UDC: 633.111“324”:631.559:006.83
DOI: 10.56407/bs.agrarian/4.2024.68

Ukrainian Black Sea Region Agrarian Science
Vol. 28, No. 4

Characteristics of soft winter wheat varieties by crop structure and grain quality indicators

Iryna Havryliuk*
Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2595-4620

Hanna Kovalyshyna
Doctor of Agriculture, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-2715-7679

Abstract. The purpose of the study was to investigate the collection of soft winter wheat varieties selected by four research institutions of Ukraine, covering Steppe and Forest-Steppe soil and climatic zones. As a result of the study, indicators of the yield structure and grain quality of 53 varieties of soft winter wheat were analysed. The obtained data allowed assessing the stability of productivity elements and identifying varieties with high indicators for further use in breeding. Based on the results obtained, tables and graphs were compiled that reflect the difference in structural indicators between varieties over the years of research, and an estimate of the frequency of distribution of such parameters as: the length of the ear rod, the weight of the ear, the number of spikelets per ear, the number of grains in the ear, the weight of grains from the ear, and the weight of 1,000 grains. Statistical analysis using ANOVA and construction of confidence intervals (significance level of 0.05) confirmed significant differences between varieties in terms of the indicators under study, which helped to identify varieties with high stability of grain yield and quality. When using correlation analysis, relationships between structural indicators were established. Special attention was paid to homeostatic varieties that showed high indicators during 2021/2022-2023/2024 studies, namely: the length of the ear rod, the number of spikelets per ear, and the weight of 1,000 grains, which are key breeding indicators to increase yields. Such indicators were determined by the specificity of genotypes, environmental conditions, and their interaction. After calculating the regression coefficient, varieties with a high level of adaptability were determined. The best varieties in terms of the parameters under study were recommended for further use in breeding programmes aimed at increasing productivity and improving the quality of soft winter wheat grain in the context of climate change

Keywords: weight of 1,000 grains; grain quality; protein; gluten; correlation; adaptability; homeostatic

INTRODUCTION

Wheat is one of the main food crops in Ukraine and the world. Increasing the productivity and adaptability of varieties directly affects food security, especially in the face of population growth, increased demand for grain, and climate change. Yield is one of the main indicators of productivity of a variety, which depends on

Article’s History:
Received: 30.07.2024
Revised: 18.10.2024
Accepted: 10.12.2024

Suggested Citation:
Havryliuk, I., & Kovalyshyna, H. (2024). Characteristics of soft winter wheat varieties by crop structure and grain quality indicators. *Ukrainian Black Sea Region Agrarian Science*, 28(4), 68-84. doi: 10.56407/bs.agrarian/4.2024.68.

*Corresponding author

various structural components, such as the number of ears per plant, the number of grains in the ear, and the weight of 1,000 grains. Evaluation of these parameters determines the most productive varieties adapted to specific growing conditions, considering climatic, soil, and agrotechnical factors. High-yielding varieties help to increase production efficiency, as they to get a stable yield with optimal use of resources. Grain quality is an equally important indicator, as it affects the nutritional and processing value of products. The main indicators of grain quality are the protein content, raw gluten, grain nature, and other parameters that affect its suitability for the bakery, confectionery, and other industries. The quality of grain also affects the possibility of its long-term storage and transportation, which is important for agro-industrial enterprises. The creation of modern wheat varieties requires a combination of inversely dependent characteristics in one genotype, such as productivity and quality, and the effectiveness of breeding will depend on the availability of genetic sources (Kyrylchuk & Kovalchuk, 2021). Therefore, it is the analysis of the crop structure and grain quality that allows breeders to identify varieties with optimal characteristics that increase the efficiency of agricultural production and meet modern market requirements (Lotysh & Kardash, 2021).

I. Shpakovych & H. Kovalyshyna (2023) investigated that the introduction of new varieties and species, in particular, the genus *Aegilops* as sources of valuable agricultural traits such as adaptability, and their inclusion in the scheme of the breeding process is an important condition for breeding. However, an important place in breeding for productivity remains for local varieties, especially in the context of climate change, soil degradation, and ecosystem destruction, including due to the consequences of military operations that do not avoid agricultural land. A. Ficiciyan *et al.* (2018) found that local varieties show high resistance to regional climatic conditions (droughts, high temperatures, frosts, etc.), which makes them stable in unstable and extreme weather conditions. In addition, such varieties are more adapted to local agroecosystems, and their study is the key to increasing the productivity of soft winter wheat varieties in modern conditions. The need to create new varieties adapted to changing climatic conditions with high yield and quality indicators determines the relevance of this study.

Numerous researchers have conducted studies to evaluate soft winter wheat varieties for yield and quality, and the results of their work have been used in the selection of modern wheat varieties. Z. Guo *et al.* (2018) investigated the impact on yield of various manipulations regarding the structure of the ear, namely, indicators of the structure of the wheat crop and how they can predict the yield and change the architectonics of the crop to increase the yield. S. Ebrahimnejad & V. Rameeh (2016) found a high coefficient of variation between the characteristics of ear weight and plant biological yield. Accordingly, the effectiveness of using such dependence in breeding for productivity will be high. In their studies, M. Lozinskiy *et al.* (2021) established the features of the development of the length of the main ear under various environmental conditions. They investigated the influence of the length of the main ear on the development of the number of spikelets per ear, the number of grains in the ear, and the weight of grain from the main ear, and based on the results obtained, they established the adaptability of soft winter wheat varieties under study.

Adaptability should be understood as the ability of a variety to combine a sufficiently high yield with stability in the face of climate change, while genotypes with hyperreaction to growth conditions should be considered sensitive (Lytvynenko *et al.*, 2013). According to M. Helguera *et al.* (2020), wheat grain quality indicators are a determining factor in its further use and the quality of products obtained on its basis. Therefore, in addition to yield indicators, grain quality indicators occupy an important place in the selection of soft winter wheat. Thus, one of the indicators used for selection in hybrid nurseries is the content of protein and raw gluten (Khan, 2019).

The purpose of the study was to analyse the structure of the crop and grain quality indicators of soft winter wheat varieties selected by various breeding and research institutions of Ukraine.

Objectives of the study:

- to establish the interdependence between crop structure indicators and grain quality;
- to identify sources of valuable traits in the varieties under study.

MATERIALS AND METHODS

The study analysed 53 varieties of soft winter wheat developed by 4 research institutes in Ukraine (Table 1). The study was conducted in accordance with the ethical standards provided for by the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973). The provisions of these documents aimed at protecting Biological Diversity and preventing threats to the species under study were observed.

Table 1. List of soft winter wheat varieties created in research institutions

No.	Names of varieties	Number of varieties	Originators of varieties
1	Spivanka Poliska, Kesaria Poliska, Namysto, Pyriatynka, Myroliubna, Pamyati Hirka, Krayevyd, Efektna, Merezhka, Poliska 90, Liubito, Polisianka, Vodohrai, Fortetsia Poliska, Shchedrivka Kyivska	15	Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine
2	MIP Yuvileyna, Svitanok Myronivskyi, Hratsia Myronivska, MIP Assol, Berehynia Myronivska, Hospodynia Myronivska, MIP Lada, Estafeta Myronivska, Oberih Myronivskyi, MIP Kniazhna, MIP Vyshyvanka, MIP Dniprianka, MIP Valencia	13	Myronivsky Institute of Wheat named after V.M. Remeslo
3	Legenda Bilotserkivska, Tsarivna, Perlyna Lisostepu, Hratsia Bilotserkivska, Ros, Romantyka, Kvitka Poliv, Lisova Pisnia, Rozumnytsia, Vodohrai Bilotserkivskyi, Vidrada, Hadzynka, Lybid, Charodiyka Bilotserkivska	14	Bila Tserkva Experimental and Breeding Station of the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences
4	Aksioma Odeska, Nota Odeska, Duma Odeska, Fortetsia, Versia Odeska, Mudrist Odeska, Sich, Oktava Odeska, Doskonalist Odeska, Optyma Odeska, Palitra	11	Plant Breeding and Genetics Institute – National Centre of Seed and Cultivar Investigation of the National Academy of Sciences of Ukraine

Source: *compiled by the authors*

The research was conducted during 2021/2022-2023/2024 in the fields of a separate division of the National University of Life and Environmental Sciences of Ukraine "Agronomic Experimental Station", located in the Forest-Steppe soil and climate zone of Ukraine. The main indicators for evaluating soft winter wheat varieties were: the length of the ear rod, the weight of the ear, the number of spikelets per ear, the number of grains in the ear, the weight of grain from the ear, the weight of 1,000 grains, the content of protein and gluten. The assessment was carried out in accordance with generally accepted methods, which allowed comparing varieties in terms of the main structural indicators and grain quality indicators and identifying the most promising ones for use in the selection of soft winter wheat. Grain quality indicators of soft winter wheat varieties were determined on the FOSS "Infratec 1241 Grain Analyzer" express whole grain analyser (Denmark) using the method of Z. Kyienko *et al*. (2017).

