Uluslararası Tarım Araştırmalarında Yenilikçi Yaklaşımlar Dergisi
International Journal of Innovative Approaches in Agricultural Research 2019, Vol. 3 (3), 480-490
https://doi.org/10.29329/ijiaar.2019.206.13

Original article

Assessment of Diversity and Association between Agronomic and Quality Traits in an Assortiment of Durum Wheat Genotypes [1]

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Abstract

The investigation included 24 durum wheat genotypes – varieties and breeding lines of different origin – Bulgaria - Field Crops Institute – Chirpan, Europe, CYMIT-Mexico and ICARDA-Syria. All genotypes were grown in field conditions in the competitive variety trials in three repetitions in harvesting years 2014/2016 and were analyzed for agronomically important traits and traits associated with grain quality. For statistical processing of the data were used variation analysis, analysis of variance and principle component analysis – PCA. Significant diversity of the studied traits based on the variation coefficients was found. In regard to the agronomic traits the greatest variation was determined for: yield, kernel weight per spike and kernel number per spike. For quality traits the highest variation was recorded for: SDS-value, gluten softening, bug damage degree. Correlation between some agronomic and quality traits was found, too. Based on the PC analysis the studied genotypes are divided into different groups. To the group with the highest SDS sedimentation belong 2 foreign varieties, 3 Bulgarian varieties and 3 breeding lines. The group characterized by the highest content of protein and wet gluten comprises 4 foreign varieties and the group with the highest yield includes 6 breeding lines.

Keywords: Durum wheat, Variability, Correlations, Multivariate methods.

Received: 31 August 2018 * **Accepted:** 10 July 2019 * **DOI:** https://doi.org/10.29329/ijiaar.2019.206.13

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[1] A part of this study was presented at the International Agricultural, Biological and Life Science Conference, Edirne, Turkey, September 2-5, 2018.

INTRODUCTION

Durum wheat is used for processing in various pastry products, which are staple food for people and due to the characteristics of its grain (composition, structure and properties) is a preferred raw material basically for the production of high quality pasta (Dexter and Matsuo, 1980; Feillet and Dexter, 1996; Petrova and Belcheva, 2000).

Basic priority in the selection of durum wheat is creation of high yield cultivars with improved grain quality. The main parameters associated with the quality of grain, semolina and pasta which selection specialists are focused on are: hectoliter weight, vitreousness, 1000 grain mass, ash content, yellow pigment content, protein content, gluten amount and strength, SDS sedimentation volume , genetic markers for quality (gliadins and glutenins), viscoelastic properties of wet gluten, compressibility and relaxation, rheological evaluation of pasta doughs.

The work of selection workers in terms of improving grain quality is associated with a number of difficulties due to various factors. The small differences in the variation of genes controlling the various grain quality parameters in modern durum wheat varieties are an important limitation in the selective improvement of these parameters (Blanco et al., 1994). This calls for a large number of genotypes of different ecological and geographical origins to be included in the selection programs. The study of the existing genetic diversity and its inclusion in hybridization programs is important for further improvement of yield and quality. Multi-variance statistical methods are widely used to assess the genetic diversity of selection materials. They serve as a graphical representation of the distance between genotypes, as well as for the characterization of variation by indicators and the relationships between them (Bozhanova et al., 2006).

The objective of the present study is to assess the diversity and relations between the agronomical and quality parameters in an assortment of durum wheat genotypes of different ecological and geographic origin.

