UDC 633.31:631.52:631.67
DOI https://doi.org/10.32848/agrar.innov.2023.21.23

ECOLOGICAL PLASTICITY AND STABILITY OF WINTER WHEAT VARIETIES IN THE CONDITIONS OF THE SOUTHERN STEPPE OF UKRAINE (PART 2 – DROUGHT YEARS)

KONOVALOVA V.M. – PhD (Doctor of Philosophy)
orcid.org/0000-0002-0655-9214
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
TYSHCHENKO A.V. – Doctor of Agricultural Sciences
orcid.org/0000-0003-1918-6223
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
BAZALII H.G. – Candidate of Agricultural Sciences, Senior Research
orcid.org/0000-0003-2842-0835
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
FUNDIRAT K.S. – Candidate of Agricultural Sciences
orcid.org/0000-0001-8343-2535
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
TYSHCHENKO O.D. – Candidate of Agricultural Sciences, Senior Research
orcid.org/0000-0002-8095-9195
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
REZNICHENKO N.D. – Candidate of Agricultural Sciences
orcid.org/0000-0002-5741-6379
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
KONOVALOV V.O.
orcid.org/0000-0002-1725-1557
Askanian State Agricultural Research Station of the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
OCHKALA O.S. – PhD (Doctor of Philosophy)
orcid.org/0000-0002-1609-5679
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine
BOROVYK V.O. – Candidate of Agricultural Sciences, Senior Research
orcid.org/0000-0003-0705-2105
Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine

Wheat (*Triticum aestivum* L.) is one of the most important crops in maintaining food security, which ensures the existence of a significant part of the world's population [4, 5, 8]. Scientific forecasts indicate that with a significant increase in the population on Earth, the production of food products will not coincide with such growth and, under the current dynamics, the food problem may turn into a deep international crisis [20, 23, 26]. Scientists' calculations show that at the current rate of population growth, in the future, world grain production per person will decrease [2].

Currently, the annual gross production of wheat is increasing by about 0.9%, but this is much slower than the growth rate of the population and, accordingly, its quantity is insufficient to meet their needs [9, 25]. Therefore, humanity must find a solution to this problem, since the rate of population growth remains too high [6].

Along with population growth, climate changes, the so-called global warming, have been observed in recent decades, which leads to significant fluctuations in the yield of winter wheat both in space and time [1, 14, 24]. Therefore, the efforts of breeders should be directed to the creation of not only high-yielding varieties, but also those that ensure the stability of the harvest in different agro-climatic conditions [11, 15, 19, 22]. To date, scientists have already investigated the agronomic and physiological mechanisms responsible for the stability of the crop [7, 16, 17, 21]. Therefore, different varieties can show contrasting reactions to environmental conditions due to their interaction [13, 18, 27].

The purpose of our research was to study and analyze the environmental stability and adaptability to different environments of winter wheat varieties selected by the Institute of Climate-oriented Agriculture of the National Academy of Sciences and the Selection and Genetic Institute of the National Center for Seed Science and Varietal Research of the National Academy of Sciences in the conditions of the Southern Steppe of Ukraine.

Materials and methods. The reaction of winter wheat varieties to different growing conditions was studied at the Askanian State Agricultural Research Station in the village of Tavrychanka, Kherson region (46°33'12"N; 33°49'13"E; 39 m above sea level) during 2015/16–2019/20. Research was conducted under different conditions of irrigation: with irrigation and without irrigation. Under conditions of natural moisture, the yield strongly depended on the amount of precipitation during the growing season, especially during the critical growing season (April–May). Average temperatures and total precipitation for all experimental seasons are shown in Table 1 along with long-term average values (1961–2005). The seasons of 2016/2017 and 2018/19 were the most favorable for natural moisture conditions, as the precipitation that fell during the growing season contrib-

Table 1

Weather conditions for research (2015–2020)

	1961-2005		2015/2016		2016/2017		2017/2018		2018/2019		2019/2020	
	T (°C)	P (mm)	T (°C)	P (mm)	T (°C)	P (mm)	T (°C)	P (mm)	T (°C)	P (mm)	T (°C)	P (mm)
October – December	4.8	98.0	6.0	81.2	3.4	42.0	5.9	75.0	5.5	53.4	7.4	67.9
January	-3.1	30.0	-3.1	59.9	-3.9	14.4	0.7	24.1	-0.3	33.8	1.0	18.3
February	-2.0	29.0	3.9	32.9	-0.9	22.0	0.1	47.0	1.1	10.6	2.2	59.6
March	2.2	26.0	6.1	20.3	6.6	10.2	1.5	35.1	5.5	5.7	7.5	3.5
April	9.6	28.0	12.4	50.5	8.5	81.8	12.9	2.7	10.3	38.9	9.5	7.5
May	15.6	38.0	15.9	95.7	15.5	25.8	19.5	13.0	17.4	72.4	14.9	42.4
June	20.0	46.0	21.5	76.2	21.7	8.0	22.4	23.0	24.5	14.1	22.2	59.3
January – June	7.1	197.0	9.5	335.5	7.9	162.2	9.5	144.9	9.8	175.5	9.6	190.6
October – June	6.0	295.0	7.8	416.7	5.7	204.2	7.7	219.9	7.7	228.9	8.5	258.5

uted to the replenishment of moisture in the soil for normal plant growth and development. The index of environmental conditions for these years was: for natural moisture 0.32 and 0.87, for irrigation 0.94 and 1.32, respectively. The 2017/18 and 2019/20 seasons were very dry, especially the critical growing season (April–May), in which air and soil drought was observed due to insufficient precipitation and high average daily temperature, and the indices of environmental conditions for natural moisture were equal to -1.85 and -1.43 and for irrigation 0.51 and 0.89, respectively. Therefore, we calculated and analyzed the parameters of stability, adaptability and ecological plasticity of 18 varieties of winter wheat separately in dry years, wet years and during the five-year period (2015/16–2019/20), which included the year 2015/2016 with too high a number precipitation (index of environmental conditions for natural moistening – -1.17, for irrigation – -0.41), which led to the laying of crops and crop losses.

They studied 18 varieties of winter wheat, which are usually grown in the south of Ukraine and are listed in the State Register of Plant Varieties. Varieties were tested on plots with an area of 50 m^2 in three repetitions by the method of randomized repetitions (blocks), the sowing rate was adjusted to 4.5 million viable seeds per ha. Research was conducted according to generally accepted methods, the amount of fertilizers and chemical treatments was adjusted according to growing conditions and the presence of diseases and pests. The studied samples were sown in the first decade of October, and the harvest was done in July.

Statistical analysis. The reaction of winter wheat varieties to growing conditions was determined by: index of environmental conditions (environmental index), obtained as the average value of all varieties in the *j*-th environment minus the overall average (*Ij*), coefficient of regression of the variety on the environment (b_i), variance of deviations from regression lines, second stability parameter (s^2_{di}) [3], an indicator of resistance to stress (*RS*), genetic flexibility (*Gf*) [10], general homeostasis (*Hom*), breeding value (*Sc*), adaptability coefficient (*CA*), the effects of general adaptive capacity (GAC_i), specific adaptive capacity (SAC_i), variance of interaction between genotype and environment ($\sigma^2_{(G\times E)gi}$), variance of specific adaptive capacity (σ^2_{SACi}), relative stability of the genotype (s_{gi}), selection value of the genotype (SVG_i), coefficient of compensation-destabilization of the genotype (K_{gi}), coefficient of non-linearity of the response of the genotype to the environment (l_{gi}) [12].

A correlation analysis was conducted between grain yield and drought resistance indices to determine the best drought-resistant varieties and indices. Principal component analysis (PCA) was performed on the observations. Correlation, cluster analyses, and PCA were performed using Microsoft ® Excel 2016/XLSTAT © -Pro (Version 2016.02.28451, 2016, Addinsoft, Inc., Brooklyn, NY, USA), Statistica data analysis software system v.8. (Sta Stof Inc., North Melbourne, Australia) and SPSS 20.00 statistical software (SPSS/PC-20, SPSS Inc., Chicago, IL, USA).