The quality class of wheat grain was determined according to DSTU 3768:2019 (2019). Statistical analysis of the data was performed using Microsoft Excel software and the online ANOVA Calculator. Basic calculations were performed using Excel, in particular, summation, calculation of average values, standard deviations, coefficients of variation, and the least significant difference (LSD) between indicators. ANOVA Calculator was used to analyse variance (ANOVA) to compare groups. Differences in the confidence level $p < 0.05$ were considered statistically significant.

Overall adaptive capacity was determined based on the calculation of the regression coefficient. If:

- $b_i = 1$ – it was considered that the variety was medium-adaptive;
- $b_i > 1$ – variety was high-yielding only under optimal growing conditions;
- $b_i < 1$ – variety was resistant to stressful environmental conditions.

Field experiments were conducted on plots of 6 m² each, with silage maize as the predecessor in all years of the study. Pre-sowing tillage included the introduction of a compensatory rate of fertilisers in the amount of $N_{90}P_{60}K_{90}$. The plots were not fertilised during the study period.

RESULTS AND DISCUSSION

As a result of three-year studies of 53 varieties of soft winter wheat, the main indicators of the crop structure and grain quality were analysed (Fig. 1). The length of the spike rod of plants in the experimental sample varied from 4.10 to 10.25 cm. The highest indicators were recorded in the varieties Legenda Bilotserkivska (the average length over the years of research was 9.08 cm) and Spivanka Poliska (the average indicator was 8.47 cm), which suggests their potential to form a larger number of spikelets per ear, and accordingly, a larger number of grains from the ear.

The number of spikelets per ear of the crop varieties under study ranged from 11.00 to 26.80 units. The number of spikelets per ear can be a limiting factor in the yield of a variety. This indicator was highest in the varieties Legenda Bilotserkivska (21.30 units), Fortetsia Poliska (19.90 units) and Kesaria Poliska (20.30 units). The number of grains in one spikelet is an indicator of seed development in a particular year under certain weather conditions and cultivation technology and directly affects the yield of the crop, and is a varietal feature of soft winter wheat. The number of grains in the ear over the years of research in varieties varied from 17.80 to 56.50 units. This indicator was highest in the following wheat varieties: Legenda Bilotserkivska (46.43 units), Spivanka Poliska (45.79 units) and Shchedrist Odeska (44.70 units). It is worth noting that in the 2023/2024 growing year, there was no significant difference between varieties, relative to the average number of grains by variety.

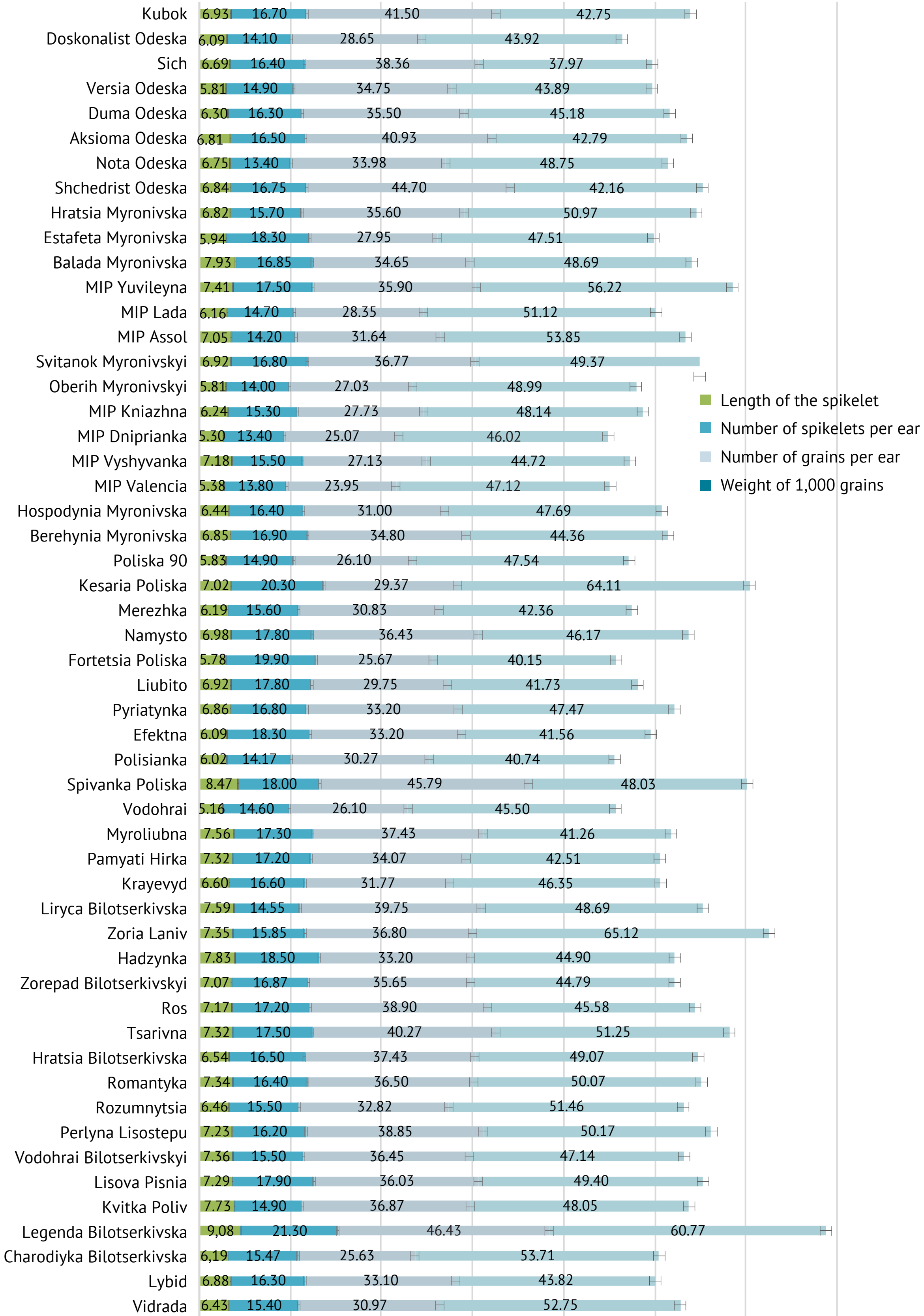

Figure 1. *Indicators of the yield structure of soft winter wheat varieties*

Source: *compiled by the authors*

Compared to previous indicators, the weight of 1,000 grains best reflects the quality and size of seeds. During the years of experiments, it ranged in varieties from 38.89 to 92.53 g. Thus, despite not significant previous indicators, high seed fullness and potentially high quality, due to the weight of 1,000 grains, were noted for a number of varieties: Vidrada (52.7 g), Charodiyka Bilotserkivska (53.7 g), Legenda Bilotserkivska (60.77 g), Perlyna Lisostepu (50.17 g), Rozumnytsia (51.46 g), Romantyka (50.07 g), Tsarivna (51.25 g), Zoria Laniv (65.10 g), Kesaria Poliska (64.11 g), MIP Assol (53.85 g), MIP Lada (51.12 g), MIP Yuvileyna (56.22 g), and Hratsia Myronivska (50.97 g). There was no significant difference between the varieties in this indicator in 2021/2022 and 2023/2024, which may indicate favourable growing conditions in these years in contrast to the 2022/2023 growing year.

Ear weight (Fig. 2) of soft winter wheat varieties under study were in the range of 0.85-3.85 g. For varieties with a high ear weight, both a high number of grains and the weight of grain from the ear were noted. These varieties include Spivanka Poliska (average weight 2.92 g) and Svitanok Myronivskyi (3.39 g). The weight of grain from the ear varied according to the varieties of soft winter wheat from 0.70 to 4.71 g. In the 2023/2024 growing year, soft winter wheat varieties did not have a significant difference in grain weight per ear relative to the average value for the year. The largest grain weight significantly different from the average value was observed for Legenda Bilotserkivska variety – 2.89 g.

