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QUALITY INDICES IN SEVERAL WINTER WHEAT GENOTYPES – COMPARATIVE PRESENTATION

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Abstract

The study comparatively analyzed 16 wheat genotypes cultivated in the specific conditions of the Western Plain of Romania, within the ARDS Lovrin. The following genotypes were studied comparatively: Biharia (WG1), Dacic (WG2), Alex (WG3), Ciprian (WG4), Trublion (WG5), Tarroca (WG6), Barbara (WG7), Centurion (WG8), Ultim (WG9), Sphere (WG10), Extrem (WG11), Rubico (WG12), Sacramento (WG13), Vivendo (WG14), Amandus (WG15), and Garavusha (WG16). Compared to the mean values, the genotypes were highlighted: genotype WG9, STARCH = 71.10±0.33% (starch content), genotype WG16, PRO = 15.90±0.26% (protein content), genotype WG4, GLT = 37.80±0.82% (gluten content), genotype WG1, SKHRD = 54.00±0.93 (single kernel hardness), genotype WG6, TKW = 44.00±1.06 g (weight of 1,000 seeds), genotype WG15, HW = 76.00±0.62 kg hl^{-1} (hectoliter weight). A statistically safe correlation was recorded between STARCH and PRO (r = -0.780***), between STARCH and GLT (r = -0.794***), between PRO and GLT (r = 0.868***), between SKHRD and MST (r = 0.812***), between TKW and T (r = 0.807***), between SKHRD and TKW (r = 0.608*), between SKHRD and T (r = -0.538*), and between MST and T (r = -0.587*). Linear and polynomial equations described the variation of quality indices, and the Ranking scaling analysis facilitated the ranking of genotypes based on the recorded quality indices.

Key words**:** *gluten, hardness, protein, regression analysis, ranking, wheat grains*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a species of the Poaceae family, a family that presents high diversity, important consistency of the included species, and represents the main plant, as a food resource, for most people [10]. The proteins contained in wheat grains play an important role in the quality of bakery products. Based on an extensive review-type study, the authors considered it important to expand the hereditary genetic base, for breeding programs. They considered this possible by reconsidering the genetic resources of the local and wild wheat populations.

A priority problem worldwide is the creation of productive wheat genotypes, with resistance to environmental factors, high production potential, and good quality indices [16]. The reconsideration of ancient wheat genotypes is considered important by the authors of the study. In this sense, the testing of ancient forms of wheat, for the evaluation of protein content, gluten and other quality indices, is of interest and at the same time an opportunity to obtain new genotypes. Based on the results, the authors identified valuable wheat genetic resources for obtaining new genotypes, with good quality indices and adapted to environmental conditions.

The improvement of cereal yield represents a present and perspective challenge, and breeding programs for improvement of yield are based more and more on methods supported by computational analysis and algorithms [6]. The authors considered in the analysis 167 wheat lines (inbred and recombined lines), and based on the analysis methods they succeeded in an efficient classification of the considered lines according to yield, in several categories. Moreover, the authors considered the information useful for farmers, for the purpose of early estimates of yields, and the establishment of measures to improve yields.

The yield and quality indices in wheat are the result of the interaction "genotype × environment × crop technology" [11]. The authors analyzed 17 quality indices, for 211 varieties of winter wheat, in the specific conditions of the crops in China (period 2006 - 2018), to evaluate the quality variability, and identify the key influencing factors. The authors determined the values of the quality indices, and found out their position relative to the quality standards. Certain levels of correlation were found, statistically assured ($p<0.001$). Certain indices, with importance in wheat quality, were found (e.g. protein). The genetic characteristics, associated with quality indices, were identified, and the authors showed the importance of new varieties in wheat cultivation, and certain appropriate agricultural practices to ensure adequate yields and quality indices.

Bonea (2024) [3] communicated the results of an extensive study on the importance of genomic editing techniques in wheat breeding, in relation to the considered yield objectives and quality indices.

The variation of some wheat quality indices was studied in relation to technology elements, such as sowing date, under conditions specific to the Mediterranean area [5]. The authors studied three varieties of wheat and recorded a different variation of the gluten index depending on the sowing time and environmental conditions. Later sowing influenced a better gluten index, according to the authors. The variation of some quality indices, such as gluten, protein, Zeleny index in wheat, was analyzed depending on certain agricultural practices, such as tillage, fertilization methods [2]. Attafy et al. (2023) [1] reported the influence of irrigation on the yield and quality parameters of wheat, under specific crop conditions in Egypt. The impact of climate change on the yield of the wheat crop, in the crop conditions in Romania, was analyzed over a five-year period, from 2017 to 2021 [15]. The influence of crop technologies on some economic elements of wheat crops was studied in the South-Eastern area of Romania, under the conditions of climate change [12].