Research results and their discussion. The obtained experimental data allow distinguishing varieties of winter wheat by maximum productivity (*Ymax*) *Mariia* – 8.61 t/ha, *Harantiia odes'ka* – 8.23 and *Nyva odes'ka* – 8.04 t/ha, *Konka* varieties by minimum productivity (*Ymin*) – 4.75 t/ha, *Kokhana* – 4.61, *Koshova* and *Zysk* – 4.67, *Lira odes'ka* – 4.99 and *Schedrist' odes'ka* – 4.65 t/ha. The lowest productivity in terms of minimum productivity was formed by the varieties *Harantiia odes'ka* – 3.01 t/ha and *Rosynka* – 3.87 t/ha, and the *Rosynka* variety was characterized by the lowest productivity in terms of maximum productivity of 5.69 t/ha (Table 2).

According to the indicator of average yield (*Ymean*), varieties *Kokhana* and *Mariia* stood out – 6.24 t/ha, *Zysk* – 6.34 and *Lira odes'ka* – 6.31 t/ha, on the other hand, *Rosynka* variety was characterized by the lowest value – 4.82 t/ha.

The level of resistance of the researched winter wheat varieties to stressful conditions reflects the index of the difference between the minimum and maximum yield (*RS*), and the smaller this difference, the higher its resistance to stress. According to this indicator, the winter wheat variety *Khersons'ka bezosta* was singled out – 1.82, while the *Mariia* and *Harantiia odes'ka* varieties were characterized by the highest values of this indicator, 4.32 and 5.22, respectively.

Table 2

Homeostaticity, ecological plasticity and adaptability of winter wheat varieties based on grain yield (2018, 2020)

Variety	Designation	Yield, t/ha		Adaptability parameters						
		Ymin-Ymax	*Ymean*	*RS*	*Sc*	*Gf*	b_i	s^2_{di}	*CA*	*Hom*
Anatoliia	G1	4.47–7.18	5.88	2.71	4.27	5.83	0.84	0.13	100.5	13.6
Burhunka	G2	4.32–7.45	5.43	3.13	3.88	5.89	0.84	0.92	92.8	11.9
Konka	G3	4.75–7.20	5.92	2.45	4.04	5.98	0.91	0.17	101.1	11.5
Kokhana	G4	4.61–7.54	6.24	2.93	4.51	6.08	0.91	0.20	106.7	14.2
Koshova	G5	4.67–7.49	6.18	2.82	4.53	6.08	0.86	0.17	105.6	14.7
Mariia	G6	4.29–8.61	6.24	4.32	4.04	6.45	1.23	0.78	106.6	10.7
Ledia	G7	4.00–6.68	5.50	2.68	4.00	5.34	0.79	0.24	94.0	12.7
Rosynka	G8	3.87–5.69	4.82	1.82	3.53	4.78	0.62	0.06	82.3	11.5
Khersons'ka bezosta	G9	4.07–7.33	5.47	3.26	3.37	5.70	1.11	0.23	93.4	8.4
Askaniis'ka	G10	4.50–7.58	6.14	3.08	4.25	6.04	0.99	0.11	104.9	12.4
Harantiia odes'ka	G11	3.01–8.23	5.38	5.22	2.57	5.62	1.55	1.60	91.8	5.6
Zysk	G12	4.67–7.56	6.34	2.89	4.48	6.12	0.96	0.14	108.3	13.5
Lira odes'ka	G13	4.99–7.53	6.31	2.54	4.75	6.26	0.69	0.55	107.9	16.4
Mudrist' odes'ka	G14	4.06–7.89	5.93	3.83	3.37	5.98	1.31	0.62	101.2	7.9
Nyva odes'ka	G15	4.16–8.04	6.18	3.88	3.72	6.10	1.26	0.57	105.6	9.1
Pylypivka	G16	4.44–7.08	5.72	2.64	3.69	5.76	1.01	0.17	97.7	9.7
Tradytsiia odes'ka	G17	4.32–7.14	5.66	2.82	3.50	5.73	1.10	0.18	96.6	8.8
Schedrist' odes'ka	G18	4.65–7.94	6.03	3.29	4.12	6.30	1.01	0.34	103.0	11.8
Medium grade		**4.33–7.45**	**5.85**	**3.13**	**3.92**	**5.89**	**1.00**	**0.40**	**100.0**	**11.4**
V, %			7.03	24.90	13.66	6.53	23.21	97.79	7.06	24.01
$S\dot{x}_{absolute}$			0.10	0.18	0.13	0.09	0.05	0.09	1.66	0.64
$S\dot{x}_{reletive}$			1.66	5.87	3.22	1.54	5.47	23.05	1.66	5.66
LSD_{01}			0.31	0.58	0.40	0.29	0.17	0.29	5.27	2.04
LSD_{05}			0.22	0.42	0.29	0.21	0.13	0.21	3.81	1.47

According to the breeding value of the variety (*Sc*), the varieties *Kokhana* – 4.51, *Koshova* – 4.53, *Zysk* – 4.48 and *Lira odes'ka* – 4.75 stood out.

Winter wheat varieties *Mariia* – 6.45, *Lira odes'ka* – 6.26 and *Schedrist' odes'ka* – 6.30 stood out according to the indicator of genetic flexibility (*Gf*), that is, such varieties form a higher yield in contrasting conditions compared to other varieties.

According to the regression coefficient (b_i), which is a criterion for assessing the level of ecological plasticity and indicates the reaction of the genotype to a change in environmental conditions, the intensive type variety (b_i > 1) *Harantiia odes'ka* – 1.55, the stable type (b_i < 1) *Rosynka* variety – 0.62 and *Lira odes'ka* – 0.69. If b_i = 1, then the genotype is well adapted to various growing conditions, the closest to this are the varieties *Askaniis'ka* – 0.99, *Pylypivka* and *Schedrist' odes'ka* – 1.01.

During the analysis of winter wheat varieties based on the variance of the deviation from the s^2_{di} regression line, the *Rosynka* variety with the highest predicted stability was singled out, with an s^2_{di} value of 0.059. On the other hand, the *Harantiia odes'ka* variety turned out to be unstable with the highest value of s^2_{di} (1.596).

The maximum values of the coefficient of adaptability (*CA*) were characterized by varieties *Kokhana* – 106.7, *Mariia* – 106.6, *Zysk* – 108.3 and *Lira odes'ka* – 107.9.

According to the indicator of homeostaticity (*Hom*), which characterizes the ability of plants to develop normally under adverse environmental conditions, the varieties *Kokhana* – 14.2, *Koshova* – 14.7 and *Lira odes'ka* – 16.4 stood out. The lowest homeostatic value (5.6) was characterized by the *Harantiia odes'ka* variety.

Winter wheat varieties had the greatest effects of general adaptive capacity (GAC_i): *Zysk* – 0.49 and *Lira odes'ka* – 0.46. *Rosynka* variety was characterized by the lowest value of this characteristic – 1.03 (Table 3).

The variance parameter (σ^2_{SACi}) characterizes the specific adaptive capacity, that is, the response of the genotype to environmental conditions. The most stable *Rosynka* variety with the lowest value of σ^2_{SACi} – 0.73 was established. The *Harantiia odes'ka* variety with the highest value of σ^2_{SACi} – 5.51 is an unstable or intensive type variety.

Rosynka – 17.8 and *Lira odes'ka* – 17.5 stood out according to the parameter of relative stability of the genotype (s_{gi}), which characterizes them as the most stable.

