

INFLUENCE OF ENVIRONMENTAL CONDITIONS ON RHEOLOGICAL PARAMETERS IN SEVERAL ROMANIAN WINTER WHEAT VARIETIES RELEASED BY NARDI FUNDULEA

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Abstract

*Bread-making quality is a major objective in wheat breeding at NARDI Fundulea. For advancing towards this aim, we use the Reomixer, a device that provide parameters that describe rheological behavior of the dough. We analyzed Reomixer parameters of nine cultivars grown in twenty environments (locations*years) and found the largest variation for parameters "breakdown" and "enwidth" (describing the breakdown of the dough phase) and "peaktime" (describing the dough development phase). Smallest variation was found for "initslope" (describing the water absorption phase) and for grain protein concentration (GPC), while dough strength ("peakheight") and estimated bread volume had intermediate variability. Environments were the main source of variation for GPC, "peakheight" and bread volume, while cultivars had larger influence for "breakdown" and "peaktime". None of the weather parameters analyzed explained more than 10% of the variation in rheological parameters, but in combination produced the observed large variation. Cultivars Pitar, FDL Columna and Voinic had the best average values for GPC, dough strength and bread volume. Our results are useful for wheat breeding programs, opening prospects of breeding for stability of bread-making quality.*

Key words: wheat, environmental conditions, rheological parameters.

INTRODUCTION

Wheat is a major crop contributing to the nutrient supply both worldwide and in Romania. A large part of wheat production is used for making bread, and this makes breadmaking quality an important breeding objective. A flour suitable for bread making was defined as having high water absorption, medium to medium-long mixing requirement, satisfactory mixing

tolerance, good loaf volume potential and a loaf with good internal crumb grain appearance and color (Finney, 1965). As such, bread-making quality is a complex character depending mostly, but not only, on grain protein concentration (GPC) and subunit composition of the proteins (Payne et al., 1984). A strong positive correlation exists between grain protein concentration and the volume of baked loaves (Finney, 1985), as well as between bread-

making quality and particular subunits of glutenin and gliadins (Payne et al., 1984; Sozinov and Poperelya, 1982; Johansson et al., 1999).

Many studies have examined the effects of genotype and environmental conditions during grain development (Peterson et al., 1997; Graybosch et al., 1995; Mikhaylenko et al., 2000; Panozzo and Eagles, 2000; Preston et al., 2001; Yong et al., 2004). The results of these studies have shown that environment, genotype, and genotype by environment ($G \times E$) interactions are all significant factors contributing to variation in quality. However, most of these studies have indicated that environment is the main contributing factor to variation in quality while $G \times E$ interaction contributes a relatively small portion to that variation (Finlay et al., 2007).

Among the methods used to estimate bread-making quality during the wheat breeding process, the Reomixer (Bohlin, 2007) is a convenient way to characterize the mixing properties of the dough (Sedláček and Horčíčka, 2014). Neacșu et al. (2009) found that most information contained in this large number of mixing parameters can be condensed by five parameters, which describe the basic rheological aspects of dough development and are most appropriate for use in breeding: initial slope - “initslope” (IS) describing the water absorption phase; development time - “peaktime” (PT), describing the mixing requirements of the dough; peak height “peakheight” (PH) describing the dough strength or elasticity; dough breakdown - “breakdown” (BD), describing the dough stability or tolerance to over-mixing; and final width - “endwidth” (EW), describing mainly the dough extensibility. The Reomixer software also estimates the bread volume (BV)

This paper reports an analysis of the effects of environments and genotypes on the rheological parameters measured with the Reomixer.

MATERIALS AND METHODS

We analyzed the above mentioned main Reomixer parameters for 180 samples (9 cultivars released by NARDI Fundulea, tested in twenty yield trials conducted all over Romania). Grain Protein concentration (GPC) was

analyzed spectrophotometrically using the FOSS Infratech 1241.

The testing sites covered a large diversity of soils, from chernozems to luvisols, and of weather conditions, which during the period 2021-2024 reflected present climate changes and were diverse, as illustrated by rainfall during the vegetation period, which varied from 211.2 to 613.8 mm. Crop management of these trials was the one recommended for each environment, including the recommended Nitrogen fertilization (which varied from 82 to 143 kg N/ha).

