 2.1 °C lower than the long–term temperature. 93 mm of precipitation fell – 172% of the long–term norm of 54 mm. In May, there were also frosts on the soil surface with a temperature of minus 2 °C. There were 3 such days with frosts. The last frost on the soil surface was registered on May 22, 2020.

During spring period, the average daily air temperature was 8.9 °C, which is 0.8 °C higher than the long–term 8.1 °C. 120 mm of precipitation fell – 91% of the long–term 132 mm. The sum of active air temperatures above plus 10°C for spring period amounted to 462 °C, when the long–term – 620 °C.

Average daily temperature in June was 23.3 °C, which is 4.5 °C higher than the long–term average index. During the first decade of the month, 37.9 mm of precipitation fell, with the average long-term norm of 19 mm. The second decade was without precipitation, but the average decadal air temperature was 26.2 °C, which exceeded the long–term index by 7.5 °C. For the whole month, 50.9 mm of precipitation fell, with the long–term index of 67 °C. Beginning of July was hot and dry, so the average ten–year air temperature for the first decade of the month was 23.1 °C, which is higher than the long–term index by 3.4 °C. 6.3 mm of precipitation fell, when the long–term norm is 26 mm.

The experiment was laid in a fall of 2019. The experiment is two-factor. Factor A – winter wheat varieties from various scientific selection institutions of Ukraine (Podolyanochka, Bohdana, Zdobna, Pylypivka, Kraevyd, Svitanok Myronivskyi). Factor B – sowing dates (September 1, September 10, September 20, October 1, October 10, October 20, November 1).

Establishment of experiments, their location in nature, phenological, biometric, agrochemical analyzes and research were carried out according to methodological recommendations [Pochynok, 1976; Sobko, 2014]. Statistical processing of yield results was carried out by dispersion analysis method according to Dospekhov methodology [1985] according to the scheme of multifactor experiment using application program package Statistica for Windows 6 [Tsarenko et al., 2000].

RESULTS AND DISCUSSION

The aim and the tasks of research work was in generalization of the research results on increasing resistance of winter grain crops to adverse weather conditions and, on their basis, improvement of adaptive technologies for growing winter wheat under conditions of unstable moisture zone of the northeastern Forest Steppe of Ukraine.

In the course of research, plant biometric indices of winter grain crops of different sowing dates after the end of vegetation in a fall of 2019 were determined (Table 1).

Physiological condition of winter wheat plants sown in the optimal sowing period (1.09–20.09) was good and satisfactory. At the same time, the phase of plant development – tillering. Weak condition of crops was characteristic for the phase of 2–3 leaves (sown after October 10). At the early (1.09) and optimal (10.09–20.09) sowing dates was noted the best condition of the crops: the plants were in the phase of tillering, and had 2–3 stems. The coefficient of tillering is 2.1. When sown on October 1, the plants were in the phase of beginning tillering. At the same time, the tillering coefficient was 1.4.

Crops with sowing dates of September 1; 10 and 20 did not differ at the time of vegetation termination according to biometric indices, because due to low moisture supply, they were shooting simultaneously after the rainfall. So, these crops of winter wheat had average, by varieties, plant density of 429–434 pcs/m^2, coefficient of tillering was 2.1. The height of such plants ranged from 14 to 16 cm depending on the variety.

Crops of winter wheat with a sowing date of October 1 had average plant density of 438 pcs/m^2, tillering coefficient – 1.4; and the height is 10–12 cm depending on variety. Winter wheat plants

Table 1. Biometric indices of winter wheat depending on sowing times after the end of autumn vegetation, 2019