The *Askaniis'ka* and *Pylypivka* varieties were characterized by the smallest values (0.04 and 0.08, respectively) of the variance of the interaction of genotype and environment $\sigma^2_{(G\times E)gi}$, but they were unstable for the compensation coefficient K_{gi} (1.03 and 1.09, respectively), which indicates the manifestation of a destabilizing effect, although they were

Table 3

Parameters of adaptive properties of winter wheat varieties based on grain yield (2018, 2020)

Variety	Designation	Yield, t/ha		Adaptability parameters						
		Ymin-Ymax	***Ymean***	GAC_i	$\sigma^2_{(G\times E)gi}$	σ^2_{SACi}	s_{gi}	SVG_i	K_{gi}	l_{gi}
Anatoliia	G1	4.47–7.18	5.88	0.03	0.11	1.36	19.8	3.52	0.74	0.079
Burhunka	G2	4.32–7.45	5.43	-0.42	0.63	1.91	25.4	2.63	1.04	0.328
Konka	G3	4.75–7.20	5.92	0.06	0.10	1.64	21.6	3.33	0.90	0.059
Kokhana	G4	4.61–7.54	6.24	0.39	0.12	1.63	20.5	3.66	0.89	0.072
Koshova	G5	4.67–7.49	6.18	0.33	0.12	1.47	19.6	3.73	0.80	0.082
Mariia	G6	4.29–8.61	6.24	0.39	0.59	3.30	29.1	2.56	1.81	0.178
Ledia	G7	4.00–6.68	5.50	-0.35	0.21	1.30	20.7	3.20	0.71	0.159
Rosynka	G8	3.87–5.69	4.82	-1.03	0.27	0.73	17.8	3.08	0.40	0.367
Khersons'ka bezosta	G9	4.07–7.33	5.47	-0.39	0.15	2.42	28.5	2.32	1.32	0.060
Askaniis'ka	G10	4.50–7.58	6.14	0.29	0.04	1.88	22.3	3.37	1.03	0.022
Harantiia odes'ka	G11	3.01–8.23	5.38	-0.48	1.59	5.51	43.7	0.63	3.01	0.289
Zysk	G12	4.67–7.56	6.34	0.49	0.06	1.78	21.0	3.64	0.97	0.036
Lira odes'ka	G13	4.99–7.53	6.31	0.46	0.51	1.22	17.5	4.08	0.67	0.421
Mudrist' odes'ka	G14	4.06–7.89	5.93	0.07	0.56	3.60	32.0	2.09	1.97	0.157
Nyva odes'ka	G15	4.16–8.04	6.18	0.33	0.48	3.32	29.5	2.49	1.82	0.143
Pylypivka	G16	4.44–7.08	5.72	-0.14	0.08	1.99	24.7	2.86	1.09	0.041
Tradytsiia odes'ka	G17	4.32–7.14	5.66	-0.20	0.10	2.33	27.0	2.56	1.28	0.045
Schedrist' odes'ka	G18	4.65–7.94	6.03	0.18	0.20	2.12	24.1	3.08	1.16	0.093
Medium grade		**4.33–7.45**	**5.85**	**0.00**	**0.33**	**2.19**	**24.7**	**2.94**	**1.20**	**0.146**
V, %			7.03	74363.30	113.82	51.43	25.77	27.09	51.45	84.59
$S\dot{x}_{absolute}$			0.10	0.10	0.09	0.27	1.50	0.19	0.15	0.03
$S\dot{x}_{reletive}$			1.66	17527.60	26.83	12.12	6.07	6.39	12.13	19.94
LSD_{01}			0.31	0.31	0.28	0.84	4.76	0.59	0.46	0.09
LSD_{05}			0.22	0.22	0.20	0.61	3.44	0.43	0.33	0.07

characterized by a linear response to a change in the environment. The compensation coefficient varied from 0.40–3.01. In *Anatoliia*, *Konka*, *Kokhana*, *Koshova*, *Ledia*, *Rosynka*, *Zysk* and *Lira odes'ka* varieties, it was less than one, which indicates a stabilization effect. *Rosynka* – 0.40 and *Lira odes'ka* – 0.67 were characterized by the lowest values. In others, it was more than one, with the highest value of 3.01 in the *Harantiia odes'ka* variety, which indicates the predominance of the destabilizing effect. When selecting stable varieties, preference should be given to varieties with K_{gi} < 1.

The varieties *Koshova* and *Lira odes'ka* with values of 3.73 and 4.08, respectively, were characterized by a high selection value of the genotype (SVG_i). Varieties of this type are the most valuable and can give maximum yields even under unfavorable conditions.

According to the parameters of adaptability, the *Kokhana*, *Koshova*, *Rosynka*, *Zysk* and *Lira odes'ka* varieties were selected as the most stable, while *Harantiia odes'ka* was selected as an intensive type variety. The varieties *Askaniis'ka*, *Pylypivka* and *Schedrist' odes'ka* can be classified as plastic.

There is no relationship between the maximum and minimum yield r = -0.015. Both yield levels of winter wheat varieties were characterized by an average positive relationship (r = 0.625–0.662) with average yield (*Ymean*), adaptability coefficient (*CA*) and general adaptive capacity (GAC_i). The maximum yield was characterized by a high positive relationship (r = 0.717–0.824) with the level of resistance to stress conditions (*RS*), genetic flexibility (*Gf*) and the regression coefficient (b_i), on the other hand, the minimum yield with genetic flexibility (*Gf*) had an average positive relationship r = 0.564, and with the level of resistance to stressful conditions (*RS*) and the regression coefficient (b_i) the average negative dependence is -0.579 and -0.571, respectively. That is, if the varieties are characterized by high values of the level of resistance to stressful conditions (*RS*) and the regression coefficient (b_i), then such varieties are classified as intensive, and if they are low, they are stable (Table 4).

The minimum yield was characterized by a high positive correlation (r = 0.768–0.886) with the selection value of the variety (*Sc*), homeostaticity (*Hom*) and the selection value of the genotype (SVG_i), on the other hand, with the maximum yield the selection value of the variety (*Sc*) and homeostaticity (*Hom*) had a low negative dependence (-0.025 and -0.234, respectively), and with the selection value of the genotype (SVG_i) – an average negative dependence (-0.346).

The variance of the deviation from the regression line (s^2_{di}), the stability of the genotype response (σ^2_{SACi}) and the compensation coefficient (K_{gi}) had an average negative relationship (-0.609, -0.674 and -0.673) with the minimum

Table 4

Matrix of correlations between the maximum and minimum yield of winter wheat varieties and homeostaticity, ecological plasticity and adaptability parameters (2018, 2020)

