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INFLUENCE OF EXTREME ENVIRONMENTAL CHANGES ON GRAIN QUALITY OF WINTER COMMON WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

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*Situation and purpose***:** A field experiment was carried out under the conditions of north-eastern Bulgaria to establish the effect of the long and severe drought in 2007 on common wheat grain quality. For this purpose, grain quality-determining parameters formed during the two contrasting years were compared.

Methods: Under the field conditions of a competitive varietal trial the most important indices which characterize grain quality were analyzed. The comparison was based on the data of the indices during year 2006 which was very favorable for formation of high quality grain. The grain quality, expressed through its specific parameters, of dozens of promising lines was analyzed in detail and compared to model cultivars. The actual change of the quality indices was followed in direct relation to the genetic nature of the investigated genotypes.

Key results: Under long drought, grain quality changed in various ways specific for each quality index. Test weight increased while protein content and sedimentation did not change significantly. All other characters were affected negatively.

Conclusions: Under drought, the indices related to dough strength and bread making quality – dough resistance, valorimetric value and loaf volume – suffered highest negative effect. When grain quality changed, the lower the genetic potential for quality of a given variety, the less its indices varied. This explains the high variation in the quality of the strong wheat varieties under changeable year conditions.

Key words: wheat, extreme environments, grain quality, drought

Introduction

Grain quality is especially important for wheat since this is a crop of global significance as a food for human consumption. Grain quality is formed under the specific growing environment (Tsenov et al., 2004; Williams et al., 2008; Hristov et al., 2010). Wheat biology is unique and allows successful cultivation under various climatic conditions, and its vegetation period varies within a very wide range (from 100 to 300 days in a season). This is a prerequisite for a tangible effect of the seasonal conditions on the product: the grain with its yield and quality (Vázquez et al., 2012; Sharma et al., 2010). Breeding for developing of accessions with high grain quality is a long and complex process, the success of which is by no means guaranteed (Knott et al., 2009; Baenziger et al., 2001). Wheat production nowadays requires high grain yield of maximum quality (Tsenov et al., 2009; Tsenov et al., 2008). According to Gomez-Beccera et al. (2010), Ortiz et al. (2008), Graybosch and Peterson (2010), the climatic changes during the recent years pose even greater challenges for high grain quality breeding, especially under conditions where water supply is a limiting factor for wheat growing.

Logically the question arises if it is possible to develop varieties with high grain quality "reserve": under the negative effect of drought or extreme high temperatures during grain filling the formed grain quality to be relatively high (Tsenov et al., 1998; Tsenov et al., 2010). The studies of Zhang et al. (2013) and Li et al. (2013) have demonstrated a significant positive impact of drought and high temperatures on various parameters of grain and bread making quality, the role of the genotype being very important. The results from our researches on different groups of varieties and during different periods of time (Atanasova et al., 2010; Tsenov et al., 2010) showed that the conditions of the growing season had the highest effect on quality while the genetics of the variety affected positively only dough strength through the pa-

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rameter dough resistance. Other publications of Atanasova et al. (2012) and Tsenov et al. (2013) reported that drought had highest and negative effect on the indices related to strength of dough: dough resistance and valorimetric value.

Therefore, this study aimed to follow the effect of drought on grain quality of winter bread wheat by investigating a large number of cultivars and promising breeding lines.

Material and Methods

Meteorological conditions

The meteorological conditions during vegetation of bread wheat in 2007 were rather unusual for the region of Dobrudzha where Dobrudzha Agricultural Institute is situated. The long periods of scarce rainfalls as compared to the climatic norm presented as a case of interesting comparison to similar extreme year conditions (Figure 1). It turned out that this season ranked first since the beginning of meteorological observations in 1953 by amount of rainfalls during wheat vegetation. Especially low were the rainfalls during autumn and winter and during active spring vegetation of the crop. The year 2007 was unique with its conditions as compared to the mean values of the two most important factors for growth and development of plants – air temperature (Figure 3) and amount of rainfalls (Figure 2). The rainfalls during wheat vegetation (October – July) in the investigated year marked and extreme **minimum.** The rainfalls distributed by periods were only 44 % from the norm of the 50-year period of observations. Lowest was the sum of precipitation during active spring vegetation (April – July), only about 1/3 of the norm for Dobrudzha region.

