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Yield components and genetic potential of winter wheat on pseudogley soil of Western Serbia

Original Article

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Abstract:

In order to determine the effect of genotype and vegetation season on the yield and components of the winter wheat yield an experiment was performed in the secondary agricultural-chemical school "Dr Đorđe Radić" in Kraljevo. Five wheat varieties (Kruna, Renesansa, Pobeda, NS 40S and Takovčanka) were examined during two growing seasons in the agro-ecological conditions of Western Serbia. Trials were arranged according to a randomized scheme in five repetitions. Grain yield (GY), 1000 grain weight (TGW) and test weight (TW) in winter wheat grain were analyzed. The study was performed as an experiment based on extremely acidic pseudogley soil. On average, for all wheat varieties, during the two-year trial, the highest yield of winter wheat 4.673 t/ha was obtained in the variety Renesansa. The Renesansa variety showed the highest yield and 1000 grain weight. The highest 1000 grain weight had been established for wheat cultivar Renesansa (43.72 g). The highest two-year average value of test weight was found in the varieties Kruna and Pobeda (77.52 kg/hl and 77.31 kg/hl). Analysis of variance revealed a highly significant effect of the growing season on the yield and test weight of wheat. A highly significant effect of genotype on 1000 grain weight and test weight was determined.

Key words:
yield components, grain yield, wheat

Apstrakt:

Komponente prinosa i genetski potencijal ozime pšenice na pseudoglejnom zemljištu zapadne Srbije

U cilju utvrđivanja uticaja genotipa i vegetacione sezone na prinos i komponente prinosa ozime pšenice izveden je ogled u Srednjoj poljoprivredno-hemijskoj školi „Dr Đorđe Radić" u Kraljevu. Ispitivano je pet sorti pšenice (Kruna, Renesansa, Pobeda, NS 40S i Takovčanka) tokom dve vegetacione sezone u agroekološkim uslovima zapadne Srbije. Ogledi su postavljeni po slučajnom blok sistemu u pet ponavljanja. Analizirani su prinos zrna (PZ), masa 1000 zrna (MHZ) i hektolitarska masa (HM) u zrnu ozime pšenice. Ogled je zasnovan na izuzetno kiselom zemljištu tipa pseudoglej. U proseku, za sve ispitivane sorte pšenice, tokom dvogodišnjeg ogleda, najveći prinos ozime pšenice od 4.673 t/ha dobijen je kod sorte Renesansa. Najveći prinos i masa 1000 zrna ustanovljena je kod sorte Renesansa. Najveća masa 1000 zrna ustanovljena je kod sorte pšenice Renesansa (43.72 g). Najveća dvogodišnja prosečna vrednost hektolitarske mase utvrđena je kod sorti Kruna i Pobeda (77.52 kg/hl i 77.31 kg/hl). Analiza varijanse pokazala je veoma značajan uticaj vegetacije na prinos i hektolitarsku masu pšenice. Utvrđen je visoko značajan uticaj genotipa na masu 1000 zrna i hektolitarsku masu.

Ključne reči:
komponente prinosa, prinos zrna, pšenica

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Introduction

Winter wheat (*Triticum aestivum* L.) is one of the most important field crops in World and Republic of Serbia. World's current average wheat production in tested period (2017-2018), was 752.841.037 tons and in Republic of Serbia 2.608.612 tons. The average area under wheat in the World in tested period was 216.141 mill. ha and in Republic of Serbia was 599.599 ha. The average wheat yield in the World was 3.483 t/ha and in Republic of Serbia was 4.333 t/ha (FAO, 2021). The average yield of wheat in 2017 in the World was 3.538 t/ha and in the Republic of Serbia 4.092 t/ha. In 2018, the average yield of wheat in the World was 3.427 t/ha, and in the Republic of Serbia 4.574 t/ha (FAO, 2021).

Wheat production in Serbia depends to a large extent on the environmental factors. The grain yield and yield components of winter wheat vary considerably depending on the cultivation system, the applied doses of nitrogen, variety and conditions during the growing year, as well as their complex interactions (Jaćimović et al., 2011; Đekić et al., 2014; Jelic et al., 2015; Terzić et al., 2018; Đekić et al., 2019a; Popović et al., 2020; Ljubičić et al., 2021).