Material and Methods

The study includes 24 durum wheat genotypes - cultivars and breeding lines of different origin: Bulgaria (FCI - Chirpan, DAI - G. Toshevo), Europe, CYMIT - Mexico and ICARDA - Syria. All genotypes were grown under field conditions in a competitive variety trial in three replications during three harvest years (2014 – 2016) in the experimental field of Field Crops Institute – Chirpan, Bulgaria and are analyzed by agronomically important traits and traits related to grain quality by conventional methodologies. For comparison the standard varieties Predel and Saturn-1 were used. The test weight and the 1000 Kernel weight are determined according to BDS EN ISO 7971: 2009 and BDS ISO 520: 2010, respectively. The vitreousness of the grain is determined according to standard BSS EN 15585:2008. Experimental grinding of the grain to semolina was performed with an adapted laboratory mill QC-109 Labor Mim. The yield of semolina is calculated on a grain basis with 14% moisture and is

corrected for moisture of the meal also 14%. Protein content in the grain has been determined by the Kjeldahl method (N x 5,7) according to BDS EN ISO 20483: 2006 and of wet gluten according to BDS EN ISO 21415-2: 2008. The gluten strength assessment has been done by sedimentation volume of whole ground grain with protein detergent sodium dodecyl sulfate (SDS) (ICC 151: 1990). The content of the yellow pigments has been determined spectrophotometrically according to BDS EN ISO 11052: 2006. The principle of the method is extraction of pigments with water-saturated n-butanol and reading the optical density of the clear filtrate at a wavelength of 440 nm. The amount of yellow pigments is calculated as ppm DM versus a standard curve with pure β-carotene. The preparation and culinary evaluation (by the Cooking Quality Score) of the baked product in the form of 7 mm diameter disks was performed according to the micromethod of Alause (1977). For statistical processing of the data software package Statistica 6.0. has been used (StatSoft Inc. 2002). Variation analysis, PCA analysis and correlation analysis have been applied.

Results and Discussion

By parameters related to the agromonical traits the greatest variation in the selection of studied genotypes average for the three years of study is observed with regard to yield from 249 kg/da for line TD-97 to 460 kg/da for line D-7557 and the highest variation coefficient has been calculated, respectively – CV-16.9 %. Significant variation has also been reported for the parameters: weight of kernels in the spike – CV-15.69 % and number of kernels in the spike – CV-13.01 % (Table 1).

Table 1. Mean values of agronomical traits in durum wheat genotypes

Genotype	Y	T	PH	SPL	SPS	KNS	KWS	TW	TKW
Predel	365	5.5	91.7	8.2	23.6	53.2	2.198	83.80	44.07
Saturn-1	290	5	83.3	8.9	21.2	69.1	2.539	80.03	39.27
Severina	256	6.5	84.6	7.9	23.7	57.1	2.555	82.30	42.50
Superdur	265	6.1	80.6	8.2	21.3	51.4	1.964	79.80	37.50
Selyemdur	322	7.1	78.9	8.8	24.7	64.1	2.485	82.82	37.80
Betadur	304	6.5	83.9	9.3	24.2	57.9	2.432	80.97	39.87
Auradur	256	6.2	86	9.1	23.2	58.4	2.321	79.82	38.93
TD-97	249	5.3	87	9.2	23.9	54.3	2.17	82.27	39.07
DF-009114002	287	5.2	80.9	8.2	23.2	60.3	2.469	83.45	38.97
D-7724	386	6.2	91.8	7.4	21.4	52	2.117	79.48	37.73
M-287	279	5.6	83.2	8.1	24.7	49.7	1.812	81.07	35.03
D-7557	460	6.6	102.5	6	22.6	46.3	2.269	82.28	45.03
M-6433	285	4.8	82	8.3	25.3	49	1.767	80.88	36.23
M-615	331	5.7	99	8.3	25.3	45.5	1.954	82.13	40.27
M-376	293	5.8	88.7	8.2	23.1	47.9	1.861	81.27	37.20
M-431	338	5.5	91.8	8.6	23.8	51.2	2.196	82.45	41.23
D-8138	310	5.2	91.9	6.6	25.6	66.7	2.024	81.18	35.20
D-8308	274	6.4	81.9	7.1	20.7	48.2	2.239	81.92	44.87
D-8326	380	5.5	87.3	6.5	20.2	56	2.427	82.92	42.47
DV-8359	323	5.5	83.1	7.9	23.1	56.3	2.595	81.33	42.27
D-8362	338	5	82.3	7.4	21.3	59	2.458	83.30	41.43
D-8370	285	6.1	72.4	7.4	22	67.2	2.842	82.12	39.20
D-7864	400	6.5	93.2	7.9	24.1	48.1	2.236	82.12	45.70
D-8367	261	5.7	81.4	7.8	22.3	67.9	3.433	83.93	43.70
Mean x	314.04	5.81	86.23	7.97	23.10	55.7	2.31	81.82	40.23
Min/Max	249-460	4.8-7.1	72.4-102.5	6.0-9.3	20.2-25.6	45.5-69.1	1.77-3.43	79.48-83.93	35.03-45.7
Variance	2824.824	0.36	44.55	0.72	2.36	52.5	0.13	1.59	9.65
Std. dev.	53.15	0.60	6.67	0.85	1.54	7.25	0.36	1.26	3.11
CV	16.9	10.35	7.74	10.67	6.65	13.01	15.69	1.54	7.72