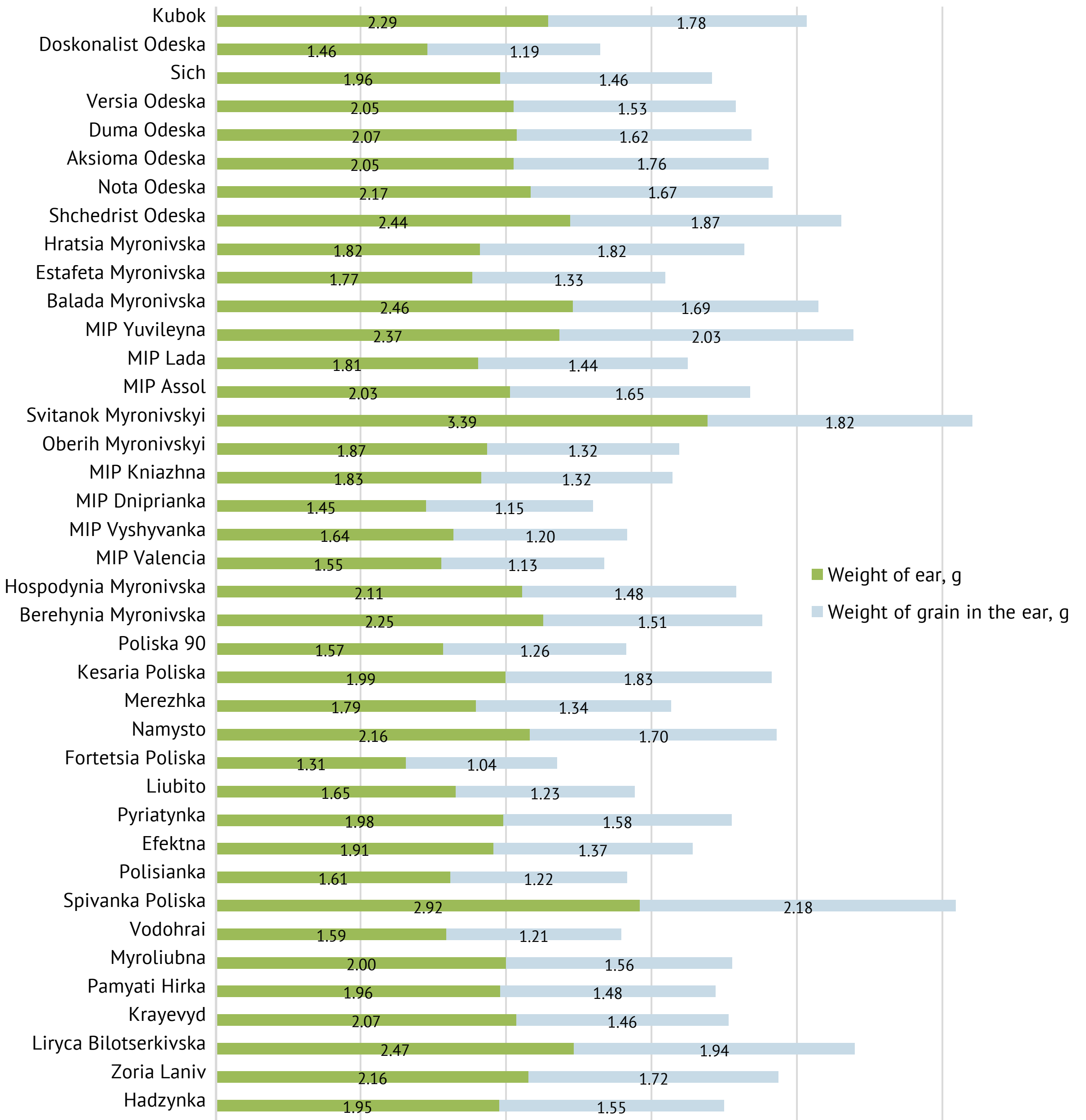

Figure 2, Continued

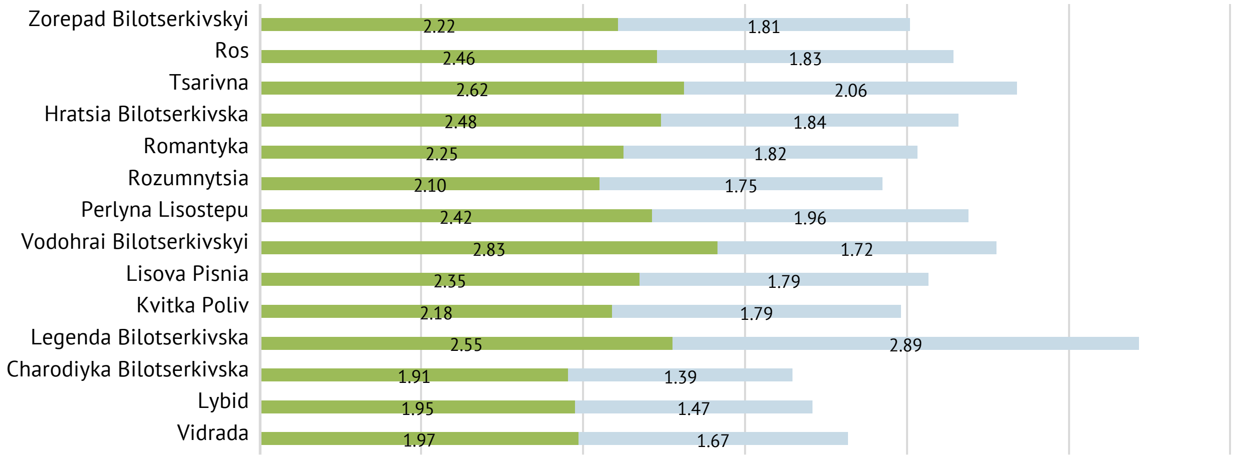

***Figure 2.** Yield of soft winter wheat varieties*

***Source:** compiled by the authors*

The variability of crop structure indicators depending on the year of research demonstrates that the 2023/2024 growing year was the most favourable for the development of soft winter wheat – all indicators are at a high level, while 2022/2023 was the least favourable. Homeostatic of the indicators under study (Table 2) indicates that the varieties of this sample have relatively stable indicators in the years of research in terms of the length of the ear rod, the number of spikelets per ear, and the weight of 1,000 seeds. Such structural indicators as the weight of the ear, the number of grains in the ear, and the weight of grain from the ear for most varieties have a high variation (>30%), respectively, it can be assumed that they depend on the environmental conditions of a particular year and cultivation technology. Several varieties of soft winter wheat were identified that strongly respond to changes in growing conditions in many respects: Legenda Bilotserkivska, Perlyna Lisostepu, Zorepad Bilotserkivskyi, Krayevyd, Pamyati Hirka, Posilianka, Liubito, Fortetsia Poliska, Merezhka, and Kesaria Poliska. These varieties have low homeostasis, so it is better to grow such varieties in regions with optimal growing conditions.

***Table 2.** Homeostatic indicators of the yield structure of soft winter wheat varieties*

No.	Variety	Coefficient of variation by indicators, %					
		spike rod length	ear weight	number of spikelets per ear	number of grains per ear	grain weight per ear	weight 1,000 grains
1	Vidrada	9.37	23.79	8.70	18.23	**36.31**	21.31
2	Lybid	12.32	20.65	5.62	20.00	28.13	10.66
3	Charodiyka Bilotserkivska	19.04	29.64	71.87	14.86	21.84	8.89
4	Legenda Bilotserkivska	6.58	12.86	**49.37**	10.95	**54.71**	**45.49**
5	Kvitka Poliv	19.63	**36.91**	17.60	**34.46**	**37.03**	4.74
6	Lisova Pisnia	15.15	21.80	3.11	10.97	17.45	9.06
7	Vodohrai Bilotserkivskyi	15.13	26.83	4.92	19.15	27.52	16.45
8	Perlyna Lisostepu	26.50	**33.18**	11.43	**32.89**	**35.19**	10.75
9	Rozumnytsia	18.53	**42.30**	9.37	28.57	**43.10**	19.70
10	Romantyka	6.31	5.72	5.49	7.46	6.34	10.11
11	Hratsia Bilotserkivska	14.44	21.52	2.78	10.71	14.26	5.40
12	Tsarivna	7.42	20.48	10.37	21.68	20.72	4.76
13	Ros	21.45	23.82	8.18	29.70	**43.64**	17.16
14	Zorepad Bilotserkivskyi	19.32	**62.25**	17.68	**44.63**	**60.72**	20.56
15	Hadzynka	19.15	**41.28**	6.23	27.43	**48.01**	22.69

