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ORIGINAL ARTICLE

Formation of flour quality indicators in different winter bread wheat (*Triticum aestivum* L.) genotypes depending on abiotic and anthropogenic factors

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One of the main tasks of agricultural science and production is to increase grain production, which meets the requirements of world standards. The quality of bread wheat grain significantly depends on the realization of genetic characteristics of the variety in interaction with soil and climatic conditions and cropping practice. Therefore, conducting research to determine the impact of abiotic and anthropogenic factors on the formation of flour quality indicators of winter bread wheat is necessary and relevant. The purpose of the study is to establish the peculiarities of flour quality indicators formation depending on hydrothermal conditions of different growing seasons and sowing dates after different preceding crops in the central part of the Ukrainian Forest-Steppe. To achieve this goal the following methods were used: field, laboratory, statistical. The growing seasons of the study were contrasting in hydrothermal regime with an uneven distribution of precipitation by months. Significant variability of flour quality indicators of winter bread wheat depending on conditions of the years of the research was noted. Reliably significant influence of genotype on all flour quality indicators was established (15.3-26.6%). Hydrothermal conditions of the growing seasons had the greatest effect on sedimentation volume and gluten deformation index (31.7 and 33.6%, respectively), and the least effect (3.8%) on protein content. The maximum effect of the preceding crops and sowing dates was found on the protein content (5.0; 1.8%, respectively), the minimum on the gluten deformation index (0.8; 0.01%, respectively). There was a significant (7.0-12.9%) influence of the interaction of genotype × growing season factors on all studied characteristics of flour quality of winter bread wheat. By individual genotypes, different ratios of the influence of growing season conditions, sowing dates, preceding crops, and their interactions on the formation of flour quality characters were revealed. The maximum content of protein (13.4%) and wet gluten (28.9%) on average for all growing seasons were after the soybean as preceding crop, the highest sedimentation volume (67 ml) was after green manure, and the lowest these quality indicators (12.5%, 26.8% and 63 ml, respectively) were after corn. There was a general tendency to increase the sedimentation volume, protein and gluten content with shift in sowing dates from September 26 to October 16. The variety MIP Kniazhna with a complex of high flour quality indicators has been identified.

Keywords: Winter bread wheat, Protein content, Gluten content, Sedimentation volume, Gluten deformation index, Hydrothermal regime, Sowing date, Preceding crop, ANOVA.

Introduction

Wheat is one of the main crops for human nutrition, as the main source of protein, carbohydrates, vitamins, minerals and other essential substances (Denčić et al., 2011). Increasing the gross harvest of high-quality grain is a priority for agricultural science and production (Zhemela and Kurochka, 2012; Gomez-Becerra et al., 2010). Currently, a significant percentage of wheat grown is flour milling (Kim et al., 2020). One of the main indicators of flour quality is protein content, wet gluten content and gluten deformation index. These quality indicators determine the nutritional value of bakery, cereal and pasta products, and also play an important role in industrial use (Karaduman et al., 2021; Doneva et al., 2018). Protein is one of the most important components of wheat grain with a range of variation from 7 to 17% and gluten content is almost 80-90% of the total protein (Koppel and Ingver, 2010). It is gluten that participates in the formation of the mechanical basis of the dough and the structure of the bread crumb structure depends on its quality (Cappelli et al., 2018).

The sedimentation volume is an informative character of quality, as it is an indirect method of assessing the technological and baking properties of bread wheat flour (Sasani et al., 2020). The method of determining the sedimentation volume is simple, inexpensive, so it can be used at all stages of breeding process, especially in the early stages, which allows effectively select promising wheat bread genotypes.

