

## Formation of the quality potential of winter common wheat varieties under the influence of the applied herbicides

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### Abstract

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The results of the present study present the formation of the quality potential of three varieties of common wheat (*Tr. aestivum* L.), belonging to different quality groups – Rada, Kosara and Pchelina, under the influence of the specific conditions of the Dobrudzha Agricultural Institute – General Toshevo, and the application of herbicides from the group of sulfonylureas – Ergon WG (5 g/da), Starane Gold (180 ml/da), Biatlon 4d + Desh (5 g/da + 50 ml/da), Corello Duo + Dasoil (26.5 g/da + 50 ml/da). The research was conducted in the period 2019–2021. The changes in the sedimentation volume, yield of wet gluten and dry gluten in 70% flour, the physical properties of the dough and the baking qualities of the analyzed varieties were monitored. It was found that the genotype factor has the strongest influence on all quality indicators. Most significantly, the weather conditions of the harvest year affect the sedimentation volume, the dough formation time, the quality number from the farinograph, the volume of the bread and its shape stability. The herbicides applied in the experiment have a statistically significant effect on the indicators of sedimentation, wet gluten, degree of softening and dough development time. The preparations Starane Gold and Biathlon 4D + Desh increase the average values of sedimentation in all three varieties, regardless of the weather conditions of the year, and Ergon WG and Corello Duo + Dasoil reflect on this quality indicator depending on the genotype. All three varieties have a high content of wet gluten yield (WG) when treated with Ergon WG herbicide. The time for dough formation is shorter in Rada and Pchelina varieties under the influence of Corello Duo + Dasoil. A similar tendency to increase the degree of softening under the influence of all applied herbicides was found for Kosara and Pchelina, while for the Rada variety the effect of the preparations was different – Ergon WG and Corello Duo + Dasoil decreased, and Starane Gold and Biathlon 4D + Desh increased the average values of the analyzed indicator. Genotype × herbicide and genotype × year interactions had a weaker but statistically significant effect on most of the technological parameters, while herbicide × year and genotype × herbicide × year interactions did not significantly affect the quality characteristics of all three cultivars.

**Keywords:** wheat; genotype; crop year; herbicides; bread-making qualities

### Introduction

The yield and quality of wheat grain can be improved not only through selection methods, but also through the application of agrotechnical practices, which are a prerequisite for a faster effect and better adaptability to different climatic conditions (Stoeva et al., 1992; Stoeva and Ivanova, 2009). Weeds are considered to be a major problem in wheat crops and cause

significant yield losses. They compete with plants for nutrients, moisture, space, light and many other growth factors and can host pests, increasing not only harvest losses, but also negatively affecting the quality of the produce and its market value (Chopra et al., 2008; Yanev, 2022). In this regard, one of the most effective agrotechnical methods for weed control in modern agriculture is the application of appropriate herbicides at optimal times and rates, which is one of the essen-

tial stages in the production of winter wheat (Mitkov et al., 2009; Marzouk, 2013; Petrova and Sabev, 2014; Penchev and Petrova, 2015; Petrova, 2017). On the other hand, agrochemical treatments, including the use of herbicides, are among the most critical technological points in the production of bread wheat (Szentpéter et al., 2001) from the point of view of the requirements of the sustainable agriculture strategy and the production of safe and healthy food for the people. Therefore, studies on the effect of herbicides on the quality indicators of wheat, which is specific to the variety and agrometeorological conditions of the harvest year, are essential (Tanács et al., 2000; Tanács et al., 2005; Mangova et al., 2013; Nankova et al., 2016; Petrova and Nankova, 2018).

The purpose of the present study is to determine the influence of herbicides from the sulfonylurea group under the specific conditions of the Dobrudzha Agricultural Institute – General Toshevo, on the quality potential of winter common wheat varieties belonging to different quality groups.

