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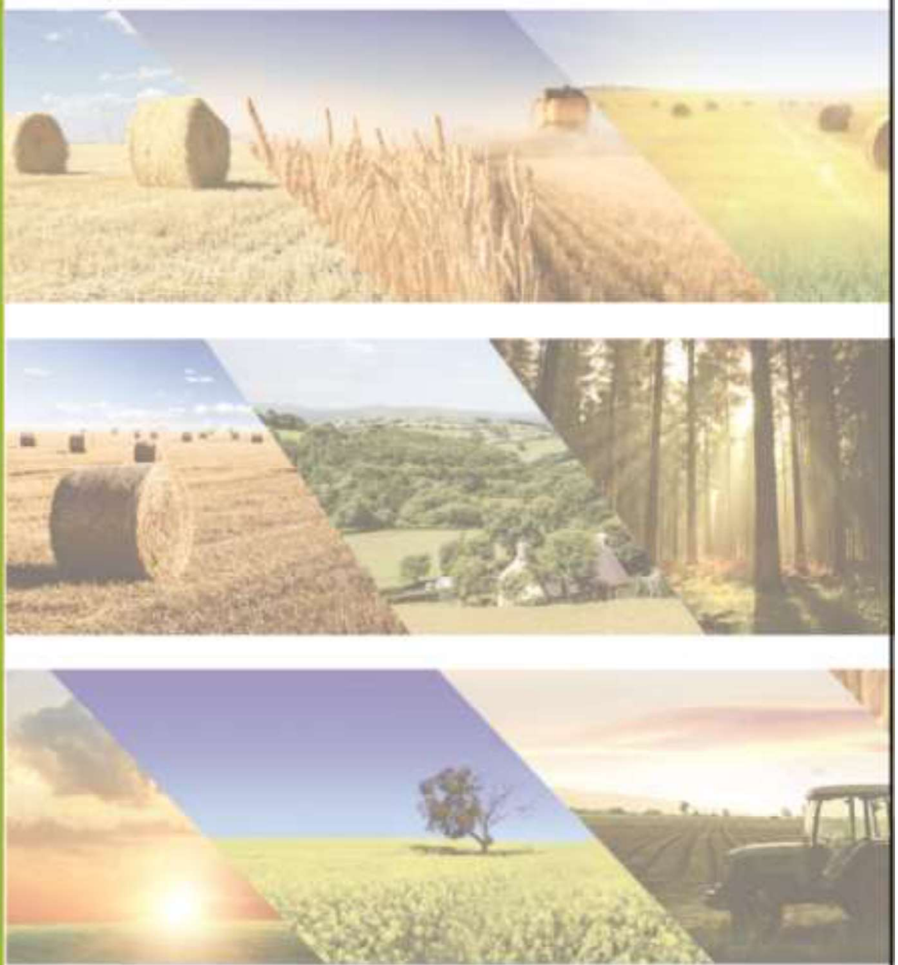

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RESPONSE OF DIFFERENT WHEAT GENOTYPES TO DROUGHT IN SEMI-ARID CLIMATE CONDITIONS

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Abstract

A two-year study was conducted on 16 wheat genotypes with the aim of examining the reaction of genotypes to different environmental conditions. Grain weight per spike is a quantitative trait, which phenotypic expression is determined by the influence of a number of minor genes and environmental factors. Therefore, this trait is a suitable phenotypic marker of influence of environmental factors on the plant. The year factor had the largest share in the variation of grain weight per spike (67.82%), while the share of the genotype and the genotype × year interaction was significantly smaller (14.98 and 10.95%, respectively).
Drought conditions, which characterized the 2016/2017 growing season, affected the reduction of grain weight per spike by 41.7%. The greatest reduction in the value of trait under stress conditions was recorded in Fundulea 4 genotype (63.14%), which achieved the highest value in favorable environmental conditions (3.5 g), while in drought conditions it had a below-average value (1.29 g). Also, Dunavka genotype made good use of favorable environmental conditions to achieve a high value of grain weight per spike (3.14 g), so it can be recommended for breeding in favorable climatic conditions. On the other hand, the highest tolerance to drought was exhibited by the Pitoma genotype, which recorded a 15.67% decrease in grain weight per spike. The high tolerance of the mentioned genotype results from the highest value of the trait achieved in the dry growing season (1.83 g), which makes this genotype a good genetic resource for breeding for drought tolerance.