The quality of wheat grain is formed due to the realization of genetic characteristics of the variety in interaction with soil and climatic conditions and cropping practice (Nadew, 2018). Realization of the genetic potential of the variety is possible only under favorable environmental conditions and with using appropriate agro-technological measures (Babiker et al., 2017). Therefore, conducting research to determine the impact of abiotic and anthropogenic factors on the formation of flour quality indicators of winter wheat is necessary and relevant. Preceding crops directly affect both yield and quality of winter wheat (Ergashev and Khalikov, 2017). Analysis of crops sown in Ukraine for 2017-2019 indicates that significant areas of winter wheat as the main food grain crop are sown after such crops as sunflower, corn, soybean, and rapeseed (Prokopenko, 2020). Different harvesting times of these preceding crops in farming, variations in water and temperature regimes of the autumn period in different years require the study of different sowing dates for winter crops (Gudzenko, 2019). Using this approach, it is possible to model the contrast conditions of growing due to the action of the same abiotic and biotic factors, but at different stages of plant growth and development. Obtaining high yields and appropriate grain quality indicators is possible only with sowing at the optimal date and after properly selected preceding crops for each variety (Ergashev and Khalikov, 2017; Bagulho et al., 2015). Selection of genotypes with a higher level of stability in terms of quality indicators after different preceding crops and at different sowing dates is very important for production conditions (Saleem et al., 2015; Zhemela and Shakalii, 2012).

The aim of the study was to establish the peculiarities of the formation of flour quality indicators in different winter bread wheat genotypes depending on hydrothermal conditions of different growing seasons, sowing date and after different preceding crops in the central part of the Ukrainian Forest-Steppe.

Methods and Materials

The study was conducted at the V.M. Remeslo Myronivka Institute of Wheat NAAS of Ukraine in 2016/17-2018/19 growing seasons. Seventeen genotypes of winter bread wheat were used as research material: G1 Podolianka (standard), G2 MIP Valensiia, G3 MIP Vyshyvanka, G4 MIP Kniazhna, G5 Trudivnytsia myronivska, G6 Balada myronivska, G7 Vezha myronivska, G8 Hratsiia myronivska, G9 Estafeta myronivska, G10 MIP Assol, G11 MIP Dniprianka, G12 Avrora myronivska, G13 MIP Vidznaka, G14 MIP Darunok, G15 MIP Lada, G16 MIP Fortuna, G17 MIP Yuvileina. They were sown in three sowing dates (I-September 26, II-October 5, III-October 16), after five preceding crops (green manure (GM), mustard (MS), soybean (SB), sunflower (SF), corn (CR)).

Soil is deep, little humus, 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.

Growing techniques is conventional for the Ukrainian Forest-Steppe (Siroshtan and Kavunets, 2016). Sowing was carried out with breeding seed drill SN-10 ts with sowing rate of 5 million viable seeds per 1 ha. Plots were placed according to the complete 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.

Protein content in the flour was determined using near-infrared reflection spectrometer (spectral range 1400-2400 nm) on the SPECTRAN 119M instrument; sedimentation volume was determined according to the micro method in acetic acid; the amount of wet gluten was determined manually by washing the dough resulted from mixing 25 g of flour with 12 ml of 2% saline solution from starch and covers of grain, and gluten deformation index (GDI) was determined by using the device IDK-1M (State Standard 3768:2019, 2019; Remeslo et al., 1971).

Statistical processing of experimental data was performed by methods of descriptive and variation statistics, as well as analysis of variance (ANOVA) using Statistica 8.0, Microsoft Excel 2013.

Results and Discussion

The 2016/17-2018/19 growing seasons of the study were contrasting in hydrothermal regime with uneven distribution of precipitation through months (Fig. 1). The annual mean air temperature exceeded the average long-term temperature (ALT) by 0.8-1.7°C. The most variation in monthly mean temperature over the seasons was observed mainly from November to March. In general, 2016/17 and 2018/19 growing seasons were the dry seasons, and the 2017/18 was the wet season. The amount of precipitation in these seasons was 78%, 91% and 120%, respectively, as compared to the ALT. Of particular note is the lack of precipitation in August in all growing seasons (on average 36 mm less than the ALT), in September 2016/17 and 2017/18 (48 and 37 mm less ALT, respectively), in October 2018/19 (18 mm less than ALT), in March 2016/17 (22 mm less than ALT), in April 2017/18 and 2018/19 (20 and 18 mm less ALT, respectively), as well as in May 2016/17 and 2017/18 (respectively 28 and 18 mm less ALT), in June 2016/17 (59 mm less ALT).

