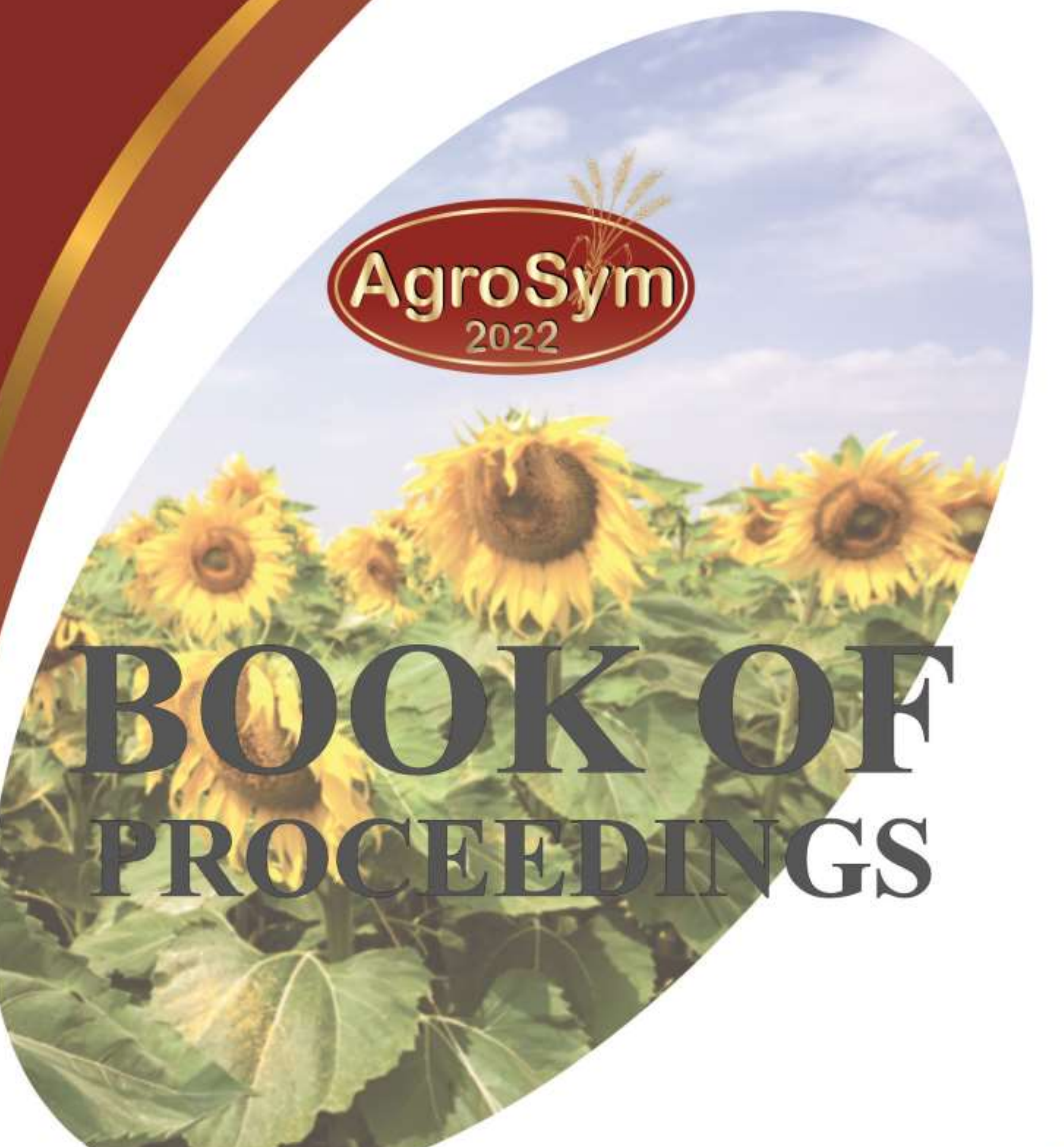

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VARIABILITY AND HERITABILITY OF GRAIN YIELD AND HECTOLITER MASS IN WHEAT

