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Differentiation and identification of winter bread wheat varieties according to a complex of baking quality indicators

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Purpose. Reveal the features of the formation of a quality indicator complex in winter bread wheat depending on the growing seasons, preceding crops and sowing dates, as well as differentiate and identify genotypes with high and stable levels of manifestation. **Methods.** Field, laboratory, statistical. **Results.** A different share of the influence of the year conditions, the preceding crop, the sowing date and their interactions on the quality indicators of some varieties was determined. A different reaction of varieties in terms of quality indicators, depending on the investigated factors was revealed. The variation was very low for test weight, water absorption ability of flour, crumb porosity. Strong variation was observed for flour strength after sunflower and soybean as preceding crops, alveograph configuration ratio after sunflower and soybean, index of elasticity dough after corn, valorimetric value after mustard, dough dilution degree after green manure, sunflower, corn and especially after mustard and soybeans. The varieties, which on average for 2016/17–2018/19 reliably exceeded the standard both in individual indicators and in general in terms of physical indicators of grain and flour quality and dough rheological properties. GYT biplot analysis identified the genotypes 'MIP Vidznaka' and 'MIP Assol' with a more optimal combination of increased yield and a complex of quality indicators in terms of different years, preceding crops and sowing dates. Some varieties, namely, 'Estafeta myronivs'ka', 'Trudivnytsia myronivs'ka', 'MIP Valensiia', 'MIP Yuvileina', 'Balada myronivs'ka', 'Vezha myronivs'ka' were inferior to them, but were significantly superior the others. **Conclusions.** The selected by quality indicators varieties as genetic sources can be used in breeding process. A more stable level of yield and quality indicators at different sowing dates after different preceding crops should be expected for growing varieties 'MIP Vidznaka', 'MIP Assol', as well as 'Estafeta myronivs'ka', 'Trudivnytsia myronivs'ka', 'MIP Valensiia', 'MIP Yuvileina', 'Balada myronivs'ka', 'Vezha myronivs'ka'. The peculiarities obtained in the research should be taken into account when evaluating and differentiating genotypes in breeding process, as well as developing basic elements of technology for growing the varieties of winter bread wheat.

Keywords: *Triticum aestivum L.; physical indicators of grain and flour quality; rheological characteristics of the dough; baking properties of the flour; sowing date; preceding crop; coefficient of variation; ANOVA; GYT biplot.*

Introduction

Bread wheat (*Triticum aestivum* L.) is a valuable source of protein, carbohydrates, vitamins, minerals and other important nutrients, and therefore is one of the key crops for nutrition of about 35% of the world population [1–3]. Wheat grain is the main raw material for bakery, cereal, confectionery and pasta industries [4, 5]. A person receives up to 50% of the daily intake of proteins and carbohydrates, 70–80% of vitamin B1 (thiamine), a significant part of other vitamins, minerals and other substances by consuming bakery products [6]. Therefore, the growth of bread wheat grain production, which will meet the requirements of world standards, is one of the important tasks of agricultural science and production [7, 8].

Triticum aestivum L. is assessed by milling (test weight, thousand kernel weight, vitreousness, size, etc.) and baking properties (protein content, sedimentation value, wet gluten content and its quality, physical properties of the dough, bread volume, etc.) [9]. Thousand kernel weight and test weight are the main physical indicators of grain and its milling properties, characterizing its size, evenness and fullness [9, 10]. Protein and gluten are the main components of wheat grain. The content of protein, wet gluten and gluten deformation index associated with the food quality of bakery, cereals and pasta [11, 12]. The protein content in bread wheat grain varies from 7 to 17%, while 80–90% of its total amount is gluten [13]. It is gluten proteins that are involved in the formation of the mechanical basis of the dough, and the structure of crumb of baked bread depends on its quality [14]. The sedimentation value is a sign of flour quality, which characterizes the potential properties of the

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protein complex [15]. The baking properties of flour are characterized by a set of indicators that are important in the technological process of making bread and determine the quality of the final product [16, 17]. Flour strength is an important indicator of baking quality, characterizing the ability to form a dough with certain physical properties. It provides the gas retention capacity of the dough, an increase in the volume of dough and bread. Quality indicators such as the tenacity and extensibility of the dough, its elasticity index and their ratio provide additional information about flour strength and characterize the form-holding capacity of hearth products.

In the technological process of making bakery products, water absorption capacity of flour, dough development time, its stability, degree of softening and valorimetric value must be taken into account. These indicators provide information about dough "behaviour" during kneading, which is important in the process of its further development [18]. The volume of baked bread makes it possible to visually characterize the baking properties [19]. The porosity of bread is related to its assimilation by the body. Well-loosened bread with uniform small, thin-walled pores is quickly wetted, easily chewed and interacts with gastric juice, and therefore is better absorbed. The general evaluation of bread includes, in addition to the above indicators, the elasticity of the crumb, its color, taste, and the appearance of the bread. So, the value of a particular variety for making bread is determined by a whole range of quality indicators that characterize relatively different aspects, or they complement each other.

Grain quality indicators, as well as wheat yield, are determined due to the realization of genetic potential in interaction with environmental conditions and cultivation technology [20, 21]. The genetic potential of a variety can be realized only if agro-technological measures that satisfy its biological needs are applied [22, 23]. A number of researchers have established the variability of grain quality indicators of bread wheat varieties during sowing at different sowing dates, after different preceding crops [24–28]. Thus, information on the optimal sowing date and preceding crop for a certain variety, as well as the creation and identification of genotypes with a relatively stable level of quality indicators after different preceding crops and at different sowing dates are important for production conditions [29, 30].

The purpose of the research is to identify the features of the formation of a complex of bread winter wheat quality indicators, depending on the growing season conditions, preceding crops and sowing dates, as well as to differentiate and identify varieties with an increased and stable level of their manifestation.

Materials and methods

The studies were carried out in 2016/17–2018/19 at the V. M. Remeslo Myronivka Institute of Wheat of the NAAS of Ukraine. Compared with the standard variety G1 'Podolianka' (St), sixteen varieties of winter bread wheat (*Triticum aestivum* L.) of mironivka breeding were studied: G2 'MIP Valensiia', G3 'MIP Vyshyvanka', G4 'MIP Kniazhna', G5 'Trudivnytsia myronivs'ka', G6 'Balada myronivs'ka', G7 'Vezha myronivs'ka', G8 'Hratsiia myronivs'ka', G9 'Estafeta myronivs'ka', G10 'MIP Assol', G11 'MIP Dniprianka', G12 'Avrora myronivs'ka', G13 'MIP Vidznaka', G14 'MIP Darunok', G15 'MIP Lada', G16 'MIP Fortuna', G17 'MIP Yuvileina'. Sowing was carried out in three dates (I – September 26, II – October 5 and III – October 16) after five preceding crops [green manure (GM), mustard (MS), sunflower (SF), corn (CR), soybean (SB)].

