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EFFECTS OF DROUGHT ON GRAIN PRODUCTIVITY AND QUALITY IN WINTER BREAD WHEAT

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Abstract

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Background and Aims: The aim of the study is to determine the influence of strong and continuous drought on yield and grain quality of bread wheat in Dobrudzha region. The levels of yield and grain quality through their components and parameters generated in contrast to both drought and favorable years are directly compared.

Methods: In field conditions in Competitive yield trails grain yield and some traits, directly or indirectly associated with it are analyzed, and the most important parameters characterizing the quality of grain, too. Basis for comparison data from a favorable yield and quality of grain in 2006 was used. A detailed analysis of any change of trait of productivity and quality index of 65 advanced breeding lines was made. Specific change of individual indexes of quality of grain depends directly on the genetic nature of the studied genotypes.

Key results: Prolonged drought reduces most grain yield, resulting in reduction of all traits associated with it. The most conservative trait is 1000 kernel weight, which changes the least, while most reduce the number of productive tillers. In grain quality the drought changes inadequate individual trait performance. Specific weight increases, and the protein content and sedimentation value is not substantially altered. All other indexes are changed in fairly negatively to varying degrees.

Conclusions: The highest grain yield under drought in Dobrudzha has breeding lines that fail to form the highest number of grains per spike. Notwithstanding the terms of the year grain yield is determined most strongly by the trait number of kernels per spike. Under drought the most negatively affected performance have the strength of the dough and the quality of the grain-dough stability, including valorimetric value and loaf volume. When changing the quality of grain as lower the genetic quality talents of a variety, so the values of its parameters are changed slightly. This explains the wide variation in quality of wheat due to strong differences in terms of year conditions.

Key words: grain yield, components of yield, grain quality, drought, breeding lines

Abbreviations: GY - grain yield; WGE - weight of grain per ear; NGS – number of grains per spike; TGW - a 1000 grain weight; NPT - number of productive tillers, DE - date ear emergence, HOS - height of the stem; WGS - Weight of Grains per Spike; STW - specific test weight; GV - grain vitreous, GH - grain hardiness; SVF - sedimentation value of flour; WGC - wet gluten content; DT - dough tolerance (stability); DS - dough softening ; Val - valorimetric value; LV - loaf volume; H/D - Ratio of the bread H/D

Introduction

Variety of wheat has an effect in realization of the productive potential of about 10-12% compared to the other factors in the growing conditions in our country. In a periodic or prolonged drought the variety can have significantly stronger effect than usual (Tsenov, 2006; Tsenov et al., 2009). Grain yield losses are so much smaller, the more tolerant varieties in production (Boyadjieva, 1999). Wheat in our environments is fully grown without irrigation, because wheat varieties used

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should have good tolerance to drought (TD) and high temperatures (heat tolerance) (Boyadjieva, 2002; Mustatea et al., 2003). Effective breeding on TD makes it very difficult mainly due to the inability to measure fully and adopt realistic evaluation criteria.

Maintaining the productivity of wheat in the emerging trend of annual meteorological anomalies nowadays can be done mainly by increasing its adaptability (Halim et al., 2002). The improvement of winter wheat by conventional breeding becomes more and more difficult. In the past and now scientists are looking for a combination of different approaches to increase the productive potential (Acreche and Slafer, 2009; Sorrells, 2007). According to several authors (Fischer and Edmedes, 2010; Kirkegaard et al., 2008; Sherman et al., 2005) only the combination of different breeding, genetic, biochemical, and physiological approaches is a prerequisite for an appreciable success, having achieved high levels of productivity in certain conditions, including native breeding (Boyadjieva et al., 2009; Tsenov et al., 2010) .

This high level of productivity coupled with drought tolerance will be a major challenge for breeding in the future in Balkan region (Boyadjieva et al., 2009; Dencic and Kobiljski, 2008). Major factor that interferes seriously on the real yield and quality of grain were growing conditions (Paunescu and Boghic, 2008; Yan and Fregeau-Reid, 2008), particularly the abiotic stress. Their share on the variation of yield and grain quality is becoming more visible and unpredictable in relation to current climate change, which is discussed in recent years (Anwar et al., 2007; Ortiz et al., 2008; Reynolds et al., 2009).

