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MANIFESTATION AND VARIABILITY LEVEL OF YIELD AND GRAIN QUALITY INDICATORS IN WINTER BREAD WHEAT DEPENDING ON NATURAL AND ANTHROPOGENIC FACTORS

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ABSTRACT

Since the yield and quality of wheat grain significantly depends on genetic potential of the variety in interaction with environmental conditions and cultivation technology, so it have been studied features of the manifestation and variability of yield and grain quality indicators of winter bread wheat depending on growing season conditions, genotype, sowing date and preceding crop in environment of the central part of the Ukrainian Forest-Steppe. The conditions of the growing season had a decisive influence on yield, 1000 kernel weight, and test weight. The preceding crop had more influence on yield, test weight, 1000 kernel weight, protein content; sowing date had more influence on yield. The significant influence of the genotype on the water absorption of flour, dough tenacity, alveogram configuration ratio, bread volume and evaluation score, protein content was established. There were determined the quality indicators with stable strong correlations under the influence of various natural and anthropogenic factors. The identified features of the manifestation and variation of grain quality indicators should be taken into account when growing winter bread wheat for baking, as well as in breeding process to increase the efficiency of selection of promising genotypes, reduce the number of tests and "capacity" of laboratories.

Keywords: *Triticum aestivum* L., yield, grain quality indicators, growing season conditions, sowing date and preceding crop.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the main crops for human nutrition that provides about one-fifth of all nutrients (Li S. et al., 2021; Karaduman et al., 2021). Therefore, increased production of high-quality grain is one of the important tasks of agricultural science and practice (Betsiashvili et al., 2020; Li T. et al., 2021). The quality of wheat grain used for bread production is evaluated by flour milling (test weight, 1000 kernel weight, grain vitreousness, grain size, etc.) and baking properties (protein content, sedimentation volume, wet gluten content and its quality, physical properties of the dough, volume bread, etc.) (Zhygunov et al., 2018).

Physical indicators of grain quality, namely, 1000 kernel weight, test weight, characterize large, uniform, well-filled grain (Deivasigamani and Swaminathan, 2018; Ulianych, 2020). The nutritional value of bakery products, groats and pasta is related to the protein content, wet gluten content and its quality (Al-Saleh and Brennan, 2012; Doneva et al., 2018; Jernigan et al., 2018). Potential properties of the protein complex are characterized by sedimentation value (Sasani et al., 2020). The quality of the final product depends on the physical properties of the dough, namely, deformation energy (or flour strength), dough tenacity, dough extensibility, alveograph configuration ratio (the ratio of tenacity to extensibility), elasticity index, water absorption ability of flour, dough development time, dough stability time, degree of dough softening, valorimetric value, which determine its behavior in the technological process, characterize the shape-retaining ability of products and determine the volume of the final product (Cappelli et al., 2018; Sapirstein et al., 2018; Boltenko et

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al., 2019; Cappelli and Cini, 2021). Volume of baked experimental breads and bread crumb quality by quality score visually characterize the baking properties of the studied wheat samples (Živančev et al., 2019).

Wheat yield and grain quality largely depends on the characteristics of the variety, abiotic and anthropogenic factors (Bagulho et al., 2015; Nadew, 2018). Realization of genetic potential of the variety, both in terms of yield and in quality indicators, at a high level is possible under effective agronomic management practices (Senapati, 2019). Only when sowing at the optimal time and after properly chosen preceding crops, it is possible to obtain a sufficient level of grain yield with high quality (Silva et al., 2014). The influence of sowing dates, preceding crops on yields and certain grain quality indicators of winter wheat is covered in the scientific papers by other researchers (Kulig et al., 2010; Saleem et al., 2015; Madhu et al., 2018; Siroshtan et al., 2021).

The aim of the research is to identify the features of the manifestation and variability of yield and grain quality indicators of winter bread wheat depending on the growing season, genotype, sowing date and preceding crop in conditions from the central part of the Ukrainian Forest-Steppe.

MATERIAL AND METHODS

The tests were conducted during three the crop years (2016-17 – 2018-19) at the V. M. Remeslo Myronivka Institute of Wheat NAAS of Ukraine in the Tsentralne village, Obukhiv district, Kyiv region, Ukraine (49°38’41.5’’ N latitude, 31°05’33.2’’ E longitude). The experiment included seventeen genotypes of winter bread wheat (*Triticum aestivum* L.) bred at Myronivka: ‘Podolianka’ (St), ‘MIP Valensiia’, ‘MIP Vyshyvanka’, ‘MIP Kniazhna’, ‘Trudivnytsia myronivska’, ‘Balada myronivska’, ‘Vezha myronivska’, ‘Hratsiia myronivska’, ‘Estafeta myronivska’, ‘MIP Assol’, ‘MIP Dniprianka’, ‘Avrora myronivska’, ‘MIP Vidznaka’, ‘MIP Darunok’, ‘MIP Lada’, ‘MIP Fortuna’, ‘MIP Yuvileina’ which were sown in three sowing dates (I – September 26, II – October 5, and III – October 16) after five preceding crops [GM: green manure (mustard), MS: mustard, SF: sunflower, CR: corn, SB: soybean].

Soil is deep, with low humus content, slightly leached chornozem. The thickness of the humus horizon is 38-40 cm. The content of humus is 3.7-3.9%, alkaline hydrolyzed nitrogen is 55-64 mg, phosphorus is 205-238 mg, exchangeable potassium is 82-110 mg per 1 kg of soil. Soil pH is 5.1-6.6. The specific weight of the solid phase of the soil is in the range of 2.62-2.71 g cm^{-3}.The soil bulk density in the profile does not exceed 1.29 g cm^{-3}, in the arable layer it is 1.27 g cm^{-3}.

