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Effect of Drought on the Yield Components of Common Winter Wheat Cultivars

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Abstract

Drought is a typical frequent phenomenon for Bulgaria occurring with variable severity every 5 or 6 years. Since the end of the 20th century a tendency has been observed toward lower amount of rainfalls and warmer weather during the vegetation period. Therefore special attention is to be paid to the tolerance of the cultivars and their ability to preserve to a high degree their high productivity under drought as well. This investigation was carried out under greenhouse construction at the Laboratory Complex of Dobrudzha Agricultural Institute – General Toshevo (DAI). Fifteen common winter wheat cultivars were tested for three years in two variants – under conditions of severe and long-lasting drought and under regular watering. The plants from the drought variant were watered only once after planting and were grown under progressive drought till harvest. The check variant was watered at planting and during the vegetation soil moisture close to the optimal was maintained. The traits related to productivity were investigated: date to heading, stem height, number of spikes per row, number of grains per spike, 1000 kernel weight, weight of grain per spike. Using principal component analysis (PCA), the behavior of the cultivars under long-lasting drought, their productivity and the components determining it were studied. The yield from a row in the watered variant was determined mostly by the number of spikes per row, the grain size and the productivity of the spike. Under drought, the productivity of the spike became most important for yield, followed by number of spikes, grain size and number of grains per spike. The highest level of stress did almost linear the relation of grain weight per spike with grain weight per row. Cultivars Ludogorie, Progress, Karat, Kristy, Antitsa and Galateya were referred to the category of the drought-resistant standard Yantur. Under watering, these cultivars gave yields exceeding the average value of the investigated group, cultivars Kristy and Ludogorie being with the highest production potential.

Keywords: Common winter wheat, drought, productivity, components of productivity.

Introduction

The global climatic changes observed since the end of the 20th century have noticeable effect on the Balkan Peninsula and in Bulgaria as well (Alexandrov, 2002). It has been found out that the long-term variations of air temperatures and the sum of effective temperatures during the potential period of vegetation tend toward higher values, and the precipitation sum – toward lower values (Slavov and Georgieva, 2002). There is a tendency toward greater shortage of moisture in soil as a result from higher evapotranspiration; in some regions, including Dobrudzha, shortening of the actual vegetation period is observed (Alexandrov, 2010). The unfavorable combination of higher temperature with lower amount of rainfalls during vegetation imposes the necessity to make changes in the growing technology and to develop cultivars which are less demanding to the amount of water reserves during the formation of yield and the filling of grain (Kazandzhiev et al., 2011).

The aim of this investigation was: 1. To study the behavior of common winter wheat cultivars under long and progressive drought; 2. To follow the variations of the traits which determine productivity and their participation in the formation of yield; 3. To determine the role of stress for the expression of the cultivars and their differentiation by drought resistance.

Materials and Methods

The investigation involved 15 common winter wheat cultivars: Antitsa, Dona, Enola, Galateya, Karat, Korona, Kristy, Kristora, Laska, Liliya, Ludogorie, Progress, as well as Yantur, Bezostaya 1 and Dobrudzhanka which were used as standards of drought resistance in our trials. The cultivars were grown during 2006 – 2009 in a greenhouse construction for simulation of drought on the territory of the Lab complex (Dobrich) at Dobrudzha Agricultural Institute – General Toshevo. The construction was covered with reinforced polyethylene, and the sides were closed with net walls. The plants were sown in rows each 1 m long, with 0.15 m interspacing, 70 germinating seeds per row (one row being a replication). Prior to soil tillage and after planting watering was applied with a certain amount of water through a sprinkling installation. The variant subjected to drought was not watered during the vegetation. The check variant was watered at the first opportunity in spring (beginning of March) and after that – when necessary to avoid water stress. The trial was designed in four replications. During vegetation and after harvesting the following traits were recorded: heading (number of days from the beginning of April till the date to heading), plant height (cm) and length of spike (cm, measured on 10 plants from each replication), number of spikes per row, number of grains per spike, 1000 kernel weight (g), weight of grains per spike (g) and grain yield per row (g). The intensity of drought D, the index of susceptibility of the cultivars S (Fischer and Maurer, 1978), and the indices of resistance STI and MSTI (k_2STI) (Fernandez, 1992; Farshadfar and Sutka, 2002; Shahryari et al., 2008) were also calculated.

Using principal component analysis (PCA), the behavior of the cultivars under long-lasting drought was investigated by traits and genotypes, as well as their productivity and the components which determine it (Yan and Rajcan, 2002). Microsoft Excel^{xp} and STATISTICA 7 were used for processing of the data.