Table 2, Continued

No.	Variety	Coefficient of variation by indicators, %					
		spike rod length	ear weight	number of spikelets per ear	number of grains per ear	grain weight per ear	weight 1,000 grains
16	Zoria Laniv	13.38	20.67	17.40	22.29	20.56	**41.00**
17	Liryca Bilotserkivska	7.27	1.43	0.49	1.60	1.10	2.70
18	Krayevyd	17.66	**45.41**	29.45	**43.93**	**40.84**	10.55
19	Pamyati Hirka	**30.33**	**50.61**	29.75	**41.16**	**51.77**	11.54
20	Myroliubna	3.62	21.57	11.88	18.05	24.93	8.04
21	Vodohrai	16.87	29.63	10.51	27.18	**36.38**	10.26
22	Spivanka Poliska	18.31	27.71	4.40	24.41	24.88	15.68
23	Polisianka	9.38	**55.38**	18.11	**52.72**	**48.38**	4.22
24	Efektna	17.55	18.14	14.56	18.82	15.72	7.20
25	Pyriatynka	12.35	8.23	12.32	7.33	8.42	1.24
26	Liubito	18.59	**39.18**	12.45	**37.83**	**34.94**	6.02
27	Fortetsia Poliska	27.23	**40.48**	**32.45**	**36.57**	**40.81**	4.22
28	Namysto	14.82	18.66	8.28	21.43	27.82	8.59
29	Merezhka	21.83	**45.00**	16.06	**42.26**	**50.77**	11.46
30	Kesaria Poliska	12.71	**59.03**	28.98	**41.75**	**39.29**	**30.84**
31	Poliska 90	12.60	**35.68**	18.86	29.15	**37.53**	9.11
32	Berehynia Myronivska	5.70	12.03	6.51	17.47	14.16	22.07
33	Hospodynia Myronivska	16.33	**35.38**	3.00	27.42	27.50	11.25
34	MIP Valencia	19.19	27.37	12.30	3.25	15.71	18.91
35	MIP Vyshyvanka	9.40	13.82	5.95	10.68	11.28	1.16
36	MIP Dniprianka	9.49	17.20	15.37	12.45	14.78	13.33
37	MIP Kniazhna	7.24	6.15	7.03	24.55	16.24	8.65
38	Oberih Myronivskyi	8.56	19.82	3.12	6.52	8.95	7.66
39	Svitanok Myronivskyi	6.25	**56.06**	3.43	8.61	16.69	7.86
40	MIP Assol	19.06	10.82	3.50	14.94	24.60	**38.60**
41	MIP Lada	3.33	3.45	1.45	10.73	5.24	5.36
42	MIP Yuvileyna	13.27	11.06	0.81	3.55	22.70	19.23
43	Balada Myronivska	2.77	8.05	11.33	13.26	15.90	2.66
44	Estafeta Myronivska	26.67	18.83	11.24	4.30	11.70	7.41
45	Hratsia Myronivska	**32.48**	**61.67**	2.70	12.31	17.09	4.83
46	Shchedrist Odeska	2.79	8.85	10.55	13.29	1.51	11.79
47	Nota Odeska	11.43	**33.89**	1.06	22.17	26.76	4.73
48	Aksioma Odeska	2.54	10.35	3.87	3.71	14.91	11.22
49	Duma Odeska	4.49	22.55	23.93	17.93	28.81	11.17
50	Versia Odeska	1.46	6.90	10.44	7.12	15.71	8.64
51	Sich	1.28	24.77	0.92	24.49	23.57	0.71
52	Doskonalist Odeska	5.57	5.35	11.03	23.94	22.58	**45.30**
53	Kubok	1.63	2.17	1.27	1.75	1.99	0.24

Notes: *varieties with a high level of variability are highlighted in bold*
Source: *compiled by the authors*

Soft winter wheat varieties with high homeostaticity are important for breeding programmes, especially for regions with unstable climates. Homeostatic varieties in the years of research turned out to be: Lybid, Charodiyka Bilotserkivska, Lisova Pisnia, Vodohrai Bilotserkivskyi, Romantyka, Hratsia Bilotserkivska, Tsarivna, Zoria Laniv, Liryca Bilotserkivska, Myroliubna, Vodohrai, Spivanka Poliska, Efektna, Pyriatynka, Namysto, Berehynia

Myronivska, MIP Valencia, MIP Vyshyvanka, MIP Dniprianka, MIP Kniazhna, Oberih Myronivskyi, MIP Lada, MIP Yuvileyna, Balada Myronivska, Estafeta Myronivska, Shchedrist Odeska, Aksioma Odeska, Duma Odeska, Versia Odeska, Sich, and Kubok. The most variable indicators of the structure of the yield of soft winter wheat were the number of grains in the ear and the weight of grains from the ear. The most stable indicators were the length of the ear rod and the number of spikelets per ear.

Since the influence of year conditions on the structural indicators under study is established, it is advisable to determine statistically significant differences over the years of research using the Tukey HSD test. Based on the data of the analysis of soft winter wheat varieties by the length of the ear rod, the weight of the ear, the number of spikelets per ear, the weight of grain from the ear, and the weight of 1,000 grains (Table 3), the following conclusions can be drawn: over the course of three years, a significant increase in the studied indicators was observed, especially between the second and third years. This may indicate an improvement in growing conditions or an improvement in agrotechnical measures, which contributed to an improvement in these indicators of soft winter wheat in the last year of research. However, between the 2021/2022 and 2022/2023 growing years, the differences in indicators are not significant, which may indicate stable or similar conditions during these periods.

Table 3. *Comparison of indicators of the structure of the yield of soft winter wheat by years of observation (ANOVA)*

Pair of years	Average difference between the compared groups	Standard error, SE	Tukey's range test, Q	Confidence interval limits		Critical average	p-value
by the length of the spike rod							
xI-xII	0.2611	0.1813	1.4405	-0.3462	0.8684	0.6073	0.5664
xI-xIII	0.6787	0.1704	3.9832	0.1078	1.2497	0.5709	0.01527
xII-xIII	0.9398	0.1747	5.3789	0.3544	1.5253	0.5854	0.0006207
by ear weight							
xI-xII	0.1037	0.09391	1.1041	-0.211	0.4183	0.3146	0.7155
xI-xIII	0.4271	0.08866	4.8169	0.13	0.7242	0.2971	0.002474
xII-xIII	0.5308	0.0909	5.8393	0.2262	0.8353	0.3046	0.0001846
by the number of spikelets per ear							
xI-xII	0.2644	0.1581	1.6718	-0.2655	0.7942	0.5298	0.4658
xI-xIII	0.812	0.1493	5.4388	0.3118	1.3123	0.5003	0.0005335
xII-xIII	1.0764	0.1531	7.0323	0.5635	1.5893	0.5129	0.000005748
by weight of 1,000 grains							
xI-xII	4.2114	1.2653	3.3283	-0.02833	8.4511	4.2397	0.05197
xI-xIII	4.7673	1.1947	3.9903	0.7642	8.7705	4.0031	0.01506
xII-xIII	0.5559	1.2248	0.4539	-3.548	4.6599	4.1039	0.9448
by the number of grains in the ear							
xI-xII	6.8646	1.2181	5.6355	2.7831	10.946	4.0814	0.000319
xI-xIII	2.8242	1.1501	2.4556	-1.0295	6.6779	3.8537	0.1954
xII-xIII	9.6888	1.1791	8.2172	5.7381	13.6395	3.9507	1.232e-7
by grain weight per ear							
xI-xII	0.1648	0.07508	2.1952	-0.08675	0.4164	0.2516	0.27
xI-xIII	0.2764	0.07089	3.8989	0.03887	0.5139	0.2375	0.01808
xII-xIII	0.4412	0.07268	6.071	0.1977	0.6848	0.2435	0.00009746

Source: *compiled by the authors*

The previous trend is changing for the number of grains in an ear, because the indicators did not have a significant difference in 2021/2022 and 2023/2024, while in the 2022/2023 growing year such a difference was observed. This indicates the similarity of weather and climatic conditions during the flowering period of soft winter wheat in the first and last year of research. A large proportion of soft winter wheat varieties in 2021/2022 and 2022/2023 g.y. had a spike rod length of 6-7 cm, while in the 2023/2024 growing year this indicator increased to 7-8 cm (Fig. 3a). A significant proportion of varieties had a grain weight in 2021/2022 g.y. (growing year) in the range of 1-2. 5 g,in 2022/2023 – 2-2.5 g, in 2023/2024 – 2-3 G (Fig. 3b). The number of spikelets per ear of a significant proportion of varieties during three years of research was in the range of 15-17.5 units (Fig. 3c). Figure 3d shows a significant variation between varieties in terms of the number of grains in the ear. A significant proportion of varieties had 35-40 grains per ear in 2021/2022 g.y., in 2022/2023 this number decreased to 20-25 grains, and in 2023/2024 it increased to 40-45 grains. Given that the number of spikelets per ear has not changed significantly over the years of research, it can be assumed that the decrease in seed setting in 2022/2023 g.y. was caused by unfavourable weather conditions, and a significant increase in the number of seeds in the ear in 2023/2024 g.y. was caused by favourable conditions. The weight of grains in the ear of most varieties in 2021/2022 g.y. was 1.5-2.0 g, in 2022/2023 it decreased to 1.0-1.5 g, and in 2023/2024 g.y. it increased again to the limits of 1.5-2.0 g (Fig. 3e), which also indicates the impact of adverse weather conditions on the indicator. The weight frequencies of 1,000 grains of soft winter wheat are quite dense over the years of research – this indicates that most varieties have similar values, namely in the range of 40-50 g (Fig. 3f).