The soil and weather conditions of the research years were described in detail in the previous communication [31]. The cultivation technique generally accepted for the Forest-Steppe zone was used [32]. Sowing was carried out with a seed planter CN-10 Ts with a seeding rate of 5 million germinable seeds per hectare. The plots were placed in a randomized manner in four replicates. Accounting area was 10 m^2. Harvesting was by direct combining ("Sampo-130").

Qualitative indicators were assessed for each repetition. Thousand kernel weight (TKW) was taken into account by counting two samples of 500 grains, each was weighed with an accuracy of 0.1 g (the difference between the weight of the two weighed portions did not exceed 5%). Test weight (TW) in g/l was determined using a Liter Purk (the difference between the parallel definitions did not exceed 5 g). The protein content in flour (PC) was measured using a near-infrared reflectance spectrometer (spectral range 1400–2400 nm) on the SPEKTRAN 119M. The sedimentation value (SE) was assessed by the micromethod according to A. Ya. Pumpianskyi. The amount of wet gluten content (WGC) was determined by washing the dough formed by mixing 25 g of flour with 12 ml of 2% saline solution. Gluten deformation index (GDI) was assessed using the IDK-1M device. An Alveograph Chopin was used to measure deformation energy (which is referred to as flour strength or baking strength) (W), dough tenacity (P), alveogram configuration ratio (P/L) and dough elasticity index (Ie). Water absorption capacity of flour (WA), dough degree of softening (DS) and valorimetric value (VV) were analyzed on a device Farinograph Brabender. The dough was kneaded in a Swanson dough mixer, model 100-200 A. A 505-CC thermostat was used to ferment and hold the dough. The bread were baked in an electric oven with a horizontally rotating hearth (t = 230 °C). The volume of bread (VB) was measured on an OMKh-1 device.

The statistically obtained data were processed by descriptive statistics and analysis of variance (ANOVA) using Microsoft Excel 2013, Statistica 8.0. The GYT (genotype by yield * trait) biplot analysis was used to differentiate and isolate genotypes combining a complex of quality indicators with an increased level of yield for all experimental variants [33]. The GEA-R program was used to plot the graphs.

