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WINTER WHEAT PRODUCTIVITY UNDER FAVORABLE AND DROUGHT ENVIRONMENTS. II. EFFECT OF PREVIOUS CROP

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Abstract

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During the growth period of field crops, drought (both short and long lasting) is becoming increasingly frequent. Drought is an abiotic stress factor of the environment, which reduces the yield from cereals worldwide. The effect of different previous crops on the productivity of common winter wheat genotypes was investigated under favorable and drought environments. The investigated cultivars were grown in two successive years – 2006, which was very favorable for wheat growth, and 2007 when one of the severest and longest droughts in Bulgaria occurred. The genotypes were grown after four previous crops (bean, sunflower, grain maize and fodder maize) at three levels of mineral fertilization according to the type of previous crop. Grain yield and the productivity components were studied: 1000 kernel weight, test weight, number of productive tillers, plant height, number and weight of grains per spike. The correlations of grain yield with the traits related to it were analyzed after different previous crops under contrasting conditions of the environment. A marked positive role of bean as previous crop under drought conditions was established. Bean decreased with only about 9% the productivity of the wheat genotypes grown after it. The high negative effect of sunflower and grain maize was stronger under drought. The productivity of the wheat genotypes grown after these two predecessors dropped down with 22-25%. Fodder maize had an intermediate effect. The cultivars grown after it decreased their productivity with about 21%, but it was the best predecessor for formation of 1000 kernel weight. Regardless of the year conditions, correlations of grain yield with its components were inversely proportionate to the “good” predecessors.

*Key words: w*heat – drought – yield – year – previous crop
Abreviations: GY – grain yield (t.ha^{-1}); TKW – 1000 kernel weight (g); TestW – test weight (kg); NPT – number of productive tillers; HOS – plant height (cm); WGS – weight of grains per spike (g); NGS – number of grains per spike

Introduction

The geographic position of Bulgaria is a prerequisite for the development of agricultural production under condition of annual hazard due to unpredictable changes of the meteorological factors. It is an undisputable fact that the recent global warming leads to lower rainfalls in most geographic regions of Bulgaria and has a negative effect on the productivity of the crops (Kirkova and Petrova, 2011). Short and longer droughts occur more frequently during the growth season of the

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field crops. The response of the plants to drought is mainly yield decrease manifested through its various components (Gramatikov and Koteva, 2005; Stoilova and Berova, 2007; Vulchev, 2007; Kirkova and Petrova, 2011).

Drought is an abiotic stress factor of the environment, which affects the growth, and development of plants. Wheat occupies annually almost 1/3 of the arable land in Bulgaria and losses may be great even under short drought (Tsenov et al., 2009).

In years with insufficient rainfalls, the role of the previous crop is greater (Zarkov, 2010). The development of suitable crop rotation schemes is one of the most challenging tasks toward sustainable agricultural system. The well-structured crop rotation and the observing of the proper agronomy practices for cultivation of the crops involved in it ensure the better utilization of soil moisture and significantly decrease the negative effect of drought (Koteva et al., 2010; Zarkov and Koteva, 2010). In combination with suitable varieties structure, it can partially compensate for eventual losses and secure stable grain production by years (Tsenov, 2006). Therefore, complex solutions should be sought when applying the agronomy practices according to the stress factors; these solutions should allow more efficiently using the compensatory mechanisms of the crop (Ivanova and Tsenov, 2010).

The aim of this investigation was to: *i*) find out the effect of the different previous crops on the productivity of the common wheat genotypes in two contrasting years; *ii*) analyze the correlations of grain yield with the investigated traits after different types of previous crops.

Material and Methods

During two successive years (2006 and 2007), the productivity of several common wheat cultivars with different biological and economic properties was investigated. The investigation was carried out in the trial field of Dobrudzha Agricultural Institute – General Toshevo. The detailed design of the trial, the investigated traits and the used evaluation methods have already been described in a previous publication (Ivanova and Tsenov, 2011).