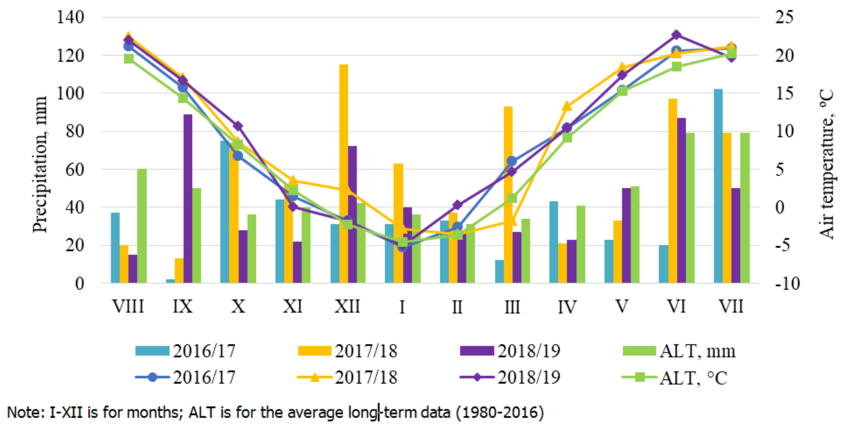

Fig. 1. Average monthly data of the hydrothermal regime during 2016/17-2018/19 growing seasons.

Significant variability of quality characteristics of winter wheat flour depending on hydrothermal conditions of the years of the research was noted (Table 1). Karaduman et al. (2021) and Denčić et al. (2011) obtained similar results. The most variability in protein and wet gluten content was observed in 2018/19, the lowest one was in 2017/18. The sedimentation volume varied significantly in 2016/17, and the gluten deformation index in 2017/18, however, the lowest variation in these indicators was observed in 2018/19.

On average, for the whole panel of genotypes after five preceding crops for three sowing dates, the maximum of protein content (13.4%), wet gluten content (31.1%) and sedimentation volume (73 ml) were observed in 2016/17. During the growing seasons, the quality of winter wheat wet gluten corresponded to the first group.

Table 1. Variation of flour quality characteristics of winter bread wheat genotypes depending on the conditions of growing seasons

Quality characteristics	**2016/17**		**2017/18**		**2018/19**		**2016/17-2018/19**	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Protein content,%	10.1-17.0	13.4	10.4-15.4	12.8	9.5-17.9	13.0	11.1-15.7	13.1
Wet gluten content,%	18.6-42.0	31.1	19.5-35.3	26.4	11.9-39.8	26.4	20.4-38.5	28.2
Sedimentation volume, ml	42-91	73	41-87	66	41-81	58	51-80	66
GDI, GDM units	34-109	74	26-105	53	48-119	77	42-98	68

Note: GDI is for gluten deformation index, GDM is for gluten deformation meter.

According to the results of analysis of variance (Table 2), reliably significant influence of the genotype on all flour quality indicators was established (15.3-26.6%). The conditions of growing season had the greatest effect on sedimentation volume and gluten deformation index (31.7 and 33.6%, respectively), and the least effect (3.8%) on protein content.

Table 2. The part of sum square (%) for flour quality characteristics of winter bread wheat, 2016/17-2018/19.

Sources of variation	**df**	**Protein content**	**Wet gluten content**	**Sedimentation volume**	**GDI**
Genotype (A)	16	15.3	19.8	22.2	26.6
Growing season (B)	2	3.8	19.7	31.7	33.6
Preceding crop (C)	4	5.0	2.6	1.6	0.8
Sowing date (D)	2	1.8	1.2	0.5	0.01
A × B	32	11.9	9.7	7.0	12.9
A × C	64	3.6	2.7	2.2	2.7
A × D	32	2.1	1.6	1.6	0.8
B × C	8	14.8	10.6	5.9	2.2
B × D	4	1.4	0.9	0.5	0.3
C × D	8	2.5	1.5	0.5	0.5
A × B × C	128	6.0	5.8	4.9	7.7
A × B × D	64	3.1	2.4	2.6	1.9
B × C × D	16	7.9	5.8	2.0	1.1
A × C × D	128	5.5	5.3	4.3	3.1
A × B × C × D	256	12.2	9.4	9.2	4.9
Error	2295	3.0	1.0	3.3	1.1

Note: df is for degrees of freedom, GDI is for gluten deformation index.