Needs in terms of quality of wheat are constant, the traditions and the established products for consumption (Shewry, 2009). In turn, this is why improving the quality of grain is one of the main tasks for the breeding of winter wheat (Drezner et al., 2006). Expectations for high quality production of grain received in all of the chain to the production of bread and bakery products are now huge (Hristov et al., 2010; Tsenov et al., 2010), mainly due to the strong influence of the conditions on its formation even in consecutive seasons. Therefore, even in a drought and other climatic anomalies (Ivanova and Tsenov, 2009; Tsenov et al., 2008) new varieties is necessary to realize the maximum of their genetic potential. The combination of high yield and quality of grain is the most serious challenge to modern wheat breeding (Dencic and Kobiljski, 2008; Trethowan et al., 2001; Tsenov et al., 2010), because it is associated with a number of negative correlations to overcome that requires continuous and systematic breeding efforts (Baenziger et al., 2001; Eagles et al., 2002; Williams et al., 2008).

The purpose of this study was to observe the effect of drought on the productivity and quality of the grain in winter wheat cultivars, with different genetic potential for quality.

Materials and Methods

Weather conditions during the growing of wheat in 2007 were very unusual for the area. Detailed analysis showed that 2007 is unique as conditions on the average of the two most important factors for the growth and development of plants - rainfall (Figure 1) and air temperature (Figure 2). In terms of precipitation during the growing season of wheat (October-July) this year has seen extreme minimum. Precipitation during different periods of the growing season for wheat is only 44% of normal for 50 years of observation period. The lowest amount of rainfall is during the active spring growing season (April-July), which is only about 1/3 of normal for Southern Dobrudzha.l.

When the air temperature is monitored as a whole, was achieved a maximum throughout the whole cycle of growing wheat 2007 ranks first in value of the average monthly

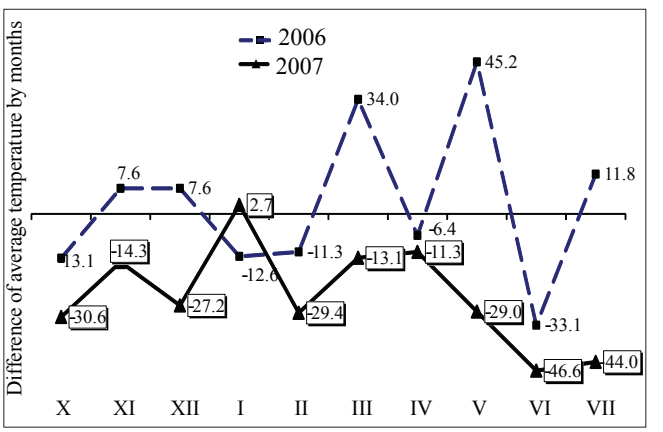

Fig. 1. Difference between the sum of precipitation by months in the years and the long-term average 1953-2009

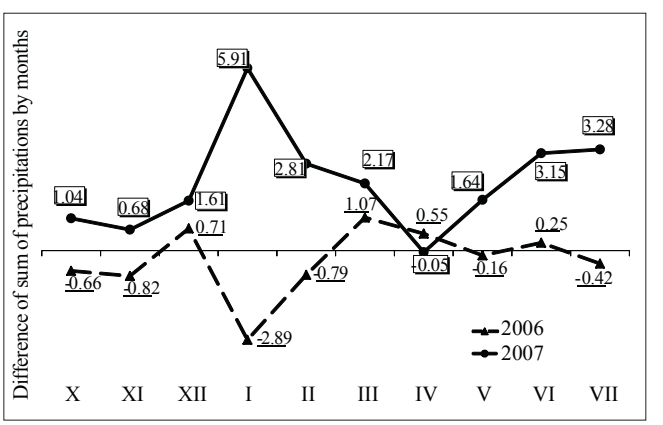

Fig. 2. Average daily temperature by months in both years studied

temperature of 2.5^{0}C higher than the norm. The highest was the difference in temperature during the winter months (up to almost 6 degrees more in January) and during grain filling in June and July.