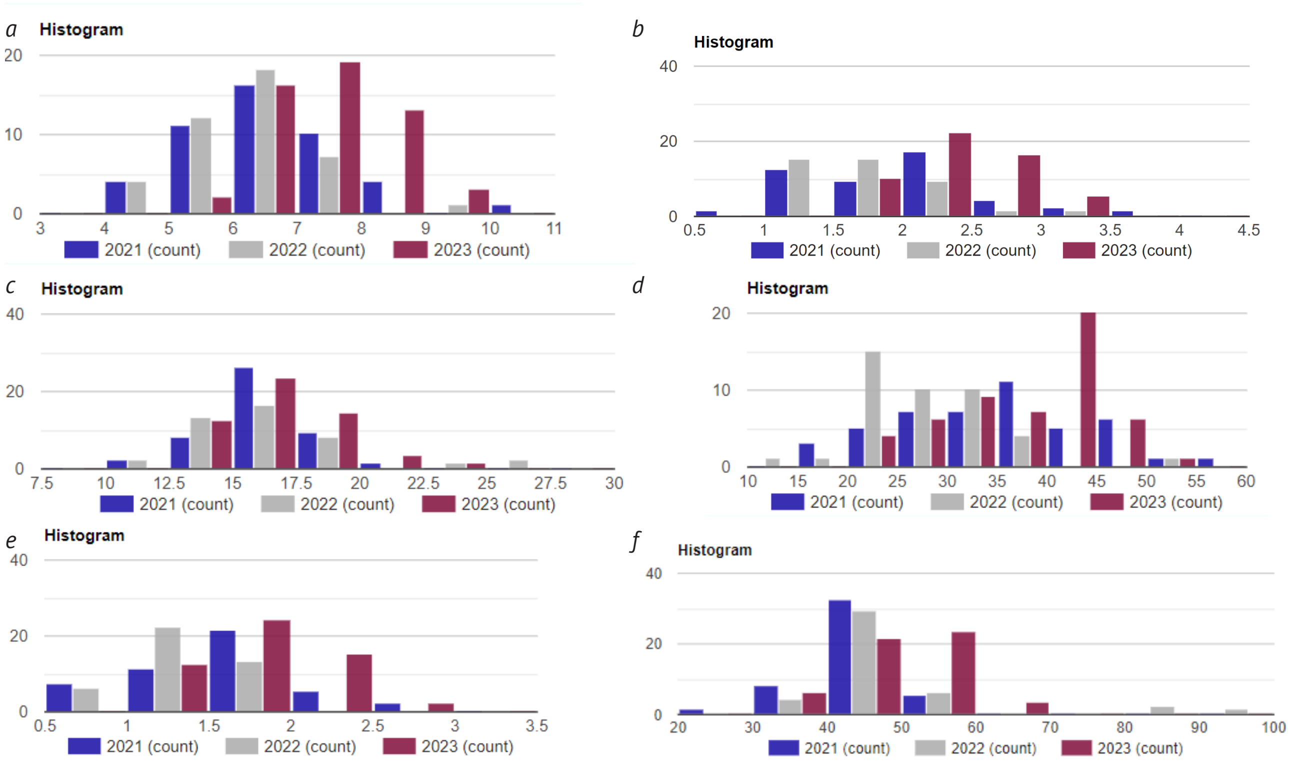

Figure 3. *Distribution of frequencies of indicators of the yield structure of soft winter wheat varieties for 2021/2022-2023/2024*
Notes: *a) by the length of the ear rod; b) by the weight of the ear; c) by the number of spikelets per ear; d) by the number of grains in the ear; e) by the weight of grains from the ear; f) by the weight of 1,000 grains. ANOVA Calculator was used to build diagrams*
Source: *compiled by the authors*

Analysis of confidence intervals for 95% of the significance level indicates fluctuations in the values of indicators of the structure of the crop of soft winter wheat by year (Fig. 3). It follows that the most stable indicator by year for all the crop varieties under study is the number of spikelets per ear (Fig. 4c), because only for this indicator can the average value be within acceptable limits for all years of research. By the length of the spike rod (Fig. 4a), the weight of the ear (Fig. 4b), and the weight of grains from the ear (Fig. 4e) in 2023/2024 g.y., the values of indicators went beyond the confidence intervals of previous years, which may indicate a positive impact of this year's weather conditions on these indicators. However, the development of the number of grains in the ear was negatively affected by the weather indicators of 2022/2023 g.y. (Fig. 4d), since the confidence intervals in the studied years do not coincide. Confidence intervals for the weight of 1,000 grains also fluctuated over the years (Fig. 4f). The largest range of indicator values was found in 2022/2023 g.y., while in 2021/2022 the weight of 1,000 grains was the lowest, and in 2023/2024 the values were within the range of the previous year. Hence, it can be assumed that the weather conditions of 2023/2024 g.y. were favourable for the gradation of wheat varieties according to the best seed fullness.

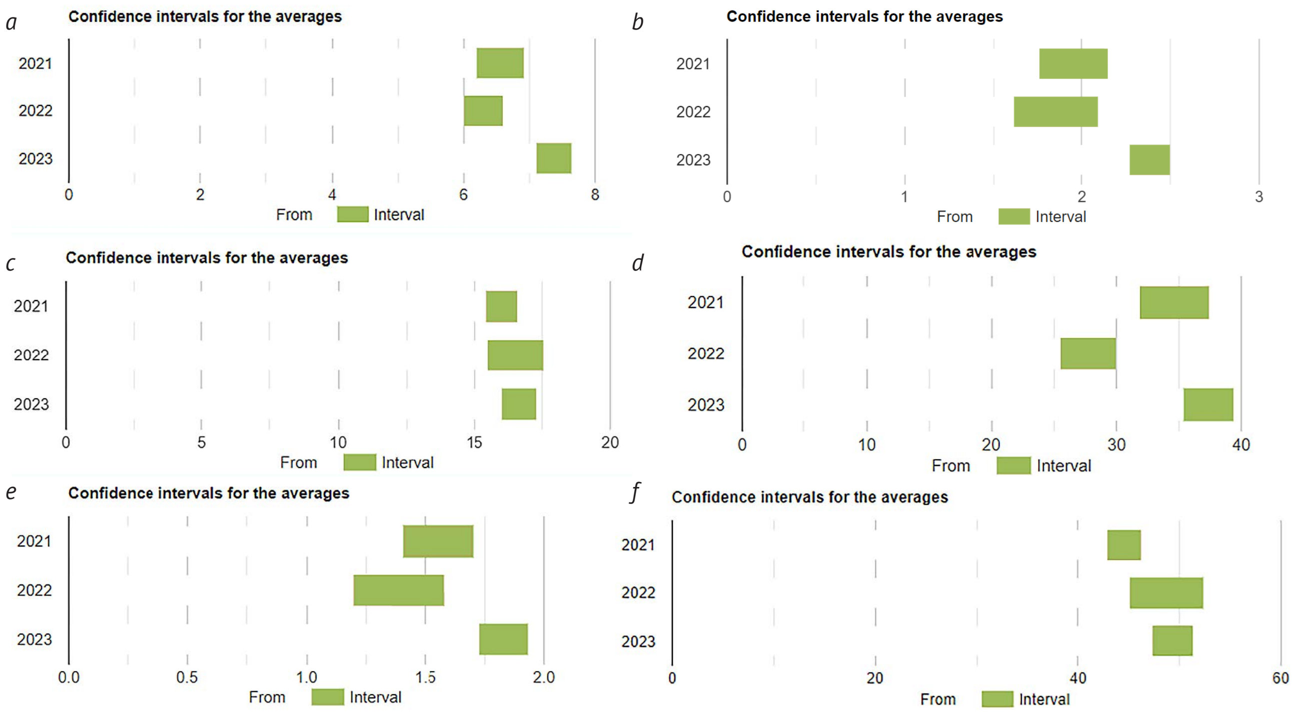

Figure 4. *Confidence intervals (0.05 significance level) for average structural yield indicators of soft winter wheat varieties for 2021/2022-2023/2024*

Notes: *a) by the length of the ear rod; b) by the weight of the ear; c) by the number of spikelets per ear; d) by the number of grains in the ear; e) by the weight of grains from the ear; f) by the weight of 1,000 grains. ANOVA Calculator was used to build diagrams*

Source: *compiled by the authors*

The protein content in the grain of soft winter wheat varieties in 2021/2022-2023/2024 ranged from 8.5 to 13.3% (Table 4), with an average value of 10.07%. According to DSTU 3768:2019 (2019), the first class of wheat includes a grain that has a protein content of at least 14%, and a raw gluten content of at least 28%. Over the years of research on the quality indicators of seeds of soft winter wheat varieties, not a single variety was identified that would belong to class 1, which is conditioned by the specificity of the soil and climatic conditions of the zone. The highest quality indicators of crop varieties were observed in the 2021/2022 growing year. Most varieties of soft winter wheat this year had seed quality corresponding to class 3, and Poliska 90 – class 2 (protein content of 13.3% and gluten content of 24.2%. In 2022/2023 g.y., the seed quality indicator for all varieties was quite low, so the grain was classified as feed. However, MIP Kniazhna (protein content 11.0%, gluten content 19.6%), MIP Lada (11.2 and 19.6%, respectively) and Hratsia Myronivska (11.0 and 18.8%) varieties had higher grain quality indicators, which corresponded to class 3.

