Agronomy Research **19**(2), 540–551, 2021
https://doi.org/10.15159/AR.21.071

Evaluation of selected soft winter wheat lines for main ear grain weight

M. Lozinskiy[1], L. Burdenyuk-Tarasevych[1], M. Grabovskyi[2,*], T. Lozinska[3], V. Sabadyn[1], I. Sidorova[1], T. Panchenko[2], Y. Fedoruk[2] and Y. Kumanska[1]

[1]Bila Tserkva National AgrarianUniversity, Department of Genetics, Breeding and Seed production, Sq. Soborna 8/1, UA09100 Bila Tserkva, Ukraine
[2]Bila Tserkva National Agrarian University, Department of Technologies in Plant Growing and Plant Protection, Sq. Soborna 8/1, UA09100 Bila Tserkva, Ukraine
[3]Bila Tserkva National Agrarian University, Department of Forestry, Botany and Plant Physiology, Sq. Soborna 8/1, UA09100 Bila Tserkva, Ukraine
[*]Correspondence: nikgr1977@gmail.com

Received: February 28th, 2021; Accepted: May 8th, 2021; Published: May 12th, 2021

Abstract. Studies to assess the breeding samples of soft winter wheat by weight of grain from the main ear anddetermine the indicators of adaptability were conducted at the Bila Tserkva Research and Selection Station (BTRSS) in 2011–2013. The study revealed significant differences in breeding lines in the range of variability of grain mass from the main ear and identified small, medium and significantcoefficients of variation, which indicates their excellent response to environmental conditions. It was due to genotype, year conditions and their interaction. Line 42 KS had significantly higher than the standard grain weight of the main ear (0.14 g) and the lowest value of the coefficient of variation (8.7%). According to the indicators of adaptability(GAC, $\sigma^2(GxE)gi$, σ^2SACi, $\sigma SACi$, etc.) the lines 42 KS, 24 KS and 44 KS were distinguished. There was asignificant correlation between the weight of grain from the ear and the weight of 1,000 grains (0.603–0.674) and the direct influence of the weight of grain from the main ear on the weight of grain from the plantand grain yield (0.805–0.942). Selected lines as a result of research (2015–2020) from these populations of soft winter wheat are competitively tested in the conditions of Bila Tserkva Research and Selection Station, forming high grain yields (7.39–8.12 t ha^{-1}) and will be transferred to 2021 for the State variety test for inclusion in the Register of plant varieties suitable for distribution in Ukraine.

Key words: winter wheat, correlation, variability, plasticity, stability, adaptability.

INTRODUCTION

Wheat is grown in most countries, occupying an important place among cereals and is the main food crop (Shpaar, 2012). The sown area of winter wheat (*T. aestivum* L.) in Ukraine is about 5.5–6 million hectares(Litvinenko, 2011). An important factor in the growth and stabilization of crop yields, especially in adverse conditions, is not only the creation and implementation of varieties with high yield potential into production, but also increase their environmental sustainability. Plants with almost the same biological characteristics maydiffer in requirements for environmental conditions, i.e. ecological characteristics (Kochmarsky, 2012; Kulyk et al., 2020). Different environmental conditions were found to affect dry matter remobilization from the leavesand sheath, current photosynthesis, grain yield, and the relative contributions by the stem and the ear to grain yield (Golabadi et al., 20215).

The priority direction is the creation of a source material for selection with improved economically valuable traits, such as increased productivity, early-maturing, disease resistance, balanced chemical composition of grain (Artemchuk, 2013).

Creating wheat varieties with the highest possible level of productivity is the goal of every breeder, as increasing yields is one of the most important tasks due to its considerable difficulty and complexity (Bagan et al., 2012).

Selection played a major role in the increase in winter wheat yield after 1946 in France. The contribution of selection to this increase depended on the agronomic treatment and varied from one third to one half. Reduction of height was the most important factor. The number of grains per unit area had increasedover time without alteration of the weight of the grains. The negative relationship between 1,000 grain weightand grain number per m^2 was therefore shifted and new cultivars were thus able to fill more grains than older entries (Brancourt-Hulmel et al., 2003).

The tasks of adaptive selection can be solved if the methods for studying the plasticity of genotypes ofplants at early stages of selection are developed and varieties and forms of winter wheat that are identified according to these characteristics are included. The problems of adaptive selection of winter wheat are to be solved from the perspective of organization of selection process (finding, storage, identification and usage of appropriate genetic sources) and closely related systems of variety testing with elements of varietal agrotechnics (Bazalii et al., 2019).