Winter wheat growing techniques is conventional for the Ukrainian Forest-Steppe. Sowing was carried out with breeding seed drill SN-10 Ts to a depth of 3-4 cm, with sowing rate of 5 million viable seeds per 1 ha. Plots were placed according to randomized scheme in four repetitions with net area 10 m^2. The crop was harvested by direct combining with “Sampo-130” and converted to standard (14%) grain moisture.

Grain quality indicators were determined from each replication. Thousand-kernel weight (TKW) was determined by subtracting and weighting two samples of 500 grains to the nearest 0.1 g (the difference between the masses of the two samples did not exceed 5%) and summing these values; test weight (TW) was determined using a Liter Purk in two repetitions, the difference between the parallel definitions did not exceed 5 g, the final result was taken as the arithmetic mean of the two measurements and expressed in g l^{-1}; protein content of flour (PC) was determined using the near-infrared reflection spectrometer (spectral range 1400-2400 nm) on the SPECTRAN 119M instrument; sedimentation value (SE) was determined according to the micro method by A.Ya. Pumpianskyi; wet gluten content (WGC) was determined after manually washing the dough resulted from mixing 25 g of flour with 12 ml of 2% saline solution from starch and covers of grain; gluten deformation index (GDI) was determined by using the device IDK-1M; deformation energy (which is referred to as flour strength) (W), dough tenacity (P), alveogram configuration ratio (P/L), and dough elasticity index (Ie) were determined using the device Alveograph Chopin (France); water absorption of flour (WA), and degree of dough softening (DS), were determined using the device Farinograph Brabender (Germany); valorimetric value (VV) was determined using the device Valorimeter Brabender (Germany); kneading the dough was performed on the Swanson dough mixer, model 100-200 A; thermostat model 505-SS was used for fermentation and keeping the dough; baking bread took place in an electric oven with a horizontally rotating hearth (at t=230°C); volume of bread (VB) was determined on the device OMKh; bread evaluation was reformed on a 0 to 5 scale.

Statistical processing of experimental data was performed by methods of descriptive statistics and analysis of variance (ANOVA) using Microsoft Office Excel 2013. Clustering of yields and sixteen quality indicators of winter bread wheat was performed using the program Statistica 12 with Ward's method. The 1-Pearson r distance was used as a measure of the similarity of the studied indicators to detect the relationship between variables.

RESULTS AND DISCUSSION

Hydrothermal mode

Growing seasons in 2016-17 – 2018-19 had significant differences (Table 1), compared with long-term data and influenced the formation of yield and grain quality indicators of winter bread wheat.

Table 1. Average monthly values of hydrothermal regime for the period of the research (2016-17 – 2018-19)

Growing season	Month												Indicator	
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.		
Air temperature, °C													Average, °C	± to ALT
2016-17	21.1	15.7	6.7	1.4	-1.8	-5.3	-2.6	6.0	10.4	15.4	20.6	20.9	9.0	0.8
2017-18	22.4	17.0	8.6	3.5	2.2	-2.9	-3.6	-1.8	13.3	18.4	20.2	21.1	9.9	1.7
2018-19	22.0	16.7	10.6	0.0	-1.8	-5.0	0.3	4.6	10.4	17.4	22.7	19.6	9.8	1.6
ALT	19.5	14.4	8.2	2.2	-2.3	-4.6	-3.7	1.2	9.1	15.3	18.5	20.2	8.2	-
Precipitation, mm													Sum, mm	% to ALT
2016-17	37	2	75	44	31	31	33	12	43	23	20	102	453	78
2017-18	20	13	74	52	115	63	37	93	21	33	97	79	697	120
2018-19	15	89	28	22	72	40	26	27	23	50	87	50	529	91
ALT	60	50	36	40	42	36	31	34	41	51	79	79	579	-

*ALT: the average long-term value for 1980-2016.

During the period 2016-17 – 2018-19, the annual mean air temperature exceeded the average long-term (ALT) temperature by 0.8-1.7°C. The most variation in monthly mean temperature over the years was observed mainly from November to March. In general, 2016-17 and 2018-19 were the dry growing seasons, and the 2017-18 was the wet one, with the amount of precipitation of 78%, 91% and 120%, respectively, as compared to the ALT amount. It should be noted the lack of precipitation in August, September, May, and June in 2016-17; in August, September, April, and May in 2017-18; in August, October, and April in 2018-19.

Level of manifestation and variability of yield and quality indicators

Table 2 shows the average values for varieties of winter bread wheat by sowing dates after different preceding crops in experimental years. The maximum values of yield (6.28 t ha^{-1}), 1000 kernel weight (42.6 g), test weight (782 t ha^{-1}) for all genotypes and sowing dates for experimental years were observed after preceding crop green manure; the most protein content (13.4%) and wet gluten content (28.9%) were after soybean, sunflower, and green manure; high levels of deformation energy (298-301 10^{-4}J) bread volume (843-856 cm^3) and bread evaluation (3.2-3.3 points) were after mustard, sunflower, and soybean. After the preceding crop mustard there were received the minimum degree of dough softening and the maximum valorimetric value, because these is strong negative correlation between them. In studies by Gawęda et al. (2021) the maximum yield, protein content and sedimentation volume were obtained after soybean. Significantly the lowest yield, protein content, and wet gluten content were obtained after corn as preceding crop (Zhemela and Shakalii, 2012; Zaitsev and Kovalenko, 2020).