We analyzed data using ANOVA, regression, and correlations. Regressions on average values of the trial were used to analyze cultivar response to environment (Finlay and Wilkinson, 1963). We used weather data on rainfall and temperatures to study relationships with Reomixer parameters.

RESULTS AND DISCUSSIONS

All analyzed parameters showed exceptionally large variations among the 180 samples (Table 1). The largest variation was found for Breakdown and Peaktime, and the smallest for Grain protein concentration and Initslope.

Table 1. Variation of Reomixer parameters

	BV	GPC	IS	PT	PH	BD	EW
s%	16.96	11.4	11.64	44.32	17.04	98.83	32.48
Max.	1247.5	16.9	9.7	10.0	7.0	5.5	2.95
Min.	512	9.0	5.1	1.3	2.9	0	0.45
Amplitude	735.5	7.9	4.6	8.7	4.1	5.5	2.5
Amplitude, %	85.98	61.4	62.5	181.8	85.1	509.5	172.4

Environments were the main source variation for Bread volume, GPC and Peakheight, while cultivars contributed most to the variation of Peaktime and Breakdown (Table 2). The interaction Cultivar*Environment had a smaller contribution, being the main source variation only for Endwidth.

Table 2. Sources of variation contribution to the variation of Reomixer parameters (%),

	BV	GPC	IS	PT	PH	BD	EW
Environments	59.6	76.6	41.7	29.7	57.5	18.1	26.3
Cultivars	12.8	4.2	21	43.4	15.2	43.5	34
C*Env	27.6	19.2	37.3	26.9	27.3	38.4	39.7

Figures 1-4 illustrate the different contribution of the three sources of variation to the total variation of different parameters.

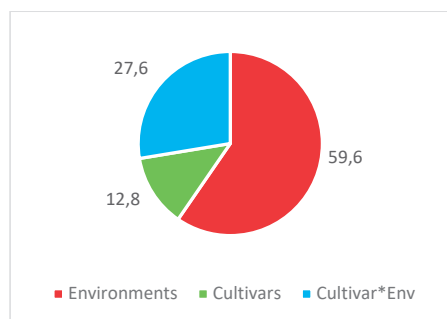


Figure 1. Sources contribution to the variation of BV

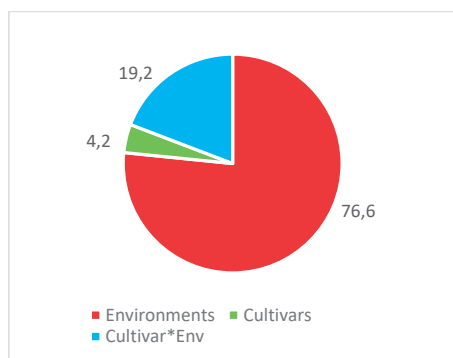


Figure 2. Sources contribution to the variation of GPC

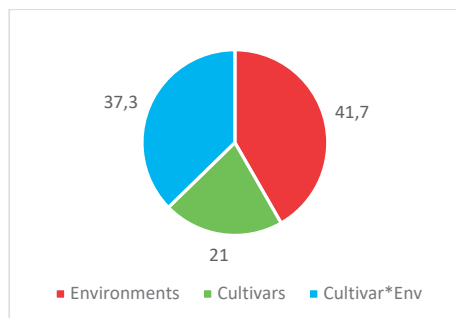


Figure 3. Sources contribution to the variation of IS

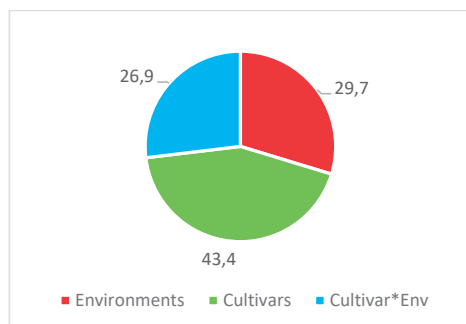


Figure 4. Sources contribution to the variation of Peaktime

For the analyzed samples, grain yield was not significantly correlated with rheological parameters (Table 3), except for the phenotypic negative correlation between yield and both IS and BD.

