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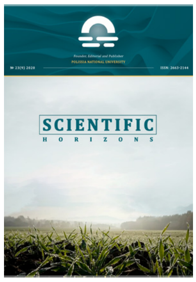

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Productivity of winter wheat depending on sowing dates and fertilisation

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Abstract. Modern varieties of winter wheat have high genetic productivity potential that can be realised through improved cultivation techniques, including sowing dates optimisation, fertiliser system optimisation, and the application of microelements, which determines the relevance of this study. The purpose of the study is to substantiate the specific features of winter wheat productivity formation based on cultivation techniques in the Carpathian region. The research utilised field, laboratory (for grain quality determination), and statistical methods (for data reliability assessment). Field studies were conducted during 2021-2022 on grey forest surface-eroded soils. The

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growth and development characteristics of the Estafeta Myronivska, Dovira Odeska, and Akhim winter wheat varieties sown at different dates (September 20, October 5, October 20) were investigated. It was found that grain yield and individual productivity indicators of the studied winter wheat varieties varied depending on sowing dates, mineral fertilizer doses, foliar feeding, and varietal traits. The highest individual plant productivity indicators were achieved by the Estafeta Myronivska, Dovira Odeska, and Akhim varieties sown on October 5 with mineral fertiliser application $N_{120}P_{90}K_{90}$ (including $N_{30}P_{90}K_{90}$ applied during cultivation, N_{15} after soil thawing, N_{45} (in the BBCH 29-30 growth stage), N_{30} (BBCH 55-57) with dual application of micronutrients (Aidamin-complex foliar feeding). As a result of the studied factors, an increase in the number of productive stems, grains per stem, and grain weight per spike was observed. The highest grain yield among the studied varieties was achieved by the Estafeta Myronivska variety (5.65 t/ha) when sown on October 5 with $N_{120}P_{90}K_{90}$ and Aidamin-complex foliar feeding. The research results can be used to adjust the cultivation techniques of winter wheat in production conditions to increase yield and grain quality

Keywords: winter wheat; varieties; mineral fertilizers; foliar feeding; cultivation techniques

INTRODUCTION

An essential aspect of introducing new varieties of winter wheat into production is the improvement of existing cultivation techniques. In the current context of global warming and climate change, it is particularly important to justify and develop measures to mitigate the negative impact of changing temperature regimes and soil moisture deficits. According to L. Wilson *et al.* (2021), since the beginning of the 20th century, the average annual air temperature has increased by 2.0 degrees, including 1.2 degrees since the 1990s. Climate change, according to O. Tarariko *et al.* (2022), observed in recent decades, the extension of the autumn vegetation period, the increase in winter temperatures, and the reduction of the spring period, prompt the need to adjust cultivation techniques for agricultural crops, including reviewing sowing dates, which directly affect the growth, development, winter survival, yield, and grain quality of winter wheat plants.

B. Bliznyuk *et al.* (2019) described how sowing dates in various soil-climatic zones differ and significantly depend on weather conditions, soil moisture reserves, predecessors, and other factors. Only by sowing at optimal dates is it possible to achieve high grain yield and corresponding quality.

Several researchers, including U. Madhu *et al.* (2018) and A. Siroshtan *et al.* (2021), highlighted the influence of sowing dates and predecessors on the yield and certain quality indicators of winter wheat grain in their studies. S. Poltoretskyi *et al.* (2020) indicate the trend of shifting optimal sowing dates for winter wheat to later periods due to the rise in autumn temperatures. According to V. Petrychenko & O. Korniychuk (2018) note that the warming of the first half of November amounts to 1.8°C, significantly reducing the impact of late sowing dates on plant winter survival and yield formation, allows for the extension of acceptable sowing dates to later periods. I. Yarchuk & T. Melnyk (2018) similarly mention the 1.8°C warming in the first half of November, weakening the influence of late sowing dates on plant winter survival and yield formation, also permits the shift of acceptable sowing dates to later periods. Specifically, the shift of winter wheat sowing dates towards later periods is indicated by O.L. Ulich (2018): by 30 days compared to sowing dates in the 1950s, and by 10 days in the 1990s.