With the shift of the sowing date from September 26 to October 16, it was established a general tendency of decreasing average yield, 1000 kernel weight, test weight, but increasing sedimentation volume (significantly after sunflower and corn), protein content and wet gluten content. On average in the experiment, the significant impact of sowing dates on other quality indicators was not found. Saleem et al. (2015) and Arshad et al. (2017) also obtained higher yields on early sowing dates. Seleiman et al. (2011) and Saleem et al. (2015) obtained a higher protein content and wet gluten content on late sowing dates, they also found a significant increase in the water absorption of flour. In our studies, we followed a similar trend for water absorption, but within the least significant difference. Sasani et al. (2020) did not establish a significant impact of sowing dates on quality indicators of winter wheat.

Table 2. Yield and quality indicators of winter bread wheat depending on preceding crops and sowing dates (2016-17 – 2018-19)

Pre-crops*	Sowing dates**	YLD*** t ha^{-1}	Quality indicators****															
			TKW, g	TW, g l-1	PC, %	SE, ml	WGC, %	GDI, un. GDM	W, 10^{-4} J	P, mm	P/L	Ie, %	WA, %	DS, UF	VV, UV.	VB, cm^3	PB, %	BE, points
GM	I	6.71	42.8	785	13.3	67	28.6	69	292	105	1.4	60	60.7	87	50	781	80	3.0
	II	6.56	43.3	782	13.3	66	28.6	71	284	104	1.5	60	61.2	92	48	789	81	3.0
	III	5.57	41.7	778	13.1	67	28.4	71	285	104	1.5	59	61.0	80	50	822	80	3.1
	Mean	**6.28**	**42.6**	**782**	**13.2**	**67**	**28.5**	**71**	**287**	**104**	**1.5**	**60**	**61.0**	**87**	**49**	**797**	**80**	**3.0**
	LSD_{05}	0.32	0.8	2	0.4	3	0.7	3	20	7	0.2	2	0.7	8	2	44	2	0.2
MS	I	5.35	41.7	774	13.0	66	28.6	71	307	109	1.5	62	61.1	78	53	840	81	3.1
	II	5.25	40.9	771	12.7	66	28.0	69	295	106	1.6	61	60.6	81	52	847	82	3.3
	III	4.58	40.4	767	13.2	67	28.6	66	302	106	1.5	62	60.7	80	52	841	82	3.2
	Mean	**5.06**	**41.0**	**770**	**12.9**	**66**	**28.4**	**69**	**301**	**107**	**1.5**	**61**	**60.8**	**80**	**52**	**843**	**82**	**3.2**
	LSD_{05}	0.33	0.7	2	0.4	3	0.7	3	19	8	0.2	2	0.7	7	3	43	2	0.2
SF	I	5.14	40.0	760	12.9	65	27.6	68	288	104	1.5	61	60.9	85	50	851	82	3.3
	II	4.52	39.4	759	13.0	65	28.1	64	300	106	1.5	63	60.8	82	51	865	82	3.3
	III	3.81	39.2	757	13.7	68	30.1	68	307	106	1.5	63	61.1	83	52	851	82	3.2
	Mean	**4.49**	**39.5**	**759**	**13.2**	**66**	**28.6**	**67**	**298**	**105**	**1.5**	**62**	**60.9**	**83**	**51**	**856**	**82**	**3.3**
	LSD_{05}	0.34	0.7	2	0.4	3	0.8	3	20	8	0.2	2	0.7	7	3	42	2	0.2
CR	I	4.61	40.5	759	11.9	60	25.1	65	277	102	1.5	60	60.1	86	46	818	81	3.1
	II	4.58	39.4	757	12.7	64	27.1	65	284	104	1.5	60	60.6	89	47	814	81	3.1
	III	3.86	39.9	761	13.0	64	28.1	67	284	102	1.5	62	60.6	85	47	806	81	3.2
	Mean	**4.35**	**39.9**	**759**	**12.5**	**63**	**26.8**	**66**	**282**	**103**	**1.5**	**60**	**60.4**	**87**	**47**	**813**	**81**	**3.1**
	LSD_{05}	0.34	0.7	2	0.4	3	0.7	3	20	8	0.3	2	0.7	7	2	41	2	0.2
SB	I	5.38	39.3	756	13.3	66	28.4	67	295	101	1.4	62	60.8	86	51	866	82	3.3
	II	4.95	39.2	753	13.3	66	28.9	69	300	101	1.4	62	60.9	88	51	862	81	3.2
	III	3.81	38.4	750	13.6	67	29.3	68	308	105	1.4	63	61.2	92	50	831	81	3.0
	Mean	**4.72**	**39.0**	**753**	**13.4**	**66**	**28.9**	**68**	**301**	**102**	**1.4**	**62**	**61.0**	**89**	**51**	**853**	**81**	**3.2**
	LSD_{05}	0.33	0.7	2	0.4	3	0.7	3	19	7	0.2	2	0.7	8	2	44	2	0.2

*For pre-crops GM: green manure; MS: mustard; SF: sunflower; CR: corn; SB: soybean; **For sowing dates I: September 26; II: October 5; III: October 16; ***YLD: yield; **** For quality indicators TKW: 1000 kernel weight; TW: test weight; PC: protein content; SE: sedimentation value; WGC: wet gluten content; GDI: gluten deformation index; W: deformation energy; P: dough tenacity; P/L: alveogram configuration ratio; Ie: dough elasticity index; WA: water absorption of flour; DS: degree of softening dough; VV: valorimetric value; VB: volume of bread, PB: porosity of bread crumb, BE: bread evaluation score; un. GDM: units device of gluten deformation meter; UF: units device of Farinograph Brabender; UV: units device of Valorimeter Brabender; LSD_{05} is the least significant difference at $p<0.05$.