Results and Discussion

The amount of water supplied to the variant under drought and to the check variant of our trial is given in Table 1. The plants were watered most abundantly during 2006 – 2007. In the next two years the amount of water was significantly lower in both variants. In spite of the approximately equal watering in 2007 – 2008 and 2008 – 2009, the intensity of drought D was highest in the last year. Evidently the yields obtained depended not only on the supplied amount of water but also on the meteorological conditions beyond our control: air temperature and humidity, cloudiness, winds, etc. The intensity of drought was lowest in 2006 – 2007.

During the three years of the testing, different levels of intensity of the stress factor were applied. This allowed evaluating the behavior of the productivity components and the yield under more or less severe drought. Highly significant differences were found with regard to genotype, year and variant of watering (Table 2). Highly significant were the interactions cultivar x year and cultivar x variant of watering.

To find out the correlations of the investigated traits under drought and regular watering, factor analysis was performed based on the principal components (PCA). The initial data on the traits were standardized before making the calculations. The principal component analysis was made for each individual year. Five principal components explained 87.0 % (2007), 93.0 % (2008) and 91.8 % (2009) of the total variation. Khayatnezhad et al. (2011) also reported the involvement of five components describing 82.5 % of the total variation in a study on durum wheat under drought. Mollasadeghi et al. (2011) identified 4 factors in an investigation on 9 common wheat genotypes under drought stress.

The sum contribution of the first two main components (PC1 and PC2) for the three respective years of our investigation

Table 1. Amount of water (l m^{-2}) applied to plants under drought (C) and to the checks (K) and drought intensity (D).

	In autumn		In spring		Total		Intensity of drought
	C	K	C	K	C	K	(D)
2006/07	247	266	-	463	247	729	0.265
2007/08	143	172	-	177	143	349	0.561
2008/09	152	173	-	216	152	389	0.791

Table 2. Analysis of variances of the investigated traits

Source of variation	df	Heading		Stem height		Length of spike		Number of spikes per row	
		MS	F	MS	F	MS	F	MS	F
A (cultivar)	14	369	230.6***	5108	286***	11.0	70.4***	6306	83.0***
B (year)	2	139	86.7***	776	43***	38.8	247.7***	5936	78.1***
C (variant)	1	2496	1559.0***	66436	3719***	101.6	649.2***	20375	268.1***
A x B	28	33	20.6***	357	20***	1.7	10.8***	576	7.6***
B x C	2	15	9.4***	97	5**	0.3	2.1	98	1.3
A x C	14	25	21.7***	2915	163***	2.6	16.3***	715	8.7***
A x B x C	28	2.1	1.3*	82	4.6***	0.2	1.4*	159	2.1**
E (error)	267	1.6		17		0.2		76	

Table 2 (continuation)

Source of variation	df	Number of grains per spike		1000 kernel weight		Grain weight per spike		Grain weight per row	
		MS	F	MS	F	MS	F	MS	F
A	14	518	32.6***	471	55.2***	1.00	60.5***	19098	86.3***
B	2	463	29.2***	244	28.6***	1.23	74.2***	7793	35.2***
C	1	19523	1227.8***	7475	875.3***	48.4	2924***	477726	2157.6***
A x B	28	70	4.4***	226	26.5***	0.10	6.3***	1416	6.4***
B x C	2	46	2.9	2.8	0.3	0.07	4.5**	438	1.98
A x C	14	479	30.2***	112	12.6***	0.69	41.9***	4061	18.3***
A x B x C	28	25	1.6*	24.1	2.9***	0.04	2.5***	474	2.1**
E (error)	267	15		8.5		0.02		221	

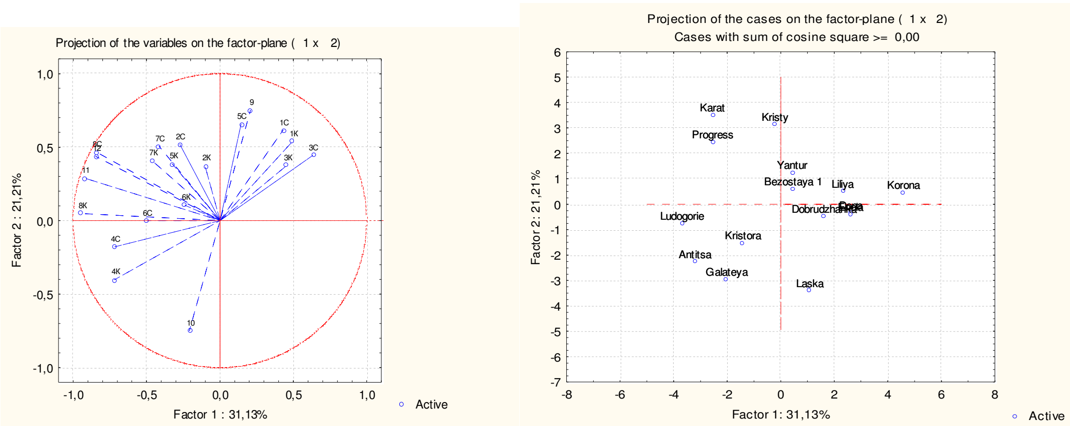
was 52.3%, 56.1% and 60.9% from the total variation (Figure 1).