## Materials and Methods

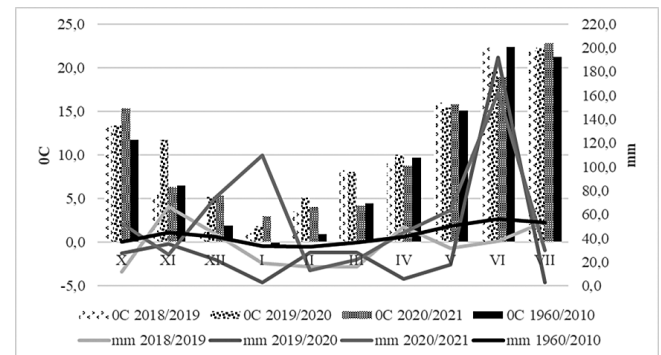
The studies were conducted in the period 2019–2021 at Dobrudzha Agricultural Institute (DAI) – General Toshevo. The studied materials are the winter common wheat varieties Rada, Kosara and Pchelina. The varieties Rada and Kosara belong to the group of medium-strength wheats with increased quality (quality group B), and the variety Pchelina belongs to the group of strong wheats in quality (quality group A). All three varieties have disease resistance (powdery mildew, brown yellow and black rust, septoria). They are characterized by good drought tolerance and very high (Pchelina) to very good (Rada and Kosara) cold and winter resistance. The field experiment was sown in a block method in three replications with an experimental area size of 10.5 m<sup>2</sup>. Two controls are included: C<sub>1</sub> – clean of weeds, maintained as such until the heading of wheat and C<sub>2</sub> – weeded, until the end of the vegetation of the crop. Before planting the wheat, an artificial background of weeding was created with the most widespread weeds in the DAI region – General Toshevo: the annual broad-leaved weeds, ivy-leaved Easter – *Veronica hederifolia* L., wild mustard – *Sinapis arvensis* L., three-horned stickleback – *Galium tricornes* Stok,

chamomile – *Matricaria chamomila* L., field wort – *Anthemis arvensis* L., oriental raioca – *Consolida orientalis* J. Gay; and the perennial broadleaf weeds *Cirsium arvense* L. scop and *Convolvulus arvensis* L. Prior to herbicide application, weed density by species was quantified per unit area.

The sowing dates were 15 October 2019, 21 October 2020, and 1 November 2021; the sowing rate was 550 seeds/m<sup>2</sup>. Herbicides (Table 1) were applied on 22 April 2019, 10 April 2020 and 13 April 2021 in the stage “end of tillering” (phase 29) according to Zadoks et al. (1974). The harvesting dates were 7 July 2019, 3 July 2020 and 16 July 2021.

The grain samples of the three varieties were ground to 70% flour with an MLU-202 mill. The technological indicators were analyzed: sedimentation volume (Pumpyanskiy, 1971), yield of wet gluten and dry gluten in 70% flour (Bulgarian State Standart 13375-88). The physical properties of the dough were determined with a “Brabender” farinograph, and the bread-making qualities were established by a routine bread-making method in the laboratory of technological qualities of DAI – G. Toshevo (Stoeva, 2000; Stoeva and Penchev, 2004; Stoeva, 2012).

In the 2018/2019 harvest year, the meteorological parameters – temperature and precipitation, do not present significant differences compared to the long-term period (1960–2010) (Fig. 1). The meteorological situation is characterized by optimal temperature and precipitation. In the 2019–2020



**Fig. 1 Meteorological parameters (temperature and precipitation) from DAI meteorological station during the wheat growth period (2019–2021)**

Source: Authors' own elaboration

**Table 1. Herbicides and their active agents and treatment doses in 2019–2021**

№	Commercial name	Active agent	Doses
1	Ergon WG	metsulfuron-methyl + thifensulfuron-methyl	50 g/ha
2	Starane Gold	florasulam + fluroxypyr	1.8 l/ha
3	Biatlon 4D + Desh	tritosulfuron + florasulam	50 g/ha + 0.5 l/ha
4	Corello Duo + Dasoil	piroxulam + florasulam + cloquintocet-mexyl	260.5 g/ha + 0.5 l/ha

Source: Authors' own elaboration

crop year, based on the precipitation parameter, extreme values were recorded in the month of June – 192.2 mm, immediately before the wheat harvest, which had a negative effect on the values of the technological parameters – sedimentation and wet gluten yield. Based on the temperature indicator, no significant differences are observed with the long-term period (1960–2010). In 2020/2021, based on temperature, no significant differences are observed with those of the long-term period (1960–2010). Significant differences were found in the precipitation in January 2021 – 109.7 mm and June 2021 – 162.7 mm, which is a prerequisite for the very good development of the crops of the tested varieties and the good technological indicators of the grain.