During the process of plant breeding and selection of new winter wheat cultivars a lot of attention is paid to the improvement of the main components of grain yield-number of ears/m^2, number of grains per ear and 1,000 seed weight. Production of cultivars that achieve a large number of fertile ears per unit area, a largenumber of grains per ear and a heavy 1,000 seed weight, even with a lower density, would mean that a high grain yield is achieved with lower costs. On the grounds of the results obtained by a statistical analysis it wasestablished that the sowing rate did not have a statistically significant influence on the other two grain yield components - number of grains per ear and 1,000 seed weight. The investigated cultivars had a statistically very significant influence ($P < 0.01$) on the number of grains per ear, and a statistically significant influence on 1,000 seed weight, whereas there were no statistically significant differences between the investigated cultivarsin relation to the number of ears per unit area (Guberac et al., 2000).

Wheat grain yield is determined by three main factors, namely the ear number per square, grain numberper ear, and 1,000 grain weight. Breeding practice has indicated that increase the grain number per ear is the most effective way for improving of yield in China. The increase of grain number per ear will therefore be ofwidespread concern in future yield improvements (Yen et al., 1995).

Most studies have attributed the increased wheat yields in past decades to increases in grain number per ear (Siddique et al.,1989), thousand grain weight, or both (Donmez et al., 2001, Zhang et al., 2007). The number of grains per ear was the yield component that most closely followed the pattern of adaptation observedfor grain yield (Sanchez-Garcia et al., 2012).

In breeding research, Diordiieva et al. (2018) installed positively correlations between grain weights from main ear with yield capacity and can be used in selecting high-yielding genotypes at early stages of breeding work.

The main element of productivity that determine the yield of a particular plant in an ecosystem is the grain weight per ear, which consists of the number and the weight of grains. The elements of productivity have different variability depending on the interaction of the genotype and environment factors (Manukyan et al., 2019).

Studies have shown that grain weight per ear has greatly contributed to genetic improvements in wheatyield (Xiao et al., 2012).

In the conditions of left-bank side of North-east forest steppe of Ukraine a direct relation between: a ripeness group → plant height ($r = 0.96$) → resistance to overwintering ($r = 0.78$) → ripeness group ($r = 0.92$) winter wheat was noted. Having analyzed the received indices as for homeostasis and adaptability made sure that its genetic potential 40–80% under the conditions of north-east forest steppe of Ukraine (Vlasenko et al., 2018).

According to research, Innes et al. (1985) have shown that no differences in number of ears m^{-2} or in number of grains per ear between the early and the late selections. Mean weight per grain of the early selectionswas greater than that of the late selections. There were no differences in number of ears m^{-2} between the shortand the tall selections. The number of grains per ear was greater and mean weight per grain was less for the short selections than for the tall selections.

Feng et al. (2018) determined that the significant increases in grain yield in the past 60 years were mainly due to increases in grain number per ear and grain weight, while ears number per m^2 has not changed significantly. Improvements in thousand grain weight from the 1950s to 2010s have occurred at four grain positions (G1 to G4). The increase in grain number per ear since the 1950s was mainly due to an increase in grain number at G1, G2 and G3, with the relative contribution of grain position to grain number being G1 > G2 > G3 > G4.

While grain numbers and grain weights at the four grain positions increased at different rates from the1950s to 2010s, the total grain weight gradually increased, which greatly improved grain yield. Grain numberand grain weight per spikelet differ between spikelet and grain positions (Li et al., 2016).

Growth rate per grain depended on floret position within the ear, varied between cultivars (those withlarger grains at maturity having a faster rate), and increased with rise in temperature. With cultivars in which grain number per ear was markedly affected by illuminance, light had relatively little effect on growth rate pergrain (Sofield et al., 1977).

The aim of the research was to estimate the breeding samples of soft winter wheat by grain weight from the main ear and to determine the indicators of plasticity and stability.

MATERIALS AND METHODS

The research was conducted at the Bila Tserkva Research and Selection Station (BTRSS) in 2011–2013 (49°72'52.6"N30°09'89.2"E). The soil of the experimental field is typical chernozem, low humus, medium and light loam. The humus content in the soil layer 0–30 cm - 3.4–3.8%, the reaction of the soil solution is close to neutral. This type of soil is common in the Right Bank Forest-Steppe of Ukraine. The sowing period for soft winter wheat is from September 20 to October 1. The experiments were based on complete randomized blocks. Sowing was carried out three replication with a seeder CH-10, the accounting area each plot - 10 m^2. Mineral fertilizer was applied for pre-sowing cultivation at the rate of $N_{16}P_{16}K_{16}$ kg ha^{-1}. In the spring, soft winter wheat (BBCH 30) were fertilized of ammonium nitrate (N_{50} kg ha^{-1}). The predecessor is peas.

The following lines were studied: 7 KS, 8 KS, 42 KS, 29 KS, 26 KS, 24 KS, 12 KS, 44 KS, 54 KS, 22 KS, 17 KS. The standards were varieties Bilotserkivska napivkarlykova, Perlyna Lisostepu and Podolyanka. The experiments were performed according to the methodology (Volkodav, 2003; Rokitsky (1973); Dospekhov (1985); Snedecor (1961)).