Y-Yield, kg/da / T- Productive tillering, number / PH-Plant height, sm / SPL-Spike length, sm / SPS-Spikelets per spike, number / KNS-Kernel number per spike, number / KWS-Kernel weight per spike, g / TW-Test weight, kg/hl / TKW-1000 Kernel weight, g

The variation of traits related to grain quality is given in Table 2. It is the most significant in relation to the traits: SDS-sedimentation volume – CV-44.20 %, gluten softening – CV-37.88 % and damage wheat bug – CV-27.63 %. Insignificant damage has been reported by parameters: semolina yield – CV-1.57 % and protein content in the grain - CV-4.43 %.

The results obtained show that strong gluten by all parameters is available in 3 selection lines - D-8367, D-8362, D-8370 and the 6 foreign genotypes. The SDS-sedimentation volume of these lines varies from 51-74.33 cm^3, while the parameters softening and compressibility of of wet gluten in the grain are within range of about 4-7 mm and 58-85 IDK units, respectively. Concerning yellow pigments, the variation ranges from 6.04-10.71 ppm, with most of the genotypes analyzed being characterized by sufficiently high levels of yellow pigments (8-9 ppm) suitable for the production of pasta with a pleasant yellow colour. The highest content of yellow pigments is typical for the line M-431 (10.71 ppm). The total loss in all genotypes studied ranges from 13.6-28.9%, which are not high values, and the least loss of pigments is typical for the lines TD-97 (13.6%) and Superdur variety (15.1%). Protein content in the grain ranges from 13.96-16.26%. The highest grain protein content on average for the three analyzed years is typical for the lines M-376 (16.26%) and M-6433 (16.19%). The data from the culinary evaluation of cooked pasta products show that 8 of the analyzed genotypes, depending on the combination of weak gluten with the protein content (14-15% DM), show medium cooking quality (CS = 5-5.6), 2 of the lines exhibit good cooking quality (CS = 6-6.6), 8 genotypes are with very good cooking quality (CS = 7-7.6) and 6 genotypes are characterized by excellent cooking quality (CS = 8). The standard varieties Predel and Saturn-1 show very good cooking quality (CS = 8 and CS = 7).