## Results and Discussion

The genotype of the variety is one of the main factors determining the quality indicators of wheat. They are also sensitively affected by the growing conditions of the culture, which includes the use of plant protection preparations, fertilizing, as well as the abiotic conditions of the environment during the growing season.

The results of the variance analysis show the presence of a significant effect of the genotype on all the investigated quality parameters (Table 2). The effect of the herbicides used in the experiment is also statistically significant. Their influence is strongest on sedimentation (SED), wet gluten (WG), degree of softening (DS) and dough development time (DDT), while the volume of the bread is not affected by the applied herbicides. Harvest year is another factor with a statistically significant effect on the analyzed quality parameters, except for dry gluten content and dough stability. Most significantly, the weather conditions of the harvest year affect

the sedimentation, the time of dough formation, the quality number from the farinograph, the volume of the bread and its dimensional stability (the ratio between the height and the length of the bread). A similar, weaker, but statistically significant effect on quality indicators was found when the interaction of genotype x herbicide and genotype x year was analyzed. The herbicide x year and genotype x herbicide x year interactions did not significantly affect the quality characteristics of the varieties Rada, Kosara and Pchelina.

Figures 2–11 confirm that all investigated quality indicators significantly depend on the genotype, and its influence is less pronounced on the dry gluten content (Fig. 4) and the coefficient of shape stability of the bread (Fig. 10). Next in importance is the effect of the harvest year, which has a strong impact on the quality parameters: dry gluten (DG) (Fig. 4), dough development time (DDT) (Fig. 5) and quality number from the farinograph (QN) (Fig. 8). Substantial differentiation between quality indicators can also be made based on the influence of herbicides. In this regard, the impact of herbicides on sedimentation (SED) (Fig. 2), wet gluten yield (WG) (Fig. 3), dough development time (DDT) (Fig. 5) and degree of softening (DS) (Fig. 7) is the strongest and relatively similar. Dough stability (DSt) (Fig. 6), farinograph quality number (QN) (Fig. 8) and bread medium quality (QM) (Fig. 11) were less affected by herbicides. Herbicides had almost no effect on dimensional stability of bread (H:D but it is strongly dependent on the genotype x herbicide interaction (Fig. 10). All other interactions – genotype x year, herbicide x year, genotype x herbicide x year have no significant influence on quality characteristics. The presented results show that treatment with herbicides significantly affects the bread-making qualities of common wheat varieties Rada, Kosara and Pchelina, included in the present study.

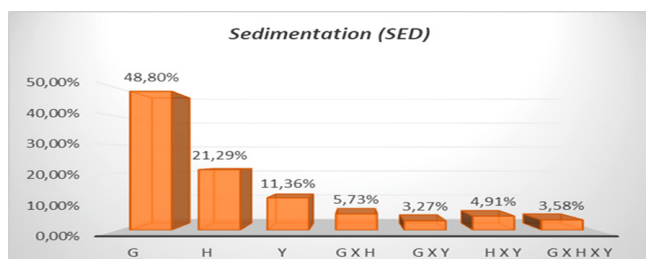
**Table 2. ANOVA of quality characteristics of winter common wheat varieties (2019–2021)**