Variety	Plant density, pcs/m^2		Coefficient of tillering	Phase of development	Plant height, cm
	Plants	Stems			
September 1					
Podolianka	420	882	2.1	Tillering	14
Bogdana	444	932	2.1	Tillering	14
Zdobna	435	957	2.2	Tillering	15
Pylypivka	456	1003	2.2	Tillering	14
Kraievyd	429	858	2.0	Tillering	16
Svitanok Myronivsky	420	924	2.2	Tillering	15
Average	434	911	2.1	Tillering	15
September 10					
Podolianka	447	939	2.1	Tillering	14
Bogdana	429	901	2.1	Tillering	14
Zdobna	435	957	2.2	Tillering	15
Pylypivka	435	957	2.2	Tillering	14
Kraievyd	426	852	2.0	Tillering	16
Svitanok Myronivsky	414	911	2.2	Tillering	15
Average	431	905	2.1	Tillering	15
September 20					
Podolianka	438	920	2.1	Tillering	14
Bogdana	447	939	2.1	Tillering	14
Zdobna	411	904	2.2	Tillering	15
Pylypivka	435	957	2.2	Tillering	14
Kraievyd	429	858	2.0	Tillering	16
Svitanok Myronivsky	414	911	2.2	Tillering	15
Average	429	901	2.1	Tillering	15
October 1					
Podolianka	468	655	1.4	Beginning of tillering	11.3
Bogdana	429	644	1.5	Beginning of tillering	12.0
Zdobna	435	566	1.3	Beginning of tillering	11.0
Pylypivka	447	536	1.2	Beginning of tillering	10.3
Kraievyd	426	511	1.2	Beginning of tillering	10.0
Svitanok Myronivsky	423	677	1.6	Beginning of tillering	11.8
Average	438	599	1.4	Beginning of tillering	11.0
October 10					
Podolianka	429	429	1	1–3 leaves	10.2
Bogdana	417	417	1	1–3 leaves	11.7
Zdobna	408	408	1	1–3 leaves	9.0
Pylypivka	456	456	1	1–3 leaves	10.0
Kraievyd	483	483	1	1–3 leaves	10.8
Svitanok Myronivsky	429	429	1	1–3 leaves	9.7
Average	437	437	1	1–3 leaves	10.1

with a sowing date of October 10 had only 3–4 leaves each. Average plant density for varieties was 437 pcs/m^2, their height by varieties ranged from 9.0 to 11.7 cm. Such crops are characterized as weak by the state of development. After sowing on October 20 and November 1, the plants entered winter in a seedling phase. First of all, it is related to insufficient number of active temperatures of more than 5 °C during a period from sowing to vegetation termination, only 181.6 °C and 97.1 °C, respectively, and low moisture supply.

The further condition of plants, especially weak and with lowered density ones, to a decisive extent depended on weather conditions, first of all, on amount of precipitation and temperature regime.

Taking into account hydrotechnical indices of January–February, there were no significant reasons for damage, and even more so for death of crops, since winter period of 2019–2020 was distinguished by increased air temperature, which is 3–5 °C higher than the average long–term norm.

Despite untypical weather for winter, condition of winter crops was within normal limits. Recovery of spring vegetation was noted on March 30. Condition of plants and winter crops was good and satisfactory.

In accordance with the set aim and tasks, taking into account agrometeorological resources and their rational use, the following was carried out: determination of optimal terms for carrying out work on the elements of cultivation technology for weather conditions of the current year, as well as developing prognostic information about weather conditions at different times of the year, especially vegetation period. This will contribute to increase of yielding capacity of agricultural crops, their gross yield and increase of cultivation sustainability.

In the reporting year, sheaf material was selected in order to determine the elements of plant crop structure depending on sowing dates and varietal characteristics (Table 2). So, during sowing on the first of September, the highest plants were formed in Bohdana and Podolianka varieties – 113 and 111 cm, respectively. Maximum productive stalk–standing was determined for Bohdana variety – 672 pcs/m^2 and Podolianka – 648 pcs/m^2, for other varieties this index was within 618–638 pcs/m^2. Pylypivka and Kraevyd varieties prevailed by the index of grain number per ear (30 pcs/ear), where the largest mass of grains from an ear was obtained, 1.22 and 1.20 g/ear, respectively. According to mass index of 1000 grains, prevailed varieties Kraevyd – 40.5 g, Pylypivka, and Zdobna – 40.0 g. for each.