The previous crops used for growing the investigated wheat cultivars (bean, sunflower, grain maize and fodder maize) were spring crops. Therefore, Figure 1 presents the meteorological conditions in 2005 and 2006 during the growing season of these crops compared to the long-term data (1953 – 2007). In this Figure 1 are the weather conditions during the vegetation of its predecessors, while conditions in the vegetation of the studied wheat varieties are discussed in a previous publication (Ivanova and Tsenov, 2011). The combina-

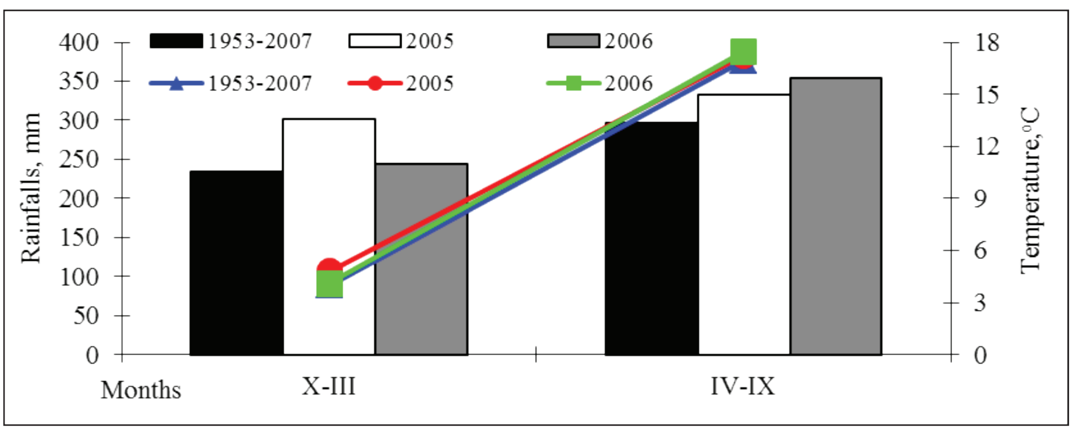

Fig. 1. Rainfalls and temperature

tion of rainfalls and mean temperatures determined the investigated years favorable for the growth and development of spring crops. The variation in the temperature sums between the studied years and the long-term data was not high. The mean temperatures were close to the norm, and in August and September (the harvesting time of the previous crops), they were higher. Overall the investigated years were a little warmer (especially 2006) than the temperature norm. Rainfalls also were a major factor for the development of the spring crops. The autumn-and-winter moisture reserve in soil (October – March) was decisive; it exceeded the precipitation norm during both years of investigation, the autumn-and-winter moisture reserves in 2005 being significantly higher than the reserves in 2006. These were good conditions for sowing of spring crops. The sum of vegetation rainfalls (April – September) during the investigated years also exceeded the precipitation norm. Their distribution during the growth season of the previous crops in the investigated period was uneven. The analysis of the index sum of rainfalls during the years of the investigation for the entire period (October – September) revealed that the sum of rainfalls in 2005 was higher. The good moisture reserves in soil in 2005 enhanced its effect in the following year providing the good development of the predecessors. This meant rich reserves of nitrogen for wheat after the bean predecessor. On the other hand, the strong growth of the other predecessors decreased soil moisture and the high amount of rainfalls at the end of their growth prolonged their vegetation period and postponed their harvesting, which affected unfavorably the wheat sown after them.

Results

In our previous study the general consequences of the drought in 2007 on the productivity of the investigated wheat genotypes were outlined (Ivanova and Tsenov, 2011). One of the conclusions in this publication was that the type of predecessor of the wheat was significant under drought. Other researchers who investigated the productivity of barley in Bulgaria (Koteva et al., 2010) have determined this relation. It was a serious prerequisite to carry out further researches in this direction to analyze the variations in wheat productivity according to the type of previous crop under contrasting years.

The decrease of the mean values of all investigated traits in 2007 was 19.5% regardless of the type of previous crop (Table 1). The only exception was observed in the number of productive tillers and test weight, which were a little higher under drought. This variation, however, was low and insignificant and therefore these two traits were not further considered. Averaged for all previous crops under drought, grain yield decreased with 38.2%. This decrease was mainly due to the reduction of grain weight per spike (about 40%) and the number of grains per spike (about 29%). Averaged for all previous crops under drought, 1000-kernel weight decreased with about 15%, and plant height – with about 19%.

Table 1
Decreasing (%) of traits in 2007 in comparison to 2006 according to previous crop

Previous crop	Traits							Average
	GY	TKW	TestW	NPT	HOS	WGS	NGS	
Bean	17.8	17.9	-3.0	-5.2	4.9	23.0	6.4	8.8
Sunflower	47.6	15.5	-3.5	-3.3	27.3	48.9	39.4	24.6
Grain maize	46.2	15.3	-4.3	6.4	27.0	41.4	30.6	23.2
Fodder maize	41.0	12.3	-3.9	-4.7	17.4	48.3	40.5	21.6
Average	38.2	15.3	-3.7	-1.7	19.1	40.4	29.2	19.5