The interaction between the genotype and environment greatly limits the effectiveness of selection, if it is performed only on the basis of the average yield (Dimitrijević et al., 2011; Laghari et al., 2011; Perišić et al., 2011; Milovanović et al., 2012; Đekić et al., 2013; Hristov et al., 2014; Jocković et al., 2014; Đurić et al., 2016; Terzić et al., 2018). Varieties that have a smaller contribution to interaction are less sensitive to changing environmental conditions, such varieties are stable. Genetic variation plays a significant role in the adaptability of wheat to stress caused by external environment (Mladenov et al., 2007; Milovanović et al., 2011; Luković et al., 2014; Đurić et al., 2018; Rajičić et al., 2020). Understanding the genetic basis of adaptation and its physiological causes is important for understanding the interactions, leading to more efficient choices of superior and stable genotypes (Perišić, 2016; Djuric et al., 2018; Luković et al., 2020).

The yield per unit area is the result of the action of factors of variety fertility in interaction with environmental factors. The main goal in breeding wheat is to create varieties with high yield potential and good grain quality suitable for animal feed or brewing industry (Milovanović et al., 2011; 2012; Hristov et al., 2014; Perišić, 2016; Đurić et al., 2018). Improved production technology has contributed to the increase in yields in recent decades, because improved production technologies enable better realization of the potential for yield. High and stable yield of wheat is the main goal of breeding, especially in institutions where it is not possible to adequately test the breeding material on quality traits. Yield increase is the result of improving germplasm and improvement of production technology (Đurić et al., 2018). The need for a variety of short or long growing season depends on the environmental conditions of a particular area. In winter wheat often variations in yield can be detected, also between the years and between locations (Đekić et al., 2015; Đurić et al., 2018; Jevtić and Đekić, 2018; Terzic et al., 2018; Luković et al., 2020).

The 1000 grain weight and test weight are direct components of grain yield and change under the influence of environmental factors, but primarily varietal characteristics. They indicate the grain size and are important criterions in breeding wheat. The 1000 grain weight in addition to the number of grains per spikes is the most important criterion in breeding wheat for yield increase (Perišić, 2016).

Production of winter wheat with high grain yield and appropriate quality is possible only by choosing varieties of good quality with appropriate cultivation conditions and appropriate production technology. The aim of this study was the determination of the varieties and ecological environmental factors influence on differences in stability and adaptability of varieties regard the grain yield, 1000 grain weight and test weight of tested winter wheat varieties. During the vegetation years (2016-2018), in the field trials, five winter wheat varieties were examined in order to determine the selection of the better varieties for the production conditions in Western Serbia.

Materials and Methods

Materials and field trials

Field experiments were performed on the experimental field of the secondary agricultural-chemical school "Dr. Đorđe Radić" in Kraljevo (43°43′00′′N, 20°40′60′′E, 198 m above sea level) during two growing seasons (2016/17 and 2017/18) in dry crop conditions, with the aim of analysing the yield and quality of winter wheat grains in Western Serbia.

The experiments were conducted in randomized block systems, with a plot size of 50 m^2 (5 m x 10 m) in five replications. Wheat has been preceded by maize in all seasons. The basic tillage was done classically, up to 25 cm deep. The sowing was carried out using a machine with row spacing of 12 cm. The soil on which the trial was conducted was uniform and well prepared. The amount of seed per square meter amounted to 400-450 viable seeds, depending on the characteristics of varieties. It was sown in the third decade of October, with 300 kg/ha of fertilizer NPK 15:15:15, which was added in the fall, while during the spring fertilization soil was carried out in 2-3 leaf stage was supplemented with 300 kg/ha (CAN-calcium-ammonium-nitrate, 27% N).