Equally important is the question of intensifying grain production by fully reaching the genetic potential of winter wheat varieties through the use of macro- and micronutrients that stimulate their growth and development. Agrotechnical measures should aim to create optimal conditions for ensuring high yields in agroecosystems. In particular, O. Markovska & T. Grechishkina (2020) highlighted the effectiveness of nitrogen fertilisation and foliar micronutrient application.

Correctly determined winter cereal sowing dates are among the most important conditions for increasing yields and reducing grain production costs, which directly influence yield indicators. Therefore, the purpose of this study is to determine the characteristics of productivity and yield formation elements of winter wheat varieties under the influence of mineral fertilisation and foliar micronutrient application at different sowing dates.

MATERIALS AND METHODS

The study was conducted during 2021-2022 in the fields of the Institute of Agriculture of the Carpathian Region of the National Academy of Agrarian Sciences of Ukraine on grey forest surface-eroded loamy soil with the following agrochemical properties (prior to the experiment initiation): humus (according to Tyurin) – 1.97-2.2%, pH (soil extract) – 4.8-5.2, labile nitrogen – 99.0-114.2 mg/kg soil (determined by the Cornfield method according to DSTU 7863:2015 (2015)), available phosphorus and exchangeable potassium – 95.2-101.1 and 107.1-112.0 mg/kg soil, respectively (analyzed by the Kirzanov method according to DSTU 4405:2005 (2005)).

Factor A – Varieties:

1. Estafeta Myronivska; 2. Dovira Odeska; 3. Akhim;

Factor B – Sowing Dates: 1. 20.09; 2. 05.10; 3. 20.10.

Factor C – Fertilisation:

1. $N_{60}P_{60}K_{60}$ ($N_{30}P_{60}K_{60}$ under cultivation + N_{30} (BBCH 29-30);

2. $N_{120}P_{90}K_{90}$ ($N_{30}P_{90}K_{90}$ under cultivation + N_{15} – on permafrost soil + N_{45} (BBCH 29-30) + N_{30} (BBCH 55-57);

3. $N_{120}P_{90}K_{90}$ ($N_{30}P_{90}K_{90}$ (under cultivation) + N_{15} (on permafrost soil) + N_{45} and Aidamin complex foliar fertilisation (1.0 l/ha) (BBCH 29-30) + N_{30} and Aidamin complex foliar fertilisation (1.0 l/ha.) (BBCH 55-57).

Sowing area of the plot – 40.8 m^2, accounting – 25 m^2, with a repetition of 4 times. Predecessor: oat for green manure. Mineral fertilisers were applied according to the experimental scheme. Micronutrient fertiliser used: concentrated chelate Aidamin complex foliar fertilisation. Plant protection measures: seed treatment with Vitavax 200 FF, 34% active substance concentration (3.0 l/ton), weed control (herbicide – Grodil Maxi, 37.5% active substance concentration (0.09-0.11 l/ha)), disease control (fungicide Alto-Super, 0.5 l/ha), pest control (insecticide Karate, 0.2 l/ha), considering EDT (economic damage threshold). Field experiments were conducted according to V. Ushkarenko *et al.* (2019). Harvesting was done using the "Sampo-130" combined with subsequent adjustment to standard (14%) grain moisture content. Statistical analysis of the results was conducted using the "Statistica 6.0" and "Excel 2003" software.

Experimental plant research (both cultivated and wild species), including plant material collection, adhered to institutional, national, or international ethical principles. The authors followed the standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS AND DISCUSSION

The effectiveness of the technological elements is primarily determined based on the productivity and yield indicators of winter wheat. These indicators comprehensively reflect the impact of growing conditions on the individual growth and development processes of the plants. The sowing dates and the fertiliser application system throughout the winter wheat's growing period play a crucial role in the system of agronomic cultivation practices. They directly influence the course of vegetation, overwintering, and the specific formation of plant productivity.