The gluten index was studied to differentiate the quality of wheat production, and the quality of flour in relation to the category of final products [4]. Based on the recorded results, the authors considered that the gluten index is important for wheat quality assessment, and can be used together with other indices.

The quality of some types of flour, associated with starch and protein (variable content, by types of flour), was evaluated in relation to the quality of the finished products [19]. It was observed how starch and protein influenced the properties and behaviour of the flour in the preparation process, as well as the quality of the resulting finished products.

Starting from the baking quality indices of wheat grains (e.g. protein content, gluten index, deformation energy, etc.), and grain yield, a synthetic index, "GY parameter", was considered useful, which expresses the relationship between grain yield and quality indices [17]. The authors of the study considered that the “GY parameter” was a tool that facilitated the objective classification of the wheat varieties studied.

The wheat quality indices were considered from a complex perspective, according to which the segments on the agro-food chain, post-harvest (processing industries, and marketing), should maximize their profit, under the conditions of cost minimization [7]. The authors of the study considered wheat quality as a "highly subjective concept" in the value flow of wheat ("milling, processing, end use and nutritional quality"). The authors considered the most important "quality of final use", which was explained by the ability of a wheat genotype to ensure obtaining a certain food, in relation to consumer preferences. The authors analyzed in detail the indices considered important in defining wheat quality (starch, gluten, grain color, and hardness), their genetic control, and the influence of the environment in their manifestation.

The quality indices of grass grain seeds are important for plant breeding programs, but also for the valorisation of grain production, as seed material (establishment of new crops), for bakery, as animal feed, industrialization. Therefore, the quantification of seed quality can be done based on different indices, and it is not always a simple process [14].

For an objective assessment of wheat quality, multivariate analysis was used in a study that analyzed 45 wheat genotypes, based on 13 physico-chemical quality indices, and three finished products [14]. In relation to the considered criteria, the authors of the study classified the varieties studied into three categories, for different bakery and pastry products. The authors considered that wheat quality indices and the obtained results will be of interest to farmers, the industry, and consumers.

An extensive study, based on 13 quality indices, 9 influencing factors and 285 winter wheat varieties, considered the classification of factors in relation to the influence on the quality indices [20]. Based on the recorded results, the authors identified the genotype as the dominant factor, which explained between 28.13% and 38.78% of wheat quality indices. Also, the authors classified the indices in relation to their variation in the "genotype × environment × technology" interaction, and identified the indices with the highest sensitivity to this interaction. The authors concluded by identifying the critical factors, with influence for most of the quality indices, and establishing a strategy for improving wheat quality indices.

In the context of the interest in wheat quality, the present study comparatively analyzed 16 wheat genotypes, based on the quality indices, described the relationship of interdependence and variation of some indices, and made a ranking of the genotypes considered in the study.

MATERIALS AND METHODS

The study made a comparative analysis of the quality indices of 16 wheat genotypes, cultivated under specific ARDS Lovrin conditions.

The following genotypes were cultivated: Biharia (WG1), Dacic (WG2), Alex (WG3), Ciprian (WG4), Trublion (WG5), Tarroca (WG6), Barbara (WG7), Centurion (WG8), Ultim (WG9), Sphere (WG10), Extrem (WG11), Rubico (WG12), Sacramento (WG13), Vivendo (WG14), Amandus (WG15), and Garavusha (WG16). To facilitate analyzes and graphical representations, WG1 to WG16 represent trial code in this study.

The comparative wheat crops were organized in conditions of chernozem soil, medium fertility, and non-irrigated crops system. At physiological maturity, BBCH code 9 [13], mechanized harvesting was done with a combine.

Within the quality indices was determined: starch content (STARCH, %); protein content (PRO, %); gluten content (GLT, %); single kernel hardness (SKHRD); weight of 1,000 grains (TKW, g); hectoliter weight (HW, kg hl^{-1}); moisture (MST, %), and temperature (T, °C).

The mean value for each quality index was calculated, against which the result of each genotype was compared, in order to create a value hierarchy.