Air temperature marked a climatic **maximum** during the entire wheat-growing season. The mean monthly air temperature was with about 2.2°C higher than the norm, which ranked year 2007 first according to this value. The temperature in 2001 ranked fourth with 1.6° higher than the norm (data not given). During the other years with extreme low rainfalls presented in Figure 1 (1968, 1974 and 1962), the air temperature was very close to the mean climatic norm. Especially high was the air temperature during grain filling (June – July), when it exceeded the norm for this period by 3.6°C. Therefore 2007 can be considered unique from the point of view of the severe and long-lasting drought generated by maximum high temperatures and minimum low rainfalls as compared to the mean values for the region.

The conditions in 2006 were characterized with temperatures close to the norm for each month of the vegetation and with rainfalls with about 10 % higher than the climatic norm of 525 mm. In this respect, the year can be considered favorable for the growth and development of wheat and for formation of

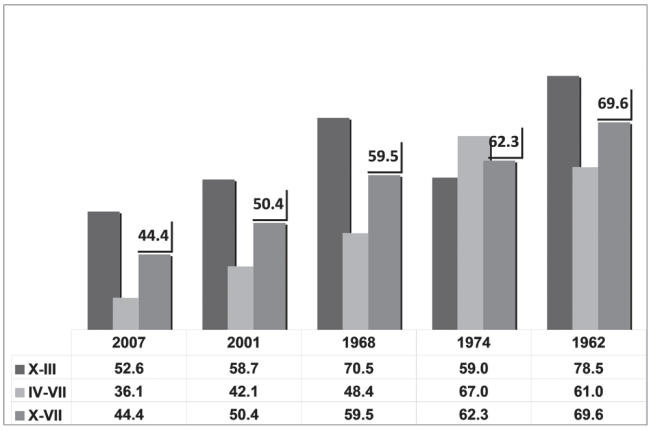

Fig. 1. Years with lowest amounts of rainfall by vegetation periods compared to the climatic norm in the region of DAI

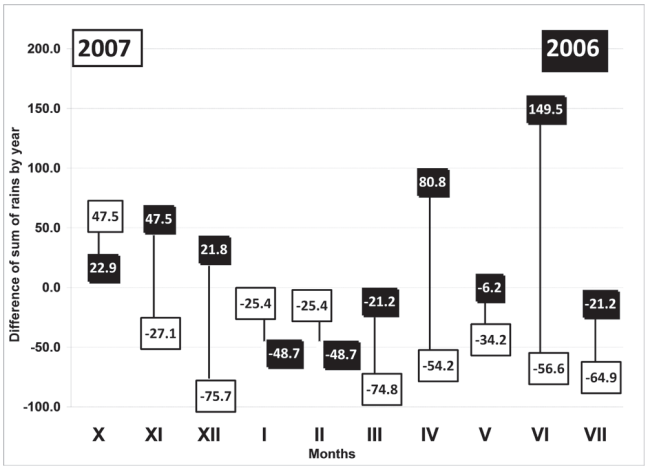

Fig. 2. Variation in the amounts of rainfalls by vegetation months according to DAI climatic norm