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Abstract

In the two-year field experiment (2013/2014 and 2014/2015), the variability of yield and hectoliter grain mass of 14 winter wheat genotypes was examined. The research was conducted in three locations across the Republic of Serbia: Centre for Small Grains in Kragujevac, Institute for forage crops in Kruševac and Agroinstitute in Sombor. Significant differences in grain yield were found between varieties, locations, years and their interactions, while the influence of the location did not show significant differences in hectoliter mass. Grain yield of studied wheat genotypes in 2013/2014 varied from 3.91 t ha^{-1} (KG-244/4) to 5.55 t ha^{-1} (KG-60-3/3), and in 2014/2015 from 5.67 t ha^{-1} (KG-162/7) to 7.08 t ha^{-1} (KG-27/6). The hectoliter mass also varied, and most often ranged from 72.1 kg hl^{-1} (KG-28/6) to 77.2 kg hl^{-1} (KG-191/5-13) in the first experimental year and from 76.7 kg hl^{-1} (KG-27/6) to 81.9 kg hl^{-1} (KG-191/5-13) in the second year. Unfavorable weather conditions which prevailed in the first experimental year, conditioned the formation of smaller and shriveled grains. As a result, the examined KG-wheat genotypes gave lower values in grain yield and hectoliter mass in 2013/2014 compared to 2014/2015. In this study, higher values of heritability in a broad sense were obtained for hectoliter mass (73.66%), and lower values for grain yield (25.82%). This indicates that direct breeding for grain yield is less efficient and it is necessary to have knowledge about the nature of the inheritance of important yield components in order to improve this complex trait.

Keywords: *wheat, yield, hectoliter mass, variability,heritability.*

Introduction

Expression of the plant phenotype is under the control of genes that determine its development. Genetic control in quantitative traits is very complex, conditioned by a large number of minor genes (Joshi et al., 2002). However, the expression of these traits is greatly influenced by environmental factors, as well as their genotype × environmental interaction. In order to achieve success in breeding, it is very important to determine and assess the extent to which factors such as genotype, environment and their interaction contribute to the variation of wheat traits. The influence of genetic factors in determining a trait is different, and for an efficient breeding process, it is very important to know the share of the hereditary component that is passed on to the off spring. Therefore, it is necessary to determine heritability, because the value of heritability of a trait indicates whether it is more conditioned by genetic factors or environmental factors. Erkul et al., (2010) stated that the assessment of heritability is an important parameter in determining the genetic gain from selection.

In most wheat breeding programs, the main focus is on grain yield and yield components (number of ears per unit area, length of ears, number of ears, number of grains per ear, grain weight per ear and weight of 1000 grains) (Luković et al., 2020a). The most important components of spike fertility are considered to be: spike length, number of spikelets per spike, number of grains per spike and number of sterile spikelets per spike, from which the last three are also important indicators of spike fertility (Milovanović et al., 2019). Spikes with a greater number of grains per spikelet and a higher mass can be easily observed in the selection process from the generation of segregation, so these productivity indicators have an important role in the future increases of yield. Perišić et al. (2011) stated that work on improving the length of spikes and the number of spikelets per spike has greatly contributed to the increase in average wheat yields. The above authors stated that today's wheat varieties are capable of producing a greater number of grains per ear and unit area compared to formerly grown varieties. The aim of this study was to evaluate the variability and heritability of hectoliter mass and grain yield of divergent wheat genotypes grown in different agro-ecological conditions.

Materials and methods

Perspective lines of winter wheat (14 genotypes of wheat) created at the Center for Small Grains in Kragujevac and the standard variety Pobeda served as material in these studies. Two-year field trials (2013/2014 and 2014/2015) were performed at the experimental field of the Center for Small Grains in Kragujevac, the Agroinstitute in Sombor and the Institute for Forage Plants in Kruševac. The experiments were performed in three replications. Experimental plots of 4 m^2 were established according to a random block system. After harvest, the grain yield for each plot was measured in three replications and then converted to t ha^{-1}. Hectolitre mass was determined according to the standard method (JUS E.B1.200). Climatic conditions during the trial conducting were published (Luković, 2020b), so they are not presented in this paper.

To examine the influence of genotype, year and location on the analyzed traits of wheat, a model of three-factor ANOVA analysis using a completely randomized block design was used. Testing the significance of differences between wheat genotypes and locations was performed by the *Duncan* test. Lowercase and uppercase Latin letters were used to indicate significant differences between genotypes, and between locations, respectively. Components of phenotypic variance were calculated based on variance analysis data (Falconer, 1981; Jovanović et al., 1992). Heritability in a broader sense (h^2) represents the ratio of genetic and phenotypic variance and is calculated by the formula:

$$h^2 = \frac{\sigma_G}{\sigma_F} \times 100\ (\%)$$

where is σ_G -genetic variance, and σ_F- phenotypic variance.

Statistical analysis of the data was performed using the computer statistical program SPSS Statistics 22.