Correlation analysis was applied to identify interdependent relationships between indices, and the degree of statistical certainty of these relationships. Regression analysis was used to evaluate the direct relationship and interaction of some indices. Dedicated applications [8, 9, 18] were used for the analysis and processing, mathematics and statistics, of the experimental data.

RESULTS AND DISCUSSIONS

The values of the quality indices resulting from the analysis of grain samples for the 16 studied wheat genotypes are presented in table 1. The starch content (STARCH, %) varied between 66.50±0.33% (WG4) and 71.10±0.33% (WG9). The protein content (PRO, %) varied between 12.20±0.26% (WG5) and 15.90±0.26 (WG16). The gluten content varied between 26.60±0.82% (WG12) and 37.80±0.82% (WG4). Single kernel hardness (SKHRD) varied between 41.00±0.93 (WG16) and 54.00±0.93 (WG1). The weight of 1,000 seeds (TKW, g) varied between 28.80±1.06 g (WG10) and 44.00±1.06 g (WG6). The hectoliter weight

(HW, kg hl^{-1}) varied between 67.60±0.62 kg hl^{-1} (WG16), and 76.00±0.62 kg hl^{-1} (WG15). The moisture of wheat grains, at harvest, varied between 11.30±0.62°C (WG16), and 18.70±0.62°C (WG2, WG3). Higher grain moisture values were recorded in the genotypes in which the plant fall phenomenon was recorded. The temperature of the grains at the time of harvesting varied between 30.30±0.29°C (WG1), and 34.30±0.29°C (WG10). The ANOVA test confirmed the statistical reliability of the results (Table 2).

Table 1. Values of the quality indices of the tested wheat genotypes

Trial code	STARCH	PRO	GLT	SKHRD	TKW	HW	MST	T
	(%)			Index	(g 1,000 kernel^{-1})	(kg hl^{-1})	(%)	(°C)
WG1	68.30	14.30	35.00	54.00	40.80	70.20	18.20	30.30
WG2	67.20	13.90	33.10	49.00	42.40	68.90	18.70	31.50
WG3	67.50	13.80	33.50	51.00	43.20	70.80	18.70	30.70
WG4	66.50	15.70	37.80	52.00	40.80	74.70	16.70	32.70
WG5	70.30	12.20	28.00	50.00	38.80	73.10	16.00	31.90
WG6	69.40	13.80	33.20	52.00	44.00	73.10	15.10	31.00
WG7	69.60	13.90	30.90	49.00	43.20	75.00	14.50	31.30
WG8	69.00	14.20	32.80	47.00	39.60	73.70	13.80	32.50
WG9	71.10	12.30	27.00	48.00	37.60	75.30	14.10	33.00
WG10	67.80	14.70	32.90	43.00	28.80	75.00	13.20	34.30
WG11	70.80	13.10	28.60	48.00	40.40	72.40	12.30	33.20
WG12	70.20	12.80	26.60	44.00	41.20	71.10	12.90	31.40
WG13	68.30	13.50	27.50	46.00	36.80	74.00	12.40	33.70
WG14	68.40	14.60	32.00	44.00	32.00	74.70	12.10	33.30
WG15	68.80	14.50	31.90	44.00	42.40	76.00	12.30	31.10
WG16	67.90	15.90	35.50	41.00	35.60	67.60	11.30	32.70
SE	±0.33	±0.26	±0.82	±0.93	±1.06	±0.62	±0.62	±0.29

Source: Original data.

Table 2. ANOVA Test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54839.2	7	7834.2	1062.68	9.6E-105	3.7669
Within Groups	884.645	120	7.3720			
Total	55723.9	127				

Source: Original data.

Within the comparative crops of wheat genotypes, for each quality index the mean value at the level of the experiment was calculated, against which the responses of the genotypes were analyzed and interpreted.

In the case of the starch content (STARCH, %), the mean value was 68.82±0.33%. The cultivated genotypes presented differentiated values, Figure 1.

With values above the recorded average (68.82±0.33%), it was the WG9 genotype (the highest value), followed by WG11, WG5, WG12, WG7, WG6, and WG8.

In the case of the protein content (PRO, %), the mean value calculated at the level of the experiment was 13.95±0.26%, and the studied genotypes presented different values, Figure 2. The WG16 genotype presented the highest value (15.90±0.26%), and other genotypes, WG4, WG10, WG14, WG15, WG1, etc., were also recorded with values above the mean.