The winter wheat varieties Kruna and Takovčanka originated from the Centre for Small Grains in Kragujevac and Renesansa, Pobeda and NS 40S originated from the Institute of Field and Vegetable Crops, Novi Sad were selected as the material for the experiment. The following properties were analyzed: grain yield (t/ha), 1000 grain weight (g) and test weight (kg/hl). Grain yield was measured for each plot and converted to grain yield in t/ha based on 14% grain moisture, after which a sample was taken for analysis of 1000 grain weight and test weight of the wheat.

Soil conditions

The trial at the secondary agricultural-chemical school "Dr. Đorđe Radić" in Kraljevo, was performed on soil that is characterized as pseudogley. The trial was performed on pseudogley soil, of unfavourable physical characteristics, of poor water-air regime with frequent water or air deficiencies. This soil has very bad physical properties (compacted, having a high content of silt and clay particles, with slow water percolation) and an extremely acid pH value (pH<4.5). Its total humus content is relatively fair, but microbiological activity is low, because of its poor physical properties. It is characterized by low content of available phosphorus (6.70-6.90 mg/100g of soil) and potassium (7.80-9.80 mg/100g of soil).

Meteorological conditions

This study was conducted over a two-year period in the Kraljevo, located in the Čačak-Kraljevo valley that belongs to the Western Morava river region (**Tab. 1**). It is surrounded by a large number of mountain ranges and their hills through which the wide river valleys of the West Morava, the lower Ibar and the lower Gruža intersect. It is located at 20°40´60´´E longitude and 43°43´00´´N latitude. The soil of the studied area is in a zone of temperate continental climate, with uneven distribution of precipitation by months. Based on the data of meteorological stations in Kraljevo, in the years in which the researches were carried out, the conditions differed from the long-term average characteristic of the area.

The data in **Tab. 1** for the investigated period (2016-2018) clearly indicate that the average air temperature was higher than the annual average by 0.8 ºC in 2017/18 and lower by 0.4 ºC in 2016/17 (**Tab. 1**). Average monthly air temperatures in 2016/17 were slightly lower, especially in January (-5.0 ºC) than in 2017/18. However, in both years, temperatures were within optimal limits and had no negative effects on yield.

The data presented in **Tab. 1** the wheat growing season analyzed (2016-2018) clearly suggest differences in weather conditions between the years of the study and the long-term mean for the region. The total amount of precipitation in the vegetation in 2016/17 was 524.4 mm and 758.7 mm in 2017/18. The total amounts of rainfall were above the perennial average in the surveyed growing seasons (2017/18), with a rather uneven monthly distribution. Weather conditions in the growing period in 2017/18 were marked by high rainfall during March, while rainfall in April was significantly lower. Variable and moderately warm weather, with less precipitation than average, marked May 2016/17 and 2017/18 (**Tab. 1**). During the run of the experiment, the differences between the mean precipitation values and the perennial average in the second years of the study were the highest in March and June. Higher precipitation and their better distribution in 2017/18, especially in October, March and June, contributed to better fertilizer decomposition and higher wheat grain yield.

Statistical analysis

On the basis of achieved research results the usual variational statistical indicators were calculated: average values. Experimental data were analyzed by descriptive and analytical statistics using the statistics module Analyst Program GenStat (2013) for PC/Windows 7. All evaluations of significance were made on the basis of the ANOVA test at 5% and 1% significance levels. Relative dependence was defined through correlation analysis (Pearson's correlation coefficient), and the coefficients that were obtained were tested at the 5% and 1% levels of significance.

Table 1. Mean monthly air temperatures and precipitations in Kraljevo, Serbia (2016-2018), in relation to many years average

	Months									
Interval	X	XI	XII	I	II	III	IV	V	VI	Average
	Mean monthly air temperature (ºC)									
2016/17	7.6	6.0	5.8	-5.0	4.5	10.3	11.3	16.2	22.4	8.8
2017/18	11.9	6.8	4.0	2.7	2.0	6.5	16.6	19.1	20.9	10.0
Average	11.6	7.7	2.0	0.6	3.3	7.9	12.5	16.3	20.9	9.2
	The amount of precipitation (mm)									
2016/17	84.1	77.6	9.4	22.1	35.3	57.7	82.1	99.9	56.2	524.4
2017/18	133.3	32.4	55.6	51.0	80.9	111.2	40.6	84.4	169.3	758.7
Average	73.4	37.8	56.0	48.6	51.5	80.8	80.3	112.1	82.4	622.9

Results

Grain yield and yield components

The average values of productive grain yield and yield components of the investigated winter wheat varieties grown in the secondary agricultural-chemical school "Dr. Đorđe Radić" in Kraljevo are shown in **Tab. 2**.