Results and discussion

Hectolitre mass is a genetically determined trait that varies greatly under the influence of environmental factors. At the Sombor site, in 2014, the highest average value of hectoliter grain weight was achieved by the genotype KG-47/21 (77.2 kg hl^{-1}), and in 2015 by the variety Pobeda (82.1 kg hl^{-1}). In Kruševac, in the first year of testing, the genotype KG-1/6 (77.7 kg hl^{-1}) was singled out for the observed trait, and in the second genotype KG-191/5-13 (83.6 kg hl^{-1}), whose the mean value was significantly higher than the mean value of all other genotypes.
Genotype KG-52/3 (76.6 kg hl^{-1}) achieved the highest average value of hectoliter grain mass in Kragujevac in the first year of testing, and in the second year the genotype KG-1/6 (82.2 kg hl^{-1}) performed best. The second year of testing, due to more favorable climatic conditions, was more convenientfor the comparison of hectoliter mass, so that five KG-lines showed higher values for this property compared to the standard (Tab. 1).

Table 1. Mean values per hectoliter of grain mass (kg hl^{-1}) of studied wheat genotypes

Genotype	2013/2014.				2014/2015.			
	SO	KŠ	KG	$\bar{x}$	SO	KŠ	KG	$\bar{x}$
KG-27/6	73,8^{cA}	72,1^{abA}	72,1^{aA}	72,7	73,7^{aA}	78,5^{abcB}	77,8^{abcB}	76,7
KG-244/4	76,4^{eA}	75,9^{cdA}	76,0^{cdeA}	76,1	81,0^{eB}	79,5^{abcdeAB}	77,9^{abcA}	79,5
KG-199/4	76,7^{efA}	76,9^{cdA}	76,0^{cdeA}	76,6	79,3^{eA}	77,4^{abA}	77,4^{abA}	78,0
KG-307/4	74,2^{cdA}	74,6^{bcA}	74,8^{cA}	74,5	81,2^{efC}	79,0^{abcdB}	77,7^{abcA}	79,3
KG-28/6	71,6^{bA}	71,2^{aA}	73,6^{bB}	72,1	74,5^{bA}	77,4^{abB}	79,2^{bcdB}	77,1
KG-162/7	69,0^{aA}	74,6^{bcB}	75,0^{cdB}	72,8	80,8^{eB}	77,5^{abA}	79,6^{bcdeAB}	79,3
KG-191/5-13	78,8^{gB}	76,3^{cdA}	76,3^{eA}	77,2	81,7^{fgAB}	83,6^{fB}	80,5^{defA}	81,9
KG-40-39/3	74,4^{cdA}	74,4^{bcA}	75,7^{cdeA}	74,9	80,7^{eA}	81,8^{defB}	80,4^{defA}	80,9
KG-52/23	74,6^{dA}	74,4^{bcA}	76,0^{cdeA}	75,0	81,8^{fgC}	80,6^{cdeB}	79,7^{bcdeA}	80,7
KG-60-3/3	76,0^{eA}	75,9^{cdA}	75,4^{cdeA}	76,0	77,7^{cB}	77,2^{aAB}	76,4^{aA}	77,1
KG-1/6	76,5^{efA}	77,7^{dA}	76,1^{deA}	76,8	79,1^{dA}	82,3^{efB}	82,2^{fB}	81,2
KG-52/3	76,4^{efB}	74,4^{bcA}	76,6^{eB}	75,8	80,6^{eA}	81,2^{cdefA}	81,6^{efA}	81,1
KG-47/21	77,2^{fA}	75,8^{cdA}	75,6^{cdeA}	76,2	77,8^{cA}	80,2^{bcdeB}	79,7^{bcdeAB}	79,3
Pobeda	76,6^{efA}	75,7^{cdA}	75,5^{cdeA}	76,0	82,1^{gB}	81,0^{cdefAB}	79,9^{cdeA}	81,0
Prosek	75,2	75,0	75,4	75,2	79,4	79,8	79,28	79,5

Legend: SO – Sombor, KŠ – Kruševac, KG – Kragujevac
Lowercase and uppercase Latin letters were used to indicate significant differences between genotypes, and between locations, respectively