Analysis of variance

The analysis of variance for the experimental data revealed a significant ($p \leq 0.01$) influence of the factors year (growing season), genotype, sowing date, preceding crop and their interaction on all indicators under study (Table 3). It was revealed the predominance of the influence of growing season on winter bread wheat yield (66.2%), 1000 kernel weight (63.2%), and test weight (58.8%). Significant influence of the environment on yield and physical indicators of grain quality was found by Bilgin et al. (2016), Khazratkulova et al. (2015), Van der Laan et al. (2020), and Aucamp et al. (2006). Sasani et al. (2020) found that yield of winter wheat was significantly influenced by sowing dates (68.8%), and the 1000 kernel weight was by genotype (57.1%). However, Bagulho et al. (2015) argued that formation of the 1000 kernel weight was significantly influenced by sowing date, and the test weight was by genotype.

The part of sum square in variation of sedimentation volume, gluten deformation index, deformation energy, dough elasticity index, degree of dough softening, valorimetric value, and porosity of bread crumb for growing season conditions was also significantly higher (31.7-43.1%), as compared to other factors.

There was revealed significant influence of genotype on dough tenacity (36.6%), alveogram configuration ratio (34.8%), bread volume (25.9%) and its evaluation (26.0%) and, especially, on water absorption of flour (52.1%), but a little less on protein content (15.3%). The influence on wet gluten content for year (19.7%) and genotype (19.8%) was at the same level. Bilgin et al. (2016) found less effect on protein content for genotype.

The most influence of the preceding crop was found on yield (12.5%), test weight (9.4%), 1000 kernel weight (4.8%), protein content (5.0%); the most influence of the sowing date was on yield (6.1%). Interaction of factors growing season × genotype maximally affected the volume of bread (19.5%) and water absorption of flour (16.6%). Van der Laan et al. (2020) and Kitil et al. (2020) also found a significant impact for interaction of factors growing season × genotype on both quality indicators and yield of winter wheat. The most part of sum square variation in alveogram configuration ratio (10.5%), valorimetric value (10.2%) and bread evaluation score (10.3%) was revealed for interaction of factors growing season × genotype × preceding crop.

The protein content and wet gluten content was significantly influenced by most factor interactions, except for the genotype × growing season, genotype × preceding crop, and growing season × genotype × preceding crop interactions.

Table 3. The part of sum square (%) variation in yield and quality indicators of winter bread wheat during three growing seasons (2016-17 – 2018-19)

Indicators	Sources of variation															
	Genotype (A)	Growing season (B)	Pre-crop (C)	Sowing date (D)	A × B	A × C	A × D	B × C	B × D	C × D	A × B × C	A × B × D	B × C × D	A × C × D	A × B × C × D	Error
df	16	2	4	2	32	64	32	8	4	8	128	64	16	128	256	2295
YLD	1.7	66.2	12.5	6.1	0.9	0.3	0.4	3.6	0.9	0.6	1.2	0.7	1.3	0.8	1.7	1.1
TKW	7.0	63.2	4.8	0.4	3.1	1.0	0.7	7.4	0.3	0.3	2.8	1.1	1.8	1.9	3.7	0.6
TW	12.6	58.8	9.4	0.3	2.5	1.0	0.5	6.9	0.1	0.2	2.0	0.8	1.2	1.2	2.4	0.1
PC	15.3	3.8	5.0	1.8	11.9	3.6	2.1	14.8	1.4	2.5	6.0	3.1	7.9	5.5	12.2	3.0
SE	22.2	31.7	1.6	0.5	7.0	2.2	1.6	5.9	0.5	0.5	4.9	2.6	2.0	4.3	9.2	3.4
WGC	19.8	19.7	2.6	1.2	9.7	2.7	1.6	10.6	0.9	1.5	5.8	2.4	5.9	5.3	9.4	1.0
GDI	26.6	33.6	0.8	0.01	12.9	2.7	0.8	2.2	0.3	0.5	7.7	1.9	1.1	3.1	4.9	1.1
W	21.3	41.3	0.5	0.1	6.8	3.9	1.1	3.7	0.4	0.2	8.2	1.3	1.0	3.8	5.3	1.3
P	36.6	16.1	0.4	0.01	11.8	4.7	1.0	4.0	0.6	0.2	9.2	1.9	0.4	3.4	7.5	2.5
P/L	34.8	3.9	0.8	0.04	14.0	4.9	0.9	5.0	0.7	0.1	10.5	2.0	0.8	4.1	10.6	7.1
Ie	22.2	37.9	0.5	0.1	6.9	4.1	1.2	1.7	0.2	0.2	7.7	2.0	0.9	4.3	9.1	1.1
WA	52.1	2.9	0.8	0.1	16.6	3.9	0.6	2.2	0.2	0.5	6.3	1.5	0.9	2.8	5.1	3.5
DS	21.1	37.7	0.5	0.04	8.7	3.6	1.0	4.0	0.6	0.3	7.7	1.4	0.9	3.8	7.7	1.0
VV	12.5	43.1	1.5	0.02	7.0	5.0	1.0	5.4	0.4	0.2	10.3	1.4	0.8	3.2	7.3	0.9
VB	35.9	7.8	2.6	0.03	19.5	3.5	0.9	3.6	0.9	0.6	7.4	1.7	1.6	3.5	7.2	3.4
PB	16.9	35.7	0.9	0.03	13.3	3.3	0.7	4.9	0.6	0.2	9.1	1.5	0.4	2.3	4.7	5.6
BE	26.0	17.6	1.4	0.1	11.3	4.5	1.1	9.4	0.9	0.6	10.3	1.7	1.3	2.9	6.4	4.6

Note. df: degrees of freedom; other abbreviations remained the same as in Table 2.

