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CULTIVAR AND ENVIRONMENT EFFECTS ON GRAIN WEIGHT AND SIZE VARIATION IN WINTER WHEAT, GROWN IN A SEMI-CONTINENTAL CLIMATE

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ABSTRACT

Grain weight, which can be dissected into grain length, grain width grain shape and density, is one of the determinants of wheat yield and milling performance. To get more information on cultivar and environment effects on grain weight and size variation in winter wheat, we studied by image analysis grains of 27 wheat cultivars, harvested from yield trials performed in South Romania in three years (2013-2015) with different weather conditions. We found large differences among cultivars for grain weight (TKW), length (L), width (w) and the factor Form*Density (F). Grain length was less influenced by environment than the other grain weight components. Correlation between the three components of grain weight (L, w and F) was low and not significant, suggesting that combining high values of these components might be possible to a certain extent. Considering both the amplitude of variation among studied cultivars and the lower influence of years, grain length seems to be the component with highest probability of determining genetic progress in breeding for grain weight. To obtain most effect of increased grain weight and size on yield, research on the strength and possible deviations from the negative correlation between grain weight and grain number are necessary.

Key words: wheat, grain weight, grain length, grain width, grain density, stability.

INTRODUCTION

Wheat yield can be dissected into three sequentially developed components: number of ears per area, number of grains per ear and weight of individual grains, often expressed as weight of thousand kernels (TKW). As a major contributor to yield, but also to the market value of wheat grain, given its influence milling performance (Marshall et al., 1984), grain size continues to be a major breeding target in wheat. The seed weight is determined by grain length, grain width, grain shape and density. Knowing how much genetic variability is available for these components of grain weight, and how they react to environmental conditions, can contribute to increased genetic progress in breeding for yield and yield stability.

Many recent studies have been dedicated to analysing physiological and genetic determinants of grain size (Gegasa et al., 2010; Breseghello and Sorrels, 2007; Sun et al., 2009). This research had the aim of obtaining more information on cultivar and environment effects on grain weight and size variation in winter wheat, grown in a semi-continental climate, in order to identify possibilities of progress in breeding for larger grains.

MATERIALS AND METHODS

Grain of 27 wheat cultivars, harvested from yield trials performed at Fundulea (South Romania) in 2013, 2014 and 2015 were analysed using 3 replications of 100 grains each. The cultivar set included 21 Romanian cultivars released from 1974 to 2015, and 6 cultivars from France, Russia, Ukraine, Serbia and Austria.

Weather conditions of the three years during wheat vegetation period and especially during the grain filling period, were different (Table 1).

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Table 1. Rainfall distribution and average temperatures during wheat vegetation

Month	Period	2013		2014		2015	
		average t°C	rainfall	average t°C	rainfall	average t°C	rainfall
March	1-10	5.74	2.10	5.34	36.60	4.63	24.20
	11-20	5.91	6.80	9.71	0.30	4.79	5.60
	21-31	3.13	30.10	10.19	1.20	8.09	48.90
		4.93	*39.00*	*8.41*	*38.10*	*5.84*	*78.70*
April	1-10	9.29	24.30	10.57	15.30	7.34	21.60
	11-20	12.23	14.20	9.76	54.80	13.00	15.00
	21-30	18.14	0.00	13.74	12.70	12.59	10.30
		13.22	*38.50*	*11.36*	*82.80*	*10.98*	*46.90*
May	1-10	19.29	5.80	13.53	21.50	17.41	8.00
	11-20	19.39	11.40	15.47	57.10	18.70	2.40
	21-30	18.16	79.90	20.06	22.00	18.90	19.60
		18.95	*97.10*	*16.35*	*100.60*	*18.34*	*30.00*
June	1-10	18.53	42.90	20.21	14.70	**21.53**	**1.60**
	11-20	23.24	19.80	19.40	**70.90**	**22.04**	**19.20**
	21-31	23.29	64.00	19.75	50.60	**19.87**	**31.10**
		21.69	*126.70*	*19.79*	*136.20*	*21.15*	*51.90*
Total rainfall			*354.10*		*359.40*		*248.30*

As shown in the table 1, years 2013 and 2014 had higher rainfall, but not uniformly distributed during the vegetation, while 2015 had less rainfall but more uniformly distributed in time.

For each sample, the weight of one thousand kernels (TKW) was determined as the average weight of three air dried samples of 100 grains each, and was dissected into three components:

$$TKW = L * w * F$$

where: L is the grain length;
w is the grain width;
F is a factor Form*Density, proposed by Giura and Săulescu (1996), and used to describe differences in TKW between grains having the same L and w (Gegasa et al., 2010).