In the case of gluten content (GLT, %), the calculated mean was 31.64±0.82%, and the studied genotypes were positioned differently, Figure 3.

The highest gluten content was trial WG4 (37.80±0.82%), followed by WG16, WG1, WG2, WG3, WG6, WG8, WG10.

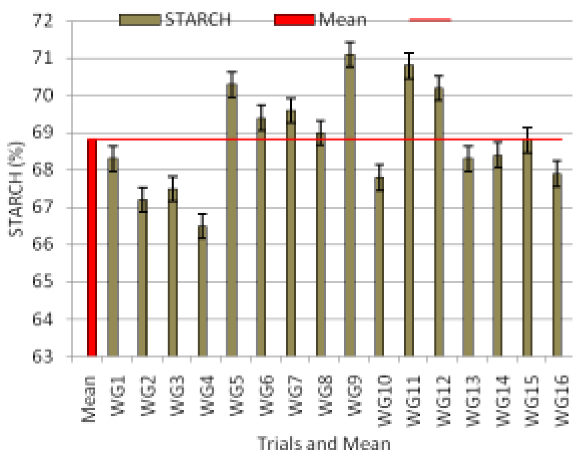


Fig. 1. The graphic representation of the starch content compared to the mean value of the studied wheat genotypes
Source: Original figure.

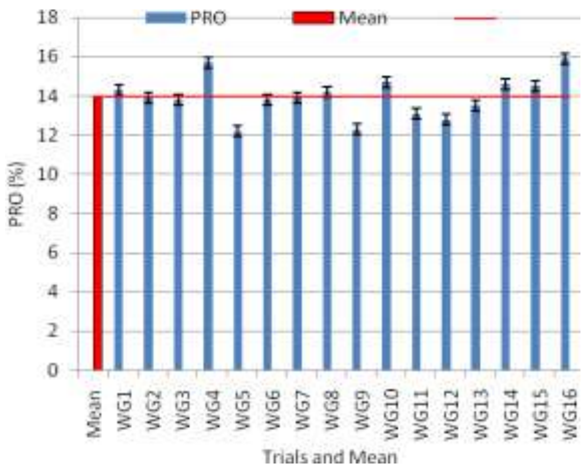


Fig. 2. Graphic representation of the protein content of the wheat genotypes studied, compared to the mean value
Source: Original figure.

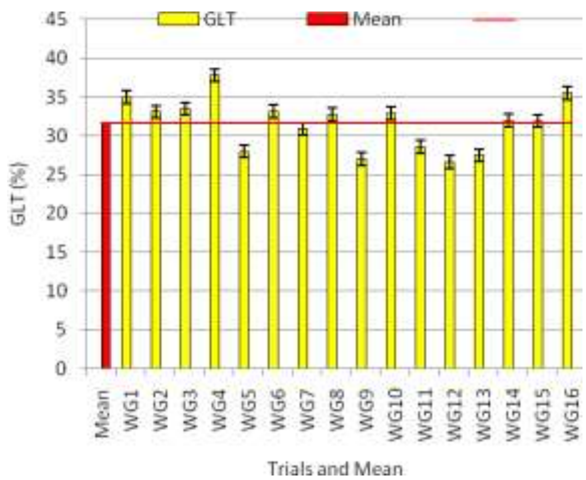


Fig. 3. Graphic representation of the gluten content of the wheat genotypes studied, compared to the mean value
Source: Original figure.

In the case of single kernel hardness (SKHRD), the mean value of the index was 47.63±0.93, and the studied genotypes presented differentiated values, figure 4. With the highest value was positioned WG1 (54.00±0.93), followed by WG4, WG6, WG3, WG5, WG2, WG7.

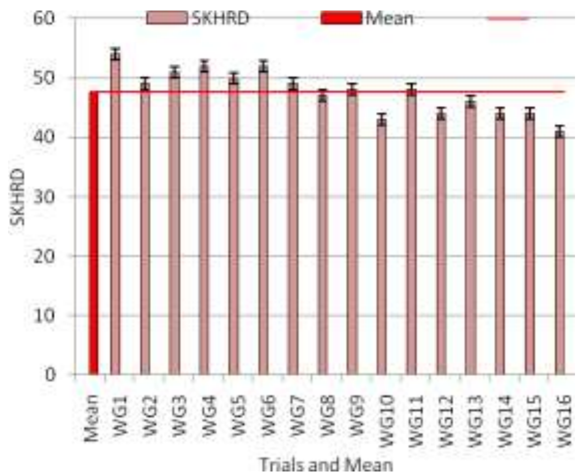


Fig. 4. The graphic representation of the values of the SKHRD index compared to the mean value for the studied wheat genotypes
Source: Original figure.