The maximum effect of preceding crops and sowing dates was found on protein content (5.0; 1.8%, respectively), the minimum effect was on gluten deformation index (0.8; 0.01%, respectively). The significant (7.0-12.9%) influence of genotype × growing season interaction on the flour quality indicators under study was noted. The most influence of growing season × preceding crop interaction on protein and gluten content (14.8; 10.6%, respectively), genotype × growing season × preceding crop × sowing date interaction on protein content (12.2%) was noted. The most part of sum square for effect of year conditions on sedimentation volume was also obtained by Sasani et al. (2020). In the experiments of Denčić et al. (2011) there was obtained a higher percentage of the influence of the interaction of these factors not only on protein content (23.8%), but also on wet gluten content (27.0%). Bagulho et al. (2015) reported an equivalent effect of growing season conditions and genotype on protein and wet gluten content, and the maximum effect of the interaction of these factors and sowing date on protein content (13.2; 9.3%, respectively).
Based on analysis of variance in the context of individual genotypes, different ratios of the influence of growing season conditions, sowing dates and preceding crops for different genotypes were revealed (Tables 3-6).

Table 3. The part of sum square (%) for factors of influence on protein content in winter bread wheat genotypes, 2016/17-2018/19.

Variety code		Growing season (B)	Preceding crop (C)	Sowing date (D)	B × C	B × D	C × D	B × C × D	Error
G1	Podolianka	11.0	7.6	0.7	33.3	1.3	15.5	25.6	4.9
G2	MIP Valensiia	11.9	15.5	15.4	20.3	10.6	4.4	19.1	2.7
G3	MIP Vyshyvanka	11.6	6.0	6.1	30.4	14.8	6.9	17.6	6.5
G4	MIP Kniazhna	24.5	9.9	3.1	11.2	8.0	6.8	32.6	3.9
G5	Trudivnytsia myronivska	2.1	16.1	1.9	27.2	2.2	10.5	33.4	6.7
G6	Balada myronivska	11.3	6.6	3.9	33.0	6.3	11.2	24.4	3.3
G7	Vezha myronivska	41.8	10.4	0.7	19.0	7.0	6.7	11.2	3.1
G8	Hratsiia myronivska	12.3	8.3	2.6	21.1	6.2	12.1	32.8	4.7
G9	Estafeta myronivska	22.7	19.8	3.6	33.2	3.9	6.3	7.8	2.7
G10	MIP Assol	21.9	5.8	1.0	14.8	6.3	12.8	33.4	4.0
G11	MIP Dniprianka	4.2	6.3	3.1	26.2	5.5	16.4	35.0	3.3
G12	Avrora myronivska	19.5	8.3	11.3	19.7	2.1	9.6	26.6	2.9
G13	MIP Vidznaka	19.4	11.8	5.4	30.7	5.6	7.8	17.3	2.1
G14	MIP Darunok	32.1	9.1	1.3	28.7	0.5	7.8	15.7	4.8
G15	MIP Lada	8.2	5.1	0.6	27.3	3.8	9.3	41.0	4.5
G16	MIP Fortuna	23.5	2.4	3.8	26.5	5.7	13.0	22.7	2.4
G17	MIP Yuvileina	22.1	19.3	8.1	15.2	1.4	5.3	25.3	3.3