Table 4. *Grain quality indicators of soft winter wheat varieties over the years of research*

No.	Variety	Protein content, %					Gluten content, %				
		2021-2022	2022-2023	2023-2024	x̄	V, %	2021-2022	2022-2023	2023-2024	x̄	V, %
1	Vidrada	12.30	9.10	9.60	10.30	16.71	22.00	16.40	17.10	18.50	16.49
2	Lybid	12.10	9.40	9.30	10.30	15.42	21.30	16.70	16.90	18.30	14.21
3	Charodiyka Bilotserkivska	12.30	8.30	9.10	9.90	21.38	21.70	15.90	16.50	18.03	17.69
4	Legenda Bilotserkivska	12.50	10.50	9.40	10.80	14.55	22.30	18.10	15.90	18.77	17.33
5	Kvitka Poliv	12.90	7.80	8.30	9.70	28.98	22.40	15.90	11.90	16.73	31.67
6	Lisova Pisnia	12.30	9.00	10.70	10.70	15.42	22.70	17.40	20.20	20.10	13.19

Table 4, Continued

No.	Variety	Protein content, %					Gluten content, %				
		2021-2022	2022-2023	2023-2024	x̄	V, %	2021-2022	2022-2023	2023-2024	x̄	V, %
7	Vodohrai Bilotserkivskyi	11.50	8.40	11.00	10.30	16.16	20.00	16.10	18.70	18.27	10.87
8	Perlyna Lisostepu	12.60	8.00	11.50	10.70	22.45	22.10	16.00	19.70	19.27	15.95
9	Rozumnytsia	12.70	8.30	12.00	**11.00**	21.49	21.70	16.00	20.20	**19.30**	15.31
10	Romantyka	10.50	9.00	11.20	10.20	11.02	19.20	17.20	21.10	19.17	10.18
11	Hratsia Bilotserkivska	11.50	9.20	12.00	10.90	13.70	20.10	16.20	22.40	19.57	16.02
12	Tsarivna	11.30	8.60	10.80	10.20	14.08	20.10	16.40	20.40	19.00	11.73
13	Ros	13.20	8.80	10.50	10.80	20.54	22.50	16.30	18.40	19.07	16.54
14	Zorepad Bilotserkivskyi	11.40	8.90	10.00	10.10	12.41	19.80	16.20	17.40	17.80	10.30
15	Hadzynka	10.80	9.50	8.70	9.70	10.93	18.10	16.60	15.80	16.83	6.94
16	Zoria Laniv	10.70	9.20	8.70	9.50	10.96	18.30	16.60	16.30	17.07	6.32
17	Liryca Bilotserkivska	10.80	10.20	8.90	10.00	9.71	17.90	17.00	16.20	17.03	4.99
18	Krayevyd	8.80	8.70	8.10	8.50	4.45	15.70	16.10	15.70	15.83	1.46
19	Pamyati Hirka	9.90	8.90	9.20	9.30	5.52	15.20	15.60	15.70	15.50	1.71
20	Myroliubna	9.40	8.30	8.50	8.70	6.74	16.10	16.00	16.10	16.07	0.36
21	Vodohrai	10.20	8.70	10.70	9.90	10.51	16.60	15.80	19.10	17.17	10.03
22	Spivanka Poliska	11.00	9.50	8.70	9.70	12.04	19.10	16.50	16.00	17.20	9.68
23	Polisianka	11.40	10.20		10.80	7.86	19.50	17.30		18.40	8.45
24	Efektna	9.60	10.70	8.40	9.60	11.98	16.50	18.00	16.00	16.83	6.18
25	Pyriatynka	9.60	9.70	9.00	9.40	4.03	17.10	17.10	16.60	16.93	1.70
26	Liubito	9.60	9.40	8.50	9.20	6.37	16.40	16.60	15.90	16.30	2.21
27	Fortetsia Poliska	10.30	9.20	8.90	9.50	7.76	19.10	16.90	16.50	17.50	8.00
28	Namysto	10.90	10.00	9.40	10.10	7.48	19.10	17.30	16.90	17.77	6.60
29	Merezhka	11.30	10.20	9.70	10.40	7.87	19.60	17.50	17.20	18.10	7.22
30	Kesaria poliska	9.50	8.30		8.90	9.53	16.40	15.70		16.05	3.08
31	Poliska 90	**13.30**	10.10	11.30	**11.60**	13.94	**24.20**	17.40	20.60	**20.73**	16.41
32	Berehynia Myronivska	12.10	10.30	8.90	10.40	15.42	21.50	17.80	16.40	18.57	14.19
33	Hospodynia Myronivska	12.00	9.90	9.10	10.30	14.54	20.80	17.80	16.50	18.37	12.01
34	MIP Valencia	11.80		9.30	10.60	16.68	19.80		16.40	18.10	13.28
35	MIP Vyshyvanka	10.60	10.30	8.80	9.90	9.74	18.10	17.80	16.20	17.37	5.88
36	MIP Dniprianka	11.80	9.80	8.90	10.20	14.55	20.60	17.30	16.10	18.00	12.95
37	MIP Kniazhna	12.70	11.00	9.50	**11.10**	14.42	22.90	19.60	17.30	**19.93**	14.12
38	Oberih Myronivskyi	10.80	10.20	10.00	10.30	4.04	18.80	17.40	17.50	17.90	4.36
39	Svitanok Myronivskyi	9.90	10.40	10.00	10.10	2.62	17.70	18.20	18.20	18.03	1.60
40	MIP Assol	10.00		9.70	9.90	2.14	17.30		17.40	17.35	0.41
41	MIP Lada	11.10	11.20	10.10	10.80	5.63	19.30	19.60	17.60	18.83	5.73

Table 4, Continued

No.	Variety	Protein content, %					Gluten content, %				
		2021-2022	2022-2023	2023-2024	$\bar{x}$	V, %	2021-2022	2022-2023	2023-2024	$\bar{x}$	V, %
42	MIP Yuvileyna	10.00	9.80	10.50	10.10	3.57	17.90	17.60	11.20	15.57	24.31
43	Balada Myronivska		10.60	9.50	10.10	7.70		18.10	16.70	17.40	5.69
44	Estafeta Myronivska	9.70	10.70	9.70	10.00	5.77	17.00	18.70	17.40	17.70	5.02
45	Hratsia Myronivska	10.90	11.00	9.60	10.50	7.44	18.10	18.80	16.90	17.93	5.36
46	Shchedrist Odeska	9.50	10.30	9.30	9.70	5.46	16.50	18.00	16.80	17.10	4.64
47	Nota Odeska	10.20	9.40	9.50	9.70	4.49	16.80	16.80	19.00	17.50	7.2
48	Aksioma Odeska	9.80	9.60	8.00	9.10	10.84	16.10	17.20	15.30	16.20	5.89
49	Duma Odeska	10.60	10.20	8.50	9.80	11.38	19.50	18.10	15.90	17.83	10.18
50	Versia Odeska	10.80	10.30	8.80	10.00	10.41	19.40	18.20	16.10	17.90	9.33
51	Sich	9.90	10.90	8.60	9.80	11.77	17.40	19.00	15.90	17.43	8.89
52	Doskonalist Odeska	11.50	10.30	8.60	10.10	14.43	19.80	17.70	16.10	17.87	10.39
53	Kubok	10.60		10.70	10.70	0.66	18.70		18.60	18.65	0.38
	$\bar{x}$	11.01	9.63	9.54	10.07	11.05	19.17	17.20	16.89	17.76	9.91

Source: *compiled by the authors*

Based on the above data (Table 2; Figs. 3, 4) it is possible to distinguish varieties that can maintain stable productivity and quality under various environmental conditions (Table 5). High adaptive ability according to the indicators under study was established for the following varieties: Romantyka, Liryca Bilotserkivska, Pyriatynka, MIP Vyshyvanka, MIP Lada, Estafeta Myronivska, and Kubok.