Similar results were obtained for sowing on September 10. Thus, Podolianka and Bohdana varieties had plant height of 111 and 112 cm, respectively. The index of grain number per ear and its mass was somewhat higher. Thus, the maximum indices were obtained for Pylypivka and Kraevyd varieties at the level of 33 and 32 pieces, and their mass was 13.3 and 12.9 g.

Indices of harvest structure of the first sowing terms 1.09; 10.09; and 20.09 differed little from each other. For later terms, starting from 1.10, was observed a tendency to height decrease of winter wheat plant depending on the time of sowing. On average, by varieties, this index decreased from 94 to 85 cm, while during early sowing period it was 104–117 cm.

During later sowing periods (10.10–01.11), the index of grain mass from an ear and the mass of 1000 grains were slightly lower than during early and optimal periods. On average, by varieties, the mass of grains from an ear at late sowing dates was 0.9 and 1.0 g/ear, and the mass of 1000 grains was 31.9–33.8 g, while at early and optimal sowing dates these indices varied within 1.4–1.17 g/ear and 37.8–38.4 g.

In the reporting year, average yielding capacity of winter wheat by varieties, depending on sowing time, varied between 4.87–5.73 t ha^{-1}. It was the maximum under conditions of sowing on September 1, the excess of control (sowing date on September 10) was 0.19 t ha^{-1} on average by variety. The lowest index was obtained for sowing on October 10, which is less than control variant by 0.67 t ha^{-1}. Among the studied periods, Kraevyd, Pylypivka and Zdobna were the most productive varieties for all sowing periods. The maximum yield in the experiment was obtained for Kraevyd variety – 6.88 t ha^{-1} with sowing on October 20, which exceeds the control by 0.70 t ha^{-1} (11.3%). Kraevyd variety was the least sensitive to the factor of sowing time. Thus, its yield in the experiment varied between 6.18–6.88 t ha^{-1} and was the lowest for sowing on September 10. While yielding capacity of most varieties under conditions of sowing in later periods decreased and was lower than in the control variant, the yield index of Kraevyd variety even when sown on November 1 exceeded the control by 0.42 t ha^{-1}, which is 6.8% higher than the control (Table 2).

The least productive in the reporting year was variety Svitanok Myronivsky, yielding capacity of which was 3.78–4.88 t ha^{-1} depending on sowing date and these indices were the same to the last sowing dates.

Thus, under conditions of 2020, yielding capacity of winter wheat by sowing dates (on average by variety) was as follows: September 1 – 5.72 t ha^{-1}, September 10 – 5.54 t ha^{-1}, September 20 – 5.41 t ha^{-1}, October 1 – 5.45 t ha^{-1}, October 10 – 4.87 t ha^{-1}, October 20 – 5.11 t ha^{-1}, November 1 – 5.06 t ha^{-1}. Protein content value

Table 2. Elements of the crop structure and yielding capacity of winter wheat varieties depending on sowing dates, 2020