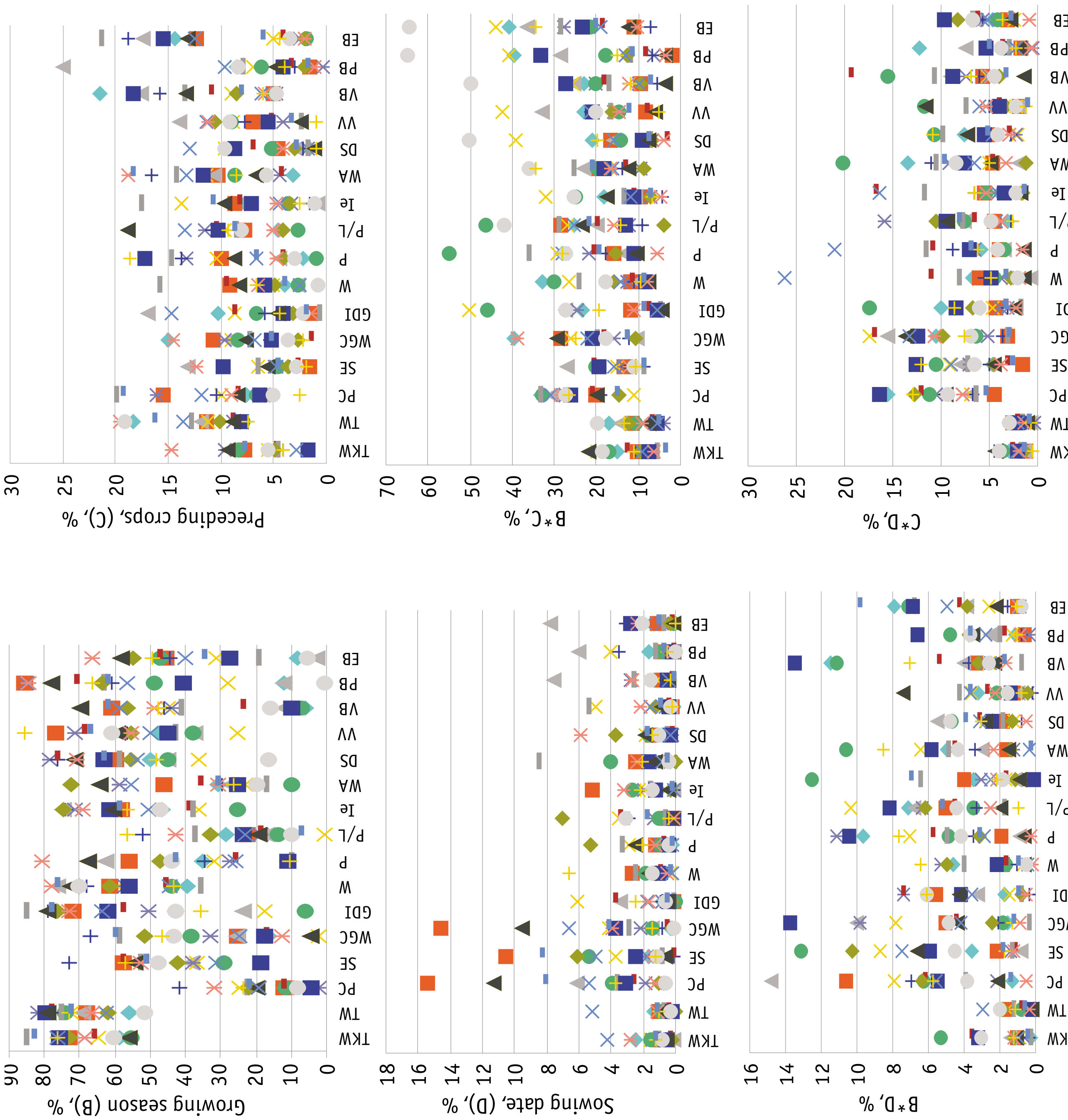
Research results

Figure 1 shows the shares of the influence of the growing season, preceding crops, sowing date and their interaction on the quality indicators of the studied genotypes. A different ratio of the influence of these factors for different varieties was revealed. In particular, the share of the influence of growing season conditions varied most of all in terms of the porosity of bread (from 0.8% for the variety G15 'MIP Lada' to 85.5% for the G2 'MIP Valensiia'), as well as the dough elasticity index (from 6.2% from G6 'Balada myronivs'ka' to 85.0% from G9 'Estafeta myronivs'ka'); preceding crop – for porosity of bread (from 0.3% for G5 'Trudivnytsia myronivs'ka' to 24.9% for G3 'MIP Vyshyvanka'); sowing date – wet gluten content (from 0.1% for G15 'MIP Lada' to 14.5% for G2 'MIP Valensiia'); interactions growing season * preceding crop – porosity of bread (from 2.1% for G2 'MIP Valensiia' to 64.9% for G15 'MIP Lada'), bread evaluation (from 7.1% for G7 'Vezha myronivs'ka' to 64.4% for G15 'MIP Lada'); interactions growing season * sowing date – protein content (from 0.5% for G14 'MIP Darunok' to 14.8% for G3 'MIP Vyshyvanka'), wet gluten content (from 0.4% for G9 'Estafeta myronivs'ka' to 13.7% in G11 'MIP Dniprianka'); interactions preceding crop * sowing date – flour strength (from 0.8% for G3 'MIP Vyshyvanka' to 26.1% for G13 'MIP Vidznaka'), dough tenacity (from 1.4% for G12 'Avrora myronivs'ka' to 21.0% in G13 'MIP Vidznaka'); interactions growing season * preceding crop * sowing date – protein content (from 7.8% for G9 'Estafeta myronivs'ka' to 41.0% for G15 'MIP Lada'), wet gluten content (from 8.4% for G7 'Vezha myronivs'ka' to 40.1% for G8 'Hratsiia myronivs'ka'), dough tenacity (from 4.1% for G14 'MIP Darunok' to 35.3% for G11 'MIP Dniprianka').

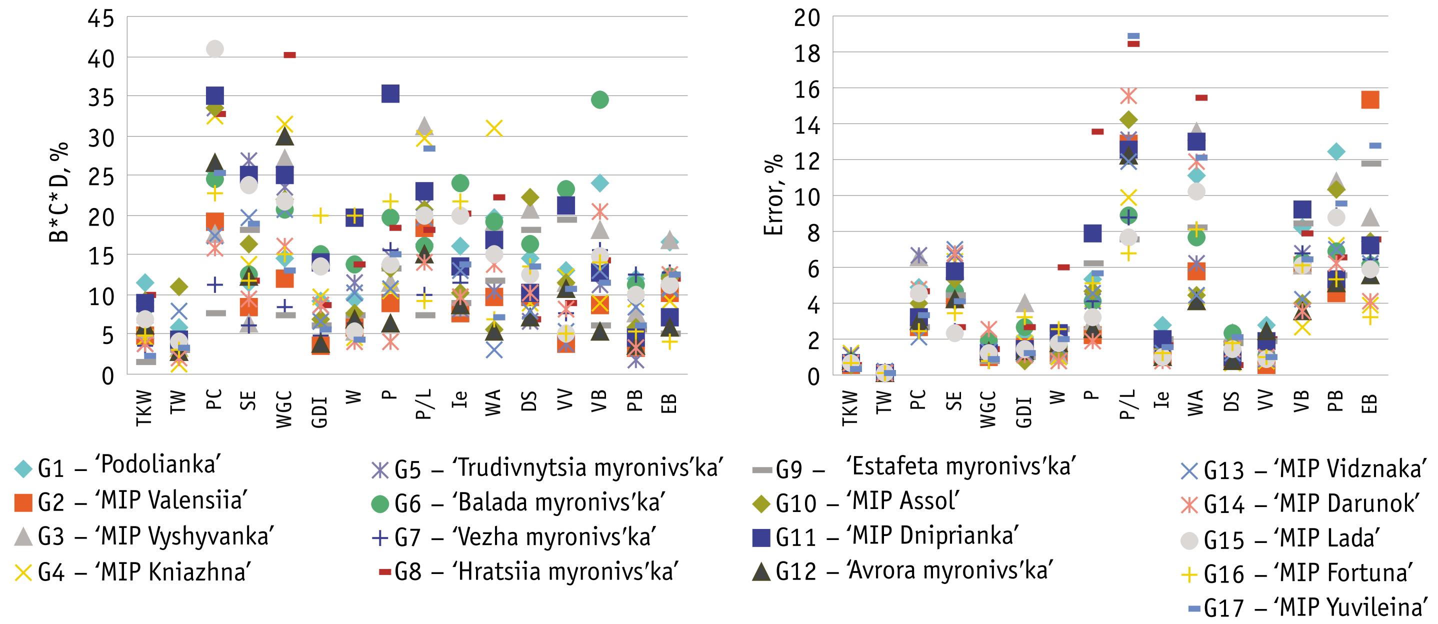
A lesser influence of growing season conditions on most quality indicators was revealed in varieties G4 'MIP Kniazhna', G15 'MIP Lada', G6 'Balada myronivs'ka' and G1 'Podolianka'; preceding crop – G10 'MIP Assol', G16 'MIP Fortuna', G15 'MIP Lada', G6 'Balada myronivs'ka'; sowing date – G10 'MIP Assol', G3 'Vyshyvanka myronivs'ka', G8 'Hratsiia myronivs'ka'. At the same time, a number of varieties reacted more strongly to changes in natural and anthropogenic factors in terms of most quality indicators, in particular, for the growing season conditions – G7 'Vezha myronivs'ka', G5 'Trudivnytsia myronivs'ka', G12 'Avrora myronivs'ka', G14 'MIP Darunok'; preceding crop – G3 'MIP Vyshyvanka', G14 'MIP Darunok', G9 'Estafeta myronivs'ka', G13 'MIP Vidznaka'; sowing date – G2 'MIP Valensiia', G12 'Avrora myronivs'ka'.

Differences in the value of the coefficient of variation in varieties for certain quality indicators at different sowing dates after different preceding crops were revealed (Fig. 2). The variability was weak (coefficient of variation (CV) $< 5\%$) in the level of manifestation of test weight, water absorption ability of flour, and porosity of bread. A significant coefficient of variation (CV $> 20\%$) was revealed for such indicators of the quality of winter wheat as the strength of flour after the preceding crops of sunflower and soybean (up to 28.0 and 30.1%, respectively); alveogram configuration ratio after sunflower and soybean (up to 22.2 and 20.5%, respectively); dough elasticity index after corn (up to 23.6%); valorimetric velue after mustard (up to 21.0%); degree of softening dough after green manure, sunflower, corn, and especially after mustard and soybean (up to 23.2, 25.9, 26.8, 37.3 and 33.1%, respectively).