In terms of each year, there was found an increase in the part of sum square variation in yield and quality indicators for the factors such as genotype, preceding crop, sowing date and their interactions (Table 4). At the same time, the part of sum square varied significantly over the years, which also indicates a significant influence of growing season conditions on yield and quality indicators of winter bread wheat. Such features are confirmed by studies of Cesevičienė et al. (2009).

As for genotype high (more than 60%) part of sum square variation was found in 2016-17 for dough tenacity (64.43%); in 2017/18 for water absorption of flour (78.08%), wet gluten content (70.84%), sedimentation volume (65.59%), gluten deformation index (61.93%); in 2018/19 for volume of bread (81.65%), water absorption of flour (73.04%), porosity of crumb bread (65.51%), test weight (65.25%), bread evaluation score (64.52%), gluten deformation index (63.76%), dough degree of softening (63.72%), deformation energy (62.98%), dough tenacity (61.14%). The share of genotype influence in all years of the research for gluten deformation index and water absorption of flour was more than 50%.

Table 4. The part of sum square (%) variation in yield and quality indicators of winter bread wheat depending on growing season conditions

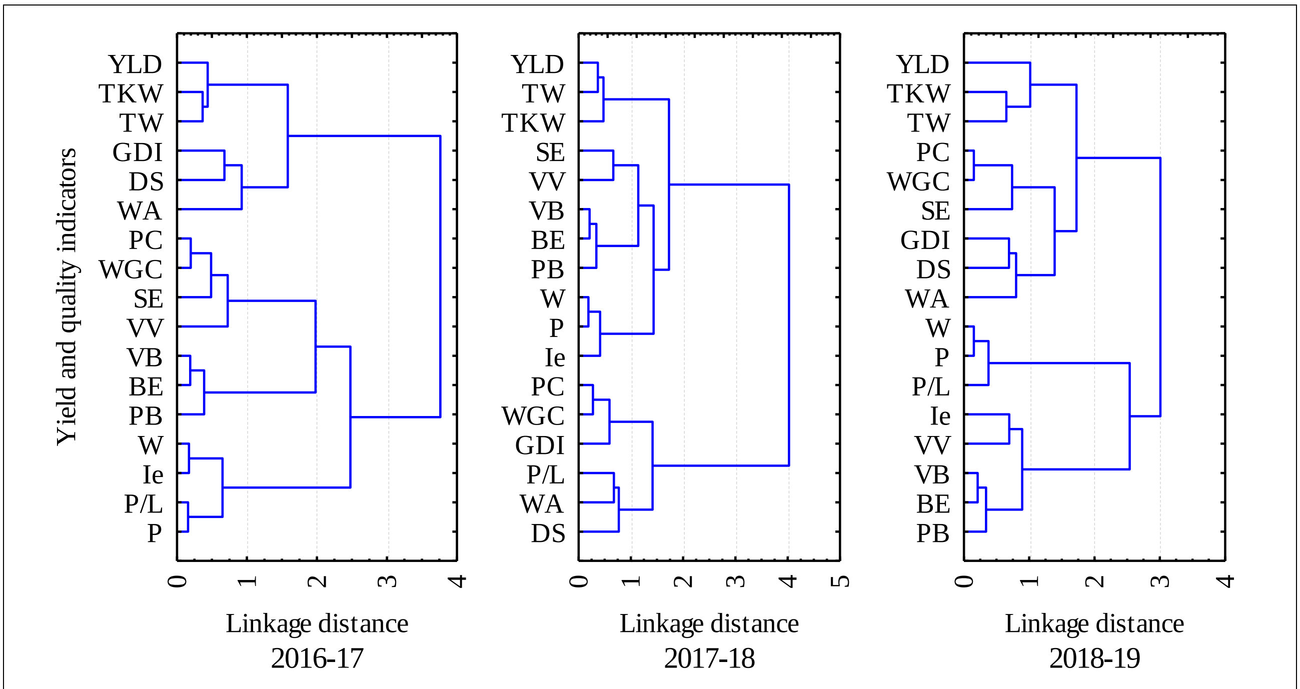
Indicators	Sources of variation							
	Genotype (A)	Pre-crop (C)	Sowing date (D)	A × C	A × D	C × D	A × C × D	Error
df	16	4	2	64	32	8	128	765
2016-2017								
YLD	1.90	75.02	4.86	3.61	2.15	3.63	6.42	2.41
TKW	27.15	39.78	0.81	6.68	4.27	4.60	15.79	0.92
TW	38.78	35.07	0.74	6.30	3.47	2.64	12.83	0.18
PC	12.43	30.24	0.96	11.58	4.13	12.83	24.12	3.70
SE	21.08	17.01	2.48	14.93	6.16	5.52	28.80	4.02
WGC	20.62	22.46	0.86	13.51	5.53	10.62	25.61	0.80
GDI	53.23	7.50	0.86	17.32	4.11	3.06	12.40	1.53
W	48.86	8.67	0.80	21.26	3.77	2.59	12.60	1.45
P	64.43	1.50	0.75	15.29	3.25	0.84	11.61	2.32
P/L	49.26	4.47	0.32	17.91	3.69	1.36	17.03	5.97
Ie	45.67	6.88	0.21	21.84	4.62	1.51	17.94	1.33
WA	55.22	4.47	0.74	16.89	2.75	1.86	13.32	4.75
DS	29.10	4.30	2.55	29.11	4.91	2.78	24.57	2.69
VV	23.78	15.60	0.65	36.26	3.21	1.74	17.76	1.00
VB	46.26	17.66	1.42	10.72	2.97	0.94	16.13	3.90
PB	35.13	16.69	0.58	22.36	4.71	0.39	10.58	9.56
BE	43.10	22.18	1.08	14.75	2.79	1.04	9.90	5.15
2017-2018								
YLD	14.22	38.93	25.77	4.65	3.31	2.39	6.43	4.30
TKW	30.07	31.81	1.82	7.78	4.70	10.69	11.01	2.11
TW	25.03	55.92	1.17	4.95	3.34	4.92	4.47	0.19
PC	50.76	2.49	1.65	9.67	10.00	5.02	14.90	5.51
SE	65.59	3.03	0.34	5.57	6.51	1.84	12.30	4.83
WGC	70.84	2.49	1.46	5.85	6.14	2.79	7.98	2.45
GDI	61.93	2.86	0.16	16.32	5.04	1.98	10.05	1.66
W	38.65	7.50	0.54	22.02	4.87	1.24	22.20	2.99
P	48.18	10.98	1.03	18.32	3.10	0.45	15.06	2.88
P/L	54.84	8.35	1.55	15.23	1.90	0.71	11.19	6.24
Ie	40.08	0.86	0.14	21.40	6.22	1.57	27.78	1.95
WA	78.08	1.14	0.02	8.78	1.75	1.09	6.54	2.61
DS	41.53	11.75	0.65	22.22	3.70	1.53	17.45	1.17
VV	43.24	11.48	0.52	19.51	5.99	2.00	15.37	1.89
VB	49.55	2.97	1.54	19.46	3.67	5.75	13.33	3.73
PB	32.20	13.15	2.12	28.20	3.01	1.51	10.39	9.42
BE	33.01	11.33	2.10	27.85	3.57	4.53	12.40	5.21
2018-2019								
YLD	7.71	29.94	30.67	5.22	3.93	9.98	9.12	3.42
TKW	23.45	12.66	6.14	26.53	6.79	2.01	19.15	3.27
TW	65.25	2.80	0.24	18.86	1.75	1.17	9.36	0.58
PC	28.78	21.89	5.29	9.17	4.58	11.80	16.54	1.94
SE	45.19	12.38	1.54	9.79	5.83	3.27	15.62	6.39
WGC	41.73	15.06	5.42	9.24	3.73	10.13	13.57	1.14
GDI	63.76	2.63	0.20	13.14	3.18	1.87	13.63	1.59
W	62.98	0.56	0.46	14.18	3.40	1.71	13.60	3.11
P	61.14	2.08	0.19	15.61	3.99	0.44	12.23	4.32
P/L	45.58	3.95	0.14	14.55	3.76	0.74	19.75	11.52
Ie	57.48	0.50	0.77	10.88	5.27	2.54	20.30	2.25
WA	73.04	5.23	0.54	7.20	2.29	1.68	5.85	4.17
DS	63.72	3.35	0.77	8.53	3.82	1.75	16.63	1.43
VV	50.96	1.78	1.25	10.39	4.72	1.51	26.07	3.32
VB	81.65	0.12	0.13	6.04	1.71	0.82	6.04	3.48
PB	65.51	0.73	0.22	10.62	2.92	0.99	11.46	7.55
BE	64.52	0.84	0.05	10.33	4.04	1.2	12.12	6.9