Source of variation		Genotype (G)	Herbicide (H)	Year (Y)	G × H	G × Y	H × Y	G × H × Y	Error
	df	2	5	2	10	4	10	20	18
Sedimentation (SED, cm <sup>3</sup> )		95.5***	10.4***	22.2**	55.6*	16.8*	40.8*	70.1*	23.5
Wet gluten (WG, %)		2.8***	3.2***	0.58*	1.7*	0.76*	1.6*	0.2ns	1.07
Dry gluten (DG, %)		2.4***	0.1*	0.34ns	1.6*	0.08*	0.16*	0.16ns	0.11
Dough development time (DDT, min)		56.2**	103.2**	43.6**	16.1ns	31.7*	46ns	67.2ns	23.7
Dough stability (DSt, min)		0.32***	0.66*	0.18ns	0.84*	0.44*	0.45ns	0.72ns	0.565
Degree of softening (DS, FU)		65***	106.4***	25.8*	55.1*	33.4*	39.9ns	49.4ns	33.5
Farinograph quality number (QN)		863.1***	406.2*	566.1***	649*	343.4*	1067*	1160.2*	417.5
Bread loaf (BL, cm <sup>3</sup> )		61587.5***	2564.6ns	16876.2***	18979.2*	19256**	16768*	15145.2ns	9737.5
Shape stability coefficient (H : D) <sup>1</sup>		0.01***	0.005*	0.006**	0.131**	0.0016*	0.0036*	0.0055*	0.002
Quality of bread medium (QM)		0.162***	0.084*	0.024*	0.074*	0.04*	0.07*	0.1*	0.04

\*, \*\*, \*\*\* significant at P = 0.05; P = 0.01; P = 0.001 / ns – non significant

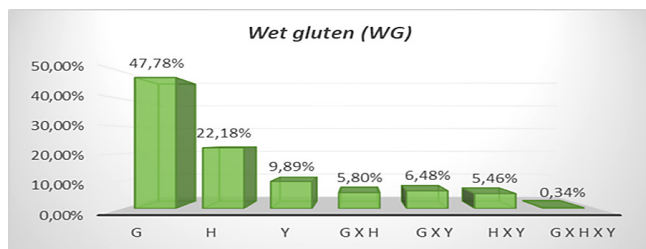
<sup>1</sup> H: D – height to length ratio of bread

Source: Authors' own elaboration



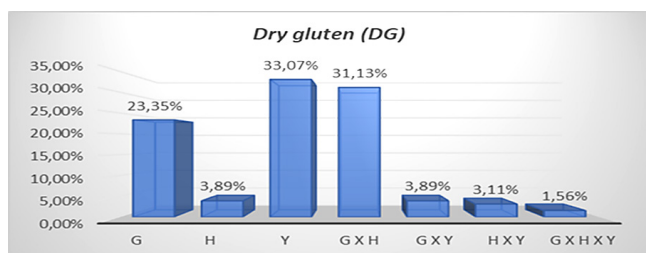
**Fig. 2 Influence of agro technical factors on the sedimentation indicator**

Source: Authors' own elaboration



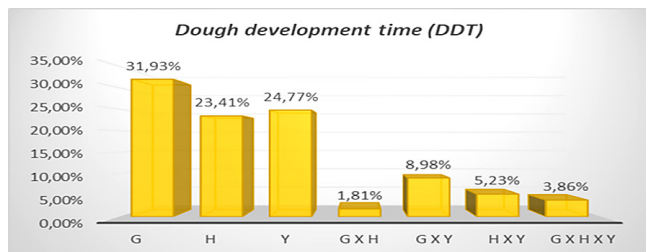
**Fig. 3 Influence of agro technical factors on indicator wet gluten yield**

Source: Authors' own elaboration



**Fig. 4 Influence of agro technical factors on dry gluten index**

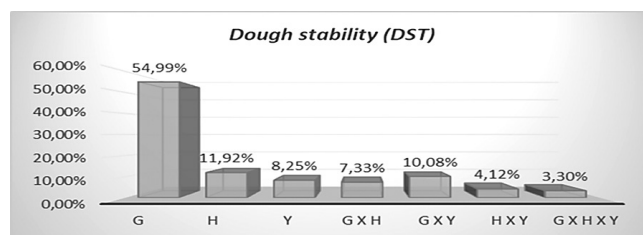
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**Fig. 5 Influence of agro technical factors on the dough development time indicator**