Biometric analyzes between the elements of the yield structure weredetermined on the average sample of 25 plants in three replication, selected at the beginning of full maturity of wheat. The strength of the connection between the was determined by Guzhov (1987): $r < 0.3$ - the relationship between the signs is weak, $0.3 < r < 0.5$ -moderate, $0.5 < r < 0.7$ - significant, $0.7 < r < 0.9$ - strong, $r > 0.9$ - very strong, close to functional.

According to Rokitsky (1973) and Dospekhov (1985) the arithmetic mean X, the range of variability (min-max), the variance (S^2) and the coefficient of variation (CV) were determined. The coefficient of ecological plasticity (bi) was determined by Finlay & Wilkinson (1963), the homeostatic index (Hom) and the selection value (Sc) by Khangildin & Litvinenko (1981). General adaptive capacity (GAC), specific adaptive capacity variance (σ^2SACi), nonlinearity coefficient (Lgi), relative genotype stability (Sgi), genotype selection value (GSVi) and compensation-destabilization coefficient (Kgi) according to Kilchevskyi & Khotyleva (1985).

In generalized estimation of the adaptive potential of lines ranking by Snedecor (1961) andcalculations of the rating of adaptability of the variety (RAV) by Vlasenko (2006) were used. The results of the experimental data were processed using Statistica 6.0.

RESULTS AND DISCUSSION

The mass of grain of one ear, i.e. its productivity is the result of the action and interaction of many hereditary factors that determine its components. The variability and ratio of the components of ear productivity determine the level of its manifestation and the nature of inheritance and variability (Orlyuk, 2012).

In 2011, the average value of the weight of grain from the main ear (1.32 g) ranged from 1.01 g (26 KS,17 KS) to 1.91 g - 24 KS (Table 1).

The highest mass of grain in the main ear of the studied genotypes was formed in 2012 with variationin the range of 1.11–2.19 g and the mean 1.71 g. This year, only the line 54 KS significantly exceeded the standards for grain weight from the main ear. In 2013, the mass of grain from the main ear was in the range from 0.97 g (Podolyanka) to 2.04 g (12 KS), the mean 1.41 g. With the exception of the line 7 KS, all others on 0.04–0.83 g significantly exceeded the standards.

A significant excess over the standards for the weight of grain from the main ear, on average for 2011–2013, was set in the samples 42 KS (1.63 g), 24 KS (1.73 g) and 54 KS (1.77 g).

Table 1. Weight of grain from the main ear, g

Lines	Years				± to standard		
	2011	2012	2013	$\bar{x}$	Perlyna Lisostepu	Bilotserkivska napivkarlykova	Podolyanka
7 KS	1.44	1.98	1.05	1.49	-	+0.19	+0.11
8 KS	1.49	1.53	1.25	1.42	-0.07	+0.12	+0.04
42 KS	1.54	1.78	1.56	1.63	+0.14	+0.33	+0.25
29 KS	1.18	1.58	1.77	1.51	+0.02	+0.21	+0.13
26 KS	1.01	1.11	1.32	1.43	-0.06	+0.13	+0.05
24 KS	1.91	1.86	1.42	1.73	+0.24	+043	+0.35
12 KS	1.04	1.13	2.04	1.40	-0.09	+0.10	+0.02
44 KS	1.65	1.76	1.27	1.56	+0.07	+0.26	+0.18
54 KS	1.28	2.19	1.83	1.77	+0.28	+0.47	+0.39
22 KS	1.13	1.74	1.55	1.47	-0.02	+0.17	+0.09
17 KS	1.01	1.85	1.48	1.45	-0.04	+0.15	+0.07
Standards							
Perlyna Lisostepu	1.43	1.83	1.21	1.49	-	-	-
Bilotserkivska napivkarlykova	1.13	1.74	1.04	1.30	-	-	-
Podolyanka	1.26	1.92	0.97	1.38	-	-	-
SD_{05}	0.11	0.06	0.02	-	-	-	-

On average over three years, the lowest variability of grain weight from the main ear (0.24–0.28 g) and insignificant coefficients of variation (CV = 8.7; 10.0%) were observed in the lines 42 KS and 8 KS. At the same time, 42 KS had significantly 0.14 g more grain weight of the main ear than all standard (Table 2).