Table 2. Mean values of quality traits in durum wheat genotypes

Genotype	V	YS	YPG	TL	PCG	WGG	SDS	GCG	GSG	DWB	CS
Predel	84.33	63.27	9.25	22.3	14.72	29.6	46	83.4	8.1	1.7	8
Saturn-1	84.33	61.47	7.76	28.9	14.3	28.1	55	80.8	7.3	4.5	7
Severina	82.83	63.37	6.25	23.9	14.87	28.97	45	84.6	7.8	3.4	7.3
Superdur	87.33	61.50	9.09	15.1	15.2	30.57	60.33	57.8	4.6	2.4	7.6
Selyemdur	83.17	61.73	9.01	27.1	14.84	29.83	70.17	69.2	5.2	2.6	8
Betadur	85.17	62.80	7.59	22.3	14.48	28.37	56.67	80.8	6.8	2.7	8
Auradur	87.33	61.87	7.79	21.4	15.22	30.6	56.33	82.4	7.2	3.8	8
TD-97	80.67	63.30	9.83	13.6	14.16	27.7	47.67	75.4	6.3	3.2	7.3
DF-009114002	85.17	62.90	7.01	21.7	15.06	30.63	74.33	84.2	7.2	2.8	8
D-7724	62.83	60.83	7.87	26.2	14.15	26.98	32	101.5	13.5	2.9	5
M-287	76.67	62.23	6.27	20.7	15.65	30.37	21.67	104.2	14.3	3.4	6
D-7557	75.33	63.40	8.5	17.9	14.04	26.9	19.67	100	12.2	2.1	5.3
M-6433	86.33	63.97	6.04	20.8	16.19	32.5	23	100.9	13.5	3.1	6.6
M-615	78.33	62.33	9.21	23.3	14.15	26.43	27.67	101.8	13.2	3.6	5
M-376	83.50	61.93	7.95	18.5	16.26	31.63	21.67	106.5	15	3.2	7.3
M-431	85.17	63.67	10.71	16.9	15.37	31.13	29.33	99.4	12	2.5	7.6
D-8138	77.33	60.70	7.27	27.4	15.1	28.57	24.67	102	13.2	3.1	5.6
D-8308	79.83	63.00	6.81	18.8	15.17	19.2	21.33	71.6	14.8	6	5
D-8326	73.17	63.30	8.67	23.2	14.19	26.57	24.67	100.5	12.6	2.3	5.3
DV-8359	79.50	62.77	8.49	16.4	14.03	26.9	19	107.7	14.6	2.6	5
D-8362	82.33	64.37	6.83	24.9	13.96	26.87	51	63.8	5.1	3	7.3
D-8370	74.50	63.53	8.91	21.7	14.5	28.63	52	72.1	6.5	2.8	7.3
D-7864	72.50	63.67	7.97	21.6	14.37	27.2	22	108.3	15.5	3.5	5
D-8367	77.17	63.03	8.38	20.2	14.88	28.37	52	71.7	6.1	3.6	8
Mean x	80.20	62.71	8.06	21.45	14.79	28.44	39.72	87.94	10.11	3.12	6.69
Min/Max	62.83-87.33	60.7-64.37	6.04-10.71	13.6-28.9	13.96-16.26	19.2-32.5	19.00-74.33	57.8-108.3	4.6-15.5	1.7-6.0	5.0-8.0
Variance	33.89	0.97	1.40	15.23	0.43	6.94	308.1	241.28	14.66	0.74	1.47
Std. dev.	5.82	0.98	1.18	3.9	0.66	2.64	17.55	15.53	3.83	0.86	1.21
CV	7.26	1.57	14.69	18.2	4.43	9.26	44.20	17.66	37.88	27.63	18.1

V-Vitreousness, % / YS-Yield of semolina, % / YPG- Yellow pigment grain, ppm / TL- Total losses,% / PCG-Protein content grain, % / WGG- Wet gluten grain, % / SDS- sedimentation value, sm^3 / GCG- Gluten compressibility of grain, IDC units / GSG- Gluten softening of grain, mm / DWB- Damage wheat bug, % / CS- Cooking score

Factor analysis was carried out using the principal components method in the collection of 24 pcs. selected durum wheat genotypes based on basic agronomic and quality parameters. As can be seen from the figure, about half of the total variation (46.67%) of the phenotypic expression of genotypes in the studied traits is due to the first two principal components - PC1 and PC2. This value is not great and indicates a significant variety of genotypes for the studied parameters. The applied PC analysis presented on Figure 1 gives information about the correlation between the studied features for the 2014-2016 conditions. Depending on the magnitude of the angle formed between the vectors of each two traits, the correlation dependences between them can be determined.