The research results show that sowing dates and the application of mineral fertilisers and foliar microelement fertilisation significantly influence the formation of individual productivity of winter wheat (Table 1). In 2021, the varieties "Estafeta Myronivska" and "Dovira Odeska" formed the highest number of productive stems during the second sowing period, with an average of 536 and 532 stems/m^2, respectively. The "Akhim" variety formed an average of 471 stems/m^2 during the sowing on September 20th. During this sowing period, the maximum biological yield of varieties was also formed: "Estafeta Myronivska" averaged 7.27 t/ha, "Dovira Odeska" – 6.34 t/ha, and "Akhim" - 6.27 t/ha. Sowing 15 days earlier than the specified date (20.09) resulted in a reduction in biological yield compared to the maximum values: "Estafeta Myronivska" had an average reduction of 1.27 t/ha, "Dovira Odeska" – 0.83 t/ha, and "Akhim" – 0.09 t/ha. Later sowing dates (20.10) led to a decrease in this indicator by 1.99, 0.82, and 1.0 t/ha, respectively.

Table 1. *Yield structure and biological yield of winter wheat depending on sowing dates and fertilization, 2021-2022*

Var. No.	Elements of the crop structure									Biological yield, t/ha		
	product quantity, stems, pcs.			number of grains in an ear, pcs.			grain weight of 1 ear, g					
	2021	2022	Avg.	2021	2022	Avg.	2021	2022	Avg.	2021	2022	Avg.
1	2	3	4	5	6	7	8	9	10	11	12	13
Estafeta Myronivska Variety (sowing period I)												
1	418	460	439	31.5	30.24	30.9	1.23	1.20	1.22	5.14	5.52	5.33
2	488	514	501	32.6	31.60	32.1	1.30	1.28	1.29	6.34	6.58	6.46
3	480	519	500	33.3	32.90	33.1	1.36	1.34	1.35	6.53	6.89	6.71
Avg.	462	498	480	31.97	31.58	32.03	1.30	1.27	1.29	6.0	6.33	6.17
Estafeta Myronivska Variety (sowing period II)												
1	532	450	491	33.2	33.6	33.4	1.28	1.27	1.28	6.81	5.69	6.25
2	540	520	530	34.4	34.6	34.5	1.38	1.39	1.39	7.45	7.23	7.34
3	536	528	532	34.9	34.9	34.9	1.41	1.40	1.41	7.56	7.39	7.48
Avg.	536	499	518	34.2	34.4	34.3	1.36	1.35	1.36	7.27	6.77	7.02
Estafeta Myronivska Variety (sowing period III)												
1	413	450	432	30.3	33.3	31.8	1.13	1.25	1.19	4.67	5.62	5.14
2	469	494	482	33.6	34.2	33.8	1.27	1.37	1.32	5.95	6.77	6.36
3	471	502	487	34.2	34.6	34.4	1.30	1.38	1.34	6.12	6.93	6.53