Table 1 shows the average for 2016/17–2018/19 value of a quality indicator complex (except for the alveogram configuration ratio and dough elasticity index) by sowing dates after different preceding crops. The varieties that reliably exceed the standard G1 'Podolianka' by some identified indicators: *thousand kernel weight* – G5 'Trudivnytsia myronivs'ka' (41.6 g), G6 'Balada myronivs'ka' (42.2 g), G11 'MIP Dniprianka' (42.1 g), G12 'Avrora myronivs'ka' (42.6 g), G14 'MIP Darunok' (42.9 g); *test weight* – G3 'MIP Vyshy-

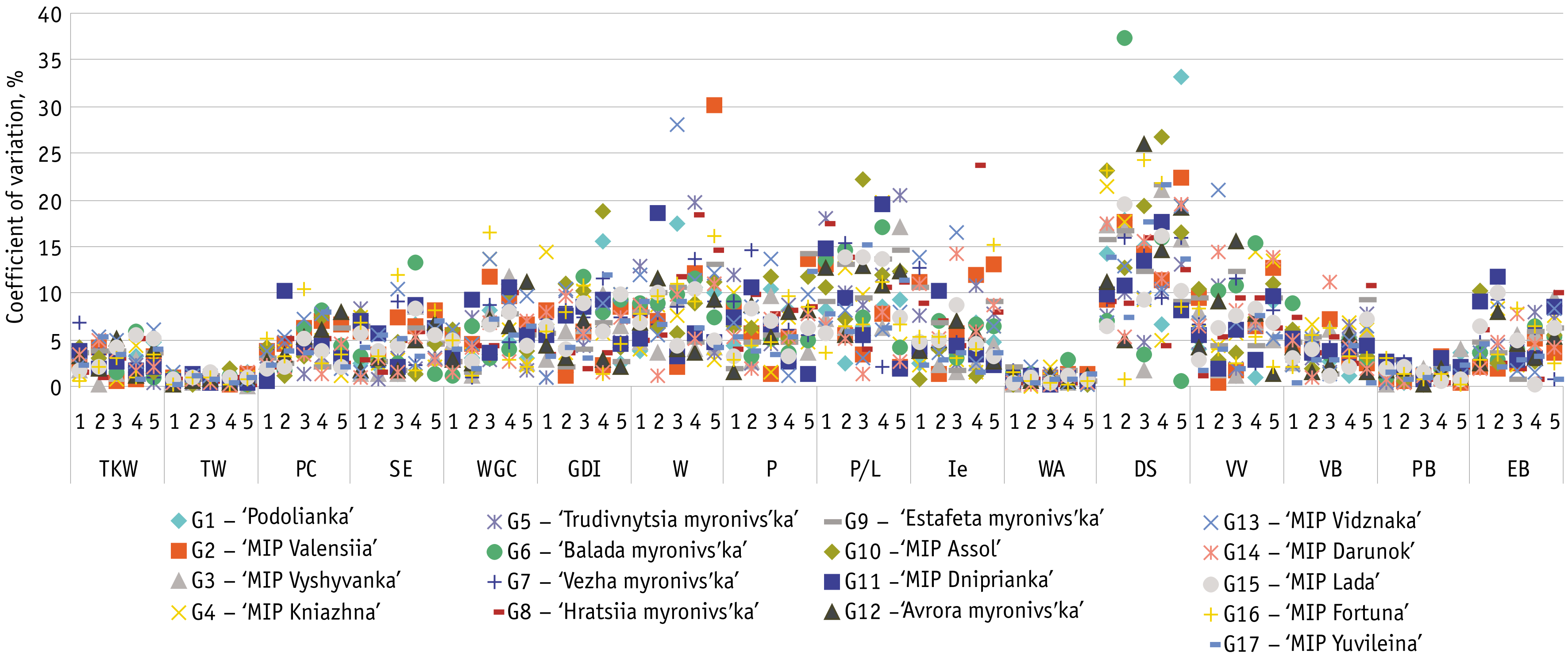


Preceding crops (C), %
B*C, %
C*D, %
Growing season (B), %
Sowing date (D), %
B*D, %
TKW
TW
PC
SE
WGC
GDI
W
P
P/L
Ie
WA
DS
VV
VB
PB
EB



Note. TKW – thousand kernel weight, TW – test weight, PC – protein content, SE – sedimentation value, WGC – wet gluten content, GDI – gluten deformation index, W – flour strength, P – dough tenacity, P/L – alveogram configuration ratio, Ie – dough elasticity index, WA – water absorption capacity of flour, DS – degree of softening dough, VV – valorimetric value, VB – volume of bread, PB – porosity of bread, EB – evaluation of bread.

Fig. 1. The share of influence (%) of factors on the quality indicators of winter bread wheat varieties (2016/17–2018/19)



Note. Preceding crops: 1 – green manure, 2 – mustard; 3 – sunflower; 4 – corn; 5 – soybean;
TKW – thousand kernel weight, TW – test weight, PC – protein content, SE – sedimentation value, WGC – wet gluten content, GDI – gluten deformation index, W – flour strength, P – dough tenacity, P/L – alveogram configuration ratio, Ie – dough elasticity index, WA – water absorption capacity of flour, DS – degree of softening dough, VV – valorimetric value, VB – volume of bread, PB – porosity of bread, EB – evaluation of bread.

Fig. 2. Coefficient of variation (%) of quality indicators of winter bread wheat genotypes depending on sowing dates after different preceding crops (2016/17–2018/19)

Table 1

Characteristics of winter bread wheat varieties by a set of quality indicators (2016/17–2018/19)