All abbreviations remained the same as in Table 2.

The most influence of the preceding crops was found in 2016-2017 on yield (75.02%), 1000 kernel weight (39.78%), test weight (35.07%), protein content (30.24%); in 2017-2018 on test weight (55.92%), yield (38.93%), 1000 kernel weight (31.81%); in 2018-2019 on yield (29.94%), protein content (21.89%), and wet gluten content (15.06%). The sowing date had the most effect on yield of winter bread wheat than on quality indicators. A significant part for the interaction of genotype × preceding crop and genotype × preceding crop × sowing date in formation of all quality indicators was followed which indicates a different response of genotypes on various sowing dates after different preceding crops.

Cluster analysis

According to the results of Ward's clustering yield and quality indicators, five groups of similar indicators were formed for each growing season, i.e. five clusters (Figure 1). In 2016-2017, Cluster 1 combined yield, 1000 kernel weight, test weight; Cluster 2 combined gluten deformation index, degree of softening dough, water absorption of flour; Cluster 3 combined protein content, wet gluten content, sedimentation value, valorimetric value; Cluster 4 combined volume of bread, bread evaluation score, porosity of bread crumb; Cluster 5 combined deformation energy, dough elasticity index, alveogram configuration ratio, dough tenacity. In 2017-2018, Cluster 1 included yield, 1000 kernel weight, test weight; Cluster 2 included sedimentation value, valorimetric value, volume of bread, bread evaluation score, porosity of bread crumb; Cluster 3 included deformation energy, dough elasticity index, dough tenacity; Cluster 4 included protein content, wet gluten content, gluten deformation index; Cluster 5 included alveogram configuration ratio, water absorption of flour, degree of softening dough. In 2018-2019, Cluster 1 combined yield, 1000 kernel weight, test weight; Cluster 2 combined protein content, wet gluten content, sedimentation value; Cluster 3 combined gluten deformation index, degree of softening dough, water absorption of flour; Cluster 4 combined content deformation energy, dough tenacity, alveogram configuration ratio; Cluster 5 combined dough elasticity index, valorimetric value, volume of bread, bread evaluation score, porosity of bread crumb.



Note. The abbreviations remained the same as in Table 2.