In the case of the weight of 1,000 grains (TKW), the mean calculated value was 39.23±1.06 g, and the genotypes showed variable values compared to the mean value, Figure 5. The highest value was recorded at WG6 (44.00±1.06 g), followed by WG3 and WG7 (tied), WG2 and WG15 (tied), WG12, WG1 and WG4 (tied), WG11.

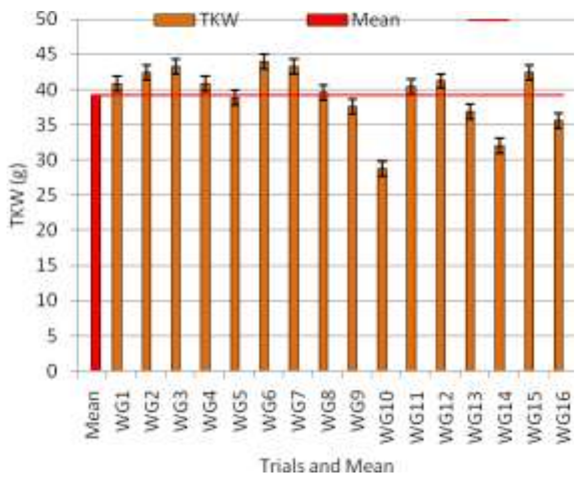


Fig. 5. Graphical representation of the TKW index values compared to the mean value for the studied wheat genotypes
Source: Original figure.

In the case of the hectoliter weight (HW, kg hl^{-1}), the calculated mean value was 72.85±0.62 kg hl^{-1}, and the studied genotypes recorded differentiated values (Figure 6).

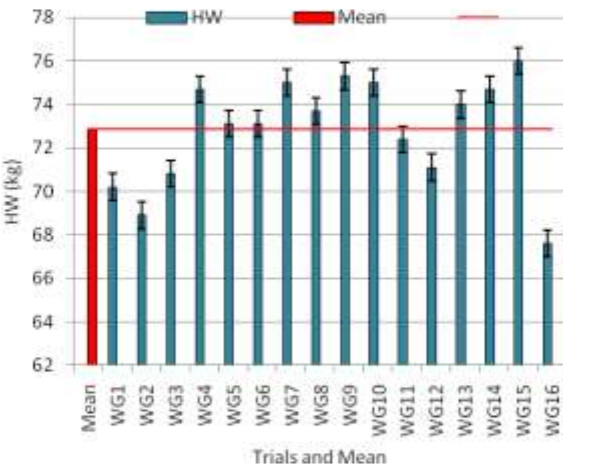


Fig. 6. The graphic representation of the HW index values compared to the mean value for the studied wheat genotypes
Source: Original figure.

The highest value was recorded in trial WG15 (76.00± 0.62 kg hl^{-1}). With values above the calculated mean, in descending order, WG9, WG7 and WG10 (with equal values), WG4 and WG14 (with equal values), WG13, WG8 etc., were positioned.

In the case of moisture (MST, %), the calculated mean value was 14.52±0.62%. Compared to the mean value, high values were recorded in WG1, WG2, WG3, followed by WG4 and WG5. The higher moisture was associated with the phenomenon of plants lodging, a phenomenon recorded in the respective variants. Moisture is a quality index in relation to the preservation of wheat production, so that the respective variants required drying for preservation. The temperature of the grains, at the time of harvesting, was between 30.30 - 34.30 ±0.29°C.

Correlation analysis was applied to identify interdependence between quality indices. The result is table 3, in which the values of the correlation coefficient and the significance of the correlations are presented.