Table 2. Parameters of variability by weight of grain from the main ear (average for 2011–2013)

Lines	$\bar{x}$, g	Lim (g)		R, g	S^2	CV, %
		min	max			
7 KS	1.49	1.05	1.98	0.93	0.22	31.5
8 KS	1.42	1.25	1.53	0.28	0.02	10.0
42 KS	1.63	1.54	1.78	0.24	0.02	8.7
29 KS	1.51	1.18	1.77	0.59	0.09	19.9
26 KS	1.43	1.01	1.32	0.31	0.03	12.1
24 KS	1.73	1.42	1.91	0.49	0.07	15.3
12 KS	1.40	1.04	2.04	1.00	0.31	39.8
44 KS	1.56	1.27	1.76	0.49	0.07	17.0
54 KS	1.77	1.28	2.19	0.91	0.21	25.9
22 KS	1.47	1.13	1.74	0.61	0.10	21.5
17 CC	1.45	1.01	1.85	0.84	0.18	29.3
Standards						
Perlyna Lisostepu	1.49	1.21	1.83	0.62	0.10	21.2
Bilotserkivska napivkarlykova	1.30	1.04	1.74	0.70	0.15	29.8
Podolyanka	1.38	0.97	1.92	0.95	0.24	35.5

The average coefficient of variation (CV = 12.1–19.9%) was characterized by the lines 26 KS, 24 KS, 44 KS and 29 KS. In lines 7 KS, 12 KS, 54 KS, 22 KS, 17 KS and standards, in yearsof researches, on weight of grain from the main ear, the greatest variability (0.61–1.00 g) with a coefficient of variation is defined (21.2–39.8%).

Significant differences in the studied selection forms, in the amplitude of variability of grain mass from the main ear, as well as insignificant, average and significant coefficients of variation, indicating their differentreaction to environmental conditions were established. It is due to the interaction of genotype with the environment. Using analysis of variance, it was found that the share of variability caused by the interaction of genotype and environment factors had the greatest impact (51.49%) on the formation of grain mass in the main ear. The influence of the conditions of the year was at the level of 25.76%, and the genotype –21.69% (Fig. 1).

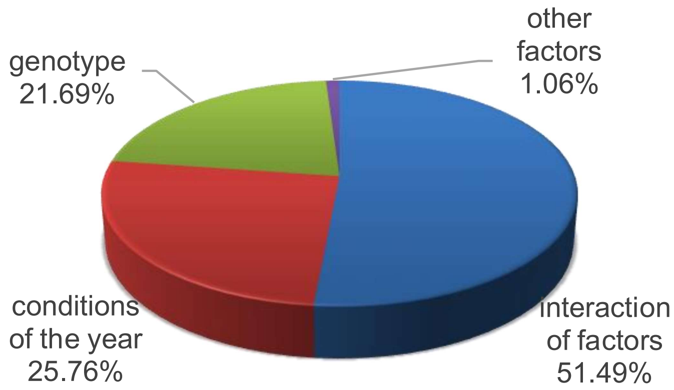

Figure 1. The share of the factors influence in the total variance according to the level of manifestation of the grain mass from the main ear (average for 2011–2013).

The results of our research coincide with the data of the Manukyan et al (2019) which found that the genotypes of the studied samples (the 'cultivar' factor) had the highest impact on the overall variability of productivity - their proportion was 50%. The proportion of variability caused by the influence of environmental conditions (the 'year' factor) was 26.5%.

To identify the mechanisms of plasticity and stability of new genotypes, it is necessary to focus on known cultivars with different types of resistance and plasticity (Kocherina, 2009).

The results of our research show that by the homeostatic indicators of grain weight of the main ear, standards (Hom = 3.93–7.06) exceeded the lines 29 KS (Hom = 7.57), 26 KS (Hom = 8.31), 44 KS (Hom = 9.47), 24 CS (Hom = 11.10), 8 CS (Hom = 13.38) and 42 CS (Hom = 19.87) (Table 3).

According to the selection value (Sc), the excess over the standards (Sc = 0.70–0.99) was observed in 29 KS (Sc = 1.01), 54 KS (Sc = 1.03), 44 KS (Sc = 1.13), 8 KS (Sc = 1.16) and 24 KS (Sc = 1.29).

The analysis showed that the line 54 KS had more than the average weight of the grain of the main ear (1.77 g) and specific adaptability to favorable conditions (bi = 2.03). Podolyanka (bi = 2.05), Bilotserkivska napivkarlykova (bi = 1.75) and samples 17 KS (bi = 1.91) and 7 KS (bi = 1.80) were determined to be the most sensitive to improved growing conditions. Perlyna Lisostepu and 22 KS had coefficients bi at the level of 1.22 and 1.32. Low-plastic were 42 KS (bi = 0.64), 44 KS (bi = 0.62), 29 KS (bi = 0.60) and 8 KS (bi = 0.31). The line 24 KS had a high grain weight of the main ear (1.73 g) and one of the minimum indicators (bi = 0.27).

Indicators of general adaptive capacity of standards (GAC = 1.73–2.18) exceeded lines 7 KS, 44 KS, 42 KS, 54 KS and 24 KS with an indicator (GAC = 2.29–2.76) (Table 4).