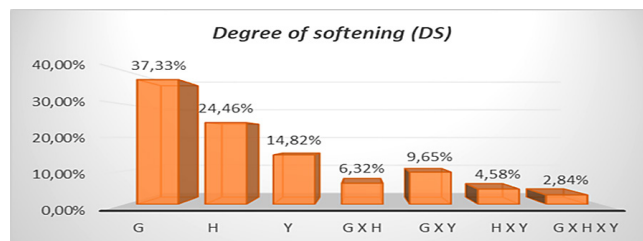
Source: Authors' own elaboration

During the study period, the herbicides Starane Gold and Biathlon 4D + Desh increased the mean values of sedimentation in all three cultivars compared to the non-weeded con-



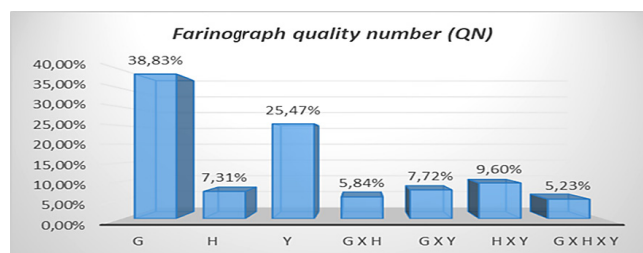
**Fig. 6 Influence of agro technical factors on dough stability indicator**

Source: Authors' own elaboration



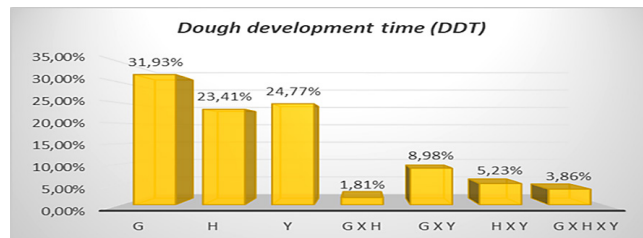
**Fig. 7 Influence of agro technical factors on the softening degree indicator**

Source: Authors' own elaboration



**Fig. 8 Influence of agro technical factors on farinograph quality number**

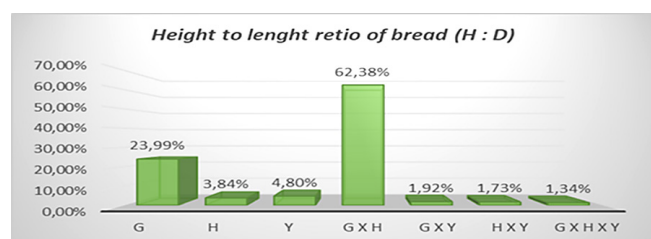
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**Fig. 9 Influence of agro technical factors on volume of bread**

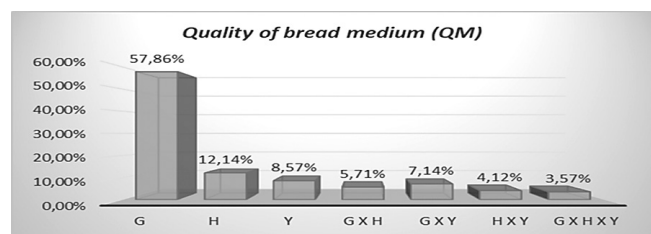
Source: Authors' own elaboration

trol, regardless of the weather conditions of the year. Herbicides Ergon WG and Corello Duo + Dasoil act differently on the sedimentation indicator, depending on the genotype



**Fig. 10 Influence of agro technical factors on the shape stability coefficient**

Source: Authors' own elaboration



**Fig. 11 Influence of agro technical factors on the quality of bread medium**

Source: Authors' own elaboration

**Table 3. Effect of herbicides on average sedimentation values (cm<sup>3</sup>) during the 2019–2021 crop years**

Herbicide	Variety		
	Rada (SED, cm <sup>3</sup> )	Kosara (SED, cm <sup>3</sup> )	Pchelina (SED, cm <sup>3</sup> )
Ergon WG	65.5	39.7	72.2
Starane Gold	64.0	41.0	83.8
Biatlon 4D + Desh	63.0	39.7	86.0
Corello Duo + Dasoil	58.5	35.0	77.3
C <sub>1</sub>	61.7	38.7	81.0
C <sub>2</sub>	61.3	33.0	69.0