Table 3. Correlations between yield and quality parameters

	Yield	GPC	IS	PT	PH	BD	EW
GPC	<i>0.02</i>	1					
	<i>0.25</i>	1					
IS	<i>-0.20</i>	<i>-0.23</i>	1				
	-0.57	0.40	1				
PT	<i>0.18</i>	0.64	-0.80	1			
	<i>0.40</i>	0.24	-0.50	1			
PH	<i>-0.47</i>	0.60	0.45	<i>-0.11</i>	1		
	<i>0.08</i>	0.85	0.65	0.04	1		
BD	<i>-0.13</i>	-0.74	0.76	-0.95	<i>-0.10</i>	1	
	-0.54	<i>-0.11</i>	0.61	-0.54	0.28	1	
EW	<i>0.13</i>	0.74	-0.80	0.97	0.07	-1.00	1
	<i>0.35</i>	0.37	<i>-0.20</i>	0.66	0.23	-0.70	1
BV	<i>-0.37</i>	0.82	0.06	0.26	0.91	<i>-0.5</i>	0.44
	<i>0.23</i>	0.92	0.49	0.17	0.97	0.11	0.32

Italic = genetic correlations;

Normal = phenotypic correlations;

Bold = significant at $P < 5\%$.

The nonsignificant correlation between grain yield and GPC was unexpected and might be due to the limited yield variation in the analyzed trials but can also suggest that combining yield potential with quality can be feasible to some extent.

Figure 5 illustrates the large cultivar differences in the relationship between yield and protein concentration.

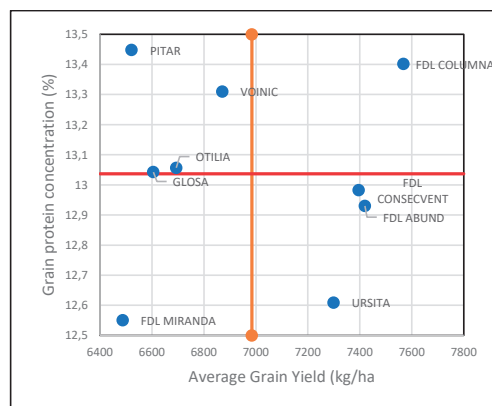


Figure 5. Relationship between grain yield and protein concentration in nine wheat cultivars

If the cultivar Pitar which had the highest protein content was among the lowest yielding cultivars, FDL Columna, the second highest in grain

protein concentration had the highest average yield. Cultivars FDL Consecvent and FDL Abund, which were placed second and third in yield had average grain protein percentage, while FDL Miranda and Ursita with the lowest grain protein concentrations had contrasting yields.

GPC was strongly correlated with bread volume, both genetically and phenotypically, with protein concentration explaining more than 65% of the bread volume variation. Higher protein content was also associated with better dough strength (PH).

Fast water absorption (high IS) was strongly associated with reduced mixing requirements (small PT) and with low dough stability (high BD), both between cultivars and between environments, High mixing requirements (PT) were associated with dough stability (low BD) and with better dough extensibility (high EW). High dough stability showed perfect genetic association with low dough extensibility (correlation of $r = -1$ between BD and EW), which suggests common genetic control. Cultivars were significantly different in all analyzed quality parameters (Table 4). Cultivar Pitar ranked first for bread volume, grain protein concentration and dough strength (peak height), while Glosa ranked first for water absorption, Otilia for peak time and FDL Abund for dough stability (low breakdown value).