These comparatively low values reveal the complex relations between the traits (Yan and Rajcan, 2002).

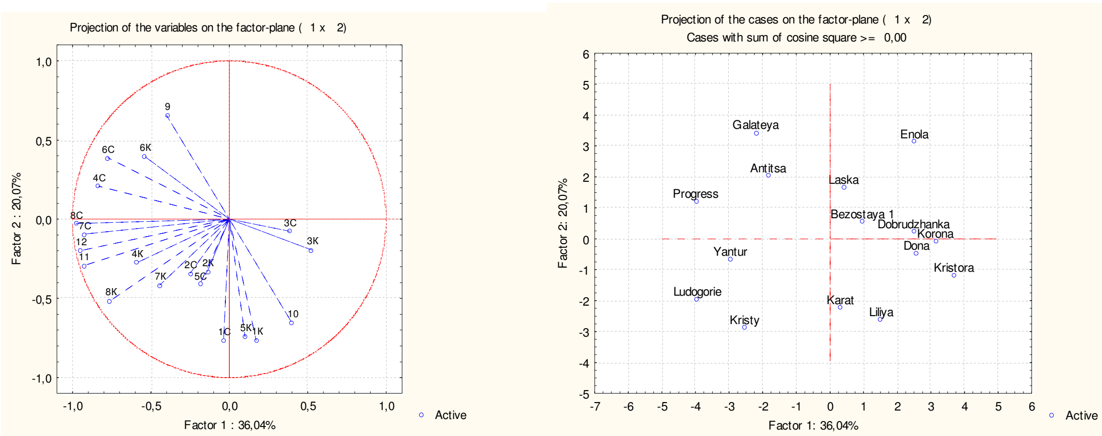
The length of the vectors of the traits showed that the highest percent of variation was due to the yield (C and K) and the indices of resistance.

This mode of presentation allowed visualizing the correlations of all traits based on the general structure of the data, while the correlation coefficients reflected the relationships only between two traits (Yan and Rajcan, 2002). When comparing the graphic representations of the three investigated years, it becomes evident that there is a definite, in some cases very high level of correlation between the expressions of the traits under both growing variants. This correlation, however, underwent changes in some traits when changing the intensity of stress. The highest stress (2009) decreased the correlation of stem height between watering and drought. The same was valid for spike length. Under the most severe drought, the number of spikes per row was not dependent at all on the potential number of productive tillers of the cultivar. The correlation between spike productivity formed under water supply close to the normal and under drought also decreased. There was a positive correlation between yield under watering and yield under drought. The highest level of stress increased the angle between the vectors of the yields under watering and under drought implying a decrease of the correlation between them. In the researches of other authors there are reports for the lack of correlation between the yields in normal years and the yields in years with drought (Paunesku and Boghici, 2008). Ginkel et al. (1998) have commented on own and other investigations concerning the relation of yield under non-limiting conditions and yield under stress. In their opinion, the high production potential of the wheat genotypes had significant contribution to their good results under drought.