Sixty five promising lines are selected and 10 varieties developed in DAI are grown in Competitive yield trail (CYT) in two contrasting years. In terms of productivity following characters were investigated: grain yield (GY); weight of kernels per spike (WGS); number of grains per spike (NGS); thousand kernel weight (TKW); number of productive tillers per m2 (NPT); date of ear emergence (DE) and height of the stem (HOS). An analysis of the effect of conditions on each of the traits, and the impact of drought on their levels is made. Means of 15 tolerant to drought and 15 sensitive promising breeding lines were compared between them and with the checks Sadovo 1 and Pryaspa, as well. Quality assessment involves analyzing a total of 75 lines and varieties of wheat. For a detailed comparison lines are divided into three groups according to their genetic potential for quality: high-qualitative (strong) (group A), medium to high strength (B) and medium strength wheat (C), where the number of each group is 15. The proper standard for each of these groups are varieties used Aglika, Sadovo 1 and Pryaspa, respectively. Differences in the expression of 10 different parameters of grain quality were examined as follows: specific weight (SW), sedimentation value (Sed), wet gluten content (WGC), protein content (PC), quality index (QI), dough tolerance (DT), dough softening (DS), valorimetric value (Val), loaf Volume (LV), ration of the bread (H/D). They are analyzed in the laboratory on technological quality of grain at the institute on methods described in detail in the publication of Atanasova et al. (2010). To establish a significant difference between promising lines "residual" values of each trait or parameter in 2007 (drought) compared to 2006 (favorable conditions) are calculated.

This comparison is done by using the statistical program IBM SPSS Statistics 19. Through another statistical program XLSTAT Ver. 2009 differences in the behavior of breeding lines are analyzed, depending on the genetics of their capacity, compared with the reference yield and grain quality varieties and compared to means for each trait or parameter.

Results

Because data on productivity and grain quality were obtained only from conditions of G. Toshevo, an analysis of whether the year environment has an effect on the change of the individual traits and parameters was done. At all traits of productivity (Tables 1, 2 and 3) occurs faithfully influence, as the conditions of the year, and genotype. This means that any differences between breeding lines against the background of two contrasting growing year conditions may be subjected to detailed analysis. Reliably and the interaction between the two factors, which is a major reason to look for differences in the behavior of each genotype from the standpoint of yield

Table 1
Analysis of Variance of traits for grain productivity

Source of variation	DF	M S	F	Level of Probability	M S	F	Level of Probability
		Date of ear emergence (DE)			Number of Productive Tillers (NPT)		
A: Year	1	5482.91	79.444	0.0000*	575378.4	302.35	0.0000*
B: Genotype	74	129.94	4.705	0.0000*	18530.22	9.74	0.0000*
Interaction A x B	74	71.32	2.585	0.0000*	6056.08	3.18	0.0000*
		Height Of Stem (HOS)			Number of kernel per Spike (NGS)		
A: Year	1	1370.73	1006.6	0.0000*	2741.45	397.22	0.0000*
B: Genotype	74	32.48	6.33	0.0000*	64.97	9.41	0.0000*
Interaction A x B	74	17.83	5.25	0.0000*	35.66	5.17	0.0000*
		Grain Yield (GY)			Weight of kernel per Spike (WGS)		
A: Year	1	9800050	10076.6	0.0000*	12.453	1137.48	0.0000*
B: Genotype	74	8740.41	8.99	0.0000*	0.104	9.51	0.0000*
Interaction A x B	74	6211.98	6.39	0.0000*	0.048	4.4	0.0000*
		Thousand kernel Weight (TGW)					
A: Year	1	1 748.376	534.85	0.0000*			
B: Genotype	74	50.221	15.36	0.0000*			
Interaction A x B	74	17.258	5.28	0.0000*			

Table 2
Univariate ANOVA of quality parameters studied

Dependent Variable	Mean Square	F	Prob Level, *p*
Test weight	285.76	63.13	0.0000
Sedimentation value	379.52	5.3	0.0025
Quality index	3.18	5.13	0.0248
Wet Gluten Content	946.58	104.6	0.0000
Dough stability	28.76	24.07	0.0000
Dough softening	7692.16	17.72	0.0000
Valorimeter value	1382.17	39.6	0.0000
Loaf Volume	511543.52	113.6	0.0000
Ration of the bread H/D	0.026	17.56	0.0000
Grain protein content	0.926	1.39	0.2387

Table 3
Means of various parameters of quality of grain on average 75 breeding lines tested in both years

Quality parameter	Year	Mean	Level of Difference, *p*
Test weight, kg	2006	80.2	0.0000
	2007	82.8	
Sedimentation value, ml	2006	43.6	0.0225
	2007	40.6	
Quality index, Sed/PC	2006	4.22	0.0248
	2007	3.94	
Wet gluten content, %	2006	24.3	0.0000
	2007	19.5	
Dough tolerance, min	2006	2.46	0.0000
	2007	1.62	
Dough softening	2006	80.8	0.0000
	2007	94.4	
Valorimeter value	2006	49	0.0000
	2007	43.2	
Loaf volume, cm^3	2006	728	0.0000
	2007	617	
Ration of the bread, H/D	2006	0.46	0.0000
	2007	0.43	
Grain protein content	2006	10.41	0.2387
	2007	10.26	

and quality of the grain, expressed by the investigated characters .