L and w were determined by image analysis of photographs of 100 grains samples, using the software *ImageJ* (http://imagej.nih.gov/ij/)

F was calculated using the formula $F=TKW/(L*w)$.

Results were analysed using ANOVA and Pearson's correlation coefficients.

RESULTS AND DISCUSSION

Large variation was found for TKW, w and F, between the three years of study, while for L the variation was small (Table 2).

Table 2. Average grain size of all genotypes studied in the years 2013, 2014 and 2015

Trait	2013	2014	2015
TKW	40.42	33.64	43.56
Grain length	6.53	6.57	6.45
Grain width	3.27	3.08	3.41
Factor Form-Density	1.90	1.66	1.98

Higher rainfall in June 2014 favoured disease attacks, which caused lower TKW, mainly by reducing grain width and grain density. Highest grain weight was recorded in 2015, with moderate temperatures and rainfall during grain filling.

Larger variations were recorded among the analysed cultivars in the three years average, maximum and minimum values of all studied parameters (Tables 3-6).

Table 3. Average, maximum and minimum values of TKW recorded for studied cultivars

Cultivar	Average TKW (g)	Maximum TKW (g)	Minimum TKW (g)
Diana	45.7	47.2	42.8
Lovrin 231	44.8	48.3	38.0
Dropia	44.7	49.4	38.0
Transilvania 1	43.0	46.2	39.7
Glosa	42.5	47.8	36.2
Flamura 85	41.9	45.7	36.0
Boema 1	41.8	45.7	36.3
Renesansa	41.3	47.0	32.9
Ceres	40.8	42.6	39.3
Pitar	40.7	46.5	35.0
Fundulea 4	39.9	46.0	30.0
Pajura	39.7	43.9	33.0
Dacia	39.4	44.0	34.4
Bezostaia 1	39.4	43.5	34.5
Iulia	39.1	43.3	32.7
Izvor	38.9	44.6	31.8
Litera	38.4	42.1	35.6
Exotic	37.8	41.5	31.6
Miranda	37.4	45.3	28.0
Alex	37.0	42.8	28.8
Otilia	36.8	42.3	30.7
Capo	36.4	37.8	36.0
Odeskaia 51	35.2	37.1	31.7
Fundulea 133	34.7	38.9	31.7
Fundulea 29	33.9	38.5	28.6
Apache	33.8	40.0	24.7
Doina	33.7	38.3	30.4

Heaviest grains were recorded in older Romanian cultivars, among which Diana (= Fiorello*Bezostaya 1), Lovrin 231 (= Bezostaya 1/Fiorello) and Transilvania 1 (= US-60-43/Avrora//T-141-65, where T141-65 was selected from the cross Bezostaya 1/Fiorello), all have in their ancestry the Italian cultivar Fiorello (= Cologna-188/Damiano, where Cologna 188 is a selection from an Italian local population) (http://wheatpedigree.net/). The cultivar Fiorello was described as a valuable parent for increasing grain weight and length (Săulescu, 1970). The same cultivars had the longest grains, on average over 7 mm, while the shortest grains, below 6 mm, were found on average in the cultivar Fundulea 133 (Table 4).

Table 4. Average, maximum and minimum values of grain length recorded for studied cultivars

Cultivar	Average grain length (mm)	Maximum grain length (mm)	Minimum grain length (mm)
Transilvania 1	7.36	7.80	6.77
Lovrin 231	7.31	7.64	7.05
Diana	7.15	7.35	7.01
Alex	6.86	6.94	6.80
Glosa	6.72	6.84	6.60
Ceres	6.69	6.93	6.32
Renesansa	6.66	6.83	6.52
Dropia	6.65	6.79	6.46
Bezostaia 1	6.65	6.97	6.26
Litera	6.61	6.81	6.35
Boema 1	6.60	6.67	6.54
Fundulea 4	6.60	6.73	6.36
Iulia	6.58	6.78	6.37
Flamura 85	6.54	6.74	6.31
Pajura	6.51	6.66	6.42
Miranda	6.45	6.52	6.34
Fundulea 29	6.35	6.73	6.13
Pitar	6.34	6.60	5.97
Apache	6.29	6.72	6.04
Exotic	6.28	6.39	6.14
Izvor	6.26	6.43	6.10
Odeskaia 51	6.23	6.56	6.03
Doina	6.21	6.48	6.08
Capo	6.07	6.15	5.94
Dacia	6.06	6.21	5.79
Otilia	6.01	6.09	5.88
Fundulea 133	5.97	6.14	5.72

Highest values of grain width were measured in cultivars Dropia, a Romanian cultivar released in 1993, in the Serbian cultivar Renesansa, and in the newer

Romanian cultivars Glosa, released in 2005, and Pajura, released in 2014 (Table 5).