Figure 1. Dendrograms of the results of cluster analysis (Ward's method, 1-Pearson r) of yield and quality indicators of winter bread wheat

Of practical breeding value are the indicators that have been consistently included in the same cluster for three different growing seasons: yield, 1000 kernel weight, test weight in the Cluster 1; volume of bread, porosity of bread crumb, baking evaluation score in the Cluster 2; protein content, wet gluten content in the Cluster 3; deformation energy, dough tenacity in the Cluster 4; fifth group water absorption of flour, degree of softening dough in the Cluster 1. These indicators have been consistently linked for each growing season. Other indicators formed different clusters that is the strength of the relationship between these indicators changed across the growing seasons.

CONCLUSIONS

As a result of the research, it was revealed a decisive influence of growing season conditions on yield, 1000 kernel weight, test weight of winter bread wheat grain.

The preceding crop was most affecting yield, test weight, 1000 kernel weight, protein content; sowing date was most affecting yield.

The genotypes realized the maximum average yield, 1000 kernel weight, test weight after the preceding crop green manure. The highest protein content and wet gluten content was achieved after soybean, sunflower, and green manure. The deformation energy, volume of bread, and bread evaluation score were achieved after mustard, sunflower and soybean. It was determined that delaying the sowing date (from September 26 to October 16), the average yield, 1000 kernel weight, test weight decreased, but the sedimentation value, protein content and wet gluten content increased.

These features of the manifestation and variation of grain quality depending on the growing season conditions, preceding crops and sowing dates should be taken into account when growing winter bread wheat for baking. Significant influence of genotype on water absorption of flour, dough tenacity, alveogram configuration ratio, bread volume, bread evaluation score, protein content was revealed.

Accordingly, these indicators are more informative and reliable for the evaluation and selection of promising genotypes in breeding process. The quality indicators belonging to the same cluster under the influence of different natural and anthropogenic factors may be interchangeable in some way when determining the baking qualities of winter bread wheat in order to reduce the number of tests and increase the “capacity” of laboratories.

REFERENCES

Al-Saleh, A., and Brennan, C.S., 2012. *Bread wheat quality: some physical, chemical and rheological characteristics of Syrian and English bread wheat samples*. Foods, 1: 3-17.

Arshad, A., Zia, U., Nawab, A., Muhammad, M.A., 2017. *Evaluation of wheat advanced lines for agronomic traits under vary sowing dates.* Agricultural Research and Technology: Open Access Journal, 7(1): 555705.

Aucamp, U., Labuschagne, M.T., van Deventer, C.S., 2006. *Stability analysis of kernel and milling characteristics in winter and facultative wheat.* South African Journal of Plant and Soil, 23(3): 152-156.

Bagulho, A.S., Costa, R., Almeida, A.S., Pinheiro, N., Moreira, J., Gomes, C., Coco, J., Costa, A., Coutinho, J., Maçãs, B., 2015. *Influence of year and sowing date on bread wheat quality under Mediterranean conditions.* Emirates Journal of Food and Agriculture, 27(2): 186-199.

Betsiashvili, M., Samadashvili, T., Simonishvili, N., Silagava, N., Lohwasser, U., 2020. *Agro-morphological and biochemical characterization of Georgian common wheat (T. aestivum) - „Dolis puri” sub-varieties.* Annals of Agrarian Science, 18(4): 448-458.

Bilgin, O., Guzmán, C., Başer, I., Crossa, J., Korkut, K.Z., Balkan, A., 2016. *Evaluation of grain yield and quality traits of bread wheat genotypes cultivated in Northwest Turkey*. Crop Science, 56(1): 1-12.

Boltenko, Y.A., Myachikova, N.I., Binkovskaya, O.V., Remnev, A.I., Semchenko, I.V., 2019. *Impact of baking properties of wheat flour on change the parameters of kneading and rheological characteristics of the dough*. EurAsian Journal of BioSciences, 13: 1067-1070.

Cappelli, A., Cini, E., Guerrini, L., Masella, P., Angeloni, G., Parenti, A., 2018. *Predictive models* *of the rheological properties and optimal water content in doughs: An application to ancient grain flours with different degrees of refining.* Journal of Cereal Science, 83: 229-235.

Cappelli, A., and Cini, E., 2021. *Challenges and opportunities in wheat flour, pasta, bread, and bakery product production chains: a systematic review of innovations and improvement strategies to increase sustainability, productivity, and product quality.* Sustainability, 13(5): 2608.

Cesevičienė, J., Leistrumaitė, A., Paplauskienė, V., 2009. *Grain yield and quality of winter wheat varieties in organic agriculture.* Agronomy Research, 7(1): 217-223.

Deivasigamani, S., and Swaminathan, C., 2018. *Evaluation of seed test weight on major field crops.* International Journal of Research Studies in Agricultural Sciences, 4(1): 8-11.

Doneva, S., Daskalova, N., Spetsov, P., 2018. *Transfer of novel storage proteins from a synthetic hexaploid line into bread wheat.* Zemdirbyste-Agriculture, 105(2): 113-122.

Gawęda, D., and Haliniarz, M., 2021. *Grain yield and quality of winter wheat depending on previous crop and tillage system.* Agriculture, 11(2): 133.

Jernigan, K.L., Godoy, J.V., Huang, M., Zhou, Y., Morris, C.F., Garland-Campbell, K.A., Zhang, Z., Carter, A.H., 2018. *Genetic dissection of end-use quality traits in adapted soft white winter wheat.* Frontiers in Plant Science, 9: 271.

Karaduman, Y., Akın, A., Yilmaz, E., Dogan, S., Belen, S., 2021. *Evaluation of bread wheat quality in bread wheat breeding programs.* Journal of Engineering Sciences and Researches, 3(1): 141-151.