Table 3. Correlation matrix table

Variable		STARCH	PRO	GLT	SKHRD	TKW	HW	MST	T
STARCH	Pearson's r	—							
	p	—							
PRO	Pearson's r	-0.780***	—						
	p	< .001	—						
GLT	Pearson's r	-0.794***	0.868***	—					
	p	< .001	< .001	—					
SKHRD	Pearson's r	-0.044	-0.214	0.226	—				
	p	0.871	0.426	0.399	—				
TKW	Pearson's r	0.119	-0.224	0.042	0.608*	—			
	p	0.662	0.404	0.879	0.012	—			
HW	Pearson's r	0.243	-0.139	-0.247	-0.037	-0.188	—		
	p	0.364	0.607	0.355	0.892	0.485	—		
MST	Pearson's r	-0.365	-0.084	0.365	0.812***	0.491	-0.305	—	
	p	0.164	0.757	0.165	< .001	0.053	0.25	—	
T	Pearson's r	0.001	0.110	-0.192	-0.538*	-0.807***	0.341	-0.587*	—
	p	0.996	0.684	0.476	0.031	< .001	0.196	0.017	—

Source: Original data.

A statistically safe correlation was recorded between STARCH and PRO ($r = -0.780^{***}$), between STARCH and GLT ($r = -0.794^{***}$), between PRO and GLT ($r = 0.868^{***}$), between SKHRD and MST ($r = 0.812^{***}$), between TKW and T ($r = 0.807^{***}$), between SKHRD and TKW ($r = 0.608^{*}$), between SKHRD and T ($r = -0.538^{*}$), and between MST and T ($r = -0.587^{*}$).

Starting from the recorded correlation levels, regression analysis was used to evaluate the variation of some quality indices.

Protein variation in relation to gluten was described by equation (1), under statistical safety conditions (R^2 = 0.753, p<0.001), with the graphical distribution in Figure 7.

$$PRO = 0.276x + 5.218 \quad (1)$$

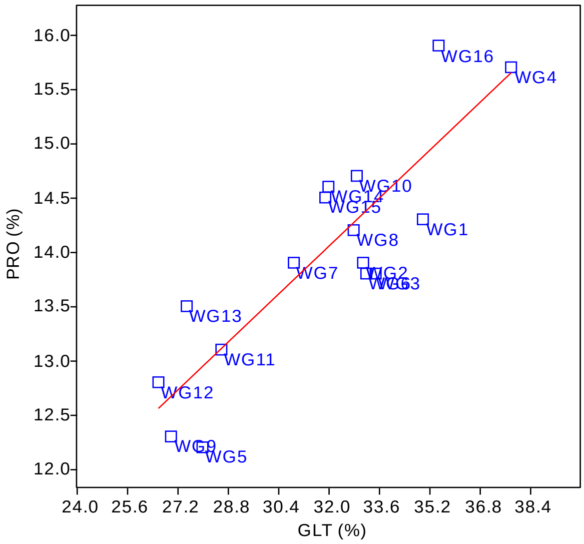


Fig. 7. Graphic variation of PRO according to GLT in the studied wheat genotypes
Source: Original figure.

The variation of the SKHRD index in relation to MST was described by the polynomial equation (2), under conditions of R^2 = 0.760, p<0.001, with the graphic distribution in Figure 8.

$$SKHRD = -0.2439x^2 + 8.637x - 24.97 \quad (2)$$

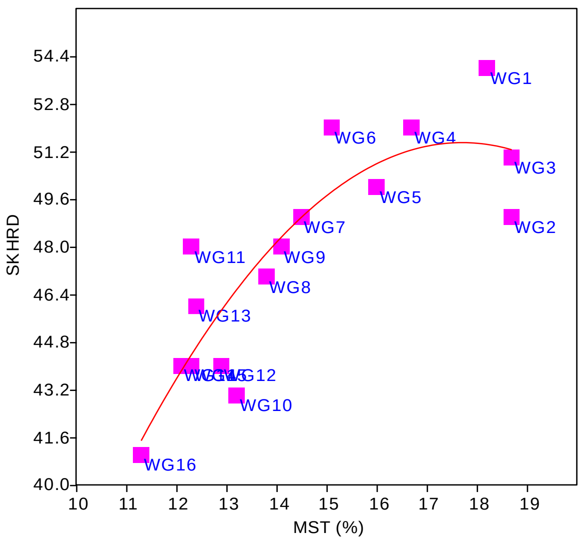
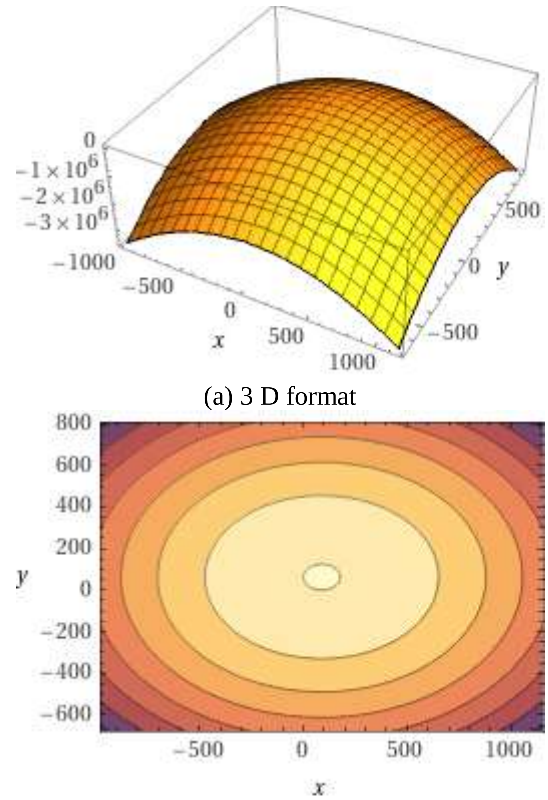