	Ymin	*Ymax*	*Ymean*	*RS*	*Sc*	*Gf*	b_i	s^2_{di}	*CA*	*Hom*	GAC_i	$\sigma^2_{(G\times E)gi}$	σ^2_{SACi}	s_{gi}	SVG_i	K_{gi}	l_{gi}
Ymin	**1.000**	-0.015	0.660	-0.579	0.886	0.564	-0.571	-0.609	0.662	0.768	0.661	-0.710	-0.674	-0.754	0.871	-0.673	-0.292
Ymax	-0.015	**1.000**	0.628	0.824	-0.025	0.817	0.717	0.592	0.625	-0.234	0.625	0.453	0.698	0.581	-0.346	0.698	-0.126
Ymean	0.660	0.628	**1.000**	0.138	0.672	0.898	0.096	-0.126	1.000	0.443	1.000	-0.241	-0.008	-0.187	0.456	-0.007	-0.380
RS	-0.579	0.824	0.138	**1.000**	-0.523	0.346	0.908	0.828	0.134	-0.626	0.134	0.772	0.951	0.901	-0.776	0.951	0.063
Sc	0.886	-0.025	0.672	-0.523	**1.000**	0.490	-0.658	-0.534	0.676	0.946	0.677	-0.602	-0.706	-0.818	0.938	-0.706	-0.155
Gf	0.564	0.817	0.898	0.346	0.490	**1.000**	0.263	0.139	0.898	0.249	0.897	-0.035	0.188	0.045	0.216	0.189	-0.273
b_i	-0.571	0.717	0.096	0.908	-0.658	0.263	**1.000**	0.635	0.090	-0.814	0.090	0.595	0.963	0.937	-0.826	0.964	-0.192
s^2_{di}	-0.609	0.592	-0.126	0.828	-0.534	0.139	0.635	**1.000**	-0.128	-0.494	-0.128	0.969	0.809	0.798	-0.746	0.808	0.534
CA	0.662	0.625	1.000	0.134	0.676	0.898	0.090	-0.128	**1.000**	0.448	1.000	-0.243	-0.013	-0.192	0.461	-0.012	-0.378
Hom	0.768	-0.234	0.443	-0.626	0.946	0.249	-0.814	-0.494	0.448	**1.000**	0.450	-0.512	-0.795	-0.877	0.935	-0.795	0.065
GAC_i	0.661	0.625	1.000	0.134	0.677	0.897	0.090	-0.128	1.000	0.450	**1.000**	-0.242	-0.014	-0.193	0.461	-0.013	-0.376
$\sigma^2_{(G\times E)gi}$	-0.710	0.453	-0.241	0.772	-0.602	-0.035	0.595	0.969	-0.243	-0.512	-0.242	**1.000**	0.789	0.780	-0.760	0.788	0.611
σ^2_{SACi}	-0.674	0.698	-0.008	0.951	-0.706	0.188	0.963	0.809	-0.013	-0.795	-0.014	0.789	**1.000**	0.977	-0.887	1.000	0.057
s_{gi}	-0.754	0.581	-0.187	0.901	-0.818	0.045	0.937	0.798	-0.192	-0.877	-0.193	0.780	0.977	**1.000**	-0.957	0.977	0.068
SVG_i	0.871	-0.346	0.456	-0.776	0.938	0.216	-0.826	-0.746	0.461	0.935	0.461	-0.760	-0.887	-0.957	**1.000**	-0.886	-0.164
K_{gi}	-0.673	0.698	-0.007	0.951	-0.706	0.189	0.964	0.808	-0.012	-0.795	-0.013	0.788	1.000	0.977	-0.886	**1.000**	0.057
l_{gi}	-0.292	-0.126	-0.380	0.063	-0.155	-0.273	-0.192	0.534	-0.378	0.065	-0.376	0.611	0.057	0.068	-0.164	0.057	**1.000**

** – Confidence interval (%): 95*

yield, on the other hand, with the maximum yield – an average positive dependence (r = 0.592–0.698). The relative stability of the genotype (s_{gi}) and the variance of the interaction between the genotype and the environment ($\sigma^2_{(G\times E)gi}$) were characterized by a high negative correlation (-0.754 and -0.710) with the minimum productivity and an average positive correlation (0.581 and 0.453) with the maximum. This suggests that the lower the value of these parameters, the more stable the variety, and, conversely, the higher the value, the more unstable the variety is, that is, it belongs to the intensive type.

According to the results of the GGE biplot analysis, the winter wheat variety *Lira odes'ka* (G13), which is in the same quarter as the minimum yield vector (*Ymin*) and is close to its peak, forms the highest yield under the worst growing conditions. Varieties *Konka* (G3), *Kokhana* (G4), *Koshova* (G5) and *Zysk* (G12), which are in the same quarter with the minimum yield vector, form high yields under worse growing conditions (*Ymin*). They are characterized by a low yield reduction when growing conditions deteriorate and a high yield under unfavorable conditions, that is, they can be classified as stable type varieties (Fig. 1).

The variety *Mariia* (G6) is in one quarter of the maximum yield vector (*Ymax*) and is close to its peak, produces the highest yield under optimal conditions and can be classified as an intensive type variety.

The variety *Schedrist' odes'ka* (G18), located on the axis between the vectors of yield levels, as well as the variety *Askaniis'ka* (G10) close to the axis, form a high yield under both conditions, and can be considered plastic.

The *Rosynka* (G8) winter wheat variety is in the II quarter and is characterized by the smallest reduction in yield when conditions deteriorate and can be considered the most stable, i.e., tolerant to changes in moisture conditions. However, it is also characterized by the lowest level of productivity under both humidification conditions.

The winter wheat variety *Harantiia odes'ka* (G11), located in the III quarter, is characterized by high productivity (8.23 t/ha) under optimal conditions and the lowest (3.01 t/ha) under unfavorable conditions. This variety can be attributed to the intensive type, that is, one that responds well to improving moisture conditions, but is characterized by a sharp decrease in productivity under stressful conditions.

Cluster analysis allows identification of winter wheat varieties based on genetically determined drought resistance. The advantage of the cluster analysis method is that its mathematical apparatus allows you to find and highlight the accumulation of objects (points) that actually exists in the feature space based on simultaneous grouping by a large number of features. Construction and analysis of dendrograms details information about the nature of relationships between lineages at the cluster level and specifies relationships between populations within their boundaries. On the dendrogram, the numbers of the objects being merged and the distance at which the merger took place are indicated (Fig. 2).

The varieties that formed five subclusters were the closest in yield and adaptability parameters: G4 – *Kokhana* and G5 – *Koshova* at a distance of 1, G1 – *Anatoliia* and G3 – *Konka*, G6 – *Mariia* and G15 – *Nyva odes'ka* at a distance of 4 and G10 – *Askaniis'ka* and G18 – *Schedrist' odes'ka* at a distance of 5 were further grouped into 1 cluster, and varieties G16 – *Pylypivka* and G17 – *Tradytsiia odes'ka* at a distance of 4 were further grouped into 2 cluster. In general, three clusters were formed: in the first cluster, at a distance

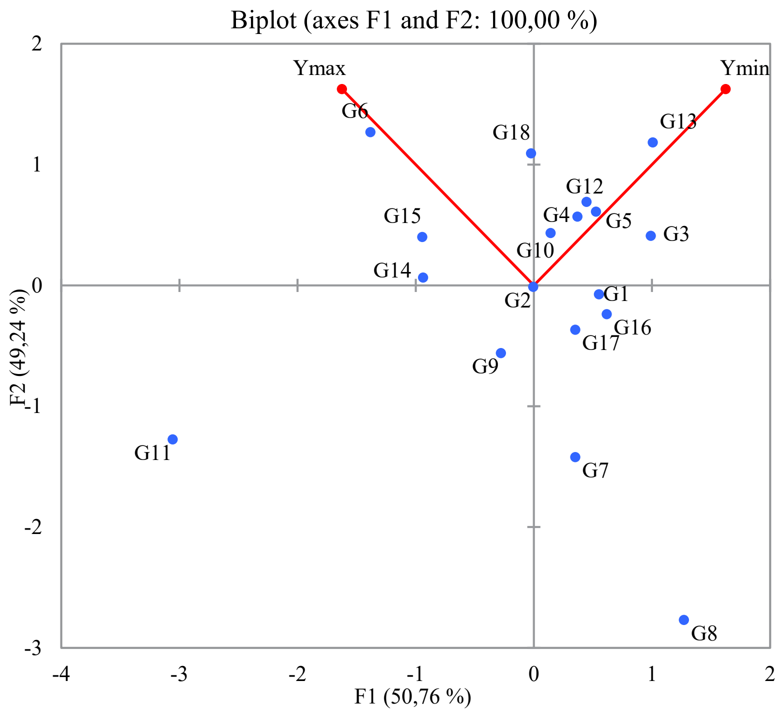
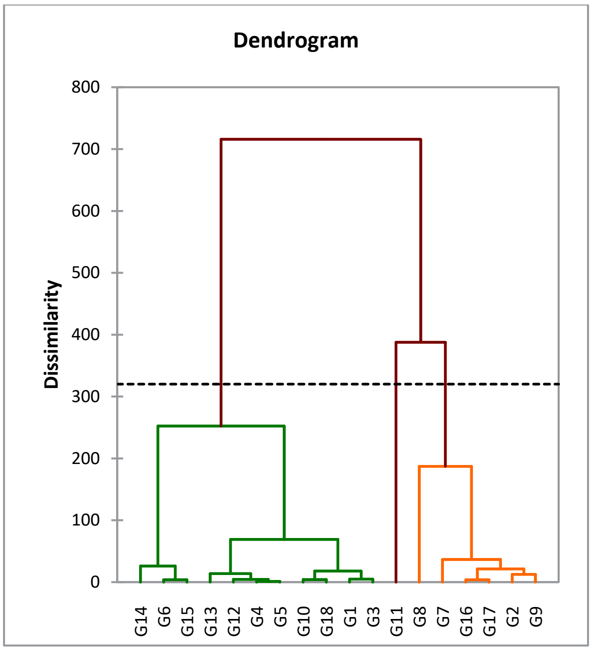


Fig. 1. Genotype-environment interaction of winter wheat varieties and environments (biplot analysis method). The lines show the eigenvectors of the leading factor loads for the environments: ● – yield level; ● – varieties

of 252, eleven varieties that are more directed to the plastic type, in the second cluster, at a distance of 187, six varieties that are more directed to the stable type were united. Grade G11 – *Harantiia odes'ka*, formed cluster 2, which is more directed to the intensive type (Table 5).