Positive correlative dependences between some agronomic and quality-related traits have been established: between spike length (SPL) and the quality traits SDS, wet grain gluten (WGG) and cooking quality score (C. Score); between the number of spikelets (SPS) and the wet grain gluten (WGG). There are also positive correlative dependences between some agronomic traits: between yield (Y) and the traits - plant height (PH), 1000 kernel weight (TKW), wet gluten compressibility (GCG). Positive correlation between SDS and kernel number per spike (KNS), kernel weight per spike (KWS) and vitreousness (V), as well as between wet gluten content with spike length (SPL) and vitreousness (V). Between the vectors of some quantitative traits and some of the agronomic trait vectors blunt angles are formed, which indicates the existence of negative correlation between them. Such relationships are found between: yield (Y) and spike length (SPL), vitreousness (V), protein content (PCG), SDS-Sedimentation Volume (SDS) and cooking quality score (C. Score). SDS and plant height (PH). Damage by wheat bug (DWB) and yield (Y), yellow pigment content (YPG) and wet gluten content (WGG). 1000 kernel protein content (TKW). Negative correlation between protein and the traits 1000 kernel weight and hectoliter weight is reported by Matsuo and Dexter (1980), while Bechere et al. (2002) reported high negative correlation between protein content and kernel weight. The interrelations between the quality parameters that are manifested re somewhat influenced by climatic conditions during grain filling. Thus, depending on temperature and humidity during this phase, the correlation coefficients between some quality attributes, such as 1000 kernel weight and protein content and yellow pigment content and SDS volume can be positive, negative or close to zero (Rharrabti et al., 2003).

Multivariance analysis methods are widely used to assess the genetic diversity of selection materials. Figure 2 shows the position of genotypes according to their principal component values PC1 and PC2. When comparing the two figures (Fig. 1 and 2), it is possible to estimate the binding of genotypes in groups by certain traits. The closer the location of the genotype points on Figure 2 to the vectors of the corresponding traits on Fig. 1, the more decisive the trait for their grouping. The studied genotypes are divided into four groups. The first group combines genotypes with the highest SDS, number of kernels per spike, weight of kernels in the spike, hectoliter weight, yellow pigment content in the grain, total losses. It includes 8 of the analyzed genotypes: the standard varieties Predel and Saturn-1, the Bulgarian variety Severina, the foreign variety Selyemdur, the foreign line TD-97 and the

Bulgarian lines D-8362, D-8367 and D-8370. To the second group characterized by the highest levels of protein, gluten, vitreousness and the longest spike belong 4 genotypes: the foreign line DF-009114002 and the three foreign varieties - Betadur, Superdur and Auradur. The third group is characterized by the highest values of the traits number of spikelets in the spike, plant height, damage by wheat bug, compressibility and gluten softening. It contains 6 genotypes - the lines M-6433, M-287, M-376, M-431, M-615, D-8138. The fourth group is characterized by the highest values of the traits yiled, tilleting capacity, 1000 kernel weight and tillering capacity. It contains 6 genotypes - the lines D-7724, DV-8359, D-7864, D-8308, D-8326, D-7557.