Khazratkulova, Sh., Sharma, R.C., Amanov, A., Ziyadullaev, Z., Amanov, O., Alikulov, S., Ziyaev, Z., Muzafarova, D., 2015. *Genotype × environment interaction and stability of grain yield and selected quality traits in winter wheat in Central Asia*. Turkish Journal of Agriculture and Forestry, 39: 920-929.

Kitil, M.A., Sarbessa, T.B., Biru, H.M., Tiliye, A., Banje, D.G., 2020. *Yield potential and stability of irrigated spring bread wheat genotypes in Central rift valley of Ethiopia*. BioTechnology: An Indian Journal, 16(1): 200.

Kulig, B., Lepiarczyk, A., Andrzej, O., Kołodziejczyka, M., 2010. *The effect of tillage system and forecrop on the yield and values of LAI and SPAD indices of spring wheat.* Eur.J. of Agron., 33(1): 43-51.

Li, S., Wang, L., Meng, Y., Hao, Y., Xu, H., Hao, M., Lan, S., Zhang, Y., Lv, L., Zhang, K., Peng, P., Lan, C., Li, X., Zhang, Y., 2021. *Dissection of genetic basis underpinning kernel weight-related traits in common wheat.* Plants (Basel), 10(4): 713-727.

Li, T., Deng, G., Tang, Y., Su, Y., Wang, J., Cheng, J., Yang, Z., Qiu, X., Pu, X., Zhang, H., Liang, J., Yu, M., Wei, Y., Long, H., 2021. *Identification and validation of a novel locus controlling spikelet number in bread wheat (Triticum aestivum L.).* Frontiers in Plant Science, 12: 611106.

Madhu, U., Begum, M., Salam, A., Sarkar, S.K., 2018. *Influence of sowing date on the growth and yield performance of wheat (Triticum aestivum L.) varieties.* Archives of Agriculture and Environmental Science, 3(1): 89-94.

Nadew, B.B., 2018. *Effects of climatic and agronomic factors on yield and quality of bread wheat (Triticum aestivum L.) seed: a review on selected factors.* Advances in Crop Science and Technology, 6(2): 356.

Saleem, M., Qureshi, T.M., Yasin Ashraf, M., Mahmood-ul-Hassan, Anwar-ul-Haq, Mahmood K., 2015. *Delayed planting and genotype affect grain protein and yield of wheat.* International Journal of Biology and Biotechnology, 12(1): 85-89.

Sapirstein, H., Wu, Y., Koksel, F., Graf, R.J., 2018. *A study of factors influencing the water absorption capacity of Canadian hard red winter wheat.* Journal of Cereal Science, 81: 52-59.

Sasani, S., Amiri, R., Sharifi, H.R., Lotfi, A., 2020. *Impact of sowing date on bread wheat kernel quantitative and qualitative traits under Middle East climate conditions*. Zemdirbyste-Agriculture, 107(3): 279-286.

Seleiman, M., Ibrahim, M., Abdel-Aal, S., Zahran, G., 2011. *Effect of sowing dates on productivity, technological and rheological characteristics of bread wheat.* Journal of Agronomy and Crop Science, 2(1): 1-6.

Senapati, N., Brown, H.E., Semenov, M.A., 2019. *Raising genetic yield potential in high productive countries: Designing wheat ideotypes under climate change*. Agricultural and Forest Meteorology, 271: 33-45.

Silva, R.R., Benin, G., Almeida, J.L. de, Fonseca, I.C. de B., Zucareli, C., 2014. *Grain yield and baking quality of wheat under different sowing dates*. Acta Scientiarum, Agronomy, 36(2): 201-210.

Siroshtan, A., Kavunets, V., Derhachov, O., Pykalo, S., Ilchenko, L., 2021. *Yield and sowing qualities of winter bread wheat seeds depending on the preceding crops and sowing dates in the Forest-Steppe of Ukraine.* American Journal of Agriculture and Forestry, 9(2): 76-82.

Ulianych, I.F., 2020. *Grits properties of soft winter wheat grain depending on variety*. Journal of Uman National University of Horticulture, 96(1): 572-582.

Van der Laan, L., Goad, C.L., Tilley, M., Rassi, G.D.-E., Blakey, A.M., Rayas-Duarte, P., Hunger, R.M., Silva, A. de O., Carver, B.F., 2020. *Genetic responses in milling, flour quality, and wheat sensitivity traits to grain yield improvement in U.S. hard winter wheat*. Journal of Cereal Science, 93: 1-8.

Zaitsev, A.M., and Kovalenko, I.N., 2020. *The influence of crop predecessor and chemicalization levels on grain quality and spring wheat productivity*. IOP Conference Series: Earth and Environmental Science, 548: 072014.

Zhemela, H.P., and Shakalii, S.M., 2012. *Influence of preceding crops on grain yield and quality of* *winter bread wheat*. Bulletin of Poltava State Agrarian Academy, 3: 20-22.

Zhygunov, D., Mardar, M., Sots, S., Barkovskaya, Y., Zhyhunova, G., 2018. *Research of technological properties of wheat and spelt grain as raw materials for flour and groats manufacturing.* Scientific Works of National University of Food Technologies, 24(5): 208-217.

Živančev, D., Jocković, B., Mirosavljević, M., Momčilović, V., Mladenov, N., Aćin, V., Pribić, M., 2019. *How a slight modification of the bread-making procedure for the evaluation of wheat cultivars affects the most important properties of bread (bread volume and bread crumb).* Journal on Processing and Energy in Agriculture, 23(4): 180-184.