Code	Variety	TKW, g	TW, g/l	PC, %	SE, ml	WGC, %	W, 10^{-4}J	P, mm	WA, %	DS, FU	VV, VU	VB, cm^3	PB, %	EB, score
G1	'Podolianka'	40.7	765	12.6	72	27.8	265	87	57.8	57	52	940	85	3.7
G2	'MIP Valensiia'	38.9	763	13.2	63	29.0	295	109	60.4	106	49	724	79	2.7
G3	'MIP Vyshyvanka'	39.7	778	12.7	70	26.8	360	124	61.4	63	51	972	85	3.8
G4	'MIP Kniazhna'	41.0	767	14.1	75	30.1	368	113	61.5	77	62	969	84	3.5
G5	'Trudivnytsia myronivs'ka'	41.6	782	12.6	62	26.1	263	96	61.8	82	49	803	82	3.1
G6	'Balada myronivs'ka'	42.2	775	12.6	67	28.2	308	107	59.4	67	54	912	80	3.3
G7	'Vezha myronivs'ka'	40.9	741	12.5	62	27.1	288	99	58.6	59	54	835	83	3.2
G8	'Hratsiia myronivs'ka'	41.0	752	13.4	62	31.4	173	62	59.7	126	39	763	81	2.9
G9	'Estafeta myronivs'ka'	39.2	781	13.5	66	29.4	301	112	62.1	88	57	740	79	2.9
G10	'MIP Assol'	38.0	758	12.7	73	28.5	314	101	59.9	65	51	941	84	3.6
G11	'MIP Dniprianka'	42.1	775	13.1	61	28.3	240	82	61.2	116	44	768	80	2.9
G12	'Avrora myronivs'ka'	42.6	759	14.5	65	34.0	257	104	64.0	120	44	685	77	2.5
G13	'MIP Vidznaka'	40.7	771	12.8	58	26.4	390	143	63.1	78	48	795	80	3.0
G14	'MIP Darunok'	42.9	757	13.0	65	26.9	336	125	61.2	97	42	797	80	3.1
G15	'MIP Lada'	38.0	744	13.1	64	26.0	289	106	61.7	94	49	794	79	3.1
G16	'MIP Fortuna'	38.8	760	12.9	59	25.7	280	113	62.2	87	49	847	80	3.1
G17	'MIP Yuvileina'	38.8	771	12.9	73	28.4	271	91	58.0	62	54	866	83	3.2
	$LCD_{0.05}$	0.7	2	0.4	3	0.7	20	8	0.7	7	2	43	2	0.2

Note. TKW – thousand kernel weight, TW – test weight, PC – protein content, SE – sedimentation value, WGC – wet gluten content, GDI – gluten deformation index, W – flour strength, P – dough tenacity, WA – water absorption capacity of flour, DS – degree of softening dough, VV – valorimetric value, VB – volume of bread, PB – porosity of bread, EB – evaluation of bread.

Table 2

Index standardized combinations of yield and a set of quality indicators for winter bread wheat varieties (2016/17–2018/19)

Code	Variety	YLD*TKW	YLD*TW	YLD*PC	YLD*SE	YLD*WGC	YLD*W	YLD*P	YLD*WA	YLD/DS	YLD*VV	YLD*VB	YLD*PB	YLD*EB	GYT index
G1	'Podolianka'	0.04	–0.09	–0.88	1.09	–0.30	–0.55	–0.91	–1.00	1.47	0.30	1.15	0.67	1.43	0.19
G2	'MIP Valensiia'	0.24	0.89	1.42	0.20	1.18	0.30	0.54	0.87	–0.80	0.31	–0.76	0.41	–0.80	0.31
G3	'MIP Vyshyvanka'	–1.27	–0.70	–1.94	0.00	–1.48	0.82	0.60	–0.88	0.72	–0.29	0.94	–0.15	1.17	–0.19
G4	'MIP Kniazhna'	–1.08	–1.28	–0.10	0.67	–0.20	0.82	0.02	–1.20	–0.17	1.16	0.70	–0.74	0.10	–0.10
G5	'Trudivnytsia myronivs'ka'	1.43	1.32	0.41	–0.05	–0.35	–0.32	–0.18	1.27	0.08	0.33	0.15	1.04	0.33	0.42
G6	'Balada myronivs'ka'	0.67	0.13	–0.90	0.27	–0.11	0.22	0.11	–0.55	0.73	0.54	0.83	–0.29	0.48	0.16
G7	'Vezha myronivs'ka'	0.56	–0.22	–0.61	–0.44	–0.29	–0.02	–0.17	–0.32	1.43	0.78	0.21	0.66	0.39	0.15
G8	'Hratsiia myronivs'ka'	–0.18	–0.72	–0.04	–0.98	1.21	–2.27	–2.19	–0.79	–1.48	–1.89	–0.97	–0.47	–0.80	–0.89
G9	'Estafeta myronivs'ka'	0.44	1.35	2.04	0.78	1.43	0.44	0.67	1.43	–0.15	1.69	–0.56	0.35	–0.30	0.74
G10	'MIP Assol'	–0.08	0.86	0.76	2.15	0.97	0.69	0.15	0.78	1.13	0.70	1.83	1.61	1.74	1.02
G11	'MIP Dniprianka'	1.01	0.51	0.44	–0.66	0.27	–0.91	–1.06	0.43	–1.16	–0.84	–0.57	–0.01	–0.54	–0.24
G12	'Avrora myronivs'ka'	–0.86	–1.84	0.05	–1.34	1.20	–1.14	–0.56	–0.97	–1.54	–1.70	–2.40	–2.57	–2.56	–1.25
G13	'MIP Vidznaka'	1.42	1.45	1.16	–0.51	0.12	2.27	2.46	2.12	0.39	0.29	0.27	0.96	0.21	0.97
G14	'MIP Darunok'	1.10	–0.13	–0.04	–0.16	–0.59	0.77	1.06	0.17	–0.69	–1.27	–0.36	–0.17	–0.16	–0.04
G15	'MIP Lada'	–1.99	–1.46	–1.21	–1.11	–1.86	–0.41	–0.22	–0.83	–0.79	–0.57	–0.95	–1.44	–0.77	–1.05
G16	'MIP Fortuna'	–0.98	–0.41	–0.60	–1.39	–1.49	–0.34	0.35	0.10	–0.37	–0.37	0.00	–0.50	–0.23	–0.48
G17	'MIP Yuvileina'	–0.47	0.34	0.06	1.47	0.28	–0.37	–0.64	–0.63	1.19	0.83	0.49	0.63	0.33	0.27

Note. YLD – yield, TKW – thousand kernel weight, TW – test weight, PC – protein content, SE – sedimentation value, WGC – wet gluten content, GDI – gluten deformation index, W – flour strength, P – dough tenacity, WA – water absorption capacity of flour, DS – degree of softening dough, VV – valorimetric value, VB – volume of bread, PB – porosity of bread, EB – evaluation of bread, GYT index – general genotype index for the combination of yield and quality indicators.