Table 3. Homeostaticity and adaptability by weight of grain of the main ear, (average for 2011–2013)

Lines	Grain weight, g	Adaptability parameters			
		Hom	Sc	bi	σ_{di}
7 KS	1.49	4.75	0.79	1.80	0.16
8 KS	1.42	13.38	1.16	0.31	0.04
42 KS	1.63	19.87	1.41	0.64	0.00
29 KS	1.51	7.57	1.01	0.60	0.15
26 KS	1.43	8.31	0.88	0.01	0.05
24 KS	1.73	11.10	1.29	0.27	0.14
12 KS	1.40	3.56	0,72	-0.59	0.58
44 KS	1.56	9.47	1.13	0.62	0.10
54 KS	1.77	6.81	1.03	2.03	0.07
22 KS	1.47	6.95	0.96	1.32	0.05
17 KS	1.45	4.97	0.79	1.91	0.05
Standards					
Perlyna Lisostepu	1.49	7.06	0,99	1.28	0.06
Bilotserkivska napivkarlykova	1.30	4.46	0.78	1.75	0.03
Podolyanka	1.38	3.93	0.70	2.05	0.12
Statistical parameters					
$\bar{x}$	**1.50**	**8.01**	**0.97**	**1.00**	**0.11**
Min	1.30	3.56	0.70	-0.59	0.00
Max	1.77	19.87	1.41	2.05	0.58

Table 4. Parameters of adaptive capacity and stability by weight of grain from the main ear (averagefor 2011–2013)

Lines	Grain weight, g	GAC	σ²(GxE)gi	σ²SACi	σSACi	Lgi	Sgi	GSVi	Kgi
7 KS	1.49	2.29	0.11	0.22	0.47	0.23	31.31	0.46	2.66
8 KS	1.42	1.95	0.04	0.02	0.15	0.26	10.55	1.09	0.28
42 KS	1.63	2.36	0.01	0.02	0.13	0.04	8.09	1.34	0.21
29 KS	1.51	1.87	0.08	0.09	0.30	0.27	19.90	0.85	1.10
26 KS	1.15	1.08	0.07	0.02	0.16	0.42	13.69	0.80	0.30
24 KS	1.73	2.76	0.09	0.07	0.27	0.34	15.54	1.14	0.88
12 KS	1.40	1.37	0.40	0.31	0.55	0.72	39.39	0.18	3.74
44 KS	1.56	2.35	0.06	0.07	0.26	0.22	16.43	0.99	0.80
54 KS	1.77	2.60	0.08	0.21	0.46	0.17	25.92	0.75	2.56
22 KS	1.47	1.90	0.03	0.10	0.31	0.09	21.14	0.78	1.19
17 KS	1.45	1.87	0.06	0.18	0.42	0.14	29.07	0.52	2.16
Standards									
Perlyna Lisostepu	1.49	2.18	0.03	0.10	0.31	0.10	21.05	0.80	1.20
Bilotserkivska napivkarlykova	1.30	1.73	0.04	0.14	0.38	0.10	29.18	0.46	1.77
Podolyanka	1.38	2.02	0.11	0.24	0.49	0.22	35.17	0.31	2.89
Statistical parameters									
$\bar{x}$	**1.48**	**2.02**	**0.09**	**0.13**	**0.33**	**0.24**	**22.60**	**0.75**	**1.55**
min	1.15	1.08	0.01	0.02	0.13	0.04	8.09	0.18	0.21
max	1.77	2.76	0.40	0.31	0.55	0.72	39.39	1.34	3.74

The lines 42 KS, 24 KS, 44 KS and 29 KS by grain weight of the main ear exceeded the standards and had lower values of σ^2SACi (0.02–0.09).

The indicators of GSVi standards exceeded 42 KS (GSVi = 1.34), 24 KS (GSVi = 1.14), 8 KS (GSVi=1.09), 44 KS (GSVi = 0.99) and 29 KS (GSVi = 0.85).

We investigated that the lower relative stability of the genotype (Sgi) and significantly higher grain weight from the main ear, compared with the standard Pearl of the forest-steppe had 44 KS (Sgi = 8.09) and 24 KS (Sgi = 15.54).

Lines of soft winter wheat, characterized by an above average weight of grain from the main ear, had a predominantly linear response to environmental conditions (Lgi = 0.04–0.34). The compensation-destabilization coefficient (Kgi) varied in the experiment from the compensating (Kgi = 0.21) to a clear destabilizing (Kgi = 3.74) level. The compensating effect (Kgi < 1) among the lines that significantly exceeded the standards for grain weight from the main ear was observed in 24 KS and 42 KS.

The results of ranking the studied genotypes by grain weight of the main ear and indicators of plasticity and stability show that the first place in the rating of adaptability of the variety was taken by the line 42 KS, which by the minimum manifestation of the trait, σ^2SACi, Sgi, SGVi, Hom, Sc and σ_{di} was the first, by the average value of the trait, GAC and the coefficient bi was the third, and by the maximummanifestation of the trait was the eighth (Table 5).