Table 4. Average reomixer parameters in nine wheat cultivars

	BV	GPC	IS	PT	PH	BD	EW
Pitar	933	13.45	7.58	6.12	5.33	0.64	1.68
Voinic	907	13.31	6.95	5.71	4.99	0.7	1.63
Glosa	906	13.04	7.85	3.49	5.25	1.56	1.25
FDL Columna	898	13.40	7.38	5.48	5.01	0.58	1.64
FDL Abund	842	12.93	6.86	6.37	4.60	0.50	1.73
Otilia	833	13.06	6.68	7.07	4.47	0.25	1.80
Miranda	829	12.55	7.59	2.97	4.8	1.94	1.11
FDL Consecvent	803	12.98	7.23	5.52	4.46	0.83	1.51
Ursita	771	12.61	7.75	3.31	4.48	2.43	1
Average	858	13.04	7.32	5.12	4.82	1.05	1.48

The analyzed cultivars responded differently to environmental conditions. To characterize the cultivar specific response to the environment we calculated the amplitude of variation and

analyzed the regression of traits for each cultivar on the average value of all cultivars in the trial, as recommended by Finlay and Wilkinson (1963). Cultivars combining high average values with low variation amplitudes and regression slopes, as well as positive intercepts would be desirable having better stability. This type of analysis is presented in table 5 for bread volume.

Table 5. Response of BV to environmental conditions in nine wheat cultivars

	Average BV	Amplitude	b	a
Pitar	933	495	1.152	-56.2
Voinic	907	426	0.922	115.5
Glosa	906	479	0.889	143.6
FDL Columna	898	624	1.117	-60.4
FDL Abund	842	539	1.12	-119.2
Otilia	833	617	1.304	-285.8
FDL Miranda	829	536	0.94	22.7
FDL Consecvent	803	552	0.985	-41.7
Ursita	771	316	0.571	280.8

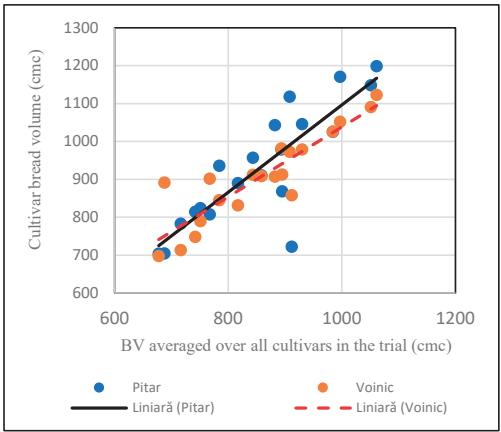


Figure 6. Bread volume variation in cultivars Pitar and Voinic

Figure 6 illustrates the difference between cultivars Pitar and Voinic, both having high values of bread volume, the last one responding less to environmental variation. Cultivars Otilia and FDL Miranda also showed different responses to environment, while having similar average bread volume (Figure 7).

The same type of analysis of cultivar response to environment is presented in Table 6 for grain protein concentration.

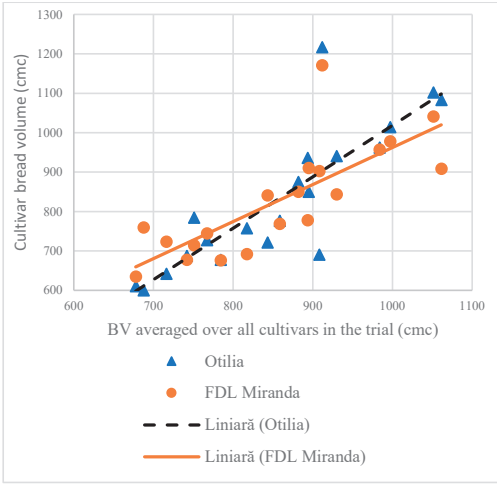


Figure 7. Bread volume variation in cultivars Otilia and FDL Miranda

The same type of analysis of cultivar response to environment is presented in Table 6 for grain protein concentration.

Table 6. Response of GPC to environmental conditions in nine wheat cultivars

	Average GPC	Amplitude	b	a
Voinic	13.3	4.4	0.739	3.70
Glosa	13.0	3.7	0.856	1.91
FDL Miranda	12.6	4.3	0.901	0.84
Ursita	12.6	4.5	0.911	0.76
Otilia	13.1	4.5	0.918	1.12
FDL Columna	13.4	6.1	1.055	-0.31
Pitar	13.4	5.8	1.066	-0.41
FDL Abund	12.9	6.7	1.097	-1.33
FDL Consequent	12.3	7.1	1.197	-2.59

The amplitude of variation between the maximum and minimum values recorded for each cultivar varied from 3.7% in cultivar Glosa to 7.1% in FDL Consequent. The regression slope varied from 0.739 to 1.197 and the regression intercept varied from +3.70 to -2.59. Figure 8 illustrates the response of GPC to environmental conditions in two contrasting cultivars, Glosa and FDL Consequent.