Fig. 8. Graphical distribution of SKHRD in relation to MST in the studied wheat genotypes
Source: Original figure.

The variation of HW indice, in relation to STARCH and PRO indices, was described by equation (3), in conditions of Multiple R = 0.712, with the graphic representation in Figure 9.

$$HW = ax^2 + by^2 + cx + dy + exy + f \quad (3)$$

where: HW – hectoliter weight (kg hl^{-1});
x – STARCH (%);
y – PRO (%);
a, b, c, d, e, f – coefficients of the equation (3);
a= -1.61432199;
b= -3.31426973;
c= 286.59803031;
d= 410.56863306;
e= -4.62264263;
f= -12648.259656



(a) 3 D format

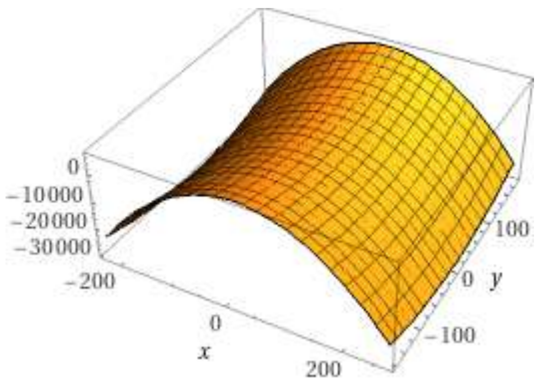
(b) isoquants format

Fig. 9. Representation of HW index variation, according to STARCH and PRO, in wheat grains
Source: Original figure.

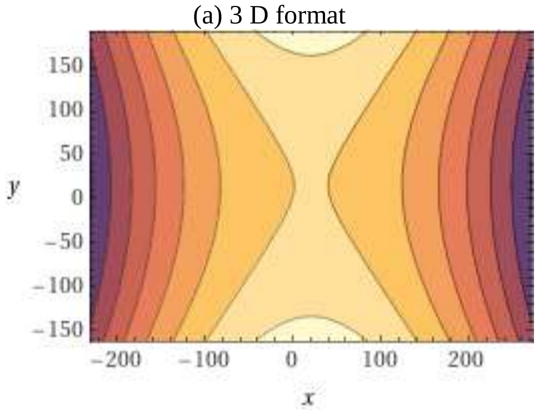
The SKHRD index variation, according to PRO and GLT indices, was described by equation (4), in conditions of R2 = 0.854, p<0.001, with graphic distribution presented in Figure 10. Based on the coefficients of equation (4) analysis, as well as the graphic distribution (figures 10 a, b), the differentiated, divergent contribution of the two indices to the variation of the SKHRD index was found.

$$\text{SKHRD} = ax^2 + by^2 + cx + dy + exy + f \qquad (4)$$

where: SKHRD – index of single kernel hardness;
x – PRO (%);
y – GLT (%);
a, b, c, d, e, f – coefficients of the equation (4);
a= -0.48460726;
b= 0.21856018;
c= 20.25679713;
d= -6.42364576;
e= -0.39564418;
f= 17.80297034



(a) 3 D format



(b) isoquants format

Fig. 10. Graphic representation of the SKHRD index variation in relation to PRO and GLT in wheat grains
Source: Original figure.

Based on the first four wheat grain quality indices (STARCH, PRO, GLT, SKHRD), the studied genotypes were ranked, according to the diagram in Figure 11.