Table 5. Ranks by grain weight from the main ear, plasticity, stability and adaptability rating (averagefor 2011–2013)

Lines	Ranks by grain weight from the main ear and adaptability parameters											Average rank	* X / average rank	Rating
	X	min	max	GAC	σ^2SACi	Sgi	SGVi	Hom	Sc	bi	σ_{di}			
42 KS	3	1	8	3	1	1	1	1	1	3	1	2	0.75	1
24 KS	2	2	5	1	5	4	2	3	2	7	11	4	0.43	2
44 KS	4	4	10	4	4	5	4	4	4	4	9	5	0.31	3
54 KS	1	3	1	2	11	9	9	9	5	12	8	6	0.28	4
8 KS	11	5	13	8	2	2	3	2	3	6	3	5	0.27	5
Perlyna Lisostepu	7	6	7	6	8	7	7	7	7	1	7	6	0.23	6
29 KS	5	7	9	10	6	6	5	6	6	5	12	7	0.22	7
22 KS	8	8	11	9	7	8	8	8	8	2	5	7	0.20	8
7 KS	6	9	3	5	12	12	12	11	11	9	13	9	0.16	9
17 KS	9	12	6	11	10	10	10	10	10	10	4	9	0.16	10
26 KS	10	13	14	14	3	3	6	5	9	11	6	9	0.13	11
Bilotserkivska napivkarlykova	14	11	12	12	9	11	11	12	12	8	2	10	0.13	12
Podolyanka	13	14	4	7	13	13	13	13	14	13	10	12	0.12	13
12 KS	12	10	2	13	14	14	14	14	13	14	14	12	0.11	14

Second and third place in the RAS, due to the optimal combination of grain weight from the main ear and the parameters of adaptability, took 24 KS and 44 KS, respectively.

Plasticity is to be understood as the ability of a variety to combine a sufficiently high yielding capacity with its stability under varying conditions, while genotypes with hyperreaction to growth conditions are to be considered sensitive to these conditions (Lytvynenko et al., 2013.).

As a result of estimation of lines by the weight of grain from the main ear and indicators of plasticity and stability selection forms, 42 KS, 24 KS and 44 KS were selected, as they are of practical interest for selection work.

The experimental data show that the correlation between grain weight from the main ear and grain yield was at the level of direct strong (0.747–0.871) in 2012–2013 and very strong, close to functional (0.914) in 2011. The direct influence of grain weight from the main ear at the level of strong and very strong, close to functional (0.805–0.942) on the weight of grain from the plant was established. Thus, it can be argued that the main ear plays an extremely important role in shaping the productivity of wheat plants and grain yields (Table 6).

Table 6. Correlation relations (r) of grain mass from the main ear with elements of productivity and grain yield of soft winter wheat

Indicators	2011	2012	2013
Aboveground mass of the plant	0.877*	0,513	0.805*
The mass of the main stem	0.964*	0.780*	0.882*
The weight of the main ear	0.995*	0.870*	0.909*
The mass of straw of the main stem	0.891*	0.387	0.802*
The length of the main stem	0.344	0.202	0.751*
The length of the ear-bearing internode	0.615*	0.451	0.613*
The length of the internode, second from the top	0.315	0.285	0.637*
The length of the main ear	0.678*	0.364	0.778*
The number of spikelets in the main ear	0.531	0.580*	0.532
The number of grains from the main ear	0.804*	0.897*	0.941*
The number of grains in the spikelet of the main ear	0.579*	0.625*	0.887*
The mass of grain from the plant	0.942*	0.887*	0.805*
The mass of 1,000 grains of the main ear	0.672*	0.674*	0.603*
Grain yield	0.914*	0.871*	0.747*

* probably at $P < 0.05$.

Direct correlations at the level of significant and strong (0.513–0.877) are observed between the mass of grain from the main ear and the aboveground mass of the plant. At the level of strong and very strong, close to functional, the correlation between the grain mass of the main ear is determined: with the mass of the main stem (0.780–0.964); mass of the main ear (0.870–0.995); and the number of grains from the main ear (0.804–0.941). The correlation between the grain weight of the main ear and the straw mass was less close (0.387–0.819) and was characterized as moderate and strong.

Studies have shown a significant positive correlation between grain weight per spike and spikelet weight per spike (Green et al., 2012).

There was a significant correlation between the weight of the grain from the ear and the weight of 1,000 grains (0.603–0.674) and the number of ears (0.531–0.580). The correlation between the mass of grain from the ear and the number of grains in the ear was not stable and varied from significant (0.579–0.625) in 2011–2012 to strong (0.887) in 2013.

The correlation between the mass of grain from the main ear was insignificant with the length of the stem (0.202–0.751), the length of the spikelet node (0.451–0.615), the length of the internode that is second from the top (0.285–0.637), the length of the main ear (0.364–0.778).

