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WINTER WHEAT PRODUCTIVITY UNDER FAVORABLE AND DROUGHT ENVIRONMENTS. I. AN OVERALL EFFECT

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Abstract

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The aim of the investigation was to determine the productivity of common wheat genotypes under contrasting environments. The investigated wheat cultivars were grown in two successive years: 2006, which was very favorable for wheat cultivation, and 2007, when one of the most severe and long-lasting droughts in Bulgaria was registered. The genotypes were grown in a complex scheme involving four previous crops and three levels of mineral fertilization, according to the type of previous crop. Grain yield and the following productivity components were studied: 1000 kernel weight, test weight, number of productive tillers, plant height, number and weight of grains per spike. The correlation of grain yield with the related traits was analyzed under contrasting environments. It was found out that the drought in 2007 caused about 30 % decrease of the productivity of the investigated common wheat genotypes. The reduction of grain yield was due to the lower weight of grains per spike (about 40%), the lower number of grains per spike (about 29%) and the smaller size of grains (about 15%). The independent effects of the genotype and the mineral fertilization were much better expressed on the studied traits under the favorable conditions of 2006, and the type of previous crop had significant effect under drought. The relation of grain yield with the number of productive tillers, plant height, weight and number of grains per spike was higher under stress during the growth period of the crop.

*Key words: w*heat, drought, yield

Introduction

Agriculture is an old human activity well adapted to the natural resources. During the last years, however, this activity was carried out under the effect of global climatic changes. The great variations of climatic factors put to test the grown field crops (Tran et al., 2002; Slavov and Moteva, 2005; European Climate Change Programme, 2007). Global warming undoubtedly leads to lower rainfalls in most geographic regions of Bulgaria and affects negatively the productivity of wheat (Koteva et al., 2010).

Wheat is one of the crops with the longest vegetation period, which encompasses almost all four seasons. This is a prerequisite the growth and development of wheat genotypes to occur under multiple changeable factors of the environment. Tendencies are observed of increasing climatic anomalies mainly during the period of active vegetation. Abiotic stress is almost an annual phenomenon on the crop in most countries (Dodig et

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al., 2008; Paunescu and Boghic, 2008; Shahryari et al., 2008).

The aim of the investigation was to *i)* determine the productivity of common wheat genotypes during two contrasting years; *ii*) analyze the correlation of grain yield with the related traits under contrasting environments.

Material and Methods

In a field trial carried out in the trial field of Dobrudzha Agricultural Institute – General Toshevo the productivity of 7 common wheat cultivars was investigated during 2006 – 2007. The cultivars were sown within the agronomy term optimal for this region by the split plot method in four replications with sowing norm 500 germinating seeds/m^2. The size of each plot was 22.5 m^2. The genotypes were grown after four previous crops: bean, sunflower, grain maize and fodder maize at different mineral fertilization levels. The fertilization was applied according to the type of previous crop: after bean – $N_6P_6K_0$ (T_2) and $N_{10}P_{10}K_0$ (T_3), after the other predecessors – $N_{10}P_{10}K_0$ (T_2) and $N_{14}P_{14}K_0$ (T_3), and check variant $N_0P_0K_0$ (T_1). Grain yield, GY ($t.ha^{-1}$) and the traits related to it were investigated: 1000 kernel weight (g) – TKW; test weight (kg) – TestW; height of stem (cm) – HOS; number of productive tillers – NPT; number of grains per spike – NGS; weight of grains per spike (g) – WGS.

Statistical processing of data was done with Statistica 7, Microsoft Excel and SPSS 13.

The productivity of the common wheat cultivars was investigated in two meteorologically contrasting years (Figure 1). The temperatures and rainfalls during 2006, as compared to the long-term data (1953 – 2007), characterized it as a year with conditions very favorable for the expression of the productivity of the studied genotypes. Year 2007 was specific in agro-meteorological respect because of the occurrence of the most severe and long-lasting drought in the last 30 years.

Rainfalls, their amount and distribution during the growth period were the decisive factor for the development of wheat, the autumn-and-winter moisture reserve and the spring critical period being most significant (Pepó and Kovačević, 2011).The amount of rainfalls in the autumn of 2006 (October – March), as compared to the mean value for a 55-year period (1953 – 2007) was higher, while in 2007 it was with 50% lower. The amount of rainfalls during April – May, when plants go through stages booting and heading, once again outlined 2006 as a year with very favourable conditions for the maximum expression of the productivity of the investigated cultivars. The combination of higher mean monthly air temperatures with significantly lower rainfalls in 2007 made it the year with one of the most severe droughts during the last decades. This allowed investigation to follow the variations of wheat productivity under contrasting environments.