Grain yield: In regard to grain yield, differences were established in the tested varieties and growing seasons. The variety with the lowest average yield in all years was variety Renesansa (4.673 t/ha). The highest average grain yield in the first year of testing was recorded for the variety Renesansa (4.273 t/ha) and the lowest for the variety NS 40S (3.894 t/ha). The average grain yield of all varieties in 2016/17 was 4.077 t/ha. In the second year of testing, the highest yield of all varieties was achieved, also in this year, with the variety Renesansa (5.073 t/ha). Average yield of winter wheat for all varieties in 2017/18 was 4.639 t/ha and the average grain yield was 4.358 t/ha. The highest average grain yield in all years was the variety Renesansa (4.673 t/ha) and the slightly lower yield the varieties Takovčanka and Pobeda (4.386 t/ha and 4.379 t/ha).

1000 grain weight: Average values for 1000 grain weight of all studied varieties are presented in **Tab. 2**. The average of 1000 grain weight of all tested varieties and years of winter wheat was 40.38 g. The variety NS 40S had the lowest 1000 grain weight for all years (34.68 g) and the highest 1000 grain weight the variety Renesansa (43.72 g). In 2016/17, the average of 1000 grain weight of all varieties was 39.48 g and in 2017/18 was 41.28 g. The growing period in 2016/17 at the time of grain loading was marked by drought and high temperatures, which reduced the weight of 1000 grains.

Test weight: The average value for all varieties and years was 76.02 kg/hl (**Tab. 2**). The lowest test weight grain of winter wheat at two years was recorded for the variety NS 40S (74.01 kg/hl), while the highest value for the varieties Pobeda and Kruna (77.31 kg/hl and 77.52 kg/hl). The average value of test weight of grain for all varieties was significantly higher in 2017/18 (77.26 kg/hl) compared to 2016/17 (74.78 kg/hl). Regardless of the year, vari-

Table 2. Average values of investigated winter wheat varieties traits

Varieties	2016/17			2017/18			Average		
	x	S	Sx	x	S	Sx	x	S	Sx
Yield, t/ha									
Kruna	4.014	0.634	0.284	4.614	0.117	0.052	4.314	0.534	0.169
Renesansa	4.273	0.443	0.198	5.073	0.475	0.213	4.673	0.604	0.191
Pobeda	4.073	0.464	0.207	4.686	0.551	0.246	4.379	0.579	0.183
NS 40S	3.894	0.353	0.158	4.178	0.207	0.093	4.036	0.311	0.098
Takovčanka	4.129	0.465	0.208	4.643	0.573	0.256	4.386	0.561	0.177
Average	4.077	0.457	0.091	4.639	0.486	0.097	4.358	0.546	0.077
1000 grain weight, g									
Kruna	39.49	0.905	0.405	40.94	1.781	0.797	40.21	1.536	0.486
Renesansa	41.64	0.689	0.308	45.79	1.728	0.773	43.72	2.512	0.794
Pobeda	40.98	0.655	0.293	43.84	1.427	0.638	42.41	1.838	0.581
NS 40S	34.45	0.636	0.284	34.91	0.578	0.259	34.68	0.622	0.197
Takovčanka	40.82	1.192	0.533	40.94	1.781	0.797	40.88	1.430	0.452
Average	39.48	2.772	0.554	41.28	4.008	0.801	40.38	3.530	0.499
Test weight, kg/hl									
Kruna	75.42	0.335	0.150	79.62	0.228	0.102	77.52	2.230	0.705
Renesansa	74.70	0.400	0.179	78.03	0.480	0.215	76.36	1.804	0.570
Pobeda	75.82	0.415	0.185	78.81	0.431	0.193	77.31	1.625	0.514
NS 40S	73.26	0.865	0.387	74.77	0.228	0.102	74.01	0.994	0.314
Takovčanka	74.70	0.400	0.179	75.06	0.817	0.365	74.88	0.636	0.201
Average	74.78	1.010	0.202	77.26	2.069	0.414	76.02	2.040	0.289