Table 1, Continued

Var. No.	Elements of the crop structure									Biological yield, t/ha		
	product quantity, stems, pcs.			number of grains in an ear, pcs.			grain weight of 1 ear, g					
	2021	2022	Avg.	2021	2022	Avg.	2021	2022	Avg.	2021	2022	Avg.
Avg.	451	482	467	32.7	34.0	33.3	1.23	1.33	1.28	5.58	6.44	6.01
Dovira Odeska Variety (sowing period I)												
1	547	445	496	25.1	27.35	26.3	0.91	1.00	0.96	4.98	4.45	4.72
2	518	475	497	28.8	29.20	29.0	1.10	1.12	1.11	5.70	5.32	5.51
3	495	490	493	30.2	30.04	30.1	1.18	1.13	1.16	5.84	5.54	5.69
Avg.	520	470	495	28.03	28.9	28.5	1.06	1.08	1.08	5.51	5.10	5.31
Dovira Odeska Variety (sowing period II)												
1	508	485	497	30.7	30.02	30.4	1.19	1.04	1.12	5.90	5.04	5.47
2	553	518	536	30.9	30.78	30.8	1.20	1.17	1.19	6.52	6.06	6.29
3	537	534	536	31.6	30.98	31.1	1.25	1.18	1.22	6.61	6.30	6.46
Avg.	532	512	523	31.1	30.6	30.8	1.21	1.13	1.18	6.34	5.80	6.07
Dovira Odeska Variety (sowing period III)												
1	426	426	426	29.7	31.16	30.4	1.12	1.00	1.06	4.77	4.26	4.52
2	493	454	474	30.4	32.41	31.4	1.18	1.20	1.19	5.82	5.45	5.64
3	489	465	477	31.4	32.80	32.1	1.22	1.25	1.24	5.96	5.81	5.89
Avg.	469	448	459	30.5	32.1	31.3	1.17	1.15	1.16	5.52	5.17	5.35
Akhim Variety (sowing period I)												
1	446	449	448	35.1	33.48	34.3	1.27	1.07	1.17	5.66	4.80	5.23
2	474	475	475	35.4	35.64	35.5	1.31	1.23	1.27	6.21	5.86	6.04
3	494	482	488	35.9	35.80	35.9	1.35	1.27	1.31	6.67	6.12	6.40
Avg.	471	469	470	35.47	35.0	35.2	1.31	1.19	1.25	6.18	5.59	5.89
Akhim Variety (sowing period II)												
1	412	451	432	34.6	34.0	34.3	1.29	1.20	1.25	5.51	5.40	5.46
2	441	510	476	36.2	35.08	35.7	1.42	1.28	1.35	6.55	6.53	6.54
3	449	514	482	36.8	35.12	36.0	1.48	1.30	1.39	6.76	6.68	6.72
Avg.	434	492	463	35.87	34.7	35.3	1.4	1.26	1.33	6.27	6.20	6.24
Akhim Variety (sowing period III)												
1	373	441	407	33.3	34.00	33.7	1.15	1.10	1.13	4.47	4.85	4.66
2	406	474	440	37.4	35.00	36.2	1.37	1.27	1.32	5.60	6.02	5.81
3	410	480	445	37.9	36.02	37.0	1.41	1.30	1.36	5.74	6.24	5.99
Avg.	396	465	431	36.2	35.0	35.6	1.33	1.22	1.27	5.27	5.70	5.49

Source: *compiled by the authors*

In 2022, the highest number of grains per spike was observed in the "Akhim" variety, averaging 34.7-35.0 grains, followed by "Estafeta Myronivska" with 31.58-34.4 grains, and "Dovira Odeska" with 28.9-32.1 grains. In terms of grain weight per spike, the "Estafeta Myronivska" variety stood out with weights of 1.27-1.35 g. The "Akhim" variety had grain weights of 1.19-1.26 g per spike, while "Dovira Odeska" had grain weights of 1.08-1.15 g. Among the studied varieties, the highest biological yield was achieved by the "Estafeta Myronivska" variety sown on October 5th, 2021, with $N_{120}P_{90}K_{90}$ fertiliser and foliar microelement fertilization (7.48 t/ha).

Across all experimental variants, regardless of sowing dates, there was an increase in the structural yield indicators (number of grains per spike, grain weight per spike) and grain quality due to the application of mineral fertiliser at a rate of $N_{120}P_{90}K_{90}$ and foliar microelement fertilisation during the IV and VIII stages of organogenesis. According to the research results, among all the varieties, the highest yield in 2021 was achieved by sowing the "Estafeta Myronivska" variety on October 5th (Table 2). The grain yield for the $N_{60}P_{60}K_{60}$ fertiliser treatment was 4.45 t/ha. Increasing the rate of mineral fertilisation to $N_{120}P_{90}K_{90}$ resulted in a significant yield increase of 1.3 t/ha compared to the control, and the use of the "Aidamin" complex fertiliser led to a yield increase of 0.25 t/ha.