Breeding lines are divided into "tolerant" and "sensitive" to the drought, according to their grain yield in terms of 2007, compared to 2006. In the different traits of productivity both groups of genotypes react in very different ways (Figure 3).

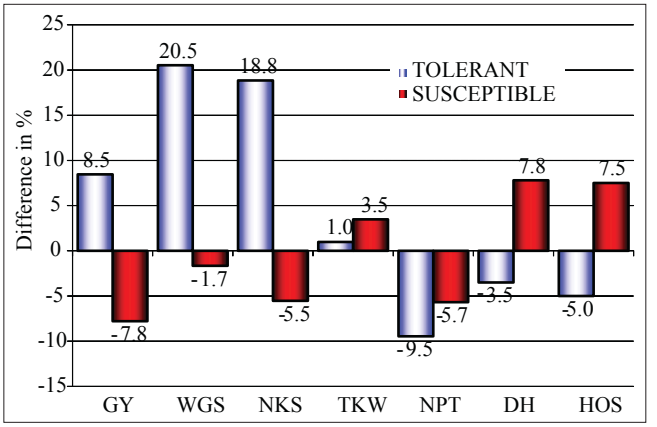

Fig. 3. Difference in the level of the individual trait in tolerant and drought sensitive breeding lines, in respect to the mean level of expression of each one

For traits date of ear emergence (7.8%) and stem of height (7.5%) susceptible genotypes have higher values than tolerant. In these traits, the tolerant group had significantly lower values and the difference in height of the stem reached to 12.5%, and for the date of the ear emergence to 11.3%.

For the traits thousand kernel weight (2.5%) and number of productive tillers (3.8%) the difference between the groups in favor of the sensitive genotypes. Tolerant varieties have an advantage in the characters weight of kernels per spike and number of kernels per spike, so their values are significantly higher (22.2%) and (24.3%), respectively. Similar results were published by Mladenov et al. (2001) and Paunescu and Boghic (2008) in the neighboring country of our growing conditions. This is evidence of the real possibilities of such an assessment of the prospective breeding material for their productive capacity in terms of stress.

Discussion

If we compare the tolerant breeding lines with the standards Sadovo 1 and Pryaspa cv. we will find interesting patterns in relation to their behavior during drought (Figure 4). First, grain yield is about 8.5% higher than that of Sadovo 1 and about 6.5% higher than that of Pryaspa cv. (differences are significant). Assuming variety Sadovo 1 is a basic yet in southern Bulgaria, where every year there is drought in the spring and Pryaspa cv. one of the most adaptable varieties, and then obviously we have progress through the behavior of the new lines under drought. Overall level of tolerant lines through their trait means is similar to that of Pryaspa cv., the differences with a few percent, which are unproven. The biggest difference is in the WKS (8.6%). That difference is

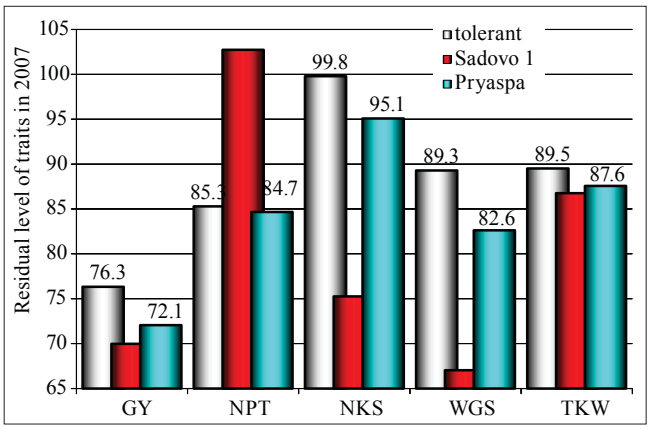

Fig. 4. Comparison between the lowering of the studied traits of drought tolerant lines with reference varieties