Under drought, the productivity of the wheat genotypes grown after bean decreased with 1/3 less than after the other previous crops. Bean had highest negative effect on grain weight per spike (23%). The decrease of grain yield and 1000 kernel weight was almost equal (18%) after bean. This previous crop had lowest negative effect on the plant height of the investigated genotypes (5%) and the number of grains per spike (6%). Under the same conditions sunflower had high negative effect in decreasing to the highest degree the investigated traits of the wheat genotypes. According to the mean values of decrease of the investigated traits, the "bad" predecessors can be ranked as follows: fodder maize (22%) > grain maize (23%) > sunflower (25%). This order, however, changes when considering the investigated traits separately by previous crop. The decrease of grain yield, 1000 kernel weight and plant height was greater after sunflower and grain maize, and the number and weight of grains per spike was negatively affected to a higher degree by sunflower and fodder maize as previous crops.

Discussion

To analyze in details the individual effect of each predecessor on the productivity of the studied genotypes, the decrease of the traits according to the type of previous crop was calculated against the background of the separate mineral fertilization norms (Table 2). The aim of the calculation was to check if the effect of each predecessor on the investigated remained the same.

Analyzing the effect of the previous crop according to the level of mineral fertilization, we found out a significant influence of its type on the investigated indices. In 2007, a strong positive effect of bean on the productivity of wheat was observed. This high positive effect has been demonstrated in numerous publications (Lopez-Bellido et al., 2007; Anderson, 2008; Gerdgikova et al., 2008; Dogan and Bilgili, 2010; Yankov, 2010). In this investigation, the positive role of bean was markedly expressed in the control variants ($N_0P_0K_0$). Under conditions without fertilization in combination with soil drought, grain yield decreased with only 1% after this predecessor. Under the same conditions highest decrease was registered for 1000 kernel weight (16%) and weight of grains per spike (19%), while plant height and number of grains per spike decreased with only 3% (Table 2A).

Much greater decrease of the values of the investigated traits was determined under extremely unfavorable conditions (drought without fertilization) after the other previous crops (Table 2B). The obtained data reveal that sunflower was the worst predecessor. Under drought without fertilization grain weight decreased with about 55%, and number of grains per spike – with 49% after previous crop sunflower. This, on its turn, caused strong decrease of grain yield (with 36%) in comparison to previous crop bean. Under the same conditions (drought without fertilization), grain yield decrease after previous crop grain maize was about 29%. It resulted from the reduced weight of grain per spike (with about 34%) and number of grains per spike (with about 26%). In the control variants ($N_0P_0K_0$), the percent of yield decrease after fodder maize was about 35%. Under the same conditions height of stems decreased with about 20%, grain weight – with 26%, and number of grains per spike – with 21% after this predecessor.

The applied mineral fertilization increased the reduction of the mean values of the investigated traits. The decrease, however, was much lower after bean in comparison to the other previous crops. Under fertilization conditions in 2007 grain yield decreased with 20-22% after previous crop bean, while the decrease of this index was with 48-49% after sunflower and grain maize. After previous crop fodder maize, the decrease was a little lower (40-41%). Under the same conditions, the plant height of the investigated wheat cultivars de-

Table 2A
Decreasing of the mean values of the traits after different predecessors
A. After bean

Fertilization	$N_0P_0K_0$			$N_6P_6K_0$			$N_{10}P_{10}K_0$		
	Mean value		Decrease %	Mean value		Decrease %	Mean value		Decrease %
Traits	2006	2007		2006	2007		2006	2007	
GY	573	569	0.8	712	571	19.8	740	574	22.4
HOS	85	83	2.6	89	85	4.3	92	86	6.7
TKW	48	40.1	16.5	45.5	37.6	17.4	45.6	37.7	17.3
WGS	1.47	1.19	18.7	1.46	1.06	27.3	1.5	1.08	28.3
NGS	31	30	3.1	32	28	12.7	33	29	13.7