The average grain yield of the studied wheat genotypes varied depending on the genotype, location and year (Tab. 2). In Sombor in 2014, the highest average grain yield was determined for genotype KG-60-3/3 (7.12 t ha^{-1}), which produced a significantly higher yield than all other genotypes in that location. In 2015, KG-307/4 (10.07 t ha^{-1}) and KG-244/4 (9.77 t ha^{-1}) stood out as the most productive genotypes. At this location, all studied wheat genotypes produced significantly higher grain yield in 2015 compared to 2014. In Kruševac, the highest grain yield, in the first year of testing, was recorded by the genotype KG-199/4 (5.40 t ha^{-1}), and in the second year, by the variety Pobeda (6.07 t ha^{-1}) and genotype KG-28/6 (5.87 t ha^{-1}) between which no significant difference in average values was found. Genotype KG-52/3 produced the highest average grain yield in Kragujevac in 2014 (4.61 t ha^{-1}), while in 2015, genotypes KG-60-3/3 (6.17 t ha^{-1}), KG-52/3 (5.77 t ha^{-1}) and KG-191/5-13 (5.76 t ha^{-1}) were the most productive.

Table 2. Mean values for grain yield (t ha^{-1}) in the studied wheat genotypes

Genotype	2013/2014.				2014/2015.			
	SO	KŠ	KG	$\bar{x}$	SO	KŠ	KG	$\bar{x}$
KG-27/6	$4,63^{cdA}$	4,40d^{efA}	$4,52^{eA}$	4,52	$9,57^{fB}$	$6,00^{eA}$	$5,68^{dA}$	7,08
KG-244/4	$4,97^{defC}$	$3,13^{aA}$	$3,63^{aB}$	3,91	$9,77^{fgC}$	$3,80^{aA}$	$5,70^{dB}$	6,42
KG-199/4	$5,17^{fgB}$	$5,40^{iB}$	$3,83^{abA}$	4,80	$8,53^{bcdC}$	$4,07^{abA}$	$4,72^{abB}$	5,77
KG-307/4	$5,43^{ghB}$	$5,33^{iB}$	$3,88^{abcA}$	4,88	$10,07^{gC}$	$4,27^{bcA}$	$4,83^{abB}$	6,39
KG-28/6	$4,70^{cdeB}$	$4,07^{cdA}$	$4,43^{deAB}$	4,40	$9,40^{efC}$	$5,87^{eB}$	$5,11^{bcA}$	6,79
KG-162/7	$4,10^{aA}$	$4,53^{fghA}$	$4,36^{cdeA}$	4,33	$8,47^{bcB}$	$4,07^{abA}$	$4,47^{aA}$	5,67
KG-191/5-13	$5,70^{hiB}$	$4,40^{defA}$	$4,58^{eA}$	4,89	$8,63^{cdC}$	$4,20^{bcA}$	$5,76^{deB}$	6,20
KG-40-39/3	$4,17^{abA}$	$4,00^{bcA}$	$4,34^{cdeA}$	4,17	$8,10^{bB}$	$4,60^{cA}$	$4,78^{abA}$	5,83
KG-52/23	$6,03^{iB}$	$4,87^{hA}$	$4,38^{deA}$	5,09	$8,53^{bcdB}$	$5,20^{dA}$	$5,50^{cdA}$	6,41
KG-60-3/3	$7,12^{jC}$	$5,33^{iB}$	$4,19^{bcdeA}$	5,55	$8,43^{bcC}$	$4,53^{cA}$	$6,17^{eB}$	6,38
KG-1/6	$5,13^{efgB}$	$4,47^{efgA}$	$4,39^{deA}$	4,66	$8,70^{cdC}$	$4,53^{cA}$	$5,53^{cdB}$	6,25
KG-52/3	$4,33^{abcA}$	$4,13^{cdeA}$	$4,61^{eA}$	4,36	$7,57^{aC}$	$4,20^{bcA}$	$5,57^{dB}$	5,78
KG-47/21	$4,60^{bcdB}$	$3,67^{bA}$	$4,00^{abcdA}$	4,09	$8,47^{bcC}$	$4,47^{bcA}$	$5,77^{deB}$	6,23
Pobeda	$5,87^{hiB}$	$4,80^{ghA}$	$4,25^{bcdeA}$	4,97	$9,03^{deC}$	$6,07^{eB}$	$4,75^{abA}$	6,62
Prosek	5,14	4,47	4,24	4,62	8,81	4,71	5,31	6,27

Legend: SO – Sombor, KŠ – Kruševac, KG – Kragujevac
Lowercase and uppercase Latin letters were used to indicate significant differences between genotypes, and between locations, respectively

The analysis of the variance of the three - factorial experiment determined a significant effect of genotype, year and location on the variation of wheat yield, while the location did not have a statistically significant influence on the expression of hectoliter mass. In addition to the individual influence, all forms of interaction had a statistically significant effect on hectoliter mass and grain yield (Table 3).