Varieties	Plant height, cm	Productive stalk-standing, pcs/m^2	Number of grains, pcs/ear	Mass of grains, g/ear	Mass of 1000 grains, g	Yielding capacity, t ha^{-1}
September 1						
Podolianka	111	648	28	0.86	36.9	5.55
Bogdana	113	672	27	0.90	36.2	5.32
Zdobna	102	630	28	1.12	40.0	6.61
Pylypivka	109	636	30	1.22	40.0	6.30
Kraievyd	94	618	30	1.20	40.5	6.69
Svitanok Myronivsky	91	623	29	0.96	32.9	4.88
Average	103	638	29	1.04	37.8	5.72
September 10						
Podolianka	111	594	30	1.13	37.7	5.46
Bogdana	112	618	29	1.07	37.2	5.33
Zdobna	99	624	31	1.24	39.4	5.67
Pylypivka	109	594	33	1.33	40.4	6.06
Kraievyd	94	606	32	1.29	40.1	6.18
Svitanok Myronivsky	87	612	27	0.95	34.5	4.52
Average	101	608	30	1.17	38.2	5.54
September 20						
Podolianka	112	546	29	1.10	37.8	4.70
Bogdana	115	558	29	1.08	37.4	4.66
Zdobna	99	600	28	1.10	39.8	6.02
Pylypivka	108	618	28	1.20	42.2	6.06
Kraievyd	95	630	28	1.21	42.3	6.24
Svitanok Myronivsky	81	660	28	0.85	30.8	4.78
Average	102	602	28	1.09	38.4	5.41
October 1						
Podolianka	96	558	28	1.05	37.9	4.80
Bogdana	99	600	27	1.00	37.1	4.85
Zdobna	94	552	29	1.20	42.0	5.60
Pylypivka	106	660	28	1.08	39.3	6.22
Kraievyd	89	582	33	1.36	41.0	6.56
Svitanok Myronivsky	80	636	26	0.81	31.1	4.65
Average	94	598	28	1.08	38.1	5.45
October 10						
Podolianka	96	690	25	0.80	32.0	4.60
Bogdana	99	588	28	0.91	32.5	4.13
Zdobna	86	762	24	0.84	35.4	4.95
Pylypivka	101	720	28	0.92	32.7	5.53
Kraievyd	85	648	32	1.14	35.8	6.21
Svitanok Myronivsky	74	582	31	0.81	26.4	3.79
Average	90	665	28	0.90	32.5	4.87
October 20						
Podolianka	95	702	27	0.74	27.6	4.28
Bogdana	96	624	26	0.85	32.3	4.27
Zdobna	83	600	28	1.07	38.1	5.18
Pylypivka	100	672	33	1.00	30.7	5.82
Kraievyd	85	606	36	1.30	36.3	6.88
Svitanok Myronivsky	74	684	28	0.74	26.6	4.20
Average	89	648	30	1.0	31.9	5.11
November 1						
Podolianka	90	528	28	1.03	36.4	4.52
Bogdana	95	516	29	1.04	35.5	4.58
Zdobna	81	612	28	1.13	35.5	5.12
Pylypivka	94	618	32	1.11	34.9	5.78
Kraievyd	80	708	30	1.08	35.9	6.60
Svitanok Myronivsky	69	606	31	0.73	24.6	3.78
Average	85	598	30	1.0	33.8	5.06
LSD_{05} t ha^{-1} for the factor sowing terms					0.41	
LSD_{05} t ha^{-1} for the factor variety					0.30	

- one of the most important indices of wheat bread quality is important in evaluating technological properties of grain. The more protein contain grain, the higher its nutritional value is. During sowing period of September 1, the highest protein content was determined for Bohdana and Kraevyd varieties – 11.9% (3rd class), gluten content for varieties Kraevyd – 23.9% and Zdobna – 23.2% (2nd class).

For sowing on September 10, the highest protein content was obtained in Pylypivka and Kraevyd varieties at the level of 11.6% (3rd class), gluten in Kraevyd and Zdobna varieties – 23.7 and 23.6% (2nd class), respectively. When sowing on September 20, October 1, all the varieties belonged to class 3 (11.0–12.2%) by protein content index and by gluten content, except for Krayevid variety - 23.5 and 23.8% (class 2), respectively. For sowing on October 10, Kraevyd variety had the maximum protein content of 12.4% (class 2), all other varieties belong to class 3 by grain quality indices. Kraevyd, Pylypivka and Zdobna varieties belong to the 2nd class (23.2 and 23.0%), all others - to the 3rd class. When sowing on October 20, most varieties, except Svitanok Myronivskyi, were distinguished by increased content of gluten, compared to other sowing dates, so this index was set at 23.0–23.7, depending on variety, which belongs to the 2nd class of grain quality. The highest protein content was formed when sowing on November 1 in varieties Kraevyd, Podolyanka and Bohdana (12.4, 12.3 and 12.2%, respectively). Gluten content during this sowing period was the highest in Kraevyd and Pylypivka varieties, 23.8 and 23.7%, respectively, which belongs to the 2nd class of grain quality (Table 3).