Table 2. *Winter wheat yield depending on sowing dates, varieties, and nutrient backgrounds, 2021-2022, t/ha*

Variant	Yield, t/ha			Increase from fertiliser, t/ha			Increase from microfertilisers, t/ha		
	2021	2022	Avg.	2021	2022	Avg.	2021	2022	Avg.
1	2	3	4	5	6	7	8	9	10
Estafeta Myronivska Variety (sowing period I)									
$N_{60}P_{60}K_{60}$	4.09	4.00	4.05	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	5.04	5.03	5.04	0.95	1.03	0.99	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	5.26	5.27	5.27	1.17	1.27	1.22	0.22	0.24	0.23
Average	4.8	4.77	4.79						
Estafeta Myronivska Variety (sowing period II)									
$N_{60}P_{60}K_{60}$	4.45	4.32	4.39	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	5.75	5.54	5.65	1.3	1.22	1.26	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	6.0	5.65	5.83	1.55	1.33	1.44	0.25	0.11	0.18
Average	5.42	5.17	5.29						
Estafeta Myronivska Variety (sowing period III)									
$N_{60}P_{60}K_{60}$	3.75	4.15	3.95	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	4.76	5.18	4.97	1.01	1.03	1.02	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	4.93	5.30	5.12	1.18	1.15	1.17	0.17	0.12	0.15
Average	4.48	4.88	4.68						
Dovira Odeska Variety (sowing period I)									
$N_{60}P_{60}K_{60}$	3.56	3.23	3.40	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	4.51	4.07	4.29	0.95	0.84	0.90	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	4.68	4.24	4.46	1.12	1.01	1.07	0.17	0.17	0.17
Average	4.25	3.85	4.05						
Dovira Odeska Variety (sowing period II)									
$N_{60}P_{60}K_{60}$	4.36	3.79	4.08	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	5.35	4.81	5.08	0.99	1.02	1.01	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	5.47	4.92	5.20	1.11	1.13	1.12	0.12	0.11	0.12
Average	5.06	4.51	4.79						
Dovira Odeska Variety (sowing period III)									
$N_{60}P_{60}K_{60}$	3.47	3.26	3.37	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	4.66	4.35	4.51	1.19	1.09	1.14	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	4.78	4.45	4.62	1.31	1.19	1.25	0.12	0.10	0.11
Average	4.30	4.02	3.75						
Akhim Variety (sowing period I)									
$N_{60}P_{60}K_{60}$	4.08	3.54	3.81	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	5.13	4.57	4.85	1.05	1.03	1.04	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	5.28	4.70	4.99	1.2	1.16	1.18	0.15	0.13	0.14
Average	4.83	4.27	4.55						
Akhim Variety (sowing period II)									
$N_{60}P_{60}K_{60}$	4.26	4.13	4.20	-	-	-	-	-	-

Table 2, Continued

$N_{120}P_{90}K_{90}$	5.29	5.07	5.18	1.03	0.94	0.99	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	5.47	5.18	5.33	1.21	1.05	1.13	0.18	0.11	0.15
Average	5.0	4.79	4.90						
Akhim Variety (sowing period III)									
$N_{60}P_{60}K_{60}$	3.54	3.68	3.61	-	-	-	-	-	-
$N_{120}P_{90}K_{90}$	4.68	4.81	4.75	1.14	1.13	1.14	-	-	-
$N_{120}P_{90}K_{90}$ + Aidamin	4.89	4.96	4.93	1.35	1.28	1.32	0.21	0.15	0.18
Average	4.37	4.48	4.43						
$HIP_{0.5}$ t/ha A (dates)	0.058	0.061							
B (fertilisers)	0.058	0.064							
C (varieties)	0.058	0.061							
ABC (interaction)	0.173	0.190							