Key words: *wheat, drought stress, tolerance, genetic resources.*

Introduction

Water deficit is a major challenge to wheat productivity under changing climate conditions, especially in arid and semi-arid regions (Ahmad *et al*., 2022). Due to the increasing impact of climate change and the increase in areas with drought stress conditions, work on genetic improvement and developing drought-tolerant varieties is one of the most important tasks of breeders (Ahakpaz *et al*., 2020; Pandey *et al*., 2022).
In the early stages of wheat plant development, drought can cause a decrease in the number of fertile spikes. Drought during the flowering stage reduces grain number, especially when drought occurs shortly after anthesis, while post-anthesis drought tends to reduce grain weight. Drought stress at the time of filling and ripening of wheat affects the reduction of grain yield because of reducing duration of grain filling period.

Heatwaves and droughts, which are among the biggest stressors, tend to occur together, and their frequency is increasing with climate change (Correia *et al*., 2022). Globally, about 40% of wheat yield variation is explained by environmental constraints, with heat waves and drought being among the biggest stressors (Zampieri et al., 2017). Plant breeders and research scientists in the semi-arid areas attempt to improve wheat yields and develop new wheat varieties that tolerate drought (Abdel-Ghani *et al*., 2020).
The aim of this research is to investigate effect of drought stress on grain weight per spike, as one of very important yield component of different wheat genotypes.

Material and Methods

Field trials and methods

A two-year trial (2015/2016 and 2016/2017) was conducted with 16 divergent genotypes of winter bread wheat (Jugoslavija, Jedina, Fundulea 4, Iskra, Dunavka, Tamiš, Kavkaz, Skopjanka, Dukat, Pitoma, Poljana, Marija, NS 58-04, Mačvanka 1, Vali PKA 7114 and Zvezda), according to the random block system in three repetitions, where the size of the basic plot was 2 m^2.
The experiment was carried out in the Novi Bečej locality in Serbia on the humogley type of soil, where the usual agrotechnics for wheat production were applied. Monoammonium phosphate (MAP) fertilizer was applied before sowing in the amount of 250 kg ha^{-1}. In both research years, sowing was done with an inter-row spacing of 12 cm, and the sowing density was 650 grains m^{-2}. Wheat was sown in the first year of the research on October 31, 2015 and in the second year on November 5, 2016. Crop feeding was carried out in the last decade of February in both growing seasons, where 250 kg of *urea* per hectare was applied. In the growing season 2015/2016, the harvest was carried out on July 4, 2016, and in the season 2016/2017, the harvest was on June 26, 2017. At the stage of full maturity of wheat, samples of 30 plants of each cultivar (10 plants per replication) were taken for yield component analysis. The grain weight per spike was determined by measuring the grain weight of the primary spike, for each plant separately. The data were processed using the statistical program SPSS IBM Statistics 23 (Trial Version), https://www.ibm.com/).

Climatic conditions

The meteorological parameters for this investigation were taken from the website of the Republic Hydrometeorological Service of Serbia (http://www.hidmet.gov.rs/). The values of the analyzed climate parameters were compared with the corresponding values of the long-term averages, for the period from 1981 to 2010 for the Bečej area (Figure 1 and 2). October 2015 and 2016 were characterized by very similar climatic conditions. In both years, October is characterized by a higher amount of precipitation than usual for this month (30 mm more compared to the multi-year average), which caused somewhat later sowing. A higher amount of precipitation improved the water-physical condition of the soil and enabled more uniform germination and sprouting of plants. The temperature in both production years did not deviate significantly from the multi-year average. During autumn and the beginning of winter, the amount of precipitation was similar in both growing seasons. From January, there were significant differences in the amount of precipitation in the examined years. In 2017, the amount of precipitation was much lower compared to 2016 and a long-term period, except for the month of April when the precipitation was at the level of the multi-year average (52.5 mm; 52.9 mm, respectively). On average for the entire vegetation period of wheat development, in 2017 there was significantly less precipitation (42.2) compared to 2016 (154.0) and the multi-year average (69.3). Such conditions caused slower growth and development of plants, which contributed to a decrease in the value of yield components.