Results

In 2007, a severe and long-lasting drought was registered in Bulgaria and as a result, the grain yields from wheat were significantly lower. The direct effect reported by Tsenov et al (2008) amounted to 30% decrease of productivity after previous crop grain peas. This investigation confirmed the decrease: grain yield was with 38% lower in 2007 under the field trial design specified above (Table 1). To explain this decrease it is necessary to analyze the traits, which determined the size of grain yield: number of grains per spike and number of productive tillers. The number of grains per spike has been long considered a key factor for the formation of the economic part of wheat productivity under various environments (Sinclair and Jamieson, 2006; Peltonen-Sainio et al., 2007; Tsenov et al., 2008; Zecevic et al., 2010). The decrease was highest in grain weight per spike (about 40%) and number of grain per spike (about 29%). The variation in the number of productive tillers during the two years was statistically insignificant (2.5%). The cultivars were with 20%

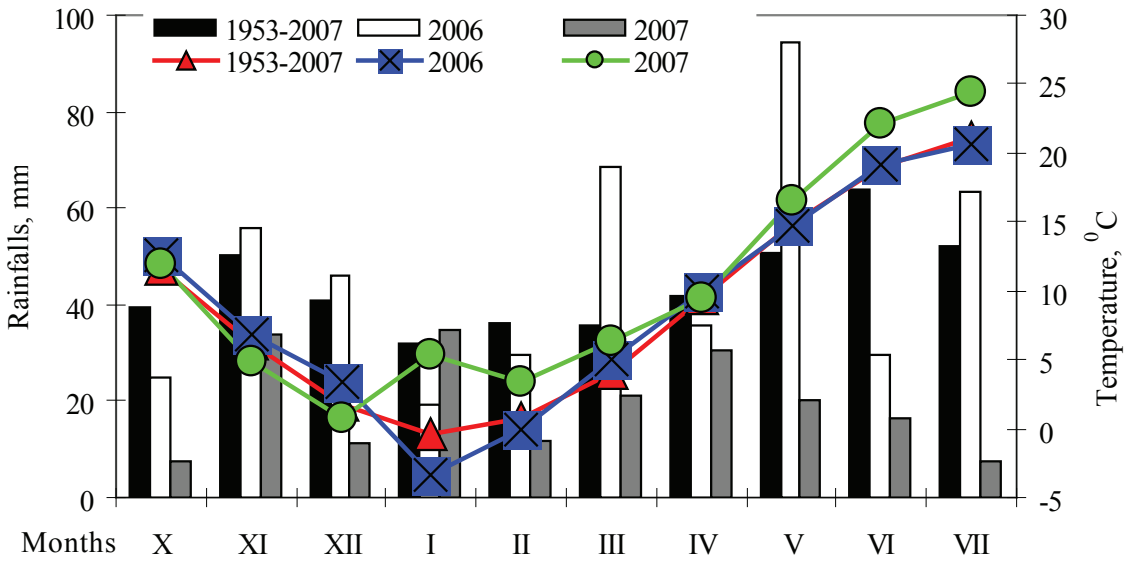

Fig. 1. Temperature and rainfalls

Table 1
Mean values of the investigated traits

Trait	Mean value		T crit	Decrease. %
	2006	2007		
GY	629.71	392.03	16.02**	38
TKW	44.64	37.81	15.51**	15.3
TestW	78.3	81.2	17.48**	103.7
NPT	473	485	1.30ns	102.5
HOS	85	68	14.03**	20
WGS	1.381	0.812	15.20**	41.3
NGS	31	22	10.26**	29.1

shorter in the unfavorable 2007, and 1000 kernel weight decreased with about 15%. Test weight was the only index, which was higher under drought, although with only 4%.

Discussion

The analysis of variances revealed both the independent effect of the agronomy factors on the investigated traits and their interactions in contrasting years (Table 2). In the recent years, the effect of drought has been studied and described in a large number of research publications (Fallahi et al., 2008; Kaur and Behl, 2010; Sugar and Berzsenyi, 2010; Jager et al., 2011). In this investigation, the independent effect of the factor "genotype" was higher in the expression of all traits during 2006, a year with favorable growing conditions. Its effect was highest on test weight and 1000 kernel weight, and its significance for grain yield formation was almost equal in the two contrasting years. The type of previous crop had great effect on the formation of the productivity of the investigated cultivars, on their stem height, number and weight of grains per spike during the drought of 2007. The independent effect of mineral fertilization was high on the greater part of the investigated traits during the favorable 2006.