Table 5. Average, maximum and minimum values of grain width recorded for studied cultivars

Cultivar	Average grain width (mm)	Maximum grain width (mm)	Minimum grain width (mm)
Dropia	3.40	3.61	3.24
Renesansa	3.40	3.37	3.21
Glosa	3.38	3.58	3.14
Pajura	3.37	3.54	3.09
Boema 1	3.37	3.54	3.14
Litera	3.35	3.44	3.19
Izvor	3.34	3.50	3.06
Pitar	3.33	3.55	3.11
Exotic	3.33	3.49	3.10
Lovrin 231	3.30	3.42	3.20
Dacia	3.29	3.55	3.09
Ceres	3.28	3.33	3.20
Flamura 85	3.27	3.57	3.12
Otilia	3.26	3.41	3.09
Alex	3.26	3.48	2.91
Doina	3.23	3.45	3.03
Apache	3.22	3.33	3.02
Transilvania 1	3.22	3.41	3.00
Diana	3.20	3.46	3.07
Fundulea 4	3.19	3.44	2.96
Odeskaia 51	3.16	3.22	3.12
Fundulea 29	3.15	3.34	2.86
Miranda	3.14	3.24	2.96
Capo	3.14	3.21	3.06
Iulia	3.13	3.32	3.03
Bezostaia 1	3.13	3.33	2.94
Fundulea 133	3.00	3.29	2.85

For the factor F, only the cultivar Diana reached a value of 2, while the lowest values were found in cultivars Alex, Apache, Doina and Fundulea 29, which had values of F lower than 1.7 (Table 6). The low values of the factor F in cultivars Doina and Apache could be explained by the softer texture of their grains.

Table 6. Average, maximum and minimum values of the factor F recorded for studied cultivars

Cultivar	Average F	Maximum F	Minimum F
Diana	2.00	2.09	1.94
Dropia	1.98	2.18	1.72
Dacia	1.97	2.00	1.92
Flamura 85	1.96	2.23	1.71
Pitar	1.94	2.35	1.73
Fundulea 133	1.93	2.03	1.84
Capo	1.91	1.98	1.83
Bezostaia 1	1.89	1.95	1.85
Iulia	1.89	2.00	1.70
Fundulea 4	1.89	2.17	1.51
Boema 1	1.88	1.97	1.75
Otilia	1.88	2.19	1.63
Glosa	1.87	2.02	1.68
Lovrin 231	1.86	2.08	1.56
Ceres	1.86	2.02	1.74
Izvor	1.86	2.12	1.66
Miranda	1.84	2.21	1.46
Transilvania 1	1.83	2.13	1.57
Renesansa	1.82	2.00	1.50
Exotic	1.81	1.99	1.60
Pajura	1.80	1.95	1.67
Odeskaia 51	1.79	1.95	1.55
Litera	1.73	1.93	1.64
Fundulea 29	1.69	1.86	1.59
Doina	1.68	1.83	1.56
Apache	1.67	1.96	1.22
Alex	1.64	1.80	1.45

The amplitude of variation of the three years averages of the studied traits among cultivars was large, being 11.9 g or 30.5% for TKW, 1.39 mm or 21.3% for L, 0.40 mm or 12.3% for w, and 0.36 or 19.5% for F. This suggests that there are considerable possibilities of progress in breeding for increased values of all traits, but mainly for grain length.

ANOVA showed that for TKW, w and F, years explained most of the overall variation, while for grain length (L) most of the observed variation was due to cultivars

(Figure 1). Despite the large difference between years, the interaction Cultivars*Years was small and not significant for all studied traits.