Table 3. Analysis of variance of the tested parameters (ANOVA)

	Effect of year on the traits analyzed			
Traits	Mean sqr Effect	Mean sqr Error	F (1. 48)8	p-level
Grain yield (t/ha)	3.948	0.223	17.733	0.000**
1000-grain weight (g)	40.825	11.874	3.438	0.070ns
Test weight (kg/hl)	76.756	2.651	28.951	0.000**
	Effect of genotype on the traits analyzed			
Traits	Mean sqr Effect	Mean sqr Error	F (4. 45)	p-level
Grain yield (t/ha)	0.515	0.279	1.842	0.137 ns
1000-grain weight (g)	120.115	2.896	41.480	0.000**
Test weight (kg/hl)	23.414	2.452	9.547	0.000**
	Effect of the year x genotype interaction			
Traits	Mean sqr Effect	Mean sqr Error	F (4. 40)	p-level
Grain yield (t/ha)	0.088	0.207	0.425	0.789 ns
1000-grain weight (g)	7.119	1.525	4.667	0.003**
Test weight (kg/hl)	5.860	0.254	23.069	0.000**

*Statistically significant (p<0.05); **Statistically high significant (p<0.01)

eties Pobeda and Kruna had the highest test weight. However, observed by years, there is considerable disagreement on their differences. The highest test weight in the first year of testing had variety Pobeda (75.82 kg/hl) and the lowest variety Kruna (75.42 kg/hl). In the second year of testing, variety Kruna (79.62 kg/hl) had the highest test weight.

Analysis of variance between observed traits of wheat

The analysis of yield variance, 1000 grain weight and test weight of winter wheat varieties during two growing seasons 2016/17 and 2017/18, are shown in **Tab. 3**.

Analysis of variance in winter wheat genotypes tested showed statistically highly significant differences in yield and test weight in relation to the growing season (p<0.01). In regard to the 1000 grain weight and test weight, statistically highly significant differences were determined between the varieties of winter wheat. Statistically highly significant difference in 1000 grain weight and test weight is determined under the influence of the interaction year x genotype.

Correlation dependence between tested wheat traits

The average values of the Pearson's coefficient of correlation (r) of investigated winter wheat traits are shown in **Tab. 4**. Correlation coefficients based on all traits tested during 2016/17 and 2017/18 had positive.

Highly significant and positive correlation coefficients, during 2016/17, were found between 1000 grain weight and test weight (r=0.673**). During 2017/18, highly significant positive correlation coefficients were found between 1000 grain weight and test weight (r=0.596**) and significant and positive dependence was determined between yield and 1000 grain weight (r=0.496*). Over a two-year study period (2016-2018), significant positive correlation coefficients were found between yields and 1000 grain weight (r=0.467*) and test weight (r=0.459*). Also, highly significant positive correlations were found between 1000 grain weight and test weight (r=0.623**).

Discussion

Wheat grain yield depends on the type of soil and its fertility, weather conditions during the vegetation period, the genetic potential of the variety and the levels applied agrotechnical measures, especially mineral nutrition of plants with nitrogen (Zafaranaderi et al., 2013; Đekić et al., 2015; Luković et al., 2016; Perišić et al., 2016; Đurić et al., 2018). Small grains are very sensitive to soil acidity, although some genotypes show different tolerances. Therefore, there is a need to grow wheat and other cereals on acid soils to isolate genotypes adapted to acid soils and different climatic conditions (Jelić et al., 2016). Numerous studies in our country and the world indicate that the combined application of organic and mineral fertilizers is the most efficient way to eliminate unfavorable production properties of acid