CONCLUSIONS

Thus, the lines of soft winter wheat 42KS, 24 KS and 54 KS were characterized by high grain weight from the main ear (1.63–1.77 g). As a result of selection by grain mass from the main ear and other economically valuable traits, properties and indicators of adaptability, lines of soft winter wheat 44 KS, 42 KS, 24 KS were involved in 2014 in hybridization in different combinations of crosses. Selected lines as a result of research (2015–2020) from these populations of soft winter wheat are competitively tested in the conditions of Bila Tserkva Research and Selection Station, forming high grain yields (7.39–8.12 t ha^{-1}) and will be transferred to 2021 for the State variety test for inclusion in the Register of plant varieties suitable for distribution in Ukraine.

REFERENCES

Artemchuk, I.P. 2013. Efficacy of mutagenic factors in induction of practically valuable mutations of winter wheat. *Factors of experimental evolution of organisms* **3**, 114–117 (in Ukrainian).

Bagan, A.V., Yurchenko, S.O. & Shakali, S.M. 2012. Variability of offspring of different morphological parts of the ear of winter wheat varieties by quantitative characteristics. *Bulletin of the Poltava State Agrarian Academy* **4**, 33–35(in Ukrainian).

Bazalii, V.V., Boichuk, I.V., Lavrynenko, Yu.O., Bazalii, H.H., Domaratskyi, Ye.O. & Larchenko, O.V. 2019. Problems and productivity of winter wheat varieties selection with increased environmental stability. *Factors of experimental evolution of organisms* **24**, 20–25. https://doi.org/10.7124/FEEO.v24.1072

Brancourt-Hulmel, M., Doussinault, g., Lecomte, C., Bérard, P., Le Buanec, B. & Trottet, M. 2003. Genetic Improvement of Agronomic Traits of Winter Wheat Cultivars Released in France from 1946 to 1992. *Crop Sci* **43**, 37–45. https://doi.org/10.2135/cropsci2003.3700

Diordiieva, I., Riabovol, L., Riabovol, I., Serzhyk, O., Novak, A. & Kotsiuba, S. 2018. The characteristics of wheatcollection samples created by Triticum aestivum L/Triticum spelta L hybridization. *Agronomy Research* **16**(5), 2005–2015. https://doi.org/10.15159/AR.18.181

Donmez, E., Sears, R.G., Shroyer, J.P. & Paulsen, g.M. 2001. Genetic gain in yield attributes of winter wheat in the Great Plains. *Crop Sci* **41**, 1412–1419. doi: 10.2135/cropsci2001.4151412x

Dospekhov, B.A. 1985. *Field experiment technique*. Moscow, 351pp. (in Russian).

Feng, F., Han, Y., Wang, S., Yin, S., Peng, Z., Zhou, M., Gao, W., Wen, X., Qin, X. & Siddique, K.H.M. 2018. TheEffect of Grain Position on Genetic Improvement of Grain Number and Thousand Grain Weight in Winter Wheat in North China. Front. *Plant Sci* **9**, 129. doi: 10.3389/fpls.2018.00129

Finlay, K.W. & Wilkinson, g.N. 1963. The analysis adaptation in a plant breeding programme 1963. Aust. *J. Agric. Res.* **14**, 742–754.

Golabadi, M., Golkar, P. & Bahari, B. 2015. Remobilization assay of dry matter from different shoot organs underdrought stress in wheat (Triticum aestivum L.). *Agronomy Research* **13**(5), 1202–1214.