During early sowing period on September 1, were obtained good yields of winter wheat grain – on average of 5.72 t ha^{-1} by variety. During this sowing period, the lowest prime cost of 1 ton of grain according to the experiment was obtained in Kraevyd variety – 93.3 € t^{-1} (was the lowest) and the maximum level of profitability was 124.8%. On average by varieties, the prime cost of 1 ton of grain for this sowing period was 110.2 € t^{-1}, and profitability level was 92.4%. Calculated profit from cultivation the crop on average by variety for this sowing period is 576.5 € ha^{-1} (Table 4).

During sowing on September 10, the prime cost of winter wheat varied between 101.0 € t^{-1} for Kraevyd variety and up to 138.0 € t^{-1} for Svitanok Myronivskyi variety. At the same time, profitability level was determined to be within 107.7% for Krayevid variety and 51.9% for Svitanok Myronivskyi variety.

The lowest indices of economic efficiency on average for the studied varieties were obtained under conditions of sowing on October 10, where the lowest crop yield was formed. On average by varieties, under these conditions, the prime cost of winter wheat grain was 131.8 € t^{-1}, and profitability was 63.6%.

Table 3. Influence of sowing dates on the quality of winter wheat grain, 2020

Variety	1.09		10.09		20.09	
	Protein	Gluten	Protein	Gluten	Protein	Gluten
Podolianka	11.7	22.2	11.3	22.9	11.7	22.5
Bogdana	11.9	22.8	11.3	22.6	11.6	22.4
Zdobna	11.1	23.2	11.1	23.6	11.3	22.7
Pylypivka	11.3	22.6	11.6	22.8	11.3	22.3
Kraievyd	11.9	23.9	11.6	23.7	11.3	23.5
Svitanok Myronivsky	11.0	21.6	11.3	20.6	11.0	20.5
Average	11.5	22.7	11.4	22.7	11.4	22.3

Variety	01.10		10.10		20.10		01.11	
	Protein	Gluten	Protein	Gluten	Protein	Gluten	Protein	Gluten
Podolianka	12.3	22.1	11.9	22.7	11.9	23.0	12.3	22.8
Bogdana	11.9	22.6	11.9	22.5	11.9	23.2	12.2	22.7
Zdobna	11.9	22.4	11.6	23.0	11.3	23.1	11.6	22.6
Pylypivka	11.6	22.7	11.6	23.0	11.9	23.6	11.9	23.7
Kraievyd	12.2	23.8	12.4	23.2	12.2	23.7	12.4	23.8
Svitanok Myronivsky	11.0	20.2	11.3	21.9	11.0	21.5	11.0	20.8
Average	11.8	22.3	11.8	22.7	11.7	23.0	11.9	22.7

Table 4. Economic efficiency indices of growing winter wheat varieties when sowing at different dates, 2020

