DOI: 10.46793/SBT30.10MM

INFLUENCE OF GENOTYPE AND YEAR ON WINTER WHEAT GRAIN YIELD

Milomirka Madić[1], Dragan Đurović[1], Vladeta Stevović[1], Dalibor Tomić[1], Milan Biberdžić [2], Branka Govedarica[3]

Abstract: During three growing seasons (2019-2022), an experiment was carried out in cooperation with the Požarevac Agricultural Expert Service in Požarevac with 6 varieties of wheat in order to analyze the influence of genotype and year of production on yield, thousand-kernel weight and hectoliter weight. The experiment was set up according to a randomized block system in three replications on the soil type. The main crop in the first year was sunflower, while in the second and third year it was corn. During the three-year research, the Agrosava Apilco and NS Igra varieties had the highest average yield, while the Zvezdana variety had the lowest average yield, but the highest thousand-kernel weight. The average grain yield differed by year (variety/year interaction). In the favorable second production year, all varieties had a significantly higher yield, thousand-kernel weight and hectoliter weight compared to the first and third year of production.

Keywords: Grain yield, genotipe, winter wheat

Introduction

The yield of wheat grain in the Republic of Serbia over the past 20 years has been variable, ranging from 2.2 t ha^{-1} (2003) to 5.7 t ha^{-1} (2021), with the yield in 2023 recorded at 5.5 t ha^{-1} (Statistical Office of the Republic of Serbia 2024), This significant variability in grain yield indicates that production in our region largely depends on the weather conditions of the year and the economic viability for producers (Dodig et al., 2015; Đurić et al., 2020). Unfortunately, various factors are increasingly present as major obstacles to greater production worldwide (Denčić et al., 2009; Knežević et al., 2020; Matković Stojšin et al., 2022). The reduction in the amount of freshwater and its increasing contamination by various toxic and destructive substances will further decrease

[1]University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, Čačak, Serbia (mmadic@kg.ac.rs)
[2]University of Priština (Kosovska Mitrovica), Faculty of Agriculture, Lešak, Serbia
[3]Faculty of Agriculture, University of East Sarajevo, East Sarajevo, Bosnia and Herzegovina

the already limited areas irrigated for wheat. Land degradation in terms of both chemistry (increased acidity and salinity) and functionality is prevalent over large areas worldwide (Denčić et al., 2009). The same authors also point out that one of the extremely negative phenomena in global warming will be heat waves, which can have catastrophic negative effects on both yield and quality during the grain filling stage. Matković Stojšin et al. (2022) found that salinity stress reduced grain yield by 30%, while drought stress during the 2016/2017 growing season decreased yield by 20%. Developing high-yielding wheat varieties of good quality is a primary goal in breeding programs. Breeders face a challenging task, given the negative correlation between seed yield and certain yield components as well as quality traits (Matković Stojšin et al., 2018). Increasing seed yield in wheat breeding programs can be achieved through genetic improvement of yield components: number of grains per spike, number of spikes per unit area, and thousand-kernel weight (Mian et al., 2019; Knežević et al., 2020; Urošević et al., 2022). Seed yield is a complex trait controlled by numerous genes for yield components, whose expression is modified by environmental factors (Miao et al., 2017; Zhang et al., 2017). The contribution of each can vary among different genotypes and under various environmental conditions, stemming from the interactions among traits within each genotype and between genotypes and environmental conditions (Madić et al., 2016; Zuo et al., 2017; Grčak et al., 2019; Madić et al., 2024). The wheat variety is one of the most significant quality factors that varies with harvest year, region, and locality (Kaya et al., 2014; Djurić et al., 2018). This study aimed to analyze the variability of winter wheat's yield components under the influence of genotype and growing season.

Materials and methods

To determine the impact of genotype and growing season on the yield and yield components of winter wheat, an experiment was conducted in collaboration with the Agricultural Advisory Service in Požarevac. Six wheat varieties (Obala, Igra, Zvezdana, NS 40 S, Galenika Avenue, Agrosava Apilco) were tested over three growing seasons (2019-2022) in the agroecological conditions of the Braničevski district.

During the 2019/2020 season, the experiment was set up in Zabela, Požarevac, on alluvial soil, with sunflower as the preceding crop. In the second year (2020/2021), it was conducted in Ćirikovac, and in the third year (2021/2022), in Metkor, Požarevac, also on alluvial soil. The preceding crop in

the second and third years was commercial corn. Soil preparation in all years was carried out in October to a depth of 30 cm, and before that, fertilization was done with NPK fertilizer (16:16:16) at a rate of 300 kg ha^{-1}. Seed sowing was performed within the optimal timeframe for all three years of the experiment, at the end of October or the beginning of November. Each variety was sown in a plot of 5 m^2 in three repetitions, in rows spaced 12.5 cm apart and 3 cm apart within the row, using a seeding rate of 110 to 290 kg ha^{-1}, depending on the variety. Fertilization of the crops was done three times: in February with KAN (27% N) at a rate of 150 kg ha^{-1}, in March with KAN at the same rate, and in April (April 21) with Fitofert speed G at a dose of 3 L ha^{-1}. Weed, disease, and pest control were conducted using chemical preparations: Secator at 0.15 L ha^{-1}, Amistar Extra at 0.75 L ha^{-1}, and Fastac at 0.1 L ha^{-1}.