vanka' (778 g/l), G4 'MIP Kniazhna' (767 g/l), G5 'Trudivnytsia myronivs'ka' (782 g/l), G6 'Balada myronivs'ka' (775 g/l), G9 'Estafeta myronivs'ka' (781 g/l), G11 'MIP Dniprianka' (775 g/l), G13 'MIP Vidznaka' (771 g/l), G17 'MIP Yuvileina' (771 g/l); *protein content* – G2 'MIP Valensiia' (13.2%), G4 'MIP Kniazhna' (14.1%), G8 'Hratsiia myronivs'ka' (13.4%), G9 'Estafeta myronivs'ka' (13.5%), G11 'MIP Dniprianka' (13.1%), G12 'Avrora myronivs'ka' (14.5%), G14 'MIP Darunok' (13.0%), G15 'MIP Lada' (13.1%); *sedimentation value* – G4 'MIP Kniazhna' (75 ml); *wet gluten content* – G2 MIP Valensiia' (29.0%), G4 'MIP Kniazhna' (30.1%), G8 'Hratsiia myronivs'ka' (31.4%), G9 'Estafeta myronivs'ka' (29.4%), G10 'IP Assol' (28.5%), G12 'Avrora myronivs'ka' (34.0%); *flour strength* – G2 'MIP Valensiia' ($295 \cdot 10^{-4}$J), G3 'MIP Vyshyvanka' ($360 \cdot 10^{-4}$J), G4 'MIP Knyazhna' ($368 \cdot 10^{-4}$J), G6 'Balada myronivs'ka' ($308 \cdot 10^{-4}$J), G7 'Vezha myronivs'ka' ($288 \cdot 10^{-4}$J), G9 'Estafeta myronivs'ka' ($301 \cdot 10^{-4}$J), G10 'MIP Assol' ($314 \cdot 10^{-4}$J), G13 'MIP Vidznaka' ($390 \cdot 10^{-4}$J), G14 'MIP Darunok' ($336 \cdot 10^{-4}$J), G15 'MIP Lada' ($289 \cdot 10^{-4}$J); *dough tenacity* – G2 'MIP Valensia' (109 mm), G3 'MIP Vyshyvanka' (124 mm), G4 'MIP Kniazhna' (113 mm), G5 'Trudivnytsia myronivs'ka' (96 mm), G6 'Balada myronivs'ka' (107 mm), G7 'Vezha myronivs'ka' (99 mm), G9 'Estafeta myronivs'ka' (112 mm), G10 'MIP Assol' (101 mm), G12 'Avrora myronivs'ka' (104 mm), G13 'MIP Vidznaka' (143 mm), G14 'MIP Darunok' (125 mm), G15 'MIP Lada' (106 mm), G16 'MIP Fortuna' (113 mm); *water absorption capacity of flour* – all varieties, except for G17 'MIP Yuvileina' (58.0%); *valorimetric value* – G4 'MIP Kniazhna' (62 VU), G6 'Balada myronivs'ka' (54 VU), G7 'Vezha myronivs'ka' (54 VU), G9 'Estafeta myronivs'ka' (57 VU), G17 'MIP Yuvileina' (54 VU).

The selected varieties can be used in the breeding process as genetic sources to improve the corresponding quality indicators. In particular, the given varieties can be chosen according to physical indicators of grain quality – G5 'Trudivnytsia myronivs'ka', G6 'Balada myronivs'ka', G11 'MIP Dniprianka'; physical indicators of flour quality – G4 'MIP Kniazhna'; rheological properties of the dough – G6 'Balada myronivs'ka', G7 'Vezha myronivs'ka', G9 'Estafeta myronivs'ka'.

In modern production conditions, commercial value is made by winter bread wheat varieties that combine high values of a complex of quality indicators with a high and stable level of yield. Index standardized values of the combination of some of the indicators of baking quality considered above and the average value of yield by growing season, sowing dates and after different preceding crops, as well as the average GYT (genotype by yield * trait) index, characterizing the generalized assessment of each genotype, are shown in Table 2. GYT biplot analysis was performed on the base of these data.

It follows from Figure 3 that the combination of yield and dough tenacity (YLD_P) had the smallest length of vectors, and, accordingly, a low differentiating ability. Greater differentiating ability (longer vectors) was characterized by combinations of YLD_VB (yield and volume of bread), YLD_EB (yield and evaluation of bread), YLD_DS (yield and degree of softening dough), YLD_PC (yield and protein content), YLD_WA (yield and water absorption capacity of flour), YLD_TW (yield and test weight), YLD_PB (yield and porosity of bread). The combination YLD_P (yield and dough tenacity) and YLD_PB (yield and porosity of bread) were the most representative, as they were closer to the mean vector for all conjugations indicated by an arrow in the small circle.

The lowest representativeness was found in the combinations of YLD_VB (yield and volume of bread), YLD_DS (yield and degree of softening dough), and YLD_WGC (yield and wet gluten content), since their vectors were the most deviated from the middle axis. Among the combinations with a sufficiently high differentiating ability and greater representativeness in comparison with others, one can distinguish YLD_TW (yield and test weight) and YLD_PB (yield and porosity of bread).

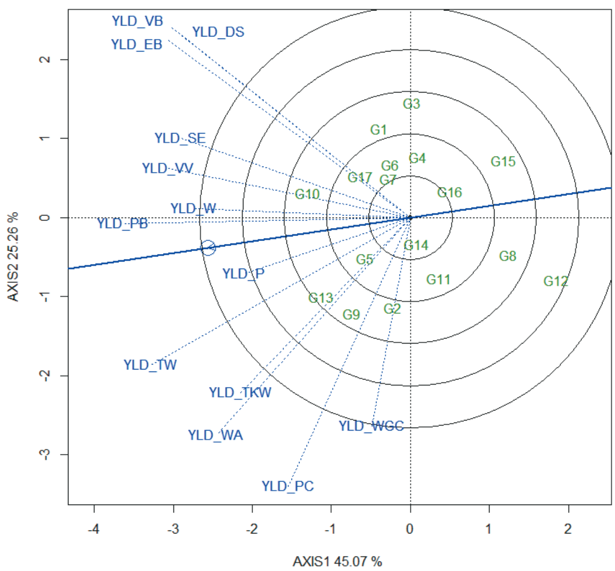


Fig. 3. The GYT biplot of differential ability and representativeness of the combination of yield and quality indicators (2016/17–2018/19)

Figure 4 allows an analysis of the interaction between individual yield combinations and quality indicators. In particular, the combinations of YLD_EB (yield and evaluation of bread), YLD_VB (yield and volume of bread) and YLD_DS (yield and degree of softening dough) had a very close arrangement of the vectors to each other, as well as their almost identical length. In the last two combinations, the directions of the vectors generally coincided.