Source: Authors' own elaboration

(Table 3). While in the varieties Rada and Kosara the application of Ergon WG increases the sedimentation values, in the variety Pchelina a lower average value of the quality indicator was found compared to the non-weeded control. The herbicide Corello Duo+Das Oil lowers the values of the sedimentation volume in all three varieties, and it takes values between the levels of the index for the weeded and unweeded variant. During the three harvest years, the average values of the indicator wet gluten yield are influenced to a different degree by the herbicides used, depending on the genotype (Table 4). The Pchelina variety is characterized by the highest value of wet gluten yield under the influence of Biathlon 4D+Desh, while in the Rada and Kosara varieties this herbicide has no significant impact and the average val-

ues of the analyzed quality indicator are at the levels of the controls. All three varieties have a higher WG content when treated with Ergon herbicide compared to Corello Duo+Das Oil herbicide. The herbicide Starane Gold increases the WG value of the Rada and Kosara varieties, while in the Pchelina variety the quality indicator is between the values of the controls.

**Table 4. Effect of herbicides on average values of wet gluten yield (%) during the 2019–2021 crop years**

Herbicide	Variety		
	Rada (WG, %)	Kosara (WG, %)	Pchelina (WG, %)
Ergon WG	33.5	31.6	34.2
Starane Gold	35.0	31.9	32.1
Biatlon 4D + Desh	31.0	28.4	37.9
Corello Duo + Dasoil	31.5	29.6	30.3
C <sub>1</sub>	31.5	31.0	33.5
C <sub>2</sub>	30.8	26.1	31.0

Source: Authors' own elaboration

Dough development time, similar to sedimentation and wet gluten yield parameters, are affected by herbicides depending on the genotype (Table 5). An unfavorable trend of increase in the average time for the formation of the dough compared to the unweeded control was measured in all three varieties under the influence of the herbicides Ergon, Starane Gold and Biathlon 4D+Desh. The dough formation process takes place in a shorter time when the Rada and Pchelina varieties are treated with Corello Duo+Das Oil, while for the Kosara variety the indicator is between the values of the two controls.

**Table 5. Effect of herbicides on mean dough development time (min) in 2019–2021 crop years**

Herbicide	Variety		
	Rada (DDT, min)	Kosara (DDT, min)	Pchelina (DDT, min)
Ergon WG	4.2	3.4	2.8
Starane Gold	4.6	3.7	2.6
Biatlon 4D + Desh	4.2	3.7	2.8
Corello Duo + Dasoil	2.4	3.0	2.2
C <sub>1</sub>	2.9	2.8	2.2
C <sub>2</sub>	3.7	3.4	2.8

Source: Authors' own elaboration

In the Kosara and Pchelina varieties, a similar, unfavorable trend of increasing the degree of softening was found compared to the two control variants under the influence of all applied herbicides, with the strongest effect of the

preparations Ergon WG and Starane Gold in the Kosara and Corello Duo + Dasoil, and Ergon in the Pchelina. The effect of herbicides on the degree of softening of the Rada variety is multidirectional. While Ergon lowers, the other herbicides increase the average values of the analyzed indicator compared to those of the unweeded control (Table 6).