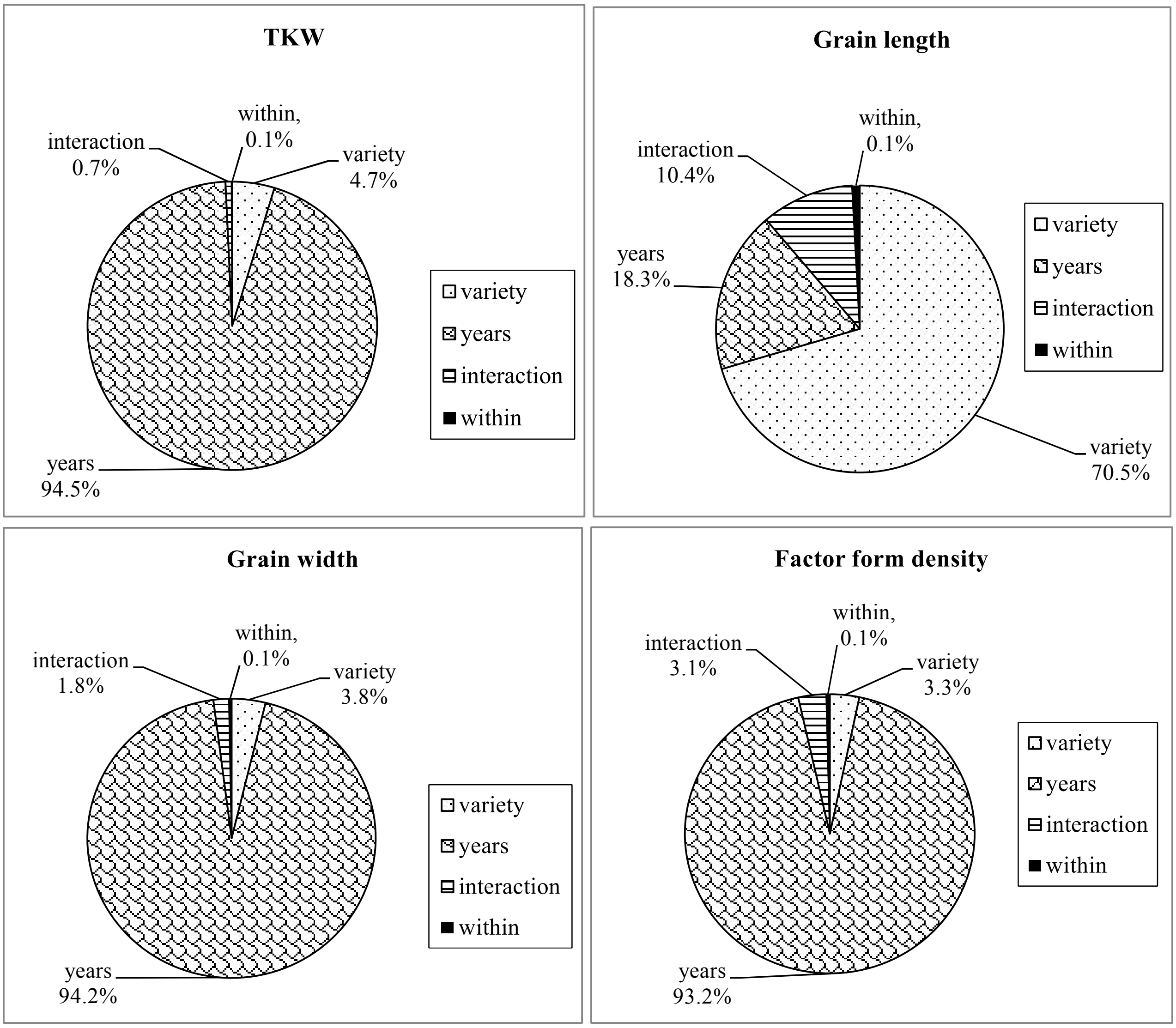

Figure 1. Share of cultivars, years and their interaction in the variation of TKW and its components

All three components of the TKW were significantly correlated with TKW with grain length showing a slightly higher correlation (Figure 2). On the other hand, the correlation among the three components was very low, suggesting that they might be combined by a certain extent. Of course these correlations should be confirmed by studying segregants in crosses between contrasting parents.

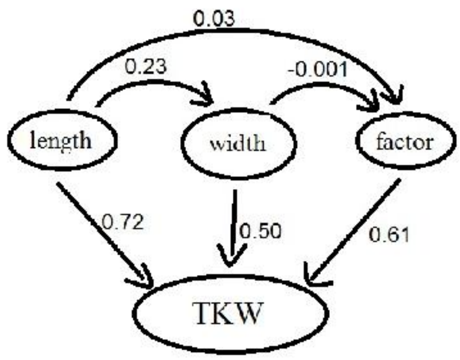

Figure 2. Correlations between TKW and its components

CONCLUSIONS

Dissecting cultivar differences in grain weight by using image analysis of wheat grains provided interesting information that can be used in breeding.

We found large differences among cultivars for grain weight (TKW), grain length (L), grain width (w) and the factor Form*Density, as well as for their stability in different weather conditions.

Grain length was less influenced by environment than the other grain weight components.

Correlation between the three components of grain weight (length, width and the factor form-density) was low and not significant, suggesting that combining high values of these components might be possible to a certain extent.

Considering both the amplitude of variation among studied cultivars and the lower influence of years, grain length seems to be the component with highest probability of determining genetic progress in breeding for grain weight.

Research on the strength and possible deviations from the negative correlation between grain weight and grain number are necessary.

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