Table 4. Analysis of variance of the tested parameters (ANOVA)

	Grain yield, GY	1000 grain weight, GW	Test weight, TW
	Correlations between the traits analysed in the 2016/17		
Grain yield, GY	1.00	0.272	0.183
1000 grain weight, GW			0.673**
Test weight, TW			1.00
	Correlations between the traits analysed in the 2017/18		
Grain yield, GY	1.00	0.496*	0.234
1000 grain weight, GW			0.596**
Test weight, TW			1.00
	Correlations between the traits analysed in the 2016-2018		
Grain yield, GY	1.00	0.467*	0.459*
1000 grain weight, GW			0.623**
Test weight, TW			1.00

*Statistically significant ($p<0.05$); **Statistically high significant ($p<0.01$)

soils, which multiplies the yields of cultivated plants (Đekić et al., 2013; Jelić et al., 2014; Biberdžić et al., 2014; Rajičić et al., 2019).

The results of our tests show that, on average for the investigated factors, the yield wheat grains amounted to 4.358 t/ha (**Tab. 2**). The studied genotypes achieved the lowest yield values in 2016/17 years of research (4.077 t/ha) and the highest yield values in 2017/18 years (4.639 t/ha). Živanović et al. (2017) gained similar wheat yields on the vertisol of Šumadija (4.310-4.440 t/ha). The expressed differences in yield can be the result of the chemical properties of the given soil, since vertisol is of the acidic reaction and has lower nitrogen, phosphorus and potassium content compared to the alluvium. Thus Stanković (2009) pointed out that the yield of wheat grains depends on the type of soil and its fertility, weather conditions during the growing period, the genetic potential of the variety and the level of applied cultural practices measures. According to the authors Đekić et al. (2019a), varieties of winter wheat tested to low soil pH values show very good results. Based on the level of yield achieved, winter wheat varieties are known to be the most tolerant the Kruna variety proved to be more adaptable. The same authors point out that grain yield of wheat cultivars ranged from 3.743 t/ha to 6.275 t/ha.

Newly created high-yielding wheat varieties have been found to be less responsive to temperature deviation than is the case with rainfall (Đurić et al., 2013; Hristov et al., 2013; Đekić et al., 2015; Jelic et al., 2015; Luković et al., 2020; Rajičić et al., 2020). Đekić et al. (2019) pointed out that intensive pre-harvest rainfall in 2010 led to crop lodging in case of wheat cultivars (Toplica and Vizija), which reduced yield. Jevtić & Đekić (2018) pointed out that the yield of wheat varieties varied significantly by years of research and amounted from 3.125 to 3.518 t/ha in 2012/13, while a much higher yield of 4.395 to 4.729 t/ha was established in 2011/12. According to the authors Terzić et al. (2018), average yield of wheat in the experiment was 5.091 t/ha, with a variation of 4.630 t/ha in the 2011/12 to 5.553 t/ha in the first year of the study (2010/11). Biberdžić et al. (2020) investigated different wheat genotypes over a two-year study and reported that yields ranged from 3.090 to 3.745 t/ha in 2016/17 and from 3.839 to 4.770 t/ha in 2017/18. The same authors pointed out that grain yield of wheat cultivars ranged from 3.464 t/ha (the variety Daria on vertisol) to 6.865 t/ha (the variety Avenue on the alluvial).

The 1000 grain weight is a very important qualitative characteristic of grain that has a strong impact on grain yield. The 1000 grain weight during the two-year study period was 40.38 g. The values obtained are slightly lower than the results obtained by Biberdžić et al. (2020), Jevtić & Đekić (2018) and Terzić et al. (2018). Jevtić & Đekić (2018), examined different wheat genotypes and stated that the 1000 grain weight ranged from 42.72 to 44.05 g. Terzić et al. (2018) performed a two-year study and the results showed that the 1000 grain weight ranged from 41.98 g to 45.0 g. Biberdžić et al. (2020) pointed out that the average weight of 1000 grains in the optimal sowing period was 41.8 g, while in the delayed time it was 40.08 g, which does not represent a statistically significant difference.