The quality of wheat production is important both for farmers (superior quality means better prices, and facilitates better capitalization on the grain market), as well as for processors, and especially for consumers of finished products [7, 14, 19].

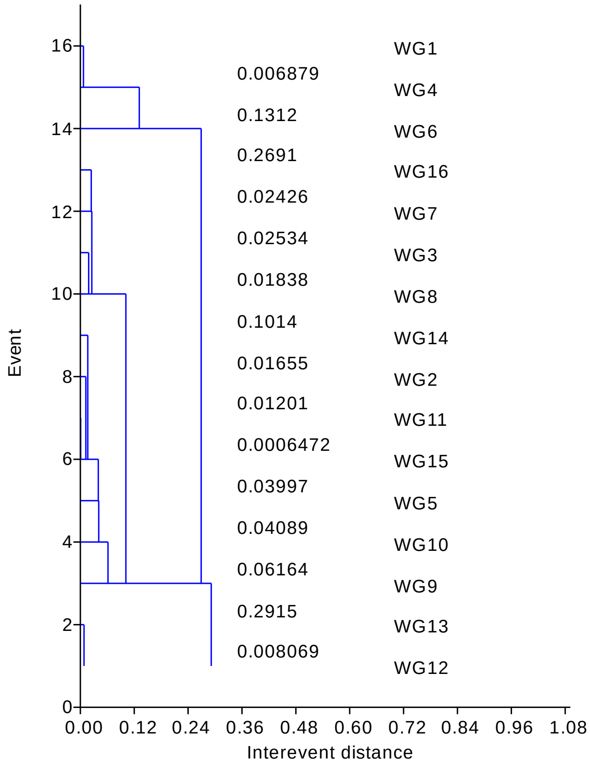


Fig. 11. Hierarchy diagram of the wheat genotypes studied
Source: Original figure.

Quality indices were analyzed individually in relation to different influencing factors, but synthetic quality indices, introduced in some studies, are considered more representative and have been increasingly promoted recently [17].

Quality indices vary in relation to the genotype, but also to the interaction "genotype × technology × environment", so testing wheat genotypes in different agricultural areas is of interest [11, 14, 20].

The classification of genotypes and the wheat genetic base is important for the selection of valuable lines in the breeding process, as well as for agricultural practice [6].

In the conditions of the present study, the quality indices considered showed specific variation for each genotype, in response to the environmental and technological conditions that were uniform for all 16 genotypes.

The recorded information is of interest for the characterization of genotypes, as possible parental forms in breeding programs, as well as for agricultural production, for farmers. The practical applicability, regarding the choice of genotypes in order to be cultivated, has high validity for the study area and neighboring areas, with similar climate and soil conditions. From the aspect of crop technologies, they can differentially influence the yield and quality index values, and can to some extent compensate for the soil and climate conditions, and thus potentiate the genotype towards better quality index values.

CONCLUSIONS

The wheat genotypes generated different values within each quality index, under the study conditions. Based on the obtained results, and the mean values, calculated for each quality indice, one genotype was highlighted, for each index, with the best results; WG9 in the case of starch content (71.10%); WG16 in the case of protein content (15.90%); WG4 genotype in the case of gluten content (37.80%); WG1 genotype in the case of SKHRD (54.00); WG6 genotype in the case of TKW (44.00 g); genotype WG15 in the case of HW (76.00 kg hl^{-1}).

Variable levels of correlation were recorded, under statistical safety conditions, between STARCH and PRO ($r = -0.780^{***}$), between STARCH and GLT ($r = -0.794^{***}$), between PRO and GLT ($r = 0.868^{***}$), between SKHRD and MST ($r = 0.812^{***}$), between TKW and T ($r = 0.807^{***}$), between SKHRD and TKW ($r = 0.608^{*}$), between SKHRD and T ($r = - 0.538^{*}$), and between MST and T ($r = -0.587^{*}$).

The regression analysis led to mathematical models (linear equations, and polynomial equations), that has described of the certain indices variation. Also, some graphical models vas generated.

Based on the coefficients of equation (4) values, and based on graphical distribution (e.g. figure 10, a, and b), it was found varied contribution of the protein and gluten content (PRO, GLT) to the variation of the SKHRD index.

The ranking of the studied genotypes was done by the Ranking analysis, based on the values of the STARCH, PRO, GLI and SKHRD indexes.

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