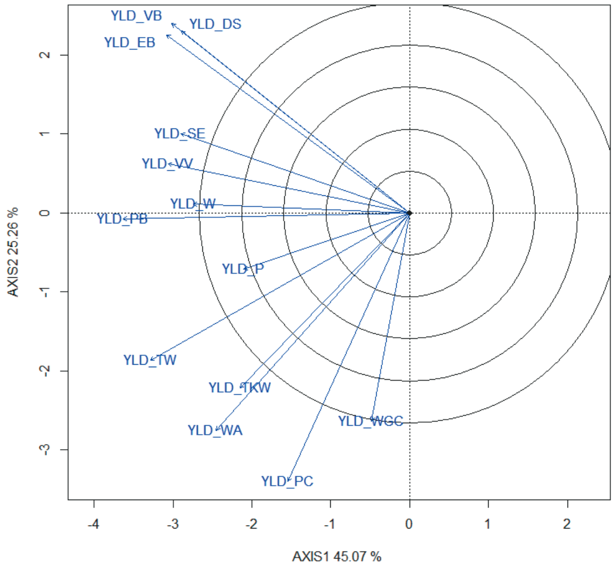


Fig. 4. The GYT biplot characterizing the relationship between individual yield combinations and quality indicators (2016/17–2018/19)

It should also be noted that the vectors YLD_TKW (yield and thousand kernel weight) and YLD_WA (yield and water absorption capacity of flour) are close to each other, although they slightly differed in differentiating ability. The lengths of the vectors slightly differed, but the combinations of YLD_W (yield and flour strength) and YLD_PB (yield and porosity of bread) were close to each other. The most distant from each other were the combinations of YLD_WGC (yield and wet gluten content), YLD_VB (yield and volume of bread) and YLD_DS (yield and degree of softening dough).

The GYT biplot «which-won-where» shows that the combinations of yield and quality indicators were distributed in three sectors, which can be characterized as mega-environments (Fig. 5).

The first included a combination of YLD_VB (yield and volume of bread), YLD_DS (yield and degree of softening dough), YLD_EB (yield and evaluation of bread), YLD_SE (yield and sedimentation value), YLD_VV (yield and valorimetric value), YLD_W (yield and flour

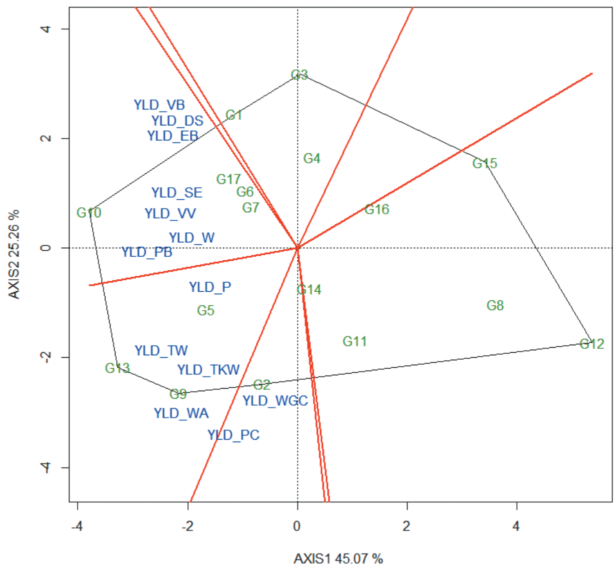


Fig. 5. The GYT biplot "which-won-where", according to the combination of yield and grain quality indicators (2016/17–2018/19)

strength) and YLD_PB (yield and porosity of bread). The G10 'MIP Assol' variety had an advantage in this environment. Varieties G17 'MIP Yuvileina', G7 'Vezha myronivs'ka' and G6 'Balada myronivs'ka' were also in this sector. Thus, for varieties G10 'MIP Assol', G17 'MIP Yuvileina', G7 'Vezha myronivs'ka' and G6 'Balada myronivs'ka', it was a number of the above combinations of yield and quality indicators that were most characteristic.

The second mega-environment is formed by combinations of YLD_P (yield and dough tenacity), YLD_TW (yield and test weight), YLD_TKW (yield and thousand kernel weight), YLD_WA (yield and water absorption capacity of flour). In it, at different tops of the polygon, two varieties were located at once – G13 'MIP Vidznaka' and G9 'Estafeta myronivs'ka'. In addition to them, G5 variety 'Trudivnytsia myronivs'ka' got into this sector. The combination YLD_WGC (yield and wet gluten content) as well as the variety G2 'MIP Valensiia' entered the third mega-environment. A combination of YLD_PC (yield and protein content) is located practically on the line dividing the second and third mega-environments. On the line dividing the third mega-environment and the sector without combinations of yield and quality indicators, there was variety G14 'MIP Darunok'. It should be noted that for breeding use the combination of each other as parental components of crossing of genotypes located in different mega-environments according to combinations of yield and quality indicators (I × II, I × III, II × III) is of considerable practical interest.

Coordination of genotypes by the average value of all combinations of yield and quality indicators, as well as the statistically calculated level of their optimal combination confirms and supplements these features (Fig. 6). In descending order – from high to low values according to the generalized assessment, varieties G13 'MIP Vidznaka', G10 MIP Assol', G9 'Estafeta myronivs'ka', G5 'Trudivnytsia myronivs'ka', G2 'MIP Valensiia', G17 'MI G6 'Balada myronivs'ka', G7 'Vezha myronivs'ka' and standard G1 'Podolianka' were arranged. The rest of the varieties were inferior to them and the mean value for the entire sample, represented by an oblique vertical line crossing the GYT biplot base.

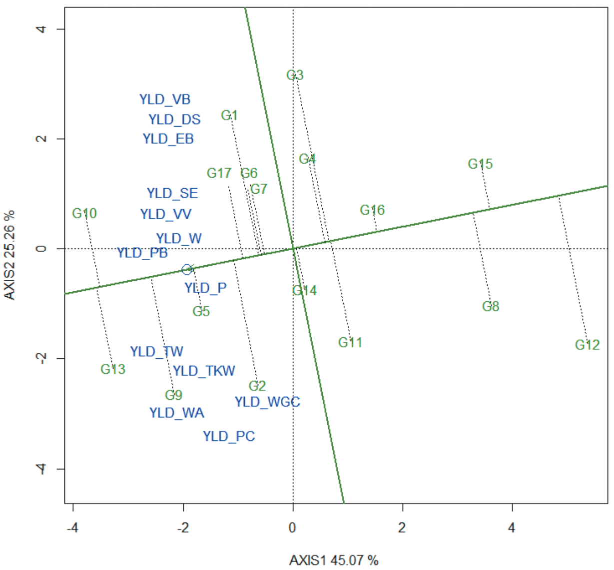


Fig. 6. The GYT biplot weighted average coordination of winter bread wheat genotypes by the level of manifestation of certain yield combinations (2016/17–2018/19)