Variety	Sowing terms		
	September 1		
	Prime cost 1 t, €	Calculated profit, € ha^{-1}	Calculated level of profitability, %
Podolianka	112.4	539.8	86.5
Bogdana	117.3	491.6	78.8
Zdobna	111.2	552.4	88.5
Pylypivka	99.0	697.1	111.7
Kraievyd	93.3	778.8	124.8
Svitanok Myronivsky	127.8	399.3	64.0
Average	110.2	576.5	92.4
September 10			
Podolianka	114.3	520.9	83.5
Bogdana	117.1	493.7	79.1
Zdobna	110.0	565.0	90.6
Pylypivka	103.0	646.7	103.7
Kraievyd	101.0	671.9	107.7
Svitanok Myronivsky	138.0	10039	51.9
Average	113.9	537.0	86.1
September 20			
Podolianka	132.7	361.6	58.0
Bogdana	133.9	353.2	56.6
Zdobna	103.6	638.4	102.3
Pylypivka	103.0	646.7	103.7
Kraievyd	100.0	648.5	109.7
Svitanok Myronivsky	130.5	378.4	60.6
Average	117.3	510.5	81.8
October 1			
Podolianka	130.0	382.5	61.3
Bogdana	128.6	393.0	63.0
Zdobna	111.4	550.3	88.2
Pylypivka	100.3	680.3	109.0
Kraievyd	95.1	751.6	120.0
Svitanok Myronivsky	134.2	351.1	56.3
Average	116.6	518.2	83.0
October 10			
Podolianka	135.6	340.6	54.6
Bogdana	151.1	242.1	38.8
Zdobna	126.0	414.0	66.4
Pylypivka	112.8	535.6	85.8
Kraievyd	100.5	678.2	108.7
Svitanok Myronivsky	164.6	170.8	27.4
Average	131.8	396.9	63.6
October 20			
Podolianka	145.8	273.5	43.8
Bogdana	146.1	271.4	43.5
Zdobna	120.4	462.2	74.1
Pylypivka	107.2	596.4	95.6
Kraievyd	90.7	818.7	131.2
Svitanok Myronivsky	148.5	256.7	41.1
Average	126.5	446.5	71.6
November 1			
Podolianka	138.0	323.8	51.9
Bogdana	136.2	336.4	53.9
Zdobna	121.9	449.6	72.1
Pylypivka	107.9	588.0	94.2
Kraievyd	94.5	760.0	121.8
Svitanok Myronivsky	165.1	168.7	27.0
Average	127.3	437.8	70.2

When growing winter wheat in the experiment the lowest economic efficiency was obtained in Svitanok Myronivsky variety for sowing on October 10: the prime cost was 164.6 € t^{-1}, calculated profit was 170.8 € ha^{-1}, and profitability – 27.4%. In general, indices of economic efficiency slightly decreased with delaying of sowing period, depending on the trend of yield changes in the experiment.

CONCLUSIONS

During winter period of 2019–2020, there were satisfactory conditions for winter crops overwintering. Since the plants did not feel negative effects of low temperatures during most of this time and they were adequately supplied with moisture, then they resumed vital processes during daylight hours. Such conditions were in favor of winter wheat crops with late sowing periods, on a significant part of which the plants reached tillering phase already in winter period. Yielding capacity of winter wheat by sowing dates (on average by variety) was obtained as following: September 1 – 5.72 t ha^{-1}, September 10 – 5.54 t ha^{-1}, September 20 – 5.41 t ha^{-1}, October 1 – 5.45 t ha^{-1}, October 10 – 4.87 t ha^{-1}, October 20 – 5.11 t ha^{-1}, November 1 – 5.06 t ha^{-1}.

The most productive winter wheat varieties under conditions of 2020 were Kraevyd and Pylypivka. Their yielding capacity, depending on the time of sowing, varied between 6.18–6.88 t ha^{-1} and 5.53–6.30 t ha^{-1}, respectively. Bohdana (4.13–5.33 t ha^{-1}) and Svitanok Myronivskyi (3.78–4.88 t ha^{-1}) were characterized by the lowest yield in the experiment. Winter wheat grain of most varieties according to quality indices belong to the 2nd and 3rd classes. In terms of grain quality, winter wheat varieties of different sowing periods differed little among themselves. Indices of economic efficiency slightly decreased with delay of sowing period, depending on the tendency of yielding capacity changes in the experiment.

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