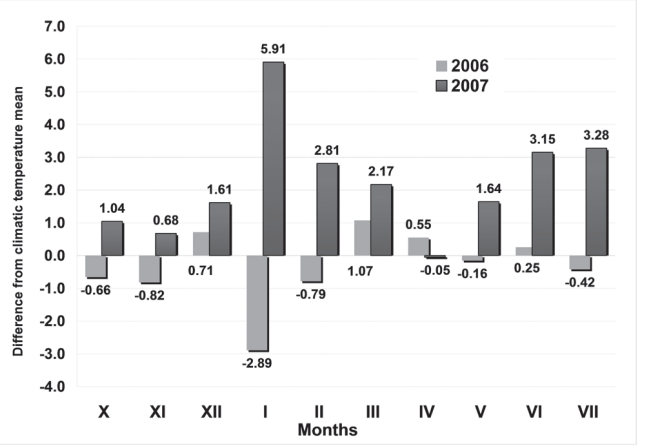

Fig. 3. Variation of the mean monthly air temperature during wheat growth in the two investigated years compared to the mean value for the period 1953-2007

high grain quality. All aspects of grain quality are influenced by the growing conditions (Atanasova et al., 2009; Stoeva et al., 2006; Tsenov et al., 2010) and in this relation, it would be interesting to compare quality under favorable conditions (2006) with quality under severe and long drought (2007).

Breeding material

Thirty-six promising lines and 72 cultivars developed at DAI, which were grown in a competitive varietal trial during two contrasting years, were selected. The breeding lines were divided into three groups according to their genetic potential for quality: strong wheats (group A), medium wheats with increased strength (group B) and wheats of medium strength (group C). Cultivars Aglika, Sadovo 1 and Pryaspa were used as respective standards for each of these groups. Ten different indices of quality were investigated: test weight, sedimentation, wet gluten content, protein content (quality index), dough resistance, dough softening, valorimeter, loaf volume and H/D ratio. These indices were analyzed at the Laboratory of bread making quality of DAI according to the methodology described in detail by Atanasova et al. (2010).

The specific combination of temperature and moisture during grain filling of wheat in 2007 implied higher grain quality (Figure 2). The obtained data, however, contradicted this implication; therefore, additional statistical analysis was performed on another two groups of lines (36) and cultivars (72) to check if wheat quality worsened overall as a result from the drought.

The data obtained from the investigation were analyzed with the help of the statistical software XLSTAT Ver. 2009, and significant differences were found between the values of the indices.

Results

The data in Table 1 show significant variations in the values of almost all indices. During the two years of study the data from 2007 were significantly lower (Table 2). Test weight, softening degree and protein content in grain (PC) were exceptions. For the first index, the stress conditions favored higher grain filling. The response of the second index, the response was in the same direction because the higher value of this index determines lower quality, so in practice there was decrease in quality. The values of the third index were not significantly different. Similar was the tendency of change in the standard cultivars of the respective quality groups: Aglika for the first group, Sadovo 1 for the second group and Pryaspa for the third group. Thus, for example, PC was lower in cultivar Aglika, which affected the high level of the quality index and it did not decrease significantly in 2007.

For a large part of the grain quality indices, this was confirmed almost entirely. Variation according to the data from Table 3 was not found only for the index test weight in both investigated groups. Variations were not observed for dough softening, grain hardiness and ratio of the bread in the group of 36 lines. The lower values of all other indices in 2007 were significant according to the Dunkan's test. Markedly distinct were the variations of the indices, which most affect dough strength: valorimeter and dough resistance, although the latter was unusually low by absolute values in both years of investigation.

When comparing the new breeding materials to the cultivars already developed, it was found that in some indices such as grain hardiness, dough softening and ratio of the bread (Table 3) the values during the two years did not differ significantly. In the group of cultivars, there were significant variations according to the above indices: positive for the first index and negative for the other two in 2007 as compared to 2006.

Discussion

Figure 4 visualizes the variation of each index in 2007 according to its values in 2006, a year which was considered a comparative basis. The values designated as "mean" were averaged for all investigated lines. To obtain a more complete characterization, this response was compared to the response of the quality standards.