It was established the least influence of growing season conditions on protein content (Table 3) in the varieties Trudivnytsia myronivska and MIP Dniprianka (2.1; 4.2%, respectively), preceding crops in the variety MIP Fortuna (2.4%), sowing dates in the varieties MIP Lada, Podolianka, Vezha myronivska (0.6; 0.7; 0.7%, respectively). The most influence of growing seasonconditions on protein content was observed in the variety Vezha myronivska (41.8%), preceding crops in the varieties MIP Yuvileina, Estafeta myronivska (19.3; 19.8%, respectively), and sowing dates in the variety MIP Valensiia (15.4%). The largest range of the part of sum square variation in protein content was revealed for preceding crops (of 2.1% in the variety Trudivnytsia myronivska to 41.8% in the variety Vezha myronivska) and for sowing dates (of 0.6% in the variety MIP Lada to 15.4% in the variety MIP Valensiia).
The least influence on wet gluten content (Table 4) was revealed for growing season conditions in the varieties MIP Kniazhna and Avrora myronivska (2.3; 4.6%, respectively), for preceding crops in the varieties Hratsiia myronivska, MIP Fortuna, MIP Assol (1.4; 2, 2; 2.6%, respectively), for sowing dates in the varieties MIP Lada, MIP Assol, Podolianka, Hratsiia myronivska (0.1; 0.2; 0.3; 0.5%, respectively). The most influence on this indicator was noted for growing season conditions in the variety Vezha myronivska (66.7%), for preceding crops in the varieties MIP Darunok, Podolianka (14.5; 15.0% respectively), for sowing dates in the variety MIP Valensiia (14.5%).
The somewhat less influence on gluten deformation index (Table 5) was revealed for hydrothermal conditions of the growing season in the variety Balada myronivska (6.2%), for preceding crops in the varieties Estafeta myronivska, MIP Valensiia, MIP Darunok, MIP Yuvileina (0.6; 1.5; 1.5; 1.9%, respectively), for sowing dates in the varieties Balada myronivska, MIP Valensiia, Estafeta myronivska, MIP Assol, MIP Dniprianka, Avrora myronivska, MIP Yuvileina, MIP Lada (0.04; 0.1; 0.1; 0.2; 0.4; 0.5; 0.5; 0.6%, respectively). The maximum influence on this indicator was found for growing season in the varieties MIP Assol, MIP Yuvileina, Avrora myronivska, Vezha myronivska and Estafeta myronivska (76.5; 77.7; 78.8; 79.0; 85.0%, respectively), for preceding crops in the varieties MIP Vidznaka, MIP Vyshyvanka (14.7; 17.0% respectively), for sowing dates in the varieties MIP Kniazhna (6.1%). The largest range of the part of sum square variation in gluten deformation index was revealed for growing season conditions (from 6.2% in the variety Balada myronivska to 85.0% in the variety Estafeta myronivska).

Table 4. The part of sum square (%) for factors of influence on wet gluten content in winter bread wheat genotypes, 2016/17-2018/19.

Variety code		Growing season (B)	Preceding crop (C)	Sowing date (D)	B × C	B × D	C × D	B × C × D	Error
G1	Podolianka	16.6	15.0	0.3	39.6	1.6	10.6	14.6	1.7
G2	MIP Valensiia	25.3	10.7	14.5	28.4	5.0	3.0	12.0	1.0
G3	MIP Vyshyvanka	25.0	9.2	1.4	10.1	10.0	15.5	27.0	1.7
G4	MIP Kniazhna	2.3	9.1	4.1	26.1	7.9	17.4	31.5	1.6
G5	Trudivnytsia myronivska	32.7	9.6	2.2	15.7	9.8	5.2	23.6	1.3
G6	Balada myronivska	38.4	8.4	1.5	20.8	1.9	6.5	20.6	1.9
G7	Vezha myronivska	66.7	5.4	0.8	12.1	2.1	3.7	8.4	0.8
G8	Hratsiia myronivska	17.0	1.4	0.5	18.3	4.5	16.9	40.1	1.5
G9	Estafeta myronivska	58.6	7.2	2.9	19.7	0.4	3.1	7.4	0.7
G10	MIP Assol	51.3	2.6	0.2	10.5	2.5	9.8	22.0	1.1
G11	MIP Dniprianka	17.3	5.3	3.7	21.0	13.7	12.5	25.2	1.3
G12	Avrora myronivska	4.6	7.5	9.5	29.2	4.3	13.6	29.9	1.4
G13	MIP Vidznaka	24.8	6.8	6.6	22.3	4.1	13.3	20.6	1.4
G14	MIP Darunok	12.6	14.5	4.0	38.8	0.8	10.7	16.1	2.5
G15	MIP Lada	43.6	3.6	0.1	17.9	4.9	6.9	21.8	1.2
G16	MIP Fortuna	46.7	2.2	1.4	24.9	1.3	7.6	15.1	0.8
G17	MIP Yuvileina	59.8	5.2	4.2	12.7	1.2	2.9	13.1	0.9

Table 5. The part of sum square (%) for factors of influence on gluten deformation index in winter bread wheat genotypes, 2016/17-2018/19.