A cluster analysis of winter wheat varieties was also carried out using the k-means method. This method differs in that before starting, you need to choose the number of clusters yourself. Based on the agglomerative hierarchical cluster analysis described above, we proposed four clusters.

Cluster 1 included eight varieties more directed towards a stable type, compared to the agglomerative hierarchical cluster analysis, with the exception of the varieties G4 – *Kokhana*, G5 – *Koshova*, G10 – *Askaniis'ka*, G12 – *Zysk*,



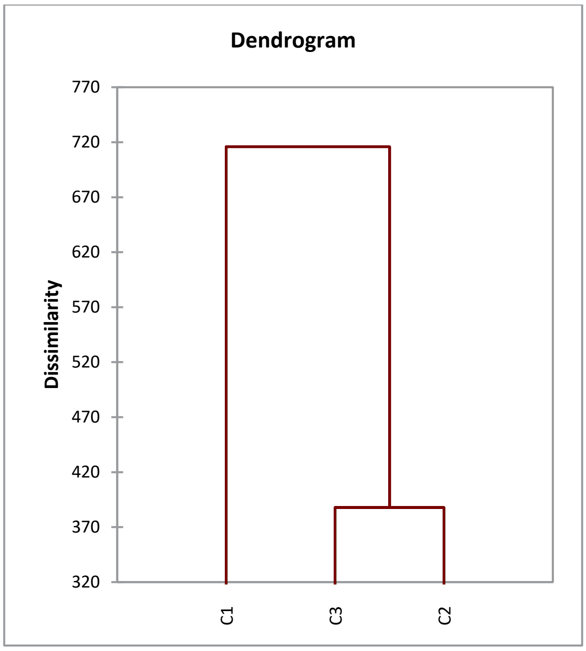


Fig. 2. Clustering dendrogram of eighteen winter wheat varieties according to drought resistance

Table 5

Clustering of eighteen varieties of winter wheat according to drought resistance by the method of k-means and agglomerative hierarchical cluster analysis

Variety	Designation	k-means clustering		Agglomerative hierarchical clustering
		Cluster	Distance to the center of the cluster	Cluster
Anatoliia	G1	1	7.241	1
Burhunka	G2	1	3.538	2
Konka	G3	1	6.641	1
Kokhana	G4	2	0.915	1
Koshova	G5	2	1.654	1
Mariia	G6	3	7.665	1
Ledia	G7	1	3.271	2
Rosynka	G8	1	13.868	2
Khersons'ka bezosta	G9	1	6.266	2
Askaniis'ka	G10	2	2.433	1
Harantiia odes'ka	G11	3	14.575	3
Zysk	G12	2	2.332	1
Lira odes'ka	G13	2	4.920	1
Mudrist' odes'ka	G14	3	1.920	1
Nyva odes'ka	G15	3	6.183	1
Pylypivka	G16	1	3.639	2
Tradytsiia odes'ka	G17	1	4.920	2
Schedrist' odes'ka	G18	2	5.079	1

G13 – *Lira odes'ka* and G18 – *Schedrist' odes'ka*, which were included and formed the second cluster, as varieties of the plastic type. G6 – *Mariia*, G14 – *Mudrist' odes'ka* and G15 – *Nyva odes'ka* moved from the first to the third cluster as intensive type varieties (Table 5).

The smallest distance to the center of the first cluster was observed in the G7 – *Ledia* variety at the level of 3.271, whereas the largest 13.868 was observed in the G8 – *Rosynka* variety. The smallest distance to the center of the second cluster was observed in the variety G4 – *Kokhana* at the level of 0.915, while the largest was 5.079 in the variety G18 – *Schedrist' odes'ka*. The smallest distance to the center of the third cluster was observed in the variety G14 – *Mudrist' odes'ka* at the level of 1.920, while the largest was 14.575 in the variety G11 – *Harantiia odes'ka*.

Conclusions. The selected parameters of adaptability are the level of resistance to stressful conditions (*RS*), the regression coefficient (b_i), the variance of the deviation from the regression line (s^2_{di}), the sign of the stability of the genotype response (σ^2_{SACi}), the variance of the interaction between the genotype and the environment ($\sigma^2_{(G\times E)gi}$), compensation coefficient (K_{gi}), relative stability of the genotype (s_{gi}), selection value of the genotype (SVG_i), selection value of the variety (*Sc*) and homeostaticity (*Hom*) by which the type of variety can be most clearly characterized.

According to the parameters of adaptability, the *Kokhana*, *Koshova*, *Zysk* and *Lira odes'ka* varieties were selected as the most stable, while *Harantiia odes'ka* and *Mariia* were selected as intensive type varieties. The varieties *Schedrist' odes'ka* and *Askaniis'ka* are selected as plastic.

BIBLIOGRAPHY:

1. Anderson W.K., Brennan R.F., Jayasena K.W., Micic S., Moore J.H., Nordblom T. Tactical crop management for improved productivity in winter-dominant rainfall regions: a review. *Crop & Pasture Science*. 2020, Vol. 71, P. 621–644. https://doi.org/10.1071/CP19315
2. Carlson R. Estimating the biotech sector's contribution to the US economy. *Nat Biotechnol*. 2016, Vol. 34, P. 247–255. https://doi.org/10.1038/nbt.3491
3. Eberhart S.A, Rassell W.A. Stability parameters for comparing varieties. *Crop Sc*. 1966. Vol. 6. № 1. P. 36–40.
4. Franco F.A., Marchioro V.S., Montecelli T.D.N., Schuster I., Polo M., Souza L.V., Lima F.J.A., Evangelista A., Santos D.A., Grave E.L. CD 1303 – Short stature, high productive potential and industrial quality. *Crop Breeding and Applied Biotechnology*. 2018, Vol. 18, P. 123–125. https://doi.org/10.1590/1984-70332018v18n1c15
5. Galetto S.L., Bini A.R., Haliski A., Scharr D.A., Borszowskei P.R., Caires E.F. Nitrogen fertilization in top dressing for wheat crop in succession to soybean under a no-till system. *Bragantia*. 2017, Vol. 76, P. 282–291. https://doi.org/10.1590/1678-4499.095
6. Lavrynenko Yu.O. Breeding heritage and its role in stabilizing production of corn grain in Ukraine. Natural sciences and modern technological solutions: knowledge integration in the XXI century: collective monograph. Lviv-Torun: Liha-Pres, 2019. P. 103–119. https://doi.org/10.36059/978-966-397-154-4/103-119
7. Ojha A. & Ojha B.R. Assessment of Morpho-Physiological, Yield and Yield Attributing Traits Related to Post Anthesis Drought in Wheat Genotypes Under Rainfed Condition in Rampur, Chitwan. *Int. J. Appl. Sci. Biotechnol*. 2020, Vol. 8, Issue 3, P. 323–335. DOI: 10.3126/ijasbt.v8i3.31609
8. Popov S.I., Leonov O.Yu., Popova K.M., & Avramenko S.V. Ecological plasticity of winter wheat varieties depending on root nitrogen nutrition in the eastern Forest-Steppe of Ukraine. *Plant Varieties Studying and Protection*. 2019. Vol. 15, Issue 3. P. 296–302. doi: 10.21498/2518-1017.15.3.2019.181087
9. Ray D.K., Mueller N.D., West P.C., Foley J.A. Yield trends are insufficient to double global crop production by 2050. *PLoS ONE*. 2013, Vol. 8, E66428. https://doi.org/10.1371/journal.pone.0066428
10. Rosielle A.A., Hamblin J. Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Science*. 1981. Vol. 21, № 6. P. 943–946. doi:10.2135/cropsci1981.0011183X002100060033x
11. Subira J., Álvaro F., del Moral L.F.G., & Royo C. Breeding effects on the cultivar × environment interaction of durum wheat yield. *European Journal of Agronomy*, 2015, Vol. 68, 78–88. https://doi.org/10.1016/j.eja.2015.04.009
12. Tyshchenko A.V., Tyshchenko O.D., Konovalova V.M., Fundirat K.S., Piliarska O.O. Methods of determining the adaptability and ecological stability of plants. *Scientific Collection «InterConf+»*, 33(155): with the Proceedings of the 1st International Scientific and Practical Conference «Modern Knowledge: Research and Discoveries» (May 19–20, 2023; Vancouver, Canada) by the SPC «InterConf». A.T. International, 2023. P. 324–342. https://doi.org/10.51582/interconf.19-20.05.2023.029 ISSN 2709-4685
13. Tyshchenko O., Tyshchenko A., Piliarska O., Kuts H., Lykhovyd P. Evaluation of drought tolerance in alfalfa *(Medicago sativa)* genotypes in the conditions of osmotic stress. *AgroLife Scientific Journal*. 2020. Vol. 9, No. 2, P. 353–358. ISSN 2285-5718
14. Vozhehova R., Tyshchenko A., Tyshchenko O., Dymov O., Piliarska O., Lykhovyd P. Evaluation of breeding indices for drought tolerance in alfalfa (*Medicago*) genotypes. *Scientific Papers. Series A. Agronomy*. 2021. Vol. LXIV, No. 2. P. 435–444.
15. Yadav R., Gupta S., Gaikwad K.B., Bainsla N.K., Kumar M., Babu P., Ansari R., Dhar N., Dharmateja P. & Prasad R. Genetic Gain in Yield and Associated Changes in Agronomic Traits in Wheat Cultivars Developed Between 1900 and 2016 for Irrigated Ecosystems of Northwestern Plain Zone of India. *Front. Plant Sci.* 2021, Vol. 12:719394. doi: 10.3389/fpls.2021.719394
16. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Димов О.М., Люта Ю.О. Особливості прояву адаптивних ознак у селекційних популяцій люцерни при вирощуванні на насіння. *Вісник СумНАУ. Серія «Агрономія і біологія»*. 2021. Випуск 2(44), С. 3–11. https://doi.org/10.32845/agrobio.2021.2.1
17. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Димов О.М., Пілярська О.О. Оцінювання посухостійкості селекційного матеріалу люцерни за показниками водного режиму в умовах Півдня України. *Plant Varieties Studying and protection*. 2021, Vol. 17, No 1. С. 21–29. https://doi.org/10.21498/2518-1017.17.1.2021.228204

18. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Гальченко Н.М. Оцінка посухостійкості популяцій люцерни кормового використання в рік сівби за математичними індексами. *Аграрні інновації*. 2022. № 13. С. 190–198. https://doi.org/10.32848/agrar.innov.2022.13.28
19. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Фундират К.С., Коновалова В.М. Особливості прояву адаптивних ознак у популяцій люцерни за кормового використання. *Аграрні інновації*. 2022. № 14. С. 135–144. https://doi.org/10.32848/agrar.innov.2022.14.20
20. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Фундират К.С., Гальченко Н.М. Оцінка посухостійкості популяцій люцерни за насіннєвого використання в рік сівби. *Аграрні інновації*. 2022. № 15. С. 89–96. DOI https://doi.org/10.32848/agrar.innov.2022.15.14
21. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Фундират К.С., Коновалова В.М. Визначення посухостійкості популяцій люцерни насіннєвого використання за математичними індексами. *Вісник аграрної науки*. 2023. № 1 (838). С. 40–48. https://doi.org/10.31073/agrovisnyk202301-05
22. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Фундират К.С., Коновалова В.М. Насіннєва продуктивність популяцій люцерни другого року життя та особливості прояву у них адаптивних ознак. *Аграрні інновації*. 2022. № 16. С. 94–103. https://doi.org/10.32848/agrar.innov.2022.16.15
23. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Фундират К.С., Коновалова В.М. Формування стійкості рослин насіннєвої люцерни в умовах різного екологічного градієнта. *Вісник аграрної науки*. 2023. № 3 (840). С. 53–62. https://doi.org/10.31073/agrovisnyk202303-08
24. Вожегова Р.А., Тищенко А.В., Тищенко О.Д., Пілярська О.О., Фундират К.С., Коновалова В.М. Посухостійкість популяцій люцерни другого року за кормового використання. *Аграрні інновації*. 2023. № 17. С. 25–36. https://doi.org/10.32848/agrar.innov.2023.17.4
25. Лавриненко Ю.О., Вожегова Р.А., Базалій Г.Г., Усик Л.О., Жупина А.Ю. Вплив зрошення на продуктивність різних сортотипів озимої пшениці в умовах Південного Степу України. *Наукові доповіді НУБіП України*. 2019. № 3 (79). http://dx.doi.org/10.31548/dopovidi2019.03.014
26. Тищенко А.В., Тищенко О.Д., Люта Ю.О. Оцінка генотипів люцерни за насіннєвою продуктивністю на посухостійкість. *Таврійський науковий вісник*. Херсон: ВД «Гельветика», 2021. № 120. С. 155–168. https://doi.org/10.32851/2226-0099.2021.120.21
27. Тищенко А.В., Тищенко О.Д., Люта Ю.О., Пілярська О.О. Адаптивна здатність – важлива ознака в селекції рослин. *Зрошуване землеробство*. 2021. № 75, С. 101–109. https://doi.org/10.32848/0135-2369.2021.75.19

REFERENCES:

1. Anderson, W.K., Brennan, R.F., Jayasena, K.W., Micic, S., Moore, J.H. & Nordblom, T. (2020). Tactical crop management for improved productivity in winter-dominant rainfall regions: a review. *Crop & Pasture Science*. 71, 621–644. https://doi.org/10.1071/CP19315
2. Carlson, R. (2016). Estimating the biotech sector's contribution to the US economy. *Nat Biotechnol*. 34, 247–255. https://doi.org/10.1038/nbt.3491
3. Eberhart, S.A & Rassell, W.A. (1966). Stability parameters for comparing varieties. *Crop Sc*. 6(1). 36–40.
4. Franco, F.A., Marchioro, V.S., Montecelli, T.D.N., Schuster, I., Polo, M., Souza, L.V., Lima, F.J.A., Evangelista, A., Santos, D.A. & Grave, E.L. (2018). CD 1303 – Short stature, high productive potential and industrial quality. *Crop Breeding and Applied Biotechnology*. 18, 123–125. https://doi.org/10.1590/1984-70332018v18n1c15
5. Galetto, S.L., Bini, A.R., Haliski, A., Scharr, D.A., Borszowskei, P.R. & Caires, E.F. (2017). Nitrogen fertilization in top dressing for wheat crop in succession to soybean under a no-till system. *Bragantia*. 76, 282–291. https://doi.org/10.1590/1678-4499.095
6. Lavrynenko, Yu.O. (2019). Breeding heritage and its role in stabilizing production of corn grain in Ukraine. Natural sciences and modern technological solutions: knowledge integration in the XXI century: collective monograph. Lviv-Torun: Liha-Pres, 103–119. https://doi.org/10.36059/978-966-397-154-4/103-119
7. Ojha, A. & Ojha, B.R. (2020). Assessment of Morpho-Physiological, Yield and Yield Attributing Traits Related to Post Anthesis Drought in Wheat Genotypes Under Rainfed Condition in Rampur, Chitwan. *Int. J. Appl. Sci. Biotechnol*. 8(3), 323–335. doi.org/10.3126/ijasbt.v8i3.31609
8. Popov, S.I., Leonov, O.Yu., Popova, K.M., & Avramenko, S.V. (2019). Ecological plasticity of winter wheat varieties depending on root nitrogen nutrition in the eastern Forest-Steppe of Ukraine. *Plant Varieties Studying and Protection*, 15(3), 296–302 doi: 10.21498/2518-1017.15.3.2019.181087 [in Ukrainian].
9. Ray, D.K., Mueller, N.D., West, P.C. & Foley, J.A. (2013). Yield trends are insufficient to double global crop production by 2050. *PLoS ONE*. 8, E66428. https://doi.org/10.1371/journal.pone.0066428
10. Rosielle, A.A., & Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Science*, 21(6): 943–946. doi:10.2135/cropsci1981.0011183X002100060033x
11. Subira, J., Álvaro, F., del Moral, L.F.G., & Royo, C. (2015). Breeding effects on the cultivar × environment interaction of durum wheat yield. *European Journal of Agronomy*, 68, 78–88. https://doi.org/10.1016/j.eja.2015.04.009
12. Tyshchenko A.V. et al. (2023). Methods of determining the adaptability and ecological stability of plants. *Scientific Collection «InterConf+», 33(155): with the Proceedings of the 1st International Scientific and Practical Conference «Modern Knowledge: Research and Discoveries» by the SPC «InterConf»*. (pp. 324–342) A.T. International. Vancouver, Canada. https://doi.org/10.51582/interconf.19-20.05.2023.029 ISSN 2709-4685
13. Tyshchenko, O., Tyshchenko, A., Piliarska, O., Kuts, H. & Lykhovyd, P. (2020). Evaluation of drought tolerance in alfalfa *(Medicago sativa)* genotypes in the conditions of osmotic stress. *AgroLife Scientific Journal*, 9(2), 353–358. ISSN 2285-5718
14. Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Dymov, O., Piliarska, O. & Lykhovyd, P. (2021). Evaluation of breeding indices for drought tolerance in alfalfa