Grain quality decreased most through the indices dough resistance (0.62); wet gluten content (0.75), loaf volume and valorimeter, with 15 and 20 %, respectively. There was almost no difference in grain protein content (1.0) and sedimentation (0.93), which reflected on an analogous reaction of the quality index (0.92). There was a low variation in test weigh (1.05) in a positive direction. The results obtained in

Table 1
Univariate ANOVA of traits studied

Dependent variable	Mean square	F	Sig.
Test weight	285.764	63.13	.0000
Sedimentation value	379.524	5.30	.0225
Wet Gluten Content	946.584	104.64	.0000
Dough tolerance	28.764	24.07	.0000
Dough softening	7692.169	17.72	.0000
Valorimetric value	1382.175	39.60	.0000
Loaf Volume	511543.524	113.56	.0000
Ratio of the bread H/D	.026	17.56	.0000
Grain protein content	.926	1.39	.2387
Quality index	3.154	5.13	.0248

this study contradict the conclusions in the publications of Zhang et al. (2013) and Li et al. (2013), who reported a positive effect of drought and high temperature on different parameters of grain and bread quality.

The response of the cultivars with different grain quality was of variable degree and direction and was the reason to subject to separate analyses the variations of the quality indices of cultivars with different genetic potential (Figure 5). To follow possible variation of the individual parameters according to their genetic grain quality potential, the variations of each index were calculated according to the variation of the entire group of investigated cultivars and lines. For the index test weight, the cultivars of different quality group reacted in a similar way.

Table 2
Mean values of the individual parameters of all breeding materials and standards of the respective groups of cultivars during the two years of the trial

Quality parameter	Year	Mean	Sig. of difference	Aglika	Sadovo 1	Pryspa
Test weight, kg	2006	80.2	.0000	81.6	79.4	76.4
	2007	82.8		83.8	84.7	79.5
Sedimentation value, ml	2006	43.6	.0225	67.0	50.0	30.0
	2007	40.6		59.0	39.0	24.0
Quality index, Sed/PC	2006	4.22	.0248	5.4	4.2	3.2
	2007	3.94		5.5	3.6	2.9
Wet gluten content, %	2006	24.3	.0000	23.9	27.1	20.7
	2007	19.5		19.7	21.8	16.1
Dough tolerance, min	2006	2.46	.0000	8.5	3.3	1.3
	2007	1.62		5.5	2.3	1.5
Dough softening	2006	80.8	.0000	50	90	95
	2007	94.4		90	70	100
Valorimeter	2006	49.0	.0000	75	52	41
	2007	43.2		56	49	42
Loaf volume, cm^3	2006	728	.0000	900	760	680
	2007	617		675	650	450
Ratio of the bread, H/D	2006	.46	.0000	0.58	0.42	0.47
	2007	.43		0.51	0.31	0.39
Grain protein content	2006	10.41	.2387	12.4	11.9	9.4
	2007	10.26		10.7	10.8	8.3

Table 3
Mean values of the quality parameters averaged for the groups of breeding lines and cultivars developed at DAI

Quality parameter	36 breeding lines		72 varieties	
	2006	2007	2006	2007
Test weight, kg	82.7 a	83.1 a	81.2 a	81.8 a
Grain vitreousness, %			34.1 b	48.1 a
Grain hardiness, index	74.2 a	75.7 a	69.7 b	80.2 a
Sedimentation value, ml	41.2 a	38.1 b	38.1 a	34.1 b
Wet gluten content, %	22.8 a	20.6 b	23.6 a	20.8 b
Dough tolerance, min	1.90 a	1.31 b	1.90 a	1.42 b
Dough softening	85.3 a	87.8 a	86.7 b	116 a
Valorimeter	45.3 a	41.9 b	45.4 a	40.5 b
Loaf volume, cm^3	659 a	624 b	694 a	620 b
Ratio of the bread, H/D	0.44 a	0.45 a	0.45 a	0.40 b