Variety code		Growing season (B)	Preceding crop (C)	Sowing date (D)	B × C	B × D	C × D	B × C × D	Error
G1	Podolianka	42.7	10.2	0.8	23.4	1.7	9.9	9.1	2.1
G2	MIP Valensiia	71.8	1.5	0.1	11.9	5.6	4.2	3.5	1.5
G3	MIP Vyshyvanka	23.6	17.0	3.4	27.4	3.2	6.6	14.9	4.0
G4	MIP Kniazhna	17.5	8.7	6.1	50.1	1.5	4.6	9.8	1.8
G5	Trudivnytsia myronivska	50.8	2.8	0.8	24.4	7.4	3.8	8.7	1.3
G6	Balada myronivska	6.2	6.7	0.0	45.7	6.1	17.4	15.2	2.7
G7	Vezha myronivska	79.0	5.9	1.0	4.9	0.3	3.1	5.0	0.8
G8	Hratsiia myronivska	57.9	8.7	3.7	7.7	7.4	3.3	8.8	2.7
G9	Estafeta myronivska	85.0	0.6	0.1	4.6	0.8	1.6	6.2	1.0
G10	MIP Assol	76.5	3.1	0.2	4.9	0.8	6.8	6.9	0.8
G11	MIP Dniprianka	62.0	4.1	0.4	5.3	4.2	8.4	14.2	1.4
G12	Avrora myronivska	78.8	4.6	0.5	4.2	4.2	2.4	3.9	1.3
G13	MIP Vidznaka	63.5	14.7	1.8	5.4	3.6	3.1	6.7	1.2
G14	MIP Darunok	73.0	1.5	1.6	11.1	0.6	2.3	8.7	1.1
G15	MIP Lada	42.9	2.3	0.6	27.1	6.1	6.1	13.5	1.4
G16	MIP Fortuna	35.9	4.5	2.5	19.2	6.1	8.6	20.0	3.2
G17	MIP Yuvileina	77.7	1.9	0.5	8.7	1.0	3.3	5.7	1.2

The lowest influence on sedimentation volume (Table 6) was determined for year conditions in the variety MIP Dniprianka (18.8%), for preceding crops in the varieties MIP Valensiia, MIP Fortuna (1.6; 1.8%, respectively), for sowing dates in the varieties Vezha myronivska, Hratsiia myronivska, MIP Vyshyvanka, Avrora myronivska, Estafeta myronivska (0.1; 0.1; 0.5; 0.6; 0.9%, respectively). The most influence on this indicator was noted for growing season conditions in the variety Vezha myronivska (72.9%), for preceding crops in the varieties MIP Darunok, MIP Vyshyvanka (12.3; 13.1% respectively), for sowing dates in the varieties MIP Yuvileina and MIP Valensiia (8, 3; 10.6% respectively).

The variety Vezha myronivska was singled out with the most response to variation in growing season conditions by all the indicators of flour quality and the MIP Fortuna variety was with the lowest effect of preceding crops.

Table 6. The part of sum square (%) for factors of influence on sedimentation volume in winter bread wheat genotypes, 2016/17-2018/19.

Variety code		Growing season (B)	Preceding crop (C)	Sowing date (D)	B × C	B × D	C × D	B × C × D	Error
G1	Podolianka	57.0	5.1	1.6	12.5	3.6	4.6	11.5	4.2
G2	MIP Valensiia	57.9	1.6	10.6	13.6	2.2	1.5	8.4	4.3
G3	MIP Vyshyvanka	38.5	13.1	0.5	27.0	0.8	7.9	6.4	5.8
G4	MIP Kniazhna	36.6	6.5	3.7	15.1	8.7	9.2	13.8	6.4
G5	Trudivnytsia myronivska	38.1	5.0	1.7	13.4	1.4	7.1	26.7	6.6
G6	Balada myronivska	29.3	4.6	5.3	20.0	13.1	10.5	12.4	4.6
G7	Vezha myronivska	72.9	3.5	0.1	8.7	1.3	4.9	6.0	2.5
G8	Hratsiia myronivska	57.8	2.7	0.1	20.8	1.2	3.1	11.7	2.6
G9	Estafeta myronivska	52.9	6.5	0.9	8.6	1.3	7.2	18.3	4.5
G10	MIP Assol	42.4	3.7	6.1	11.6	10.2	4.5	16.3	5.4
G11	MIP Dniprianka	18.8	9.8	2.5	19.5	5.9	12.5	25.2	5.8
G12	Avrora myronivska	54.1	5.5	0.6	12.2	6.6	4.5	12.3	4.3
G13	MIP Vidznaka	31.2	4.7	4.9	15.8	7.5	9.0	19.8	7.1
G14	MIP Darunok	52.9	12.3	1.4	12.1	1.2	3.8	9.4	6.8
G15	MIP Lada	47.8	2.8	1.1	11.2	4.5	6.5	23.7	2.3
G16	MIP Fortuna	57.2	1.8	1.2	10.7	1.7	12.1	11.8	3.4
G17	MIP Yuvileina	50.9	4.6	8.3	8.9	1.8	2.6	18.8	4.1