Table 5. *Adaptability of soft winter wheat varieties by grain weight of the main ear and grain quality*

No.	Varieties	General adaptive capacity, b_i		
		ear weight	protein content	gluten content
1	Vidrada	1.39	2.06	2.58
2	Lybid	0.53*	1.93	2.22
3	Charodiyka Bilotserkivska	0.74*	2.51	2.71
4	Legenda Bilotserkivska	-1.04	1.81	2.64
5	Kvitka Poliv	1.36	3.39	4.23
6	Lisova Pisnia	1.66	1.69	1.90
7	Vodohrai Bilotserkivskyi	0.03*	1.22	1.26
8	Perlyna Lisostepu	2.08	1.94	2.06
9	Rozumnytsia	2.44	1.73	1.73
10	Romantyka	0.22*	0.25*	-0.01*
11	Hratsia Bilotserkivska	1.89	0.59*	0.33*
12	Tsarivna	0.87*	1.09	0.80*
13	Ros	0.33*	2.46	2.52
14	Zorepad Bilotserkivskyi	2.97	1.35	1.47
15	Hadzynka	2.19	1.20	0.95*
16	Zoria Laniv	1.19	1.23	0.92*
17	Liryca Bilotserkivska	-0.09*	0.90*	0.65*
18	Krayevyd	2.13	0.29*	-0.09*
19	Pamyati Hirka	3.47	0.59*	-0.22*
20	Myroliubna	1.08	0.70*	0.02*
21	Vodohrai	1.50	0.32*	-0.45*

Table 5, Continued

No.	Varieties	General adaptive capacity, b_i		
		ear weight	protein content	gluten content
22	Spivanka Poliska	-0.63*	1.34	1.41
23	Polisianka	3.04	0.85*	1.10
24	Efektna	1.20	0.07*	-0.23*
25	Pyriatynka	0.53*	0.19*	0.13*
26	Liubito	2.12	0.47*	0.08*
27	Fortetsia Poliska	1.64	0.88*	1.19
28	Namysto	1.05	0.85*	0.99*
29	Merezhka	2.23	0.95*	1.11
30	Kesaria poliska	4.06	0.85*	0.35*
31	Poliska 90	1.98	1.80	2.53
32	Berehynia Myronivska	0.21*	1.78	2.18
33	Hospodynia Myronivska	2.15	1.77	1.81
34	MIP Valencia	2.41	1.73	1.66
35	MIP Vyshyvanka	0.85*	0.76*	0.56*
36	MIP Dniprianka	0.38*	1.73	1.94
37	MIP Kniazhna	-0.24*	1.74	2.22
38	Oberih Myronivskyi	1.01	0.49*	0.66*
39	Svitanok Myronivskyi	-3.68	-0.20*	-0.25*
40	MIP Assol	1.24	0.21*	-0.05*
41	MIP Lada	0.17*	0.33*	0.37*
42	MIP Yuvileyna	0.70*	-0.12*	1.79
43	Balada Myronivska	0.53*	25.43	25.78
44	Estafeta Myronivska	0.89*	-0.33*	-0.50*
45	Hratsia Myronivska	6.34	0.44*	0.14*
46	Shchedrist Odeska	1.20	-0.19*	-0.43*
47	Nota Odeska	4.18	0.52*	-0.56*
48	Aksioma Odeska	1.20	0.73*	-0.06*
49	Duma Odeska	-2.65	0.90*	1.25
50	Versia Odeska	-0.80*	0.90*	1.13
51	Sich	-2.77	0.14*	0.01*
52	Doskonalist Odeska	0.44*	1.46	1.45
53	Kubok	0.20*	-0.07*	0.05*

Notes: ** – no influence of adverse environmental factors on this indicator, that is, a high indicator of adaptability of the variety for this feature*
Source: *compiled by the authors*

For successful breeding of soft winter wheat for yield and quality, it is advisable to establish a relationship between the indicators under study. Using the correlation analysis of grain quality indicators and the structure of the yield of soft winter wheat varieties for 2021/2022-2023/2024, a strong direct relationship was established between the number of grains in the ear and the weight of grains from the ear (0.84), between the weight of grains from the ear and the length of the ear rod (0.78), between the weight of grains from the ear and the weight of the ear (0.77), between the number of grains in the ear and the weight of the ear (0.76), and with the length of the ear rod (0.74) (Table 6). The average positive correlation should be noted between the indicators of the length of the ear rod and the number of spikelets per ear (0.50) and the weight of the ear (0.65). The weight of 1,000 grains is characterised by an average positive correlation with the length of the ear rod (0.32), the weight of the ear (0.32), and the weight of grains from the ear (0.59). For the number of grains in the ear, a positive average correlation was established with the number of spikelets per ear (0.38).

Table 6. *Interdependence between the indicators under study*

	Spike rod length	Ear weight	Number of spikelets per ear	Number of grains per ear	Grain weight per ear	Weight 1,000 grains	Protein content	Gluten content
Spike rod length	1.00							
Ear weight	0.65	1.00						
Number of spikelets per ear	0.50	0.27	1.00					
Number of grains per ear	**0.74**	**0.76**	0.38	1.00				
Grain weight per ear	**0.78**	**0.77**	0.44	**0.84**	1.00			
Weight 1,000 grains	0.32	0.32	0.21	0.07	0.59	1.00		
Protein content	-0.16	0.05	-0.27	-0.06	0.08	0.21	1.00	
Gluten content	-0.13	0.06	-0.06	-0.05	0.05	0.14	**0.83**	1.00

Source: *compiled by the authors*

The obtained results demonstrate the plasticity of the indicator of the number of spikelets per ear of soft winter wheat during the studied years, and its variability, depending on the genotype (variety). Yu. Chernobai (2023) noted that the number of spikelets per ear is the most plastic indicator. According to L. Khudolii (2019), there is a direct relationship between the number of spikelets and weather conditions, the fertiliser system, and plant protection elements. Therefore, observations of varieties in these studies, which indicate a low variability of this indicator, suggest that the weather conditions during ear differentiation were similar. The effect of the fertiliser system and plant protection elements on the number of spikelets was not recorded, since these factors remained constant. The study by M. Lytus & V. Starychenko (2018) also confirmed that the number of spikelets per ear largely depends on genetic factors, in particular, on the genotype.

V. Morgun *et al.* (2015), based on many years of experience, came to the conclusion that the number of spikelets per ear is the most stable indicator, and the number of grains from the ear is the most variable. The same conclusion was obtained in the current study. In addition, the length of the ear rod and the weight of 1,000 grains were attributed to stable indicators in the years of research, and the weight of the ear and the weight of grains from the ear were attributed to variable indicators. Z. Guo *et al.* (2018) found a significant association between yield and weight of 1,000 grains. Based on these data, it can be assumed that the varieties under study with a high value of this indicator also have a high yield potential.

V. Lykhochvor (1999) argued about the direct influence of grain weight from the main ear on wheat yield. S. Ebrahimnejad & V. Rameeh (2016) found a high coefficient of variation between the characteristics of ear weight and plant yield, which is also confirmed by the results of the current research, namely, a strong direct relationship between ear weight and grain weight from the ear. A. Polyovyi *et al.* (2022) analysed the indicators of the moisture-temperature regime of the forest-steppe soil – climate zone in order to predict climate change in the coming years and concluded that there is a slight increase in temperature and a noticeable decrease in precipitation (as a result of drought), especially during the summer period – the growing season of most agricultural crops. According to M. Shtakal *et al.* (2022), climate change does not currently pose a critical threat to the high yields of modern varieties of soft winter wheat, but these varieties do not have sufficient adaptive potential to effectively counteract weather changes during the research period. However, according to the results of the research during 2021/2022-2023/2024, the influence of weather conditions on elements of wheat productivity was revealed.

A positive average correlation (0.38) was found between the number of ears and the number of grains per ear. The same conclusions were obtained by L. Burdeniuk-Tarasevych & M. Lozinsky (2013), based on which a positive correlation was established between the indicators of the length of the main ear, the number of spikelets in the ear, the number and weight of grains from the ear. This relationship of indicators is probably conditioned by the influence of weather conditions during flowering on the tying process. L. Prysiazhniuk *et al.* (2022) in their studies established a significant effect on the protein and gluten content of soft winter wheat under the conditions of the growing year, which is confirmed in this study and is a consequence of the influence of moisture supply and air temperature during grain filling and maturation on the synthesis and accumulation of nutrients.

The average correlation between the length of the ear rod and the number of spikelets in the ear (0.50) and the weight of the ear (0.65) can be explained by the fact that as the length of the ear rod increases, the number of spikelets also increases. This, in turn, contributes to the setting of more grains in the ear of wheat and the development of more ear weight.

CONCLUSIONS

As a result of a three-year study of soft winter wheat varieties in the Forest-Steppe of Ukraine, according to the indicators of the yield structure, the following donors of traits that will potentially increase the yield of new varieties were identified: by the length of the ear rod – Legenda Bilotserkivska and Spivanka Poliska varieties; by the weight of the ear – Spivanka Poliska and Svitanok Myronivskyi; by the number of spikelets in the ear – Legenda Bilotserkivska, Fortetsia Poliska, and Kesaria Poliska; by the number of grains in the ear – Legenda Bilotserkivska, Spivanka Poliska, and Shchedrist Odeska; by the weight of grain from the main ear – Legenda Bilotserkivska; by weight of 1,000 grains – Vidrada, Charodiyka Bilotserkivska, Legenda Bilotserkivska, Perlyna Lisostepu, Rozumnytsia, Romantyka, Tsarivna, Zoria Laniv, Kesaria Poliska, MIP Assol, MIP Lada, MIP Yuvileyna, and Hratsia Myronivska; by grain quality indicators – Rozumnytsia, Poliska 90, and MIP Kniazhna.