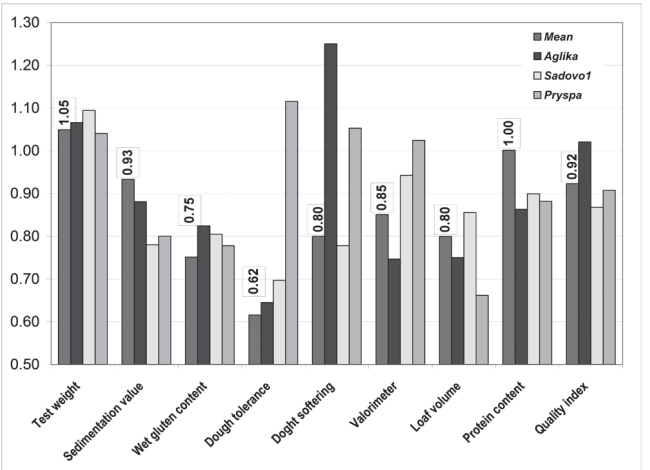

Fig. 4. Variation of the quality indices in the standard cultivars and averaged for the entire group of investigated varieties during 2007 in comparison to 2006, %

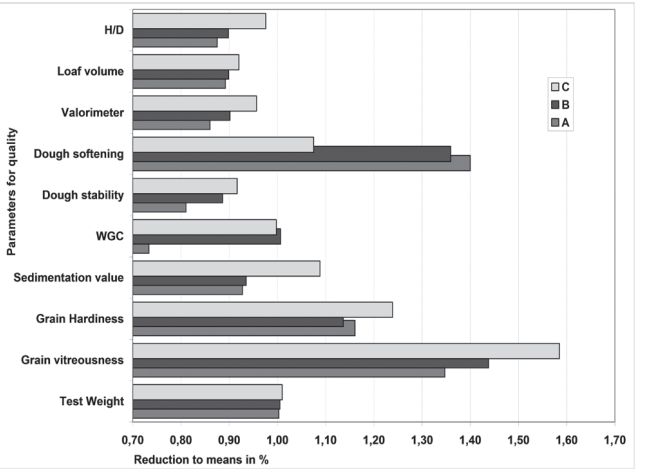

Fig. 5. Variation of the quality parameters of strong (A), medium with increased strength (B) and medium (C) quality groups of cultivars and lines during 2007 in comparison to 2006

Twenty of the high quality lines decreased to a greatest extent their values of dough resistance, degree of softening (the higher values were negative), valorimeter and loaf volume. The cultivars from the second quality group strongly decreased their values of sedimentation, wet gluten content and the quality index. In fact, these indices expressed their most negative response to the stress conditions during the year.

The cultivars with the lowest genetic potential for quality (12 cultivars) showed significantly lower variation of almost all their indices in comparison to the other two groups. The only exception was the response of test weight, but in this case, the variations were similar to that of the other groups.

The data undoubtedly show that stress has higher negative effect on the high-quality cultivars; the lower the quality, the more stable the indices of a cultivar are and less changeable under the conditions during grain filling. Similar results were published by many authors who studied the same problem under very contrasting environments (Drezner et al., 2007; Gomez-Beccera et al., 2010; Sharma et al., 2010). Many of them reach the same conclusion that the growing conditions have significant effect on grain quality (Yong et al., 2004; Graybosch and Peterson, 2010), as well as the genetic potential for quality of the cultivar (Chamurliyski et al., 2011; Li et al., 2013). Only a limited number of publications make a distinction between the response of the genotype in relation to the genetic level of grain quality, such as the investigations of (Ivanova et al., 2013; Atanasova et al., 2012).

Conclusions

Under long and severe drought caused by high air temperatures and insufficiency of soil moisture, deterioration of grain quality is observed in comparison to the normal conditions during grain filling period.

During grain filling stage under stress conditions, the indices related to the physical properties of grain increase (grain vitreousness and hardiness).

Under drought, dough strength decreases most noticeably through the indices dough resistance and valorimeter.

Under conditions of stress, the lower the quality of a given cultivar, the less changeable its quality indices are.

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