(*Medicago*) genotypes. *Scientific Papers. Series A. Agronomy*, LXIV(2), 435-444. ISSN 2285-5785
15. Yadav, R., Gupta, S., Gaikwad, K.B., Bainsla, N.K., Kumar, M., Babu, P., Ansari, R., Dhar, N., Dharmateja, P. & Prasad, R. (2021). Genetic Gain in Yield and Associated Changes in Agronomic Traits in Wheat Cultivars Developed Between 1900 and 2016 for Irrigated Ecosystems of Northwestern Plain Zone of India. *Front. Plant Sci.* 12:719394. doi: 10.3389/fpls.2021.719394
16. Vozhehova, R.A., Tyshchenko, A.V., Tyshchenko, O.D., Dymov, O.M. & Lyuta, Yu.O. (2021). Osoblyvosti proiavu adaptyvnykh oznak u selektsiinykh populiatsii liutserny pry vyroshchuvanni na nasinnia. [Features of manifestation of adaptive traits in breeding populations of alfalfa when grown from seed]. *Visnyk SumNAU. Seriia «Ahronomiia i biolohiia» – Bulletin of SumNAU. Agronomy and Biology Series*. 2(44). 3–11. https://doi.org/10.32845/ agrobio.2021.2.1 [in Ukrainian].
17. Vozhehova, R.A., Tyshchenko, O.D., Tyshchenko, A.V., Dymov, O.M. & Piliarska, O.O. (2021). Otsiniuvannia posukhostiikosti selektsiinoho materialu liutserny za pokaznykamy vodnoho rezhymu v umovakh Pivdnia Ukrainy [Evaluation of drought tolerance of alfalfa breeding material based on water regime indicators in Southern Ukraine.]. *Plant Varieties Studying and protection*, 17(1), 21–29. https://doi.org/10.21498/2518-1017.17.1.2021.228204. [in Ukrainian].
18. Vozhehova, R.A., Tyshchenko, A.V., Tyshchenko, O.D., Piliarska, O.O. & Halchenko, N.M. (2022). Otsinka posukhostiikosti populiatsii liutserny kormovoho vykorystannia v rik sivby za matematychnymy indeksamy [Assessment of drought resistance of fodder alfalfa populations in the year of sowing by mathematical indices]. *Ahrarni innovatsii – Agrarian Innovations*, 13, 190–198. https://doi.org/10.32848/agrar.innov.2022.13.28. [in Ukrainian].
19. Vozhehova, R.A., Tyshchenko, A.V., Tyshchenko, O.D., Piliarska, O.O., Fundirat, K.S. & Konovalova, V.M. (2022). Osoblyvosti proiavu adaptyvnykh oznak u populiatsii liutserny za kormovoho vykorystannia [Peculiarities of the manifestation of adaptive traits in alfalfa populations under fodder use]. *Ahrarni innovatsii – Agrarian Innovations*, 14, 135–144. https://doi.org/10.32848/agrar.innov.2022.14.20. [in Ukrainian].
20. Vozhehova, R.A., Tyshchenko, A.V., Tyshchenko, O.D., Piliarska, O.O., Fundirat, K.S. & Halchenko, N.M. (2022). Otsinka posukhostiikosti populiatsii liutserny za nasinnievoho vykorystannia v rik sivby [Assessment of drought resistance of alfalfa populations for seed use in the year of sowing]. *Ahrarni innovatsii – Agrarian Innovations*, 15, 89–96. https://doi.org/10.32848/agrar.innov.2022.15.14. [in Ukrainian].
21. Vozhehova, R.A., Tyshchenko, A.V., Tyshchenko, O.D., Piliarska, O.O., Fundirat, K.S. & Konovalova, V.M. (2023). Vyznachennia posukhostiikosti populiatsii liutserny nasinnievoho vykorystannia za matematychnymy indeksamy [Determination of drought resistance of alfalfa populations for seed use by mathematical indices]. *Visnyk ahrarnoi nauky – Bulletin of Agricultural Science***,** 1(838), 40–48. https://doi.org/10.31073/agrovisnyk202301-05. [in Ukrainian].
22. Vozhehova, R.A., Tyshchenko, A.V., Tyshchenko, O.D., Piliarska, O.O., Fundirat, K.S. & Konovalova, V.M. (2022). Nasinnieva produktyvnist populiatsii liutserny druhoho roku zhyttia ta osoblyvosti proiavu u nykh adaptyvnykh oznak [Seed productivity of alfalfa populations in the second year of life and the peculiarities of the manifestation of adaptive traits in them]. *Ahrarni innovatsii – Agrarian Innovations*, 16, 94–103. https://doi.org/10.32848/agrar.innov.2022.16.15 [in Ukrainian].
23. Vozhehova, R.A. et al. (2023). Formuvannia stiikosti roslyn nasinnievoi liutserny v umovakh riznoho ekolohichnoho hradiienta [Formation of resistance of seed alfalfa plants in conditions of different environmental gradients]. *Visnyk ahrarnoi nauky – Bulletin of Agricultural Science*, 3(840), 53–62. https://doi.org/10.31073/agrovisnyk202303-08 [in Ukrainian].
24. Vozhehova, R.A. et al. (2023). Posukhostiikist populiatsii liutserny druhoho roku za kormovoho vykorystannia [Drought resistance of second-year alfalfa populations for fodder use]. *Ahrarni innovatsii – Agrarian Innovations*, 17, 25–36. https://doi.org/10.32848/agrar.innov.2023.17.4 [in Ukrainian].
25. Lavrynenko, Yu.O., Vozhehova, R.A., Bazalii, H.H., Usyk, L.O. & Zhupyna, A.Iu. (2019). Vplyv zroshennia na produktyvnist riznykh sortotypiv ozymoi pshenytsi v umovakh Pivdennoho Stepu Ukrainy [The influence of irrigation on the productivity of different varieties of winter wheat in the conditions of the Southern Steppe of Ukraine.]. *Naukovi dopovidi NUBiP Ukrainy – Scientific reports of NULES of Ukraine*. 3(79). http://dx.doi.org/10.31548/dopovidi2019.03.014 [in Ukrainian].
26. Tyshchenko, A.V., Tyshchenko, O. D. & Lyuta, Yu. O. (2021). Otsinka henotypiv liutserny za nasinnievoiu produktyvnistiu na posukhostiikist. [Evaluation of alfalfa genotypes by seed productivity for drought resistance]. *Tavriiskyi naukovyi visnyk. Kherson: VD «Helvetyka» – Taurian Scientific Bulletin. Kherson: Helvetica*. 120. 155–168. https://doi.org/10.32851/2226-0099.2021.120.21. [in Ukrainian].
27. Tyshchenko, A.V., Tyshchenko, O.D., Liuta, Yu.O. & Piliarska, O.O. (2021). Adaptyvna zdatnist – vazhlyva oznaka v selektsii roslyn [Adaptability is an important feature in plant selection]. *Zroshuvane zemlerobstvo – Irrigated farming*, 75, 101–109. https://doi.org/10.32848/0135-2369.2021.75.19. [in Ukrainian].