Varieties G13 'MIP Vidznaka' and G10 'MIP Assol' were the closest to the statistically calculated "ideal genotype" represented by an arrow on the middle horizontal axis in the center of the centric circles (Fig. 7). Thus, they had optimal, in comparison with others, combination of yield level and quality indicators on average in three-year studies for three sowing periods after five different preceding crops. At the same time, they differed among themselves in a number of combinations of yield and quality indicators, since they were located on different sides of the middle axis and, as discussed above, in different mega-environments. Also noteworthy are varieties G9 'Estafeta myronivs'ka', G5 'Trudivnytsia myronivs'ka', G2 'MIP Valensiia', G17 'MIP Yuvileina', G6 'Balada myronivs'ka', G7 'Vezha myronivs'ka', which were slightly inferior to the above, in particular in terms of the average value and balance of indicators (G9 'Estafeta myronivs'ka', G2 'MIP Valensiia', G17 'MIP Yuvileina') or an average value (G5 'Trudivnytsia myronivs'ka', G7 'Vezha myronivs'ka', G6 'Balada myronivs'ka'), however exceeded the standard 'Podolianka', as well as an average value in the experiment and, accordingly, other varieties.

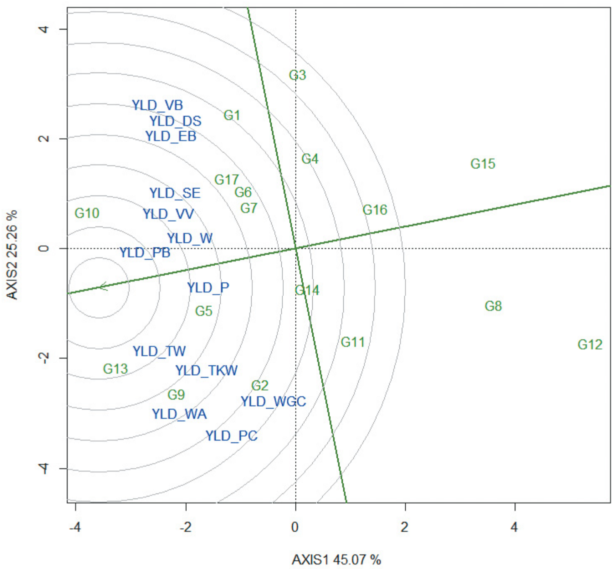


Fig. 7. GYT biplot for ranking winter bread wheat genotypes in relation to the ideal genotype according to the combination of yield and quality indicators (2016/17–2018/19)

So, the varieties described above are more stable in terms of producing an increased level of yield in combination with a set of quality indicators in the context of different growing season, preceding crops and sowing dates. Other varieties, namely G14 'MIP Darunok', G11 'MIP Dniprianka', G4 'MIP Kniazhna', G3 'MIP Vyshyvanka', G16 'MIP Fortuna', G8 'Hratsiia myronivs'ka', G15 'MIP Lada' and G12 'Avrora myronivs'ka', obviously require much more attention regarding the sowing date after the corresponding preceding crops.

Conclusions

The features revealed by the level of manifestation and variability of the complex of quality indicators of winter bread wheat, depending on the hydrothermal growing season conditions, sowing date and preceding crop, should be taken into account when assessing and differentiating genotypes in the breeding process, as well as the development of the basic elements of the cultivation technology of varieties.

The varieties that can be used as sources of a stable level of manifestation of quality indicators in the breeding process were identified. In particular, according to physical indicators of grain quality – 'Trudivnytsia myronivs'ka', 'Balada myronivs'ka', 'MIP Dniprianka'; physical indicators of flour quality – 'MIP Kniazhna'; rheological properties of the dough – 'Balada myronivs'ka', 'Vezha myronivs'ka', 'Estafeta myronivs'ka' were selected.

The combination of genotypes among themselves as parental components of the crossing, which, according to the GYT biplot, were placed in different mega-environments, according to combinations of yield and quality indicators is of particular practical interest.

A more stable level of manifestation of yield and quality indicators in production conditions at different sowing dates after different preceding crops can be expected by growing varieties 'MIP Vidznaka', 'MIP Assol', as well as 'Estafeta myronivs'ka', 'Trudivnytsia myronivs'ka', 'MIP Valensiia', 'MIP Yuvileina', 'Balada myronivs'ka', 'Vezha myronivs'ka'.

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Мета. Виявити особливості формування комплексу показників якості пшениці м'якої озимої залежно від умов року, попередників і строків сівби, а також диференціювати й виділити сорти з підвищеним та стабільним їх рівнем прояву. **Методи.** Польові, лабораторні, статистичні. **Результати.** Установлено різну частку впливу умов року, попередника, строку сівби та їхньої взаємодій на показники якості деяких сортів. Виявлено різну реакцію сортів за показниками якості залежно від досліджених чинників. Низьким був коефіцієнт варіації за показниками натури зерна, водопоглинальної здатності борошна, пористості м'якуша. Високу варіабельність виявлено для сили борошна після попередників соняшник і соя; конфігурації альвеограми після соняшника та сої; індексу еластичності тіста після кукурудзи; валориметричної оцінки після гірчиці; ступеня розрідження тіста після сидерального пару, соняшнику, кукурудзи й особливо після гірчиці та сої. Виділено сорти, які в середньому за 2016/17–2018/19 рр. достовірно переважали стандарт як за окремими, так і низкою фізичних показників якості зерна й борошна та реологічними властивостями тіста. GYT biplot аналізом виділено сорти 'МІП Відзнака' і 'МІП Ассоль' з оптимальнішим поєднанням підвищеного рівня врожайності та комплексу показників якості у розрізі різних років, попередників та строків сівби. Дещо поступались їм, але відчутно переважали решту, сорти 'Естафета миронівська', 'Трудівниця миронівська', 'МІП Валенсія', 'МІП Ювілейна', 'Балада миронівська', 'Вежа миронівська'. **Висновки.** Виділені за показниками якості сорти, можуть бути використані як генетичні джерела в селекційному процесі. Стабільніший рівень прояву врожайності та показників якості за різних строків сівби після різних попередників слід очікувати за вирощування сортів 'МІП Відзнака', 'МІП Ассоль', а також 'Естафета миронівська', 'Трудівниця миронівська', 'МІП Валенсія', 'МІП Ювілейна', 'Балада миронівська', 'Вежа миронівська'. Виявлені особливості слід ураховувати під час оцінювання та диференціювання генотипів у селекційному процесі, а також розроблення базових елементів технології вирощування сортів пшениці м'якої озимої.

Ключові слова: *Triticum aestivum L.; фізичні показники якості зерна та борошна; реологічні властивості тіста; хлібопекарські властивості борошна; строк сівби; попередник; коефіцієнт варіації; ANOVA; GYT biplot.*

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