The maximum of protein content (13.4%) and wet gluten content (28.9%) on average for all genotypes in 2016-17-2018-19 was obtained after the soybean as preceding crop, the highest sedimentation volume (67 ml) was after green manure, and the lowest these quality indicators (12.5; 26.8% and 63 ml, respectively) was after corn (Table 7). The similar results were observed by other researchers (Ergashev and Khalikov, 2017; Zhemela and Shakalii, 2012).

In studies by Saleem et al. (2015) and Çiekiç et al. (2008) higher levels of flour quality indicators were obtained for later sowing dates. In our studies, we found a general trend of increasing sedimentation volume, protein and wet gluten content with shift sowing date from September 26 to October 16 (Table 7). There was a significant decrease in the gluten deformation index by 5 GDM units with shift sowing date from September 26 to October 16 after the preceding crop mustard. The preceding crop green manure increased the GDI.

Table 7. Characters of flour quality for winter bread wheat depending on sowing dates and preceding crops, 2016/17-2018/19.

Preceding crop	Sowing date I	II	III	Mean	LSD_{05}	Sowing date I	II	III	Mean	LSD_{05}
	Protein content,%					**Wet gluten content,%**				
GM	13.3	13.3	13.1	13.2	0.4	28.6	28.6	28.4	28.5	0.7
MS	13.0	12.7	13.2	12.9	0.4	28.6	28.0	28.6	28.4	0.7
SF	12.9	13.0	13.7	13.2	0.3	27.6	28.1	30.1	28.6	0.8
CR	11.9	12.7	13.0	12.5	0.3	25.1	27.1	28.1	26.8	0.7
SB	13.3	13.3	13.6	13.4	0.4	28.4	28.9	29.3	28.9	0.7
Mean	12.9	13.0	13.3		0.4	27.7	28.2	28.9		0.7
LSD_{05}	0.4	0.4	0.3	0.4		0.7	0.8	0.7	0.7	
	Sedimentation volume, ml					**GDI, GDM units**				
GM	67	66	67	67	3	69	71	71	71	4
MS	66	66	67	66	4	71	69	66	69	3
SF	65	65	68	66	4	68	64	68	67	3
CR	60	64	64	63	3	65	65	67	66	3
SB	66	66	67	66	3	67	69	68	68	4
Mean	65	66	67		3	68	68	68		3
LSD_{05}	3	4	3	3		3	4	3	3	

Note: GM is for green manure, MS is for mustard, SF is for sunflower, CR is for corn, SB is for soybean, GDI is for gluten deformation index, GDM is for gluten deformation meter, LSD_{05} is for the least significant difference at $p<0.05$.

On average, for all variants of the experiment during three growing seasons there were identified the varieties MIP Valensiia, MIP Kniazhna, Hratsiia myronivska, Estafeta myronivska, MIP Dniprianka, Avrora myronivska, MIP Darunok, MIP Lada MIP Fortuna, MIP Yuvileina that significantly exceeded the standard Podolianka in protein content; MIP Valensiia, MIP Kniazhna, Hratsiia myronivska, Estafeta myronivska, Avrora myronivska in wet gluten content; MIP Kniazhna in sedimentation volume (Fig. 2).