Source: *compiled by the authors*

In 2021, the winter wheat varieties "Dovira Odeska" and "Akhim" also achieved their maximum yield during the second sowing date (05.10), with average yields of 5.06 and 5.0 t/ha, respectively. The yield increase from fertilisation was 0.99 and 1.03 t/ha, and from foliar fertilisation was 0.12 and 0.18 t/ha. For the sowing on October 20th, 2021, the "Estafeta Myronivska" variety formed an average yield of 4.48 t/ha, which was 0.94 t/ha lower than the yield from the second sowing date, and 0.62 t/ha lower than the yield from the sowing on September 20th, 2021.

The average yield of the "Dovira Odeska" variety (4.25 t/ha) for the first sowing date (20.09.2021) was lower than that for the October 5th sowing (5.06 t/ha) by 0.81 t/ha, and for the October 20th sowing, it was lower by 0.76 t/ha (4.3 t/ha). The "Akhim" variety also experienced a significant reduction in yield compared to the second sowing date, with an average reduction of 0.17 t/ha for the September 20th sowing and 0.63 t/ha for the October 20th sowing. The yield increase of the winter wheat varieties from applying $N_{120}P_{90}K_{90}$ mineral fertiliser was 0.95-1.05 t/ha for the first sowing date, 0.99-1.03 t/ha for the second sowing date, and 1.01-1.19 t/ha for the third sowing date. Applying foliar microelement fertilization twice during the phases of BBCH 29-30 (1.0 L/ha) and BBCH 55-57 (1.0 L/ha) resulted in a significant yield increase ranging from 0.12 to 0.25 t/ha.

In 2022, the highest yields across all sowing dates were achieved by the "Estafeta Myronivska" variety, ranging from 4.77 to 5.17 t/ha. The yield of winter wheat was lower in the "Akhim" variety, ranging from 4.27 to 4.79 t/ha, which was 0.38-0.5 t/ha less. The lowest grain yield in 2022 was also observed in the "Dovira Odeska" variety, ranging from 3.85 to 4.51 t/ha. The highest yields were achieved by all studied varieties for the October 5th sowing: "Estafeta Myronivska" averaged 5.17 t/ha, "Dovira Odeska" – 4.51 t/ha, and "Akhim" – 4.79 t/ha. For the October 20th sowing, the "Estafeta Myronivska" variety formed an average yield of 4.77 t/ha, which was 0.4 t/ha lower than the yield from the second sowing date, and 0.29 t/ha lower for the September 20th sowing (4.88 t/ha).

The average yield of the "Dovira Odeska" variety (3.85 t/ha) for the first sowing date (20.09) was lower than that for the October 5th sowing (4.51 t/ha) by 0.66 t/ha, and for the October 20th sowing, it was lower by 0.49 t/ha (4.02 t/ha). The "Akhim" variety also experienced a significant reduction in yield compared to the second sowing date, with an average reduction of 0.52 t/ha for the September 20th sowing and 0.31 t/ha for the October 20th sowing. The yield increase of the winter wheat varieties from applying $N_{120}P_{90}K_{90}$ mineral fertiliser for the first sowing date compared to the control ranged from 0.84 to 1.03 t/ha. For the second – 0.94 to 1.22 t/ha, and for the third – 1.03 to 1.13 t/ha. Dual foliar fertilisation of winter wheat crops with "Aidamin-complex foliar fertilization" in the BBCH 29-30 (1.0 L/ha) and BBCH 55-57 (1.0 L/ha) stages resulted in a significant yield increase ranging from 0.10 to 0.24 t/ha. Yield increase from applying $N_{120}P_{90}K_{90}$ ranged from 0.84 to 1.22 t/ha. Among the studied variants, the highest yield was observed for the "Estafeta Myronivska" variety (5.65 t/ha) sown on October 5th with the application of $N_{120}P_{90}K_{90}$ and Aidamin-complex foliar fertilisation.