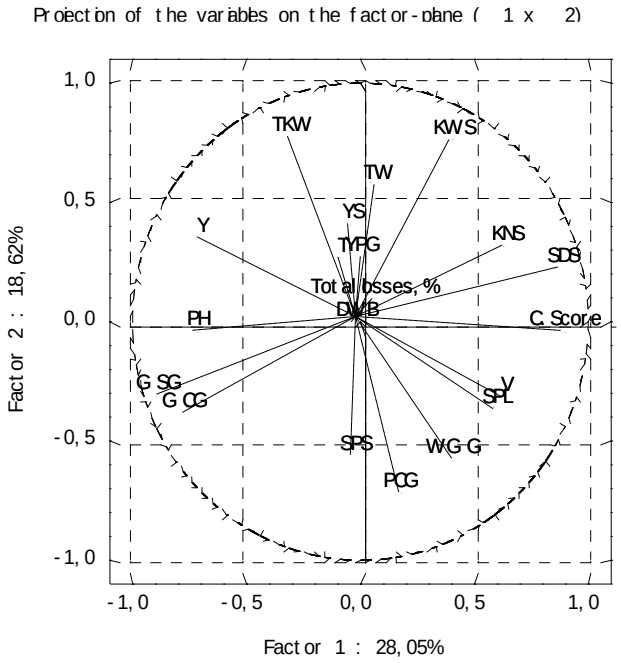

Figure 1. PC analysis of agronomic and quality traits

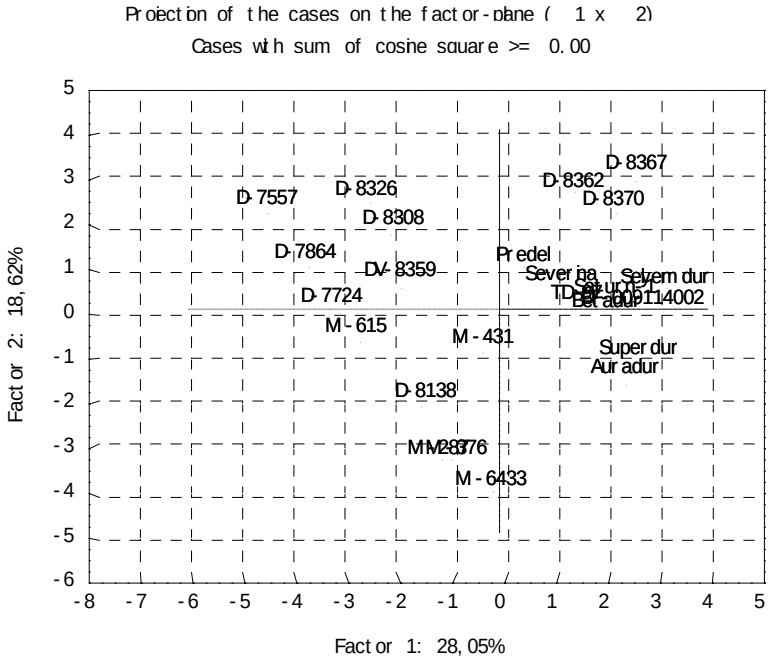

Figure 2. PC analysis of varieties and breeding lines durum wheat

Table 3. Statistically significant correlations

	Y	T	PH	SPL	SPS	KNS	KWS	TW	TKW	V	YS	YPG	TL	PCG	WGG	SDS	GCG	GSG	DWB	CS
Y			0.67	-0.53					0.43	-0.52				-0.47		-0.41	0.46		-0.44	-0.50
PH	0.67					-0.55										-0.53	0.60	0.49		-0.47
SPL										0.59					0.43	0.50				0.60
KNS			-0.55				0.69						0.49			0.60	-0.45	-0.60		0.45
KWS								0.45	0.45							0.44	-0.42	-0.49		
TW									0.53		0.62									
TKW											0.57			-0.48	-0.56					
V														0.45	0.43	0.45		-0.44		0.68
YPG																			-0.41	
WGG					0.45									0.52					-0.54	0.59
SDS																	-0.77	-0.92		0.79
GCG																		0.86		-0.61
GSG																				-0.80

Conclusions

Significant diversity of the studied traits based on the variation coefficients was found. In regard to the agronomic traits the greatest variation was determined for: yield, kernel weight per spike and kernel number per spike. For quality traits the highest variation was recorded for: SDS-value, gluten softening, bug damage degree. The clustering of genotypes based on PC analysis facilitates their evaluation by a set of attributes related to grain yield and quality, and helps to identify genotypes with the best combination between them for future use in the cross-sectional selection. Based on the PC analysis the studied genotypes are divided into different groups. To the group with the highest SDS sedimentation belong 2 foreign varieties, 3 Bulgarian varieties and 3 breeding lines. The group, characterized by the highest content of protein and wet gluten comprises 4 foreign varieties and the group with the highest yield includes 6 breeding lines. Correlation between some agronomic and quality traits was found, too. A statistically proven positive correlation was found between SDS and vitreousness, kernel number per spike, kernel weight per spike, cooking score. A statistically proven negative correlation was established between SDS and yield. A statistically proven positive correlation exists between cooking score and yellow pigment of grain.

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