Table 2B
B. After sunflower, grain maize and fodder maize

Fertilization	$N_0P_0K_0$			$N_{10}P_{10}K_0$			$N_{14}P_{14}K_0$		
Traits	Mean value		Decrease %	Mean value		Decrease %	Mean value		Decrease %
	2006	2007		2006	2007		2006	2007	
				Sunflower					
GY	479	306	36.1	751	380	49.5	741	380	48.7
HOS	82	61	26	90	64	28.9	87	63	27.1
TKW	47.3	40.9	13.5	44.2	37.7	14.5	44.3	37.7	15
WGS	1.39	0.62	55.3	1.53	0.89	41.9	1.45	0.83	42.6
NGS	30	15	48.6	35	23	32.8	33	22	32.5
				Grain Maize					
GY	334	237	29	663	346	47.8	666	337	49.4
HOS	70	56	20.2	87	63	28.1	84	60	28.3
TKW	45.6	40.6	10.9	44.1	36.9	16.2	44.3	37	16.5
WGS	0.86	0.57	33.9	1.26	0.72	42.6	1.2	0.69	42.6
NGS	19	14	26	28	20	31.5	27	19	31.2
				Fodder Maize					
GY	372	243	34.7	679	410	39.6	678	399	41.2
HOS	69	55	20.1	85	68	20	81	70	13.6
TKW	45.3	41.8	7.6	43.5	38.7	11.1	43.9	38.2	12.9
WGS	0.74	0.55	25.5	1.47	0.88	40.1	1.59	0.83	47.6
NGS	17	13	20.5	34	23	32.5	36	22	39.1

creased with 4-7% after bean, with 14-20% after fodder maize and with 27-29% after grain maize and sunflower. Under conditions of fertilization in 2007 after sunflower and grain maize, the decrease of weight (42-43%) and the number of grains per spike (31-33%) was almost the same, and stronger after fodder maize (45-48% and 32-39%, respectively). Under the same conditions, the percent of decrease of these indices after previous crop bean was again lower (27-28% for grain weight per spike and 13-14% for number of grains per spike).

An exception was observed only for 1000 kernel weight; the obtained results showed that fodder maize was the best predecessor for its formation.

The results we obtained reveal that previous crop bean has compensatory function and to a significant degree neutralizes the negative effect of fertilization under drought (Halvorson et al., 2000; Norwood, 2000; Rieger et al., 2008; He et al., 2009).

To collect further data on the correlation of grain yield with the investigated traits, correlation analysis was performed according to each predecessor during the two contrasting years (Table 3). The correlation of yield with the plant height of the investigated genotypes and with the number of productive tillers was higher during the favorable 2006, and with the weight and number of grains per spike – under drought. The values of the correlation of grain yield with the traits height of stem and number of grains per spike increased regardless of the year from bean to fodder maize. In the other two traits – number of productive tillers and 1000 kernel weight the tendency was similar but only under conditions of drought. In 2006, the values of the correlations decreased sharply from bean through sunflower towards the two types of maize predecessors. The data in Table 3 revealed another important regularity: the variation in the values of the correlation in the "good" predecessor bean, and to some extent of sunflower for the above three traits (HOS, NGS, WGS) was significantly higher under favorable conditions (2006), while in the other investigated predecessors the variations between the two years were almost insignificant or non-existent. Test weight and 1000 kernel weight correlated negatively with yield in the two years of the investigation.

The tendencies observed in the correlations partially explain the ostensible strong effect of the type of previous crop on the components of productivity and grain yield. Regardless of the observed correlations between the traits, the effect of the type of predecessor was strong under drought. According to this effect the previous crops can be ranked as follows: bean > fodder maize > grain maize > sunflower.

Conclusions

Under drought, there was a marked positive effect of previous crop bean. It decreased the productivity of the wheat genotypes sown after it with only 9%.

The high negative effect of sunflower and grain maize was greater under conditions of drought. The productivity of the wheat genotypes grown after these predecessors decreased with 23-25%.

The cultivars grown after fodder maize decreased their productivity with about 21%, but this crop proved the best predecessor for formation of the trait 1000 kernel weight.

The correlation of grain yield with its components was higher after the "worse" predecessors (sunflower, grain maize and fodder maize), and lower after previous crop bean.

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Table 3
Correlation of grain yield with the components of productivity according to type of previous crop

Traits	HOS				TestW				NPT			
Year	1*	2	3	4	1	2	3	4	1	2	3	4
2006	**0.43**	**0.60**	**0.80**	**0.83**	-0.08	-0.07	-0.25	**-0.45**	**0.66**	**0.82**	**0.75**	**-0.61**
2007	-0.19	0.28	**0.34**	**0.79**	0.24	-0.18	-0.25	-0.13	-0.01	0.05	0.27	0.28
Year	NGS				TKW				WGS			
2006	0.18	**0.55**	**0.84**	**0.88**	**-0.56**	**-0.49**	**-0.35**	-0.28	-0.08	0.29	**0.81**	**0.87**
2007	0.25	**0.72**	**0.87**	**0.86**	0.28	-0.28	**-0.61**	**-0.51**	**0.39**	**0.66**	**0.77**	**0.88**

Values in bold are significant at 0.01 level;
*1-bean; 2-sunflower; 3-grain maize; 4-fodder maize

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