The research results indicate that the productivity of winter wheat agrocenoses, the formation of yield elements, vegetation conditions, and plant overwintering directly depend on sowing dates. The timing of sowing proved to be a key factor for wheat yield. Early sowing dates promoted more active plant development, resulting in a higher number of spikes per plant. On the other hand, later sowing led to the formation of fewer spikes but with a greater number of grains per spike. These growth and development differences can be utilised depending on cultivation goals, either for obtaining higher yield or preserving grain quality. This is consistent with data of V. Petrychenko & V. Lykhochvor (2020). L. Gandjaeva (2019) draws attention to a decrease in the level of achievement of the potential of crop productivity when the sowing time deviates from optimal. However, the question of optimal sowing dates remains debatable. According to V. Tkachuk & T. Tymoshchuk (2020), in the conditions of Polissya, the highest grain yield of winter wheat (3.56 t/ha) was achieved with a sowing date of September 10th. The yield decreased by 1.02 t/ha for the October 10th sowing.

I. Yarchuk & T. Melnyk (2018) established that plants sown on September 10th had the most significant parameters at the time of cessation of autumn vegetation. Later sowing dates resulted in a reduction in all biometric indicators: plant height, plant weight, number of stems, and nodal roots. Other researchers also point to better plant development for early sowing dates. According to A. Kryvenko *et al.* (2019), a higher yield of all studied winter wheat varieties (25.5% increase) was obtained for the October 5th sowing compared to the September 25th sowing. For this sowing date, the yield was 37.6 and 53.2% higher than for the October 15th and October 25th sowing dates, respectively. For the October 5th and 15th sowing dates, the winter wheat varieties formed the highest-quality grains by weight and 1000-seed mass.

However, the rise in temperature during the autumn vegetative period of winter wheat, along with the extension of its autumn growth and development period, encourages a reevaluation of sowing dates. As of the recommendation of G. Gutsol & I. Ovcharuk (2023), in the Right Bank Forest-Steppe zone, it is advisable to shift sowing dates by 11 days toward later dates, and in some years, these dates can be shifted even later. An increase in yield due to shifting sowing dates from September 10th to October 10th was obtained in H. Chuhrii's (2019) research. R. Vozhegova & V. Bily (2019) note that the highest number of productive stems and grains per spike was achieved with later sowing dates.

One of the main measures to increase the productivity of winter wheat and improve the quality of its grain is the use of mineral fertilisers. The obtained data confirm that fertilisation indeed affects the cultivation of wheat. The application of fertilisers contributed to yield increase, regardless of the sowing date. However, it is important to consider optimal doses, as excessive fertiliser application can lead to negative effects on plant health and product quality. The specified information is consistent with the data of M. Kulyk *et al.* (2020). V. Ivanina & I. Korotenko (2022) established that yield increase in cereal crops is achieved through mineral plant nutrition. In their study, applying $N_{80}P_{60}K_{60}$ under winter wheat in rotation with peas resulted in the highest grain yield (5.42 t/ha), exceeding the control without fertilisers by 1.02 t/ha. The application of fertilisers led to increased production regardless of the sowing date. Nevertheless, it is necessary to be cautious with fertiliser dosages, as their excessive use can lead to overgrowth of plants and adversely affect yield quality.

Thus, it is worth noting that the ongoing climate changes prompt a revision of established cultivation practices, particularly adjusting sowing dates. To achieve high yield performance in production, judicious use of foliar micro-fertilizers is recommended.