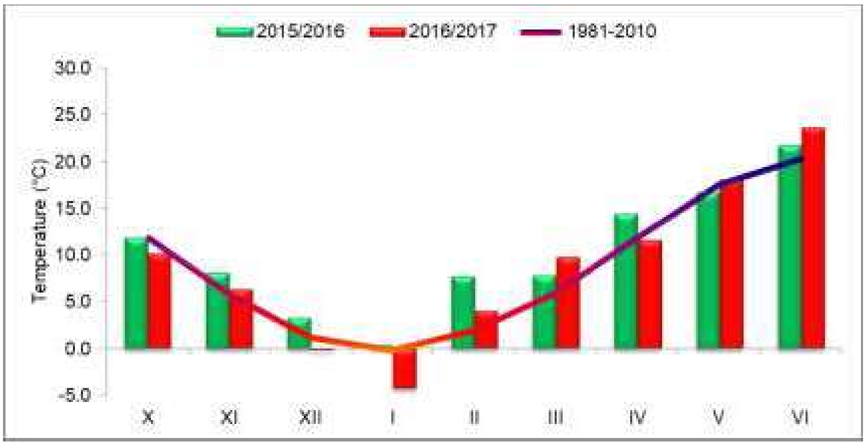

Figure 1. Average temperatures for each month during 2015/2016, 2016/2017 growing seasons and a long-term period (1981-2010)

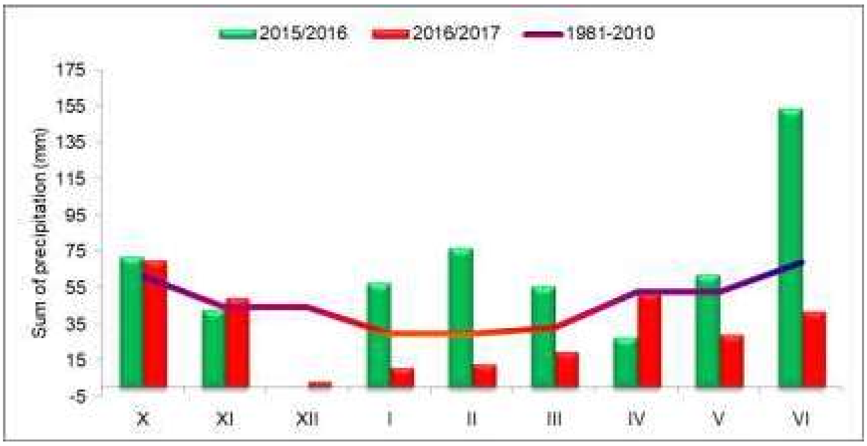

Figure 2. Sum of precipitation for each month during 2015/2016, 2016/2017 growing seasons and a long-term period (1981-2010)

Results and Discussion

The grain weight per spike was higher in the first year of research (2.49 g) than in the second year (1.45 g). The average of the whole experiment for grain weight per spike was 1.97 g (Table 1). Analysis of the standard deviation revealed a significant variability of grain weight per spike between wheat cultivars and between years in which the experiments were carried out. In 2015/2016, the coefficient of variation ranged from 16.19% (NS 58-04) to 34.19% (Kavkaz). The cultivar Kavkaz, apart from the high variability of this trait, also had the lowest value for grain weight per spike in the first year of research (1.67 g). In the first year, the cultivar Fundulea 4 had the highest grain weight per spike (3.50 g), and low variability of this trait (CV=18.65%). In 2015/2016, the climatic conditions for the development of wheat plants were more favorable than in 2016/2017 (Figure 1 and 2), when there was a decrease in the grain weight per spike, and therefore the grain yield.

In 2016/2017, there was a drought at the time of filling and ripening of grains, which led to a decrease in the grain weight per spike, whose values ranged from 1.02 g (Kavkaz) to 1.83 g (Pitoma). The variability of these properties was significantly higher in this year compared to 2015/2016 and was as much as 44.10% in the Kavkaz variety. The variety Kavkaz had a low value for grain weight per spike in both years of research, and high variability of this wheat yield component.