Konovalova V.M., Tyshchenko A.V., Bazalii H.G., Fundirat K.S., Tyshchenko O.D., Reznichenko N.D. Konovalov V.O., Ochkala O.S., Borovyk V.O. Ecological plasticity and stability of winter wheat varieties in the conditions of the Southern Steppe of Ukraine (Part 2 – drought years)

The purpose of our research was to study and analyze the environmental stability and adaptability to different environments of winter wheat varieties selected by the Institute of Climate-oriented Agriculture of the National Academy of Sciences and the Selection and Genetic Institute of the National Center for Seed Science and Varietal Research of the National Academy of Sciences in the conditions of the Southern Steppe of Ukraine. **Research materials and methods.** The reaction of 18 varieties of winter wheat to different growing conditions was studied at the Askania State Agricultural Research Station in the village of Tavrychanka, Kherson region (46°33’12”N; 33°49’13”E; 39 m above sea level) during 2015/16–2019/20. Research was conducted under different conditions of irrigation: with

irrigation and without irrigation. Analysis of environmental stability and adaptability to different environments of winter wheat varieties was carried out using various parameters. **Research results and their discussion.** The obtained experimental data allow distinguishing varieties of winter wheat by maximum productivity (Ymax) Mariia – 8.61 t/ha, Harantiia odes'ka – 8.23 and Nyva odes'ka – 8.04 t/ha, Konka varieties by minimum productivity (Ymin) – 4.75 t/ha, Kokhana – 4.61, Koshova and Zysk – 4.67, Lira odes'ka – 4.99 and Schedrist' odes'ka – 4.65 t/ha. The lowest productivity in terms of minimum productivity was formed by the varieties Harantiia odes'ka – 3.01 t/ha and Rosynka – 3.87 t/ha, and the Rosynka variety was characterized by the lowest productivity in terms of maximum productivity of 5.69 t/ha. According to the parameters of adaptability, the Kokhana, Koshova, Rosynka, Zysk and Lira odes'ka varieties were selected as the most stable, while Harantiia odes'ka was selected as an intensive type variety. The varieties Askaniis'ka, Pylypivka and Schedrist' odes'ka can be classified as plastic. Three clusters were formed: the first cluster included eleven varieties that are more oriented towards the plastic type, the second cluster included six varieties that are more oriented towards the stable type. The Harantiia odes'ka variety formed cluster 2 – to the intensive type. According to the correlation analysis, the parameters of adaptability were selected: the level of resistance to stressful conditions (RS), the regression coefficient (b_i), the variance of the deviation from the regression line (s^2_{di}), the sign of the stability of the genotype reaction (σ^2_{SACi}), the compensation coefficient (K_{gi}), the relative stability of the genotype (s_{gi}), the selection value of the genotype (SVG_i), the selection value of the variety (Sc) by which the type of variety can be most clearly characterized. **Conclusions.** Selected parameters of adaptability, according to them and biplot analysis, the varieties Kokhana, Koshova, Zysk and Lira odes'ka were selected as the most stable, on the other hand, Harantiia odes'ka and Mariia were selected as intensive type varieties. The varieties Schedrist' odes'ka and Askaniis'ka are selected as plastic.

Key words: winter wheat, variety, irrigation, natural moisture, productivity, adaptability, stability, ecogradient, biplot analysis, cluster analysis.

Коновалова В.М., Тищенко А.В., Базалій Г.Г., Фундират К.С., Тищенко О.Д., Резниченко Н.Д. Коновалов В.О., Очкала О.С., Боровик В.О. Екологічна пластичність та стабільність сортів пшениці озимої в умовах Південного Степу України (Ч. 2 – посушливі роки)

Метою наших досліджень було вивчення і аналіз екологічної стійкості та адаптивності до різних середовищ сортів озимої пшениці селекції Інституту кліматично орієнтованого сільського господарства НААН та Селекційно-генетичного інституту Національного центру насіннєзнавства та сортовивчення НААН в умовах Південного Степу України. **Матеріали і методи досліджень.** Реакцію 18 сортів озимої пшениці на різні умови вирощування вивчали на Асканійській державній сільськогосподарській дослідницькій станції у с. Тавричанка, Херсонська область (46°33'12»N; 33°49'13»E; 39 м над рівнем моря) протягом 2015/16–2019/20 рр. Дослідження проводилися за різних умов зволоження: при зрошенні та без зрошення. Аналіз екологічної стійкості та адаптивності до різних середовищ сортів озимої пшениці проводили за допомогою різних параметрів. **Результати дослідження та їх обговорення.** Отримані експериментальні дані дозволяють виділити сорти озимої пшениці за максимальною продуктивністю (*Ymax*) *Марія* – 8,61 т/га, *Гарантія одеська* – 8,23 і *Нива одеська* – 8,04 т/га, за мінімальною продуктивністю (*Ymin*) сорти *Конка* – 4,75 т/га, *Кохана* – 4,61, *Кошова* та *Зиск* – 4,67, *Ліра одеська* – 4,99 та *Щедрість одеська* – 4,65 т/га. Найнижчу урожайність за мінімальною продуктивністю сформували сорти *Гарантія одеська* – 3,01 т/га та *Росинка* – 3,87 т/га, а сорт *Росинка* характеризувався ще найнижчою урожайністю за максимальною продуктивністю 5,69 т/га. За параметрами адаптивності, як найбільш стабільні, виділені сорти *Кохана*, *Кошова*, *Росинка*, *Зиск* та *Ліра одеська*, натомість *Гарантія одеська* був виділений як сорт інтенсивного типу. Сорти *Асканійська*, *Пилипівка* та *Щедрість одеська* можуть бути віднесені до пластичних. Сформовано три кластера: в перший кластер об'єдналися одинадцять сортів які більш направлені до пластичного типу, в другий кластер об'єдналися шість сортів які більш направлені до стабільного типу. Сорт *Гарантія одеська*, утворив кластер 2 – до інтенсивного типу. За кореляційним аналізом виділені параметри адаптивності рівень стійкості до стресових умов (*RS*), коефіцієнт регресії (b_i), дисперсія відхилення від лінії регресії (s^2_{di}), ознака стабільності реакції генотипу ($\sigma^2_{САЗi}$), коефіцієнт компенсації (K_{gi}), відносна стабільність генотипу (s_{gi}), селекційна цінність генотипу (*СЦГi*), селекційна цінність сорту (*Sc*) за якими найбільш чітко можна охарактеризувати тип сорту. Висновки. Виділені параметри адаптивності, за ними та біплот-аналізом, як найбільш стабільний, були виділені сорти *Кохана*, *Кошова*, *Зиск* та *Ліра одеська*, натомість *Гарантія одеська* та *Марія* виділені як сорти інтенсивного типу. Сорти *Щедрість одеська* та *Асканійська* виділені як пластичні.

Ключові слова: озима пшениця, сорт, зрошення, природнє зволоження, урожайність, адаптивність, стабільність, екоградієнт, біплот-аналіз, кластерний аналіз.