2007



2008



2009

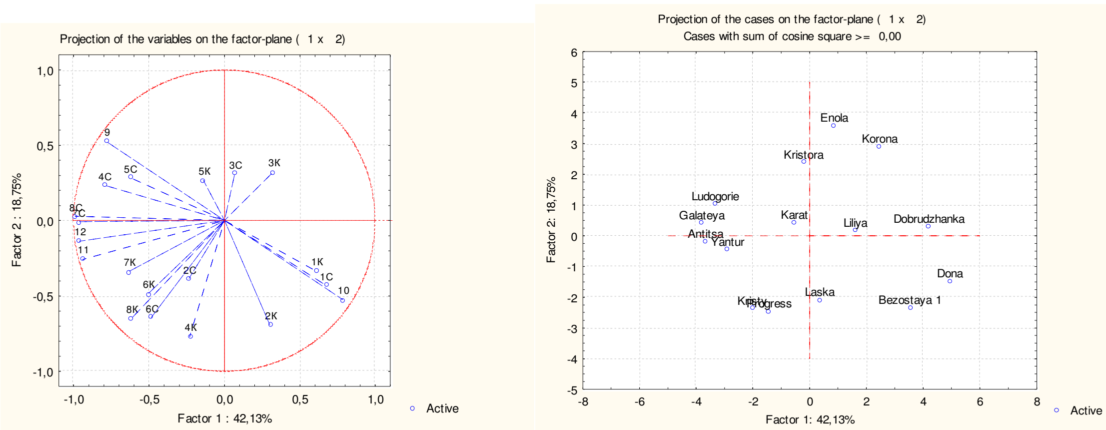


Figure 1. Projection of traits and cultivars on factor plane

Abbreviations and numbers: C – drought, K – watering;

1. heading
2. stem height
3. length of spike
4. number of spikes per row
5. number of grains per spike
6. 1000 kernel weight
7. weight of grains per spike
8. grain yield per row
9. coefficient of drought resistance C/K %
10. S
11. STI
12. MSTI

Yield per row in the variant with watering was determined mainly by the number of spikes per row, the grain size and the productivity of the spike. Under drought, spike productivity became most important for yield, followed by the size and number of grains per spike. The higher intensity of stress did almost linear the relation between weight of grain per spike and weight of grain per row.

Testing wheat lines under drought, Khan et al. (2010) found out that yield depended on the number of tillers per m^2, the number of grains per spike and the number of days to heading, while plant height, spike length and grain size had negative effect on yield. Habibpour et al. (2012) determined significant positive correlations of yield with the traits they investigated, including number of fertile tillers, stem height, spike length and number of grains per spike; the correlation of yield with 1000 kernel weight, however, was low. In durum wheat, Khayatnezhad et al. (2011) proved the significance of the number of spike-bearing tillers, and also of grain weight per main spike and 1000 kernel weight for the formation of yield under drought.

The index MSTI was in highest correlation with yield under drought, and STI was equally related to yield under drought and under watering. The coefficient of drought resistance C/K % is a relative value which does not reflect the size of yield, but under higher stress a positive correlation with yield under drought occurs. The same is valid for S, too, but in this case the correlation was negative. In the investigations on different indices of drought resistance and susceptibility, the indices STI and MSTI are considered some of the most suitable criteria for evaluation and selection for drought resistance, while S is not recommended (Tsenov et al., 2012; Paunescu and Boghici, 2008; Anwar et al., 2011; Khavarinejad and Babajanov, 2012; Farshadfar et al., 2014).

The position of the cultivars on the bipolar plane reflected to the highest degree their productivity and resistance since these traits were the main participants determining PC1. In 2007, cultivars Karat, Progress, Ludogorie, Antitsa, Kristy, Kristora and Galateya were most productive and resistant under conditions of drought; in Karat and Progress this was due to the high productivity of spike. In 2008, the cultivars with high production potential Kristy and Ludogorie maintained to a high degree their productivity under drought as well. Cultivars Progress, Yantur, Galateya and Antitsa also gave yield above the average under drought. In 2009, under the most extreme drought, shorter distance between the most resistant cultivars (Galateya, Antitsa, Ludogorie and Yantur) was observed. Cultivars Kristy and Progress combined high production potential (under watering) with high drought resistance. The good results of these two cultivars were to a high extent due to their 1000 kernel weight. Cultivar Dobrudzhanka was used as a standard of low drought resistance. The position of this cultivar was toward lower productivity, in some years together with cultivars Dona and Korona. Under strong stress, high susceptibility S and later date to heading was typical of these cultivars as compared to the rest.

When summarizing the results from the three years of testing, it becomes evident that the cultivars which can be referred to the category of the drought resistant standard Yantur are Ludogorie, Progress, Karat, Kristy, Antitsa and Galateya. These cultivars possess potential of productivity above the average for the investigated group under watering, cultivars Kristy and Ludogorie demonstrating the highest productivity.

Conclusion

Yield per row in the watered variant was determined mainly by the number of spikes per row, the grain size and the spike productivity. Under drought, the productivity of the spike was most important, followed by the number of spikes and the size and number of grains per spike. The higher stress did almost linear the relation between weight of grain per spike and weight of grain per row.

The correlation of the production potential with the yield under drought decreased with the higher levels of stress.

The cultivars which can be referred to the category of the drought resistant standard Yantur are Ludogorie, Progress, Karat, Kristy, Antitsa and Galateya. They also possess production potential above the average of the investigated group under watering, cultivars Kristy and Ludogorie being with the highest production potential.

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