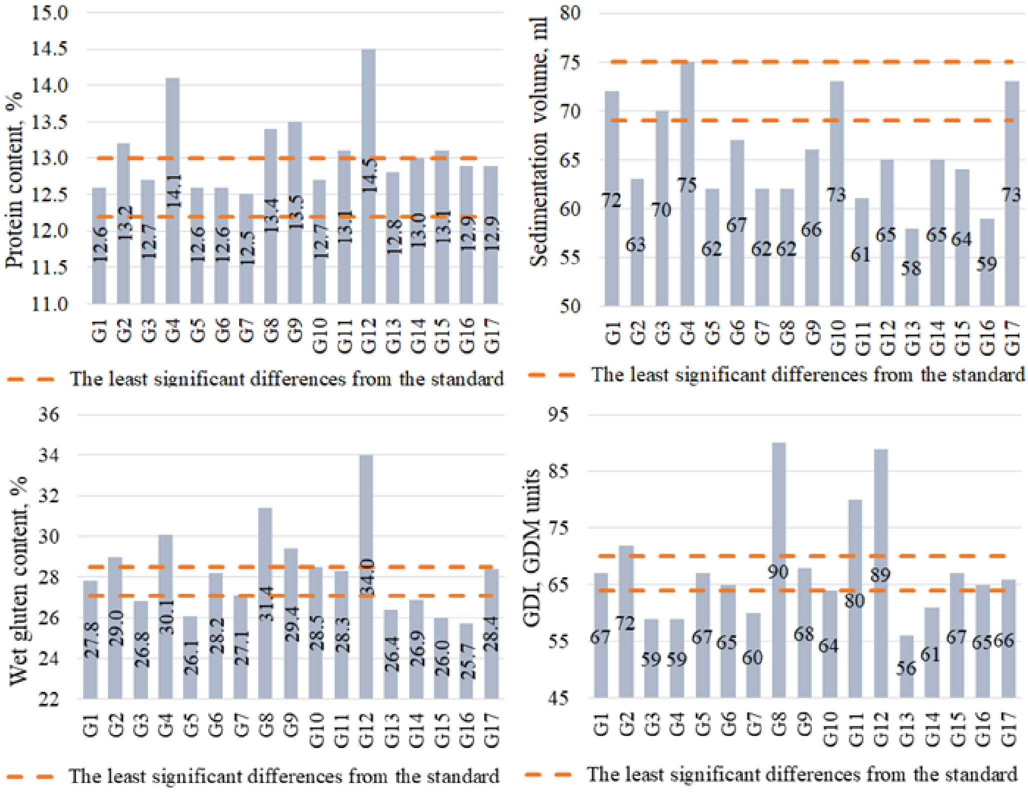

Fig. 2. Characteristics of flour quality in winter bread wheat genotypes on average for sowing dates and preceding crops, 2016/17-2018/19.

Note: GDI is for gluten deformation index, GDM is for gluten deformation meter, G1 Podolianka, G2 MIP Valensiia, G3 MIP Vyshyvanka, G4 MIP Kniazhna, G5 Trudivnytsia myronivska, G6 Balada myronivska, G7 Vezha myronivska, G8 Hratsiia myronivska, G9 Estafeta myronivska, G10 MIP Assol, G11 MIP Dniprianka, G12 Avrora myronivska, G13 MIP Vidznaka, G14 MIP Darunok, G15 MIP Lada, G16 MIP Fortuna, G17 MIP Yuvileina.

According to the gluten deformation index, most varieties had the gluten of the I group quality, only Hratsiia myronivska, MIP Dniprianka and Avrora myronivska formed gluten with the II group quality.

There was identified the variety MIP Kniazhna with a complex of high flour quality indicators, which significantly exceeded the Podolianka standard in all quality indicators on average of growing seasons, sowing dates and preceding crops.

Conclusion

As a result of the conducted researches the highest influence of the growing season conditions on the formation of sedimentation volume (31.7%) and gluten deformation index (33.6%) was established. Preceding crops and sowing dates more effected on protein content (5.0; 1.8%, respectively) than on other indicators. Reliably significant influence of genotype on all flour quality characters was revealed (15.3-26.6%). However, for certain genotypes a different ratio of the influence of growing season conditions, sowing dates and preceding crops on the formation of flour quality indicators has been established. The maximum content of protein (13.4%) and wet gluten (28.9%) on average for all growing seasons were after the soybean as preceding crop, the highest sedimentation volume (67 ml) was after green manure, and the lowest these quality indicators (12.5%, 26.8% and 63 ml, respectively) were after corn. There was a general tendency to increase the sedimentation volume, protein and wet gluten content with shift in sowing date from September 26 to October 16. The variety MIP Kniazhna with a complex of reliably high flour quality indicators has been identified.

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