Green, A.J., Berger, g., Griffey, C.A., Pitman, R., Thomason, W. & Balota, M. 2012. Genetic yield improvementin soft red winter wheat in the Eastern United States from 1919 to 2009. *Crop Sci.* **52**, 2097–2108. doi:10.2135/cropsci2012.01.0026
Guberac, V., Martinčić, J. & Marić, S. 2000. Grain Yield Components of Winter Wheat New Cultivars in Correlation with Sowing Rate. *Cereal Research Communications* **28**, 307–314. https://doi.org/10.1007/BF03543609
Guzhov, Yu.L. 1987. *Triticale –Achievements and Prospects of Selection Based on Mathematical Modeling*. Moscow, 232 pp. (in Russian).
Innes, P., Hoogendoorn, J. & Blackwell, R. 1985. Effects of differences in date of ear emergence and height on yield of winter wheat. *The Journal of Agricultural Science* **105**(3), 543–549. doi:10.1017/S0021859600059438
Khangildin, V.V. & Litvinenko, N.A. 1981. Homeostaticity and adaptability of winter wheat varieties. *Bulletin ofthe VSGI. Issue* **1**(39), 8–14 (in Russian).
Kilchevsky, A.V. & Khotyleva, L.V. 1985. A method for assessing the adaptive ability and stability of genotypes,the differentiating ability of the environment. *Genetics. Vol. XXI* **9**, 1481–1489 (in Russian).
Kocherina, N.V. 2009. *Algorithms of ecological and genetic improvement of plant productivity*.
PhD Thesis, SPb.: GNU API Rosselkhozakademii, 130 pp. (in Russian).
Kochmarsky, V.S. 2012. *Selection of winter soft wheat*. Myronivka wheat Institute, Myronivka, 816 pp. (in Ukrainian).
Kulyk, M.I., Rozhov, A.O., Kalinichenko, O.V., Taranenko, A. O. & Onopriienko, O.V. 2020. Effect of winter wheat variety, hydrothermal coefficient (HTC) and thousand kernel weight (TKW) on protein content, grain and proteinyield. *Agronomy Research* **18**(3) 2103–2116. https://doi.org/10.15159/AR.20.187
Li, Y., Cui, Z.Y., Ni, Y.L., Zheng, M.J., Yang, D.Q. & Jin, M. 2016. Plant density effect on grain number and weight of two winter wheat cultivars at different spikelet and grain positions. *PLOS ONE* 11:e0155351. doi:10.1371/journal.pone.0155351
Litvinenko, M.A. 2011. Realization of wheat field potential. *Seed production* **6**, 1–7 (in Ukrainian).
Lytvynenko, M.A., Lyfenko, S.P. & Yeryniak, M.I. 2013.Winter wheat varieties of steppe ecotype undergo extreme weather conditions better. *Seed production* **9**, 14–18 (in Ukrainian).
Manukyan, I.R., Basieva, M.A., Gneush, A.N., Arutyunova, g.Y., Udychak, M.M. & Yurin, D.A. 2019. Complexevaluation of productivity and environmental plasticity of the winter wheat breeding material for the conditions of the submontane zone of Central Caucasus. *Management, Economic Engineering in Agriculture and Rural Development* **19**(4), 159–165.
Orlyuk, A.P. 2012. *Genetics of wheat with the basics of selection.* Kherson, 436 pp. (in Ukrainian).
Rokitsky, P.F. 1973. *Biological statistics*. Minsk, 320 pp. (in Russian).
Sanchez-Garcia, M., Álvaro, F., Martín-Sánchez, J.A., Sillero, J.C., Escribano, J. & Royo, C. 2012. Breeding effects on the genotype×environment interaction for yield of bread wheat grown in Spain during the 20th century. *Field Crops Research* **126**, 79–86. https://doi.org/10.1016/j.fcr.2011.10.001.
Shpaar, D. 2012. *Grain crops: growing, harvesting, storage and use*. Kiev, 704 pp. (in Russian).
Siddique, K.H.M., Belford, R.K., Perry, M.W. &Tennant, D. 1989. Growth, development and light interceptionof old and modern wheat varieties in a Mediterranean-type environment. Aust. *J. Agr. Res.* **40**, 473–487.
Snedecor, G.W. 1961. *Statistical Methods.* The Iowa State College Press. Ames. Iowa U.S.A. 534 pp.

Sofield, I., Evans, L.T., Cook, M.G. & Wardlaw, I.F. 1977. Factors Influencing the Rate and Duration of Grain Filling in Wheat. *Functional Plant Biology* **4**, 785–797. https://doi.org/10.1071/PP9770785

Vlasenko, V.A. 2006. Estimation of adaptability of soft spring wheat varieties. *Variety research and protectionof plant variety rights*, pp. 93–103 (in Ukrainian).

Vlasenko, V.A., Bakumenko, O.M., Osmachko, O.M., Burdulaniuk, A.O., Tatarynova, V.I., Demenko, V.M., Rozhkova, T.O., Yemets, O.M., Bilokopytov, V.I., Horbas, S.M., Fanhua, M. & Qian, Z. 2018. Ecological plasticity and adaptibility of Chinese winter wheat varieties (Triticumaestivum L.) under the conditions of North-East forest steppe of Ukraine. *Ukrainian Journal of Ecology* **8**(4), 114–121.

Volkodav, V. 2003. *Methods of state testing of plant varieties for suitability for distribution in Ukraine*. Kyiv, Issue **1**, 106 pp. (in Ukrainian).

Xiao, Y.G., Qian, Z.G., Wu, K., Liu, J.J., Xia, X.C. & Ji, W.Q. 2012. Genetic gains in grain yield and physiological traits of winter wheat in Shandong Province, China, from 1969 to 2006. *Crop Sci* **52**, 44–56. doi: 10.2135/cropsci2011.05.0246

Yen, C., Zheng, Y.L. & Yang, J.L. 1995. An ideotype for high yield breeding in theory and practice. Proceedingsof 8th International Wheat Genetic Symposium. *China Agricultural Scientech Press*, Beijing, China, pp. 1113–1117.

Zhang, J.Y., Sun, J.S., Duan, A.W., Wang, J.L., Shen, X.J. & Liu, X.F. 2007. Effects of different planting patternson water use and yield performance of winter wheat in the Huang-Huai-Hai plain of China. *Agric. Water Manage* **92**, 41–47. doi: 10.1016/j.agwat.2007.04.007