Table 1. Average values and variability for grain weight per spike in wheat

Genotype	2015/2016			2016/2017			Average	
	$\overline{X}$ (g)	Sd	CV	$\overline{X}$ (g)	Sd	CV	$\overline{X}$	CV
Dukat	2.65	0.58	21.96	1.59	0.59	37.07	2.12	29.52
Dunavka	3.14	0.88	27.99	1.65	0.38	22.89	2.40	25.44
Fundulea 4	3.50	0.65	18.65	1.29	0.52	40.55	2.39	29.60
Iskra	2.09	0.57	27.03	1.53	0.40	26.39	1.81	26.71
Jedina	2.24	0.66	29.50	1.42	0.37	25.98	1.83	27.74
Jugoslavija	2.46	0.46	18.49	1.41	0.34	24.05	1.93	21.27
Kavkaz	1.67	0.57	34.19	1.02	0.45	44.10	1.35	39.15
Mačvanka 1	2.39	0.52	21.88	1.37	0.47	34.36	1.88	28.12
Marija	2.43	0.51	21.06	1.35	0.38	28.38	1.89	24.72
NS 58-04	2.52	0.41	16.19	1.27	0.43	33.77	1.89	24.98
Pitoma	2.17	0.43	19.76	1.83	0.55	29.84	2.00	24.80
Poljana	2.54	0.62	24.37	1.63	0.44	26.73	2.09	25.55
Skopjanka	2.85	0.50	17.61	1.61	0.29	18.05	2.23	17.83
Tamiš	2.58	0.55	21.16	1.21	0.37	30.31	1.89	25.73
Vali PKA-7114	2.44	0.49	20.12	1.61	0.41	25.21	2.02	22.67
Zvezda	2.18	0.40	18.21	1.39	0.41	29.56	1.79	23.88
Average	2.49	0.55	22.38	1.45	0.47	29.83	1.97	26.10
$LSD_{(G)\ 0.05}$=0.317, $_{0.01}$=0.421				$LSD_{(G\times Y)\ 0.05}$=0.448, $_{0.01}$=0.595				

The cultivar Skopjanka showed the lowest variability, that is, the homogeneity of grain weight per spike in the first year of research (CV=17.61%). Apart from the low variability of this trait, in 2015/2016 the cultivar Skopjanka was the third in terms of grain weight per spike (2.85 g) as well as the average for both years (2.23 g). Only the cultivars Dunavka and Fundulea 4 (2.40 g, 2.39 g, respectively) had higher average values for grain weight per spike than Skopjanka. Variation in genotypes can be explained by the fact that each plant presents a different defense and tolerance mechanism, which may also occur between genotypes of the same species (Nardino *et al*., 2022).

Analysis of variance revealed highly significant differences for grain weight per spike between cultivars as well as between analyzed seasons. The cultivar × year interaction was also statistically highly significant (Table 2). Thus, grain weight per spike is a quantitative property that is highly dependent on environmental factors (Zečević *et al*., 2018; 2022).

Table 2. Analysis of variance for grain weight per spike in wheat

Source of variation	df	Sum of Squares (SS)	Mean Square (MS)	F - value	p - value	Share in variation (%)
Genotype (G)	15	5.787	0.386	10.242**	0.000	14.98
Year (Y)	1	26.198	26.198	695.507**	0.000	67.82
Genotype × Year	15	4.231	0.282	7.489**	0.000	10.95
Blocks	2	0.019	0.009	0.250	-	0.05
Error	64	2.411	0.038			-
Total	95	38.627				100.00

The variation of wheat yield by year can mainly be explained by abiotic limitations. In this research, wheat genotypes in the season with favorable climatic conditions were more productive than in the dry season. Drought conditions, which characterized the 2016/2017 growing season, affected the reduction of grain weight per spike by 41.7%. Similar effects of drought on plants have also been observed by other authors, including Soomro *et al*. (2019). Also, in previous study, wheat genotypes showed considerably lower mean values for grain yield (86.6-204.7%) under stress conditions than when irrigated (Aksić *et al*., 2020). Susceptibility to drought depends on its intensity and duration, as well as on the stage of crop growth in which the drought was imposed. The physiological and quantitative genetic basis of drought tolerance is still poorly understood (Haddadin *et al*., 2013). Understanding the mechanisms and responses of genotypes to drought stress is crucial for research because it guides the positioning of genotypes in environments where they are more likely to suffer from climatic fluctuations in precipitation (Nardino *et al*., 2022).

Conclusions

The tested cultivars showed different sensitivity and adaptability to the water deficit and high temperatures that prevailed in the 2015/2016 growing season. The smallest decrease in grain mass per spike was shown by the Pitoma cultivar (0.34 g) in the dry vegetation of 2015/2016 compared to 2015/2016, which was significantly more favorable for the growth and development of wheat plants. In addition to this cultivar, a low reduction of the tested property was also found in the cultivars Iskra and Kavkaz, which amounted to about 0.60 g. Some of these cultivars could be used as parents in breeding programs for drought stress resistance and improving wheat resilience to climate change.

Acknowledgements

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