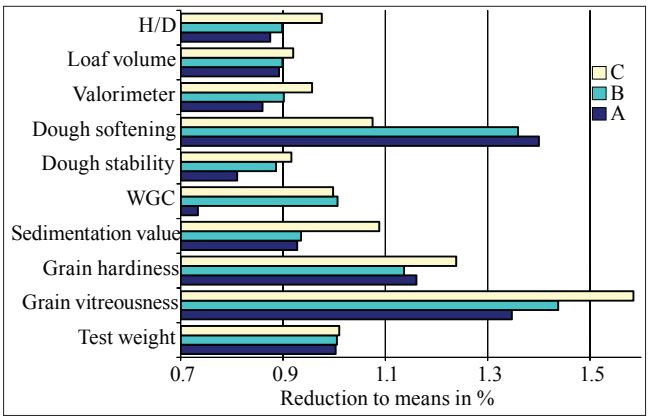

Fig. 5. Change in the enhancers (A), typically bread (C) and medium in quality (C) groups of genotypes as relative values in 2007 in comparison with their 2006-means

due to the higher degree of conservation of the characteristics of NKS (4.9%) and TKW (3.1%). The strongest effects on grain yield under drought acquire the NKS followed by TKW. Significantly lower values of NPT (-15%) in the tolerant lines, however, offset by the significantly higher number of kernels that they form, in comparison with Sadovo 1, cv. (+25%) Comparing means align with those of the checks a conclusion is formed that the NPT of new breeding material is insufficient to form a stable and high yield, irrespective of the conditions of the year. Moreover, under drought that trait in wheat, according Petrova (2003), Hoffman and Burucs (2005) is reduced at the highest degree, in comparison with the other components of the productivity.

This distinct reaction of different in grain quality varieties is the reason to analyze separately the changes in the parameters of quality in different of genetic potential, breeding lines (Figure 5). To see if there is a difference in the change of means of the different parameters depending on their genetic quality, difference in change in each parameter compared to the change of the entire group of varieties, were calculated.

The parameter specific weight in drought conditions generally formed a higher mean. Different in quality varieties react similarly, and between them there are no significant differences. The high-quality varieties lowered their values most in sustainability parameters dough softening degree (higher values are negative) valorimetric value and loaf volume. In medium-quality varieties of the second group greatly reduce the value of sedimentation, WGC and quality index. In fact, by these parameters they react most negatively to stressful conditions of the year. Genetically lowest quality varieties generally change nearly all parameters significantly less than the other two groups. The only exception is response is specific weight, but there are similar differences in other groups. The data clearly show that stress affects more negatively on qualitative wheat varieties, as the lower is the genetic nature of the quality, the performance of a variety indexes are more stable and fixed to the conditions during grain filling stage.

Similar results in variable conditions and a range of different of the quality varieties are produced by Atanasova et al. (2010), Stoeva et al. (2009) and Tsenov et al. (2004) for the winter wheat in Bulgaria and in spring wheat in Australia (Williams et al., 2008), and Mexico (Lage and Trethowan, 2008).

In conclusion it can be pointed out that the real changes of the weather conditions during the different seasons are excellent prerequisite for successful breeding of appropriate combination of high productivity, grain quality amid high tolerance to drought. Enough information in our country about the reaction of the breeding material for drought (Petrova and Tsenov, 2011; Boydjieva et al., 2009) has accumulated. In combination with other natural anomalies it has created prerequisites for the development of more new tolerant varieties, which in recent years has research reports Ivanova end Tsenov, (2010) and Tsenov et al. (2011).

Conclusion

Productivity: The conditions of the year reliably impact on the level of each of the traits, directly or indirectly linked to the productivity. Most drought decreased trait is productive tillering and weight of kernels per spike. The highest grain yields under drought in Dobrudzha are the breeding lines that manage to form the highest number of grains per spike. Regardless of the year conditions, grain yield is determined in the strongest degree of character number of grains per ear.

Grain quality: Drought and most negatively affected the parameters related to the strength of the dough - the dough tolerance and valorimetric value. In lowering the quality of grain in drought as lower genetic quality potential of a variety, the values of its indexes change less. This explains the large variation in the quality of strong wheat due to differences in the conditions of the year.

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