Test weight is an indicator of grain size and filling, and it is a very important parameter when buying

wheat. The average two-year value of test weight was 76.02 kg/hl and the highest were obtained for the genotype Kruna (77.52 kg/hl). The values obtained were slightly higher than the test weight obtained by Jevtić & Đekić (2018) and Biberdžić et al. (2020). A significant influence of the growing season on test weight in wheat is also established by Jevtić & Đekić (2018). During a two-year study, Jevtić & Đekić (2018), have found that the test weight ranged from 69.5 to 71.03 kg/hl. According to the authors Biberdžić et al. (2020), in the optimal sowing period, test weight was 71.42 kg/hl, while in the delayed time, it was 69.96 kg/hl, which does not represent a statistically significant difference.

Based on the analysis of variance, it can be concluded that the influence of growing season on grain yield was highly significant (Fexp=17.733**). Also, Biberdžić et al. (2020), Jevtić & Đekić (2018) and Terzić et al. (2018), state that differences in yields between years occur due to environmental conditions.

The 1000 grain weight in the study showed highly significant dependence on the genotypes (Fexp=41.480**) and very significant in the interaction of growing seasons and genotypes (Fexp=4.667**). The present results confirm the opinion of many authors that the 1000 grain weight are strongly modified by the nutrient status of the environment and weather conditions (Đekić et al. 2014; Jevtić & Đekić, 2018; Terzić et al., 2018; Rajičić et al., 2020).

Correlation analysis shows the intensity of dependence between studied traits. From the genetic aspect, correlation indicates links between genes, or the appearance of pleiotropic effects of genes. Gene linkage pertains to their position on the same chromosome, while pleiotropy appears when one gene regulates the expression of several traits. A strong positive correlation between small grains yields and 1000 grain weight has been found by many researchers (Terzic et al., 2018; Rajičić et al., 2020) and medium positive dependence has been identified by Jelic et al. (2013), Đekić et al. (2014) and Terzić et al. (2018). Positive and weak dependence of yield and 1000 grain weight (r=0.31) was found by Đekić et al. (2019b). Iftikhar et al. (2012) have established that the 1000 grain weight have a positive and statistically significant correlation with grain yield. Rajičić et al. (2020) found a highly significant and positive correlation between yield and 1000 grain weight in 2013/14 (r=0.683**) and highly significant and positive correlation coefficients in 2014/15 (r=0.733**). The duration of the grain filling period is significantly influenced by environmental factors, above all the high temperatures that shortened this period. Selection of early-flowering varieties can influence the formation of more flowers and a longer grain filling period, i.e. the selection of higher yielding varieties (Djuric et al., 2018).

Based on the results of the research it can be concluded that a greater number of traits have a decisive role in the formation of grain yield. The contribution of each individual trait may be different in various varieties and in various environmental conditions so that the correlation between two quantitative traits is not fixed. This results from the interaction between the traits of each genotype and the interaction of varieties with external factors.

Conclusions

The highest yield of grain, 1000 grain weight and test weight in all wheat varieties were in the second vegetation period with moderate temperatures at the time of grain filling and a large amount of precipitation. Grain yields in wheat varieties ranged from 4.036 t/ha (NS 40S) to 4.673 t/ha (Renesansa). The average 1000 grain weight in the study was 40.38 g, with a variation of 39.48 g in the vegetation year 2016/17 to 41.28 g in the vegetation year 2017/18. The test weight for all examined wheat varieties in the study was 76.02 kg/hl and varied from 74.01 kg/hl in variety NS 40S to 77.52 kg/hl in variety Kruna. Grain yield shows a tendency to grow in years with a larger amount and better distribution of precipitation during the critical phases of plant development. Analysis of variance revealed a very significant influence of the growing season on grain yield and a highly significant influence of the year x variety interaction on grain yield.

Based on these results, it can be concluded that several traits have a decisive role in the formation of grain yield. The contribution of each individual feature can be different for different varieties and the various environmental conditions so that this results from the interaction between the features within each genotype and genotype interactions with environmental factors.

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