Both a strong and weak direct correlation between the indicators of the crop structure was established, which indicates a positive effect of increasing these indicators on the yield of modern varieties of soft winter wheat. Therefore, these varieties can be recommended for use in breeding programmes aimed at increasing the yield of this crop. Based on correlation analysis, it was found that there is no strong influence of crop structure parameters on grain quality indicators in specific conditions. High adaptive capacity in the years of research was established for the following varieties: Romantyka, Liryca Bilotserkivska, Pyriatynka, MIP Vyshyvanka, MIP Lada, Estafeta Myronivska, and Kubok. These varieties have maintained the stability of grain yields and quality indicators under stressful conditions, so they can be donors of resistance to adverse environmental conditions. The prospect of further research may be to identify the interdependence of specific weather conditions on the development of crop structure indicators. It is also advisable to study the nature of inheritance of the traits under study for use in the selection of soft winter wheat for productivity and quality.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

REFERENCES

[1] Burdeniuk-Tarasevych, L., & Lozinskyi, M. (2013). Formation of the main ear length in winter wheat lines of various ecological and geographical origins. *Agrobiology*, 11(104), 30-34.
[2] Chernobai, Yu. (2023). Characterisation of newly developed soft winter wheat lines for valuable agronomic traits. *Genetic Resources of Plants*, 33, 22-30.
[3] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.
[4] Convention on the Trade in Endangered Species of Wild Fauna and Flora. (1973, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.
[5] DSTU 3768:2019. (2019). *Wheat. Technical specifications*. Retrieved from http://surl.li/axasfu.
[6] Ebrahimnejad, S., & Rameeh, V. (2016). Correlation and factor analysis of grain yield and some important component characters in spring bread wheat genotypes. *Agronomical Research in Moldavia*, 49(1), 5-15. doi: 10.1515/cerce-2016-0001.
[7] Ficiciyan, A., Loos, J., Sievers-Glotzbach, S., & Tscharntke, T. (2018). More than yield: Ecosystem services of traditional versus modern crop varieties revisited. *Sustainability*, 10(8), article number 2834. doi: 10.3390/su10082834.
[8] Guo, Z., Zhao, Y., Röder, M.S., Reif, J.C., Ganal, M.W., Chen, D., & Schnurbusch, T. (2018). Manipulation and prediction of spike morphology traits for the improvement of grain yield in wheat. *Scientific Reports*, 8(1), article number 14435. doi: 10.1038/s41598-018-31977-3.
[9] Helguera, M., *et al*. (2020). Grain quality in breeding. In *Wheat quality for improving processing and human health* (pp. 273-307). Cham: Springer. doi: 10.1007/978-3-030-34163-3_12.
[10] Khan, H. (2019). Genetic improvement for end-use quality in wheat. In *Quality breeding in field crops* (pp. 239-253). Cham: Springer. doi: 10.1007/978-3-030-04609-5_12.
[11] Khudolii, L. (2019). Morphophysiological features of winter wheat productivity formation depending on cultivation technology. *Plant Varieties Studying and Protection*, 15(3), 303-312.
[12] Kyienko, Z., Prysiazhniuk, L., Shovhun, O., Ivanytska, A., & Pavliuk, N. (2017). *Methodology for conducting qualification examination of plant varieties for distribution suitability in Ukraine. General part* (3rd ed.). Vinnytsia: IE D.Yu. Korzun.

[13] Kyrylchuk, A., & Kovalchuk, S. (2021). Breeding for quantitative and qualitative traits of winter wheat (*Triticum aestivum* L.). Expanding the genetic diversity of cultivated wheat. *Agroecological Journal*, 2, 140-148. doi: 10.33730/2077-4893.2.2021.234474.

[14] Lotysh, O., & Kardash, A. (2021). Microeconomic analysis of the global grain market. *Economy and Society*, 24. doi: 10.32782/2524-0072/2021-24-29.

[15] Lozinskiy, M., *et al*. (2021). Evaluation of selected soft winter wheat lines for main ear grain weight. *Agronomy Research*, 19(2), 540-551. doi: 10.15159/AR.21.071.

[16] Lykhochvor, V. (1999). *Yield structure of winter wheat*. Lviv: Ukrainian Technologies.

[17] Lytus, M., & Starychenko, V. (2018). Differentiation of soft winter wheat samples by the number of spikelets per spike. *Myronivka Bulletin*, 7, 68-76.

[18] Lytvynenko, M., Lyfenko, S., & Yeryniak, M. (2013). Winter wheat varieties of steppe ecotype undergo extreme weather conditions better. *Seed Production*, 9, 14-18.

[19] Morgun, V., Sichkar, S., Pochynok, V., Holik, O., & Chuhunkova, T. (2015). Analysis of the productivity structure of collection samples of rare wheat species. *Factors of Experimental Evolution of Organisms*, 16, 136-140.

[20] Polyovyi, A., Bozhko, L., Barsukova, O., & Kostyukevych, T. (2022). The impact of climate warming on the productivity of eggplant and sweet pepper in the Steppe zone of Ukraine. *Bulletin of Poltava State Agrarian Academy*, 1(104), 29-37.

[21] Prysiazhniuk, L., Khomenko, T., Liashenko, S., & Melnyk, S. (2022). Productivity indicators of new winter soft wheat (*Triticum aestivum* L.) varieties depending on cultivation factors. *Plant Varieties Studying and Protection*, 18(4), 273-282. doi: 10.21498/2518-1017.18.4.2022.273989.

[22] Shpakovych, I., & Kovalyshyna, H. (2023). Wild species of the genus aegilops as sources of valuable traits for winter wheat breeding. In *Proceedings of the international scientific and practical conference: Food and environmental security in the conditions of war and post-war recovery: Challenges for Ukraine and the world* (pp. 123-126). Kyiv: National University of Life and Environmental Sciences of Ukraine.

[23] Shtakal, M., Holyk, L., Levchenko, O., Shpakovych, I., & Ivashchenko, S. (2022). Evaluation of winter wheat varieties and lines for stable yield and adaptability under climate change in the Forest-Steppe zone. *Bulletin of Agricultural Science*, 100(3), 62-69. doi: 10.31073/agrovisnyk202203-08.

Характеристика сортів пшениці м'якої озимої за показниками структури врожаю та якості зерна

Ірина Гаврилюк
Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-2595-4620

Ганна Ковалишина
Доктор сільськогосподарських наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-2715-7679

Анотація. Метою дослідження було вивчення колекції сортів пшениці м'якої озимої селекції чотирьох науково-дослідних установ України, що охоплюють Степову та Лісостепову ґрунтово-кліматичні зони. У результаті дослідження було проаналізовано показники структури врожаю та якості зерна 53 сортів пшениці м'якої озимої. Отримані дані дозволили оцінити стабільність елементів продуктивності та виділити сорти з високими показниками для подальшого використання у селекції. На основі одержаних результатів було сформовано таблиці та графіки, що відображають різницю у структурних показниках між сортами за роками досліджень, а також проведено оцінку частоти розподілу таких параметрів, як: довжина колосового стрижня, маса колоса, кількість колосків у колосі, кількість зерен у колосі, маса зерен із колоса та маса 1000 зерен. Статистичний аналіз із застосуванням ANOVA та побудова довірчих інтервалів (рівень значущості 0,05) підтвердили суттєві відмінності між сортами за досліджуваними показниками, що дозволило виявити сорти з високою стабільністю врожайності та якості зерна. За використання кореляційного аналізу встановлено взаємозв'язки між структурними показниками. Особливу увагу було приділено гомеостатичним сортам, які демонстрували високі показники упродовж 2021/2022-2023/2024 рр. досліджень, а саме: довжину колосового стрижня, кількістю колосків у колосі та масу 1000 зерен, що є ключовими ознаками для селекції на підвищення врожайності. Такі показники зумовлені особливістю генотипів, умов навколишнім середовищем та їх взаємодією. Розрахувавши коефіцієнт регресії, визначили сорти з високим рівнем адаптивності. Кращі за досліджуваними параметрами сорти рекомендовано для подальшого використання у селекційних програмах, спрямованих на підвищення продуктивності та покращення якості зерна пшениці м'якої озимої в умовах змін клімату

Ключові слова: маса 1000 зерен; якість зерна; білок; клейковина; кореляція; адаптивність; гомеостатичність