We observed contrasting cultivar responses to environment for dough stability (Table 7). Cultivar FDL Abund, with good average dough stability, showed almost constant Breakdown value in all twenty trials, while Ursita, with the lowest average dough stability, showed exceptionally large BD variation (Figure 9).

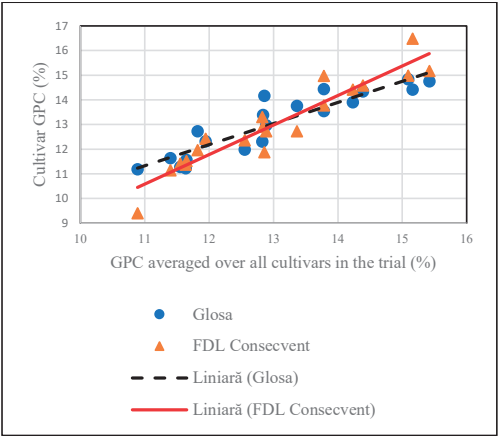


Figure 8. Variation of GPC in cultivars Glosa and FDL Consequent

Table 7. BD response to environmental conditions in nine wheat cultivars

	Average BD	Amplitude	b	a
Otilia	0.25	0.98	0.203	0.04
FDL Abund	0.36	0.99	0.217	0.13
FDL Columna	0.58	1.46	0.729	-0.17
Pitar	0.64	1.53	0.644	-0.03
Voinic	0.69	3.6	1.192	-0.53
FDL Consequent	0.83	3.37	0.825	-0.02
Glosa	1.56	3.46	1.507	0.01
FDL Miranda	1.93	3.28	1.045	0.86
Ursita	2.42	5.43	2.636	0.29

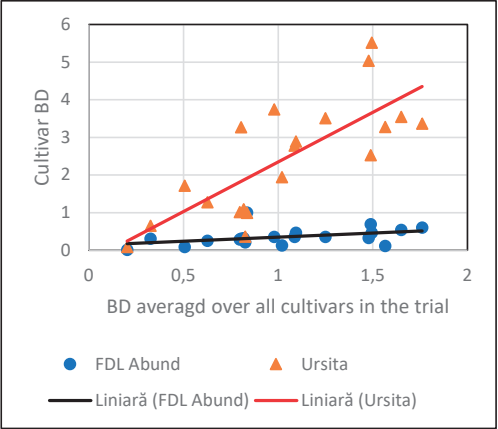


Figure 9. Variation of BD in cultivars Ursita and FDL Abund

We could not associate the variation of Reomixer parameters with specific weather data, as none of the simple, brief period analyzed weather parameters explained more than 10% of the variation in rheological results.

CONCLUSIONS

We found exceptionally large variation of all Reomixer parameters in the one hundred eighty samples analyzed, with the largest variation found for Breakdown and Peaktime, and the smallest for Grain protein concentration and Initslope. Environments were the main source of variation for GPC, “peakheight” and bread volume, while cultivars had larger influence for “breakdown” and “peaktime”. The interaction between cultivars and environments was the main source of variation for dough extensibility (EW).

Grain yield showed no genetic correlation with the Reomixer parameters. High grain protein concentrations were found in low yielding cultivars, but also in cultivar FDL Columna, which produced the highest average yield. Phenotypic correlations were significant only with IS and BD.

GPC was strongly correlated genetically and phenotypically with bread volume and with dough strength (PH), while fast water absorption (high IS) was strongly associated with reduced mixing requirements (small PT) and with low dough stability. Mixing requirements (PT) was negatively associated with dough stability and positively with dough extensibility.

The analyzed cultivars responded differently to environmental conditions as shown by contrasting amplitudes of variation, slopes, and intercepts of Finlay-Wilkinson regressions. This finding opens prospects for breeding to improve bread-making quality stability in diverse environmental conditions.

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