Most of the combined interactions cultivar x fertilization, previous crop x fertilization were significant. The individual combinations had different effects on the investigated traits during the two years. Only in test weight and 1000 kernel weight, high and significant genotype x fertilization interaction was observed, which had different directions in the two contrasting years. The com-

Table 2
ANOVA of trait x environment interaction

Factor / Trait	Years	Variety A	Previous crop B	Fertilization C	AxB	AxC	BxC	AxBxC
GY	2006	14.0**	128.9**	1582.8**	1.0ns	3.0**	37.8**	1.2ns
	2007	14.8**	1039.0**	231.2**	1.0 ns	4.6**	51.8**	1.1 ns
TKW	2006	673.6**	60.6**	335.0**	8.2**	17.4**	5.4**	4.5**
	2007	461.3**	28.0**	1331.7**	15.2**	21.7**	6.1**	7.7**
TestW	2006	1244.2**	307.0**	351.0**	5.8**	59.8**	35.9**	6.2**
	2007	541.1**	47.3**	480.7**	7.5**	48.4**	10.1**	3.9**
NPT	2006	18.1**	21.5**	83.7**	1.7 ns	2.8**	61.9**	3.2**
	2007	10.6**	17.4**	11.4**	2.9**	1.5 ns	4.9**	1.6**
HOS	2006	60.1**	96.1**	301.6**	1.4 ns	2.1**	20.6**	0.9 ns
	2007	27.7**	505.8**	86.2**	3.5**	2.0**	21.4**	1.3 ns
WGS	2006	9.8**	45.6**	126.2**	1.4 ns	2.8**	80.6**	2.4**
	2007	8.1**	159.2**	30.4**	1.7 ns	1.2 ns	22.9**	1.5 ns
NGS	2006	9.1**	43.7**	175.2**	1.3 ns	2.3**	74.6**	2.5**
	2007	3.4**	146.9**	81.6**	1.7*	1.5 ns	20.1**	1.4 ns

Table 3
Pearson's correlations between the investigated traits (above diagonal – 2007; below diagonal – 2006)

	GY	TKW	TestW	NPT	HOS	WGS	NGS
GY		-0.198**	-0.052	0.380**	0.857**	0.871**	0.876**
TKW	-0.310**		0.292**	-0.391**	-0.170*	-0.023	-0.363**
TestW	-0.139	0.074		-0.208**	0.012	0.045	-0.078
NPT	0.326**	-0.335**	0.077		0.362**	-0.106	0.029
HOS	0.750**	-0.041	0.147	0.194*		0.722**	0.733**
WGS	0.604**	-0.014	-0.195*	-0.522**	0.487**		0.933**
NGS	0.656**	-0.285**	-0.205**	-0.410**	0.466**	0.956**	

bination previous crop x fertilization had highest effect on the other traits; the significance of this combination for the formation of grain yield was higher in the unfavorable 2007. The interaction previous crop x fertilization had higher effect on the number of productive tillers, the number and weight of grains per spike in 2006.

In order to check and confirm the obtained results, correlation analysis was done, which showed the relation between the investigated traits during the two contrasting years (Table 3).

According to this analysis, the stem height of the studied wheat genotypes and the number and weight of grains per spike were typical traits deter-

mining the level of the yield under changeable environments. In this relation, numerous researches have been done which analyzed the correlation coefficients between yield and its structural elements (Lukipudis, 2002; Panayotova et al., 2004; Tsenov et al, 2008; Talebi et al., 2010). In this investigation, a high positive effect of the above indices on yield was observed, the correlation coefficients being higher in 2007. The correlation of yield with the number of productive tillers was higher under drought (0.380**) in comparison to optimal growing conditions (0.326**). Test weight and 1000 kernel weight were in negative correlation with grain yield. Highest was the correlation coefficient between the number and the weight of grains per spike under optimal conditions of the environment (0.956**).

It can be concluded that the correlations of yield with its structural elements followed the same tendency during the two contrasting years of growing. The difference was that under drought the relations between the investigated traits were stronger. This was probably due to the lower variations between the minimum and the maximum values of the indices. Regardless of the degree of variation of each trait with direct effect on grain yield as a result from the drought, the correlations between them remained the same as in favorable years. This means that wheat adapts to the stress gradually in the process of its growth through adequate variation of each of the above traits.

Conclusions

The drought in 2007 caused about 38 % decrease of the productivity of the investigated common wheat genotypes. The decrease of grain yield was due to the lower grain weight per spike (about 40%). This resulted from the lower number of grains per spike (about 29%) and the smaller size of grains per spike (about 15%).

The independent effect of the genotype and the mineral fertilization on the investigated traits was much better expressed under the favorable conditions of 2006, and the type of previous crop had significant effect under drought.

The correlation of grain yield with the number of productive tillers, the stem height and the number and weight of grain per spike was higher under stress during the growth period of the crop.

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