CONCLUSIONS

The results of the two-year study indicate that in the soil and climatic conditions of the Western Forest-Steppe, the maximum productivity of winter wheat sowing was achieved on October 5th. For this sowing date, the studied varieties achieved average yields of 4.79 t/ha (Dovira Odeska), 4.9 t/ha (Akhim), and 5.29 t/ha (Estafeta Myronivska). Shifting sowing dates either towards earlier (20.09) or later (20.10) resulted in yield reduction. Deviations from these indicators for the Estafeta Myronivska variety were 0.5 and 0.61 t/ha, for Dovira Odeska – 0.74 and 1.04 t/ha, for Akhim – 0.35 and 0.47 t/ha.

Increasing the rate of applying $N_{120}P_{90}K_{90}$ mineral fertilisers led to increased grain yield for all sowing dates. Depending on the variety and research variant, the yield increase ranged from 0.9 to 1.14 t/ha. Foliar fertilisation of plants with Aidamin-complex micro-fertiliser in the BBCH 29-30 and BBCH 55-57 stages resulted in additional yield growth of 0.11 to 0.23 t/ha. Among all varieties, the highest yield during the years of the study (5.65 t/ha) was achieved by the agrocenosis of the Estafeta Myronivska variety sown on October 5th, with the application of $N_{120}P_{90}K_{90}$ mineral fertilisers and Aidamin-complex foliar fertilisation (1.0 L/ha). The yield increase from mineral fertilisers was 1.22 t/ha, and from foliar micro-fertilisation, it was 0.11 t/ha.

The prospects for further research are associated with the selection of high-productivity winter wheat varieties, the search for new effective micro-fertilisers that would mitigate the impact of stress factors during the vegetation period and ensure yield stability. Another possible area is the influence of biological methods and modern technologies on the effectiveness of winter wheat cultivation.

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CONFLICT OF INTEREST

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Анотація. Сучасні сорти пшениці озимої мають високий генетичний потенціал продуктивності, реалізувати який можна за рахунок удосконалення елементів технології вирощування, зокрема строків сівби, оптимізації системи удобрення, застосування мікроелементів, що обумовлює актуальність дослідження. Метою роботи було обґрунтувати особливості формування продуктивності пшениці озимої залежно від елементів технології вирощування в умовах Карпатського регіону. У процесі виконання роботи використовували наступні методи: польовий, лабораторний (для визначення якісних показників зерна пшениці), та статистичний (для оцінки достовірності даних). Польові дослідження проводили впродовж 2021-2022 рр. на сірих лісових поверхнево оґлеєних ґрунтах. Досліджували особливості росту і розвитку сортів пшениці озимої Естафета миронівська, Довіра одеська і Ахім, висіяні в різні строки (20.09; 05.10; 20.10). Встановлено, що урожайність зерна і показники формування індивідуальної продуктивності досліджуваних сортів пшениці озимої змінювалися залежно від строків сівби, дози мінеральних добрив, листкового підживлення та сортових особливостей. Найвищі показники індивідуальної продуктивності рослин пшениці озимої сортів Естафета миронівська, Довіра одеська і Ахім сформовано за сівби 05.10 на фоні мінерального удобрення $N_{120}P_{90}K_{90}$ (із внесенням $N_{30}P_{90}K_{90}$ під культивацію, N_{15} – по мерзлоталому ґрунті, N_{45} (у фазу ВВСН 29-30), N_{30} (ВВСН 55-57) та дворазового внесення мікродобрив (Айдамін-комплексний листкове підживлення). У результаті дії досліджуваних факторів відзначено зростання кількості продуктивних стебел, зерен у колосі і ваги зерна з 1 колоса. Максимальну врожайність зерна з поміж досліджуваних сортів сформував сорт Естафета миронівська (5,65 т/га) за сівби 05.10 на варіанті внесення $N_{120}P_{90}K_{90}$ і листкового підживлення Айдаміном комплексним. Результати досліджень можуть бути використані для корегування елементів технології вирощування пшениці озимої у виробничих умовах для підвищення врожайності та якості зерна

Ключові слова: пшениця озима; сорти; мінеральні добрива; листкове підживлення; технології вирощування