Table 3. Analysis of variance for hectoliter mass and grain yield

Source of variation	**df**	**Hectoliter mass**		**Grain yield**	
		MS	F	MS	F
Block	2	0.662	0.595^{ns}	0.153	2.652^{ns}
Genotypes G	13	38.956	35.024^{**}	1.946	33.733^{**}
Years Y	1	1177.460	1058.618^{**}	173.022	2999.422^{**}
Environmental E	2	0.203	0.183^{ns}	147.761	2561.504^{**}
G×Y	13	10.889	9.790^{**}	1.354	23.474^{**}
G×E	26	4.868	4.377^{**}	1.125	19.502^{**}
Y×E	2	4.130	3.713^{*}	67.138	1163.865^{**}
G×E×Y	26	7.260	6.528^{**}	1.032	17.894^{**}
Eror	166	1.112		0.058	
Total	251				

** Significant at P = 0.01 level;* Significant at P = 0.05level;^{ns} Non significant

Heritability in a broader sense was calculated based on the results of the analysis of variance after disassembly of the variance components of the examined traits.It is a relative indicator and is calculated from the ratio of genotypic and phenotypic variance. The calculated values of the components of variance indicated which factors and with what intensity influenced the manifestation of the analyzed properties. The value of heritability for hectoliter mass was 73.66% and indicated a significant influence of genotype × location × year, as well as genotype on the formation of this trait. Grain yield had low heritability (25.92%) and the expression of this trait depended mostly on the interaction of locality × year (Table 4).

Table 4. Components of variance and heritability in a broader sense for hectoliter mass and grain yield

Traits	Componentsof variance and heritability for hectoliter mass and grain yield									
	σ^2_G	σ^2_Y	σ^2_L	σ^2_{GL}	σ^2_{GY}	σ^2_{LY}	σ^2_{GLY}	σ^2_E	σ^2_F	h^2 (%)
HM	1.692	0.247	0.443	0	0.403	0	2.049	1.112	2.297	73.66
Y	0.028	0	0	0.015	0.036	1.574	0.325	0.058	0.108	25.92

Legend: Y-Yield; HM- hectoliter mass

Lower values of heritability in the broader sense for grain yield are in accordance with the results (31.1%) obtained by Akçura (2009). Ali and Shakor (2012) obtained a lower value of heritability for durum wheat grain yield (41.27%) in dry growing conditions and a high value of heritability for grain wheat grain yield (92.60%). Taneva et al. (2019) found moderately high heritability values for hectoliter weight (72%) and lower heritability values for grain yield (36%). The authors point out that a lower coefficient of heritability is associated with lower genetic gain for grain yield, which indicates non-additive gene action and reveals slower breeding progress in improving these traits. Therefore, efficient selection of genotypes by phenotype in early generations is not possible for these traits.
According to the results obtained in these studies, a strong influence of genotypes, locations, as well as years on grain yield and hectoliter mass can be observed and this indicates the reaction of genotypes to different environmental conditions during growth and development. The first experimental year is characterized by a mild winter with a small amount of water sediment. However, the stages of earing, fertilization and grain filling took place at a lower air temperature and an extremely large amount of precipitation. Such unfavorable weather conditions negatively affected the processes of filling and maturing wheat grains, causing the formation of smaller, poorly filled grains. As a result, the examined KG-genotypes of wheat achieved lower values of grain yield and hectoliter mass in 2013/2014 years compared to 2014/2015 cropping season. The obtained results are in accordance with the respective of Rajičić et al. (2019), who fount significantly lower values of hectoliter mass and grain yield in 2009/2010, which is characterized by extremely high rainfall in April-June.

Conclusion

The year 2014 is characterized by extremely large amounts of precipitation in the Republic of Serbia, especially during April and May, which caused catastrophic floods in some parts of Serbia. Only in this period, 356.1 mm of rain fell in Kragujevac, 315.4 mm in Krusevac and 187.8 mm in Sombor. As a result, the examined KG-genotypes of wheat achieved lower values of grain yield and hectoliter mass in 2013/2014 years compared to 2014/2015 year. Observed for all locations, in both years, in comparison with the standard for grain yield, the Kragujevac lines KG-52/23, KG-307/4, KG-60-3/3 and KG-28/6 stood out the most.
In this study, higher values of heritability in a broader sense were obtained for hectoliter mass (73.66%), and lower values for grain yield (25.82%). This indicates that direct breeding for

grain yield is less efficient and it is necessary to have knowledge about the nature of the inheritance of important yield componentsin order to improve this complextrait.

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