**Table 6. Impact of herbicides on the average values of the degree of softening (FU) in the 2019 – 2021 crop years**

Herbicide	Variety		
	Rada (DS, FU)	Kosara (DS, FU)	Pchelina (DS, FU)
Ergon WG	40.5	139	71.3
Starane Gold	75.8	135.8	68.2
Biatlon 4D + Desh	64.2	164	68.0
Corello Duo + Dasoil	53.8	132.8	95.5
C <sub>1</sub>	48.2	99.2	59.8
C <sub>2</sub>	76.0	111.2	68.0

Source: Authors' own elaboration

The results of the present study show that herbicides, which are mainly applied to protect wheat crops from weeds, have an impact on the baking qualities of wheat. The same trend has been proven by other authors. A number of herbicides have been found to increase the content of crude protein, wet and dry gluten – DMA 6-D, 2,4-D ester, Optica, optica Trio (Tanásk et al., 1993; Tanásk et al., 2005; Mehmeti et al., 2016), the water absorption capacity of flour (Tanács et al., 2005), farinographic number (Szentpétery et al., 2001), the gluten spreading (Tanács et al., 2000). Manthey et al. (2024) reported that glyphosate and paraquat increased gluten index, dough stability and dough development time (DDT), while Metsulfuron + 2, 4-D lowered gluten index but decreased DDT, which was the favorable trend. Some herbicides reduce the falling number – Dikamin D, Dikotex 40 and others do not change the quality indicators compared to the untreated control – Banvel 480, Protugan, Mecaphar, Segal 65WG (Tanák et al., 2000). Matuz et al. (1993) concluded that the effects of the same herbicides on quality characteristics varied and depended on the variety. This was also confirmed by the cultivar × herbicide interaction analysis, which showed that herbicides increased or decreased dry and wet gluten content depending on the genotype (Tanács et al., 2005; Mangova et al., 2013). The interaction between different varieties of wheat and some herbicides (Starane 250 EC, Pardner, Bromoxynil, Banvel 480, Dicamba), with which the treatment was carried out in provocative doses and at a later stage, immediately before harvesting, showed minor changes in the quality characteristics of the flour, as a result of which it turns out that the volume and symmetry of the

bread, as well as the quality of bread medium are not affected by the applied herbicides (Szentpétery et al., 2001; Manthey et al., 2024).

## Conclusions

Common wheat varieties Rada, Kosara and Pchelina, studied during three different harvest years in the specific conditions of the Dobrudzha region, realize their quality potential in a different way depending on the applied herbicides. The statistical analysis of the obtained results shows that the genotype factor has a stable effect on all the investigated quality indicators, but the dry gluten content and the coefficient of shape stability of the bread are less dependent on the variety. The effect of the harvest year has the most pronounced impact on the quality parameters: dry gluten, dough formation time and quality number from the farinograph. Differentiation between quality indicators based on the influence of herbicides is essential. Their impact is strongest on sedimentation, wet gluten yield, dough formation time and degree of softening, and weaker on dough stability, the quality number from the farinograph and the quality of the bread medium. Herbicides had almost no effect on shape stability coefficient of bread, but it was highly dependent on the genotype × herbicide interaction. All other interactions – genotype × year, herbicide × year, genotype × herbicide × year have no significant influence on quality characteristics. The herbicides Starane Gold and Biathlon 4D + Desh increase the average values of sedimentation regardless of the genotype, and Corello Duo + Dasoil lowers them in all three varieties. The action of the Ergon herbicide is multidirectional – it increases the sedimentation volume in the Rada and Kosara varieties, and lowers it in the Pchelina variety. The variety is decisive for the effect of herbicides on the average values of the indicator wet gluten. Treatment with Biathlon4D + Desh increases the values of the quality indicator WG in the variety Pchelina, but not in the varieties Rada and Kosara. A significant effect and increase of the wet gluten index in Kosara and Rada varieties was reported under the influence of Starane Gold herbicide. Treatment with the herbicides Ergon, Starane Gold and Biathlon 4D + Desh led to an unfavorable trend of increasing the time of the dough development time, regardless of the genotype. The process of forming the dough takes place in a shorter time at Rada and Pchelina varieties under the influence of Corello Duo + Dasoil. An unfavorable trend of increasing the degree of softening was proven in Kosara and Pchelina varieties under the influence of all applied herbicides. In the case of the Rada variety, a multidirectional effect was reported – Ergon WG lowers, and the other herbicides increase, the average values of the degree of softening indicator.

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