A two-way analysis of variance (ANOVA) was performed, with cultivar and year as factors, and mean differences were assessed using the LSD test in SPSS software (1995).

Meteorological Conditions

Table 1. Average monthly temperature and precipitation amount

Vegetation season / month	Average monthly temperature (°C)			Precipitation amount (mm)		
	2019/20	2020/21	2021/22	2019/20	2020/21	2021/22
XI	11.7	6.4	8.4	25	12	69
XII	4.7	5.0	3.2	54	37	126
I	0.6	2.7	0.1	23.5	68.5	25
II	5.3	3.6	4.6	75	41.5	29
III	8.1	5.4	4.8	50	37	14
IV	12.4	9.2	11.0	21	66.5	80
V	16.0	16.5	18.2	101	64	26
VI	20.4	21.9	22.6	95.5	49	32
VII	22.0	24.8	23.9	32	5	26
Average/Sum	11.24	10.6	10.75	477	380.5	427

The first production year (2019/2020) had the highest average temperature and the greatest amount of precipitation (477 mm) compared to the following two years. The beginning of the growing season in 2019/2020 was marked by warm weather, the warmest in the last 50 years, with an average temperature of 11.7 °C and typical precipitation levels until March, which positively influenced the development of winter wheat. Air temperatures during most of March and

April were above average, with low precipitation of 21 mm in April. However, at the beginning and end of May, rainfall totaling 101 mm was relatively well distributed, somewhat mitigating the effects of the earlier drought.The average temperature during the growing season of 2020/21 was 10.6 °C, while in 2021/22 it was 10.75 °C. The lowest amount of precipitation was recorded in the second year of the experiment (380 mm), which is approximately 87 mm less than in the first year and 37 mm less than in the third year. This amount of precipitation was more evenly distributed compared to the previous and following years (Table 1), with particularly favorable rainfall distribution during the period of intense plant growth.

Results and discussion

Grain yield and yield components of wheat, such as thousand-kernel weight and hectoliter weight, are quantitative traits that depend on genetic background (i.e., variety), ecological factors, and applied agronomic practices during the growing season of wheat plants (Đekić et al., 2015, Knežević et al., 2020; Urošević et al., 2023). The grain yield of the analyzed winter wheat varieties varied significantly both between the varieties and across the years of study (Table 2). The highest average grain yield, thousand-kernel weight, and hectoliter weight of wheat were recorded in the second production year of the study, followed by the first year, while the lowest values were noted in the third year. The conditions for growth (year) had a significant effect on yield and yield components, and a significant interaction effect between genotype and year was also observed. Analyzing the grain yield values of the winter wheat varieties over the three growing seasons (Table 2), the highest average yield for all three years was recorded for the varieties Agrosava Apilco, NS 40 S, and Zvezdana. The average grain yield varied by year (interaction of variety/year). All varieties had significantly higher yields in the favorable second production year compared to the previous and following years. The varieties Galenika Avenue, Agrosava Apilco, and NS 40 S had yields significantly greater than those of the other varieties. When observing grain yield by year, discrepancies were noted for the varieties Obala and Galenika Avenue.

The quality of wheat grain is a complex concept that includes several properties: physical characteristics of the grain (hectoliter weight, thousand-kernel weight, specific weight, size and shape of the grain, glassiness and flouriness, grain color, and purity), health status, chemical composition, and more. For evaluating quality based on physical properties, it is simplest to

determine the thousand-kernel weight, hectoliter weight, and specific weight of the grain. A lower weight indicates a higher amount of hulls in the grain and lower compactness of the endosperm (Kovačević and Rastija, 2014).

Table 2. Average values of grain yield (kg ha^{-1}), thousand-kernel weight (g), and hectoliter weight (kg hL^{-1}) of wheat varieties over a three-year period.

		Grain yield	Thousand-kernel weight	Hectoliter weight
Year (A)	2019/20	6 073^{b}	43.91^{b}	77.15^{b}
	2020/21	7 780^{a}	45.22^{a}	78.20^{a}
	2021/22	5 773^{c}	43.10^{c}	73.13^{c}
Cultivar (B)	Obala	6 569^{b}	46.75^{a}	75.10^{d}
	Igra	6 714^{a}	45.68^{b}	75.76^{c}
	Zvezdana	6 199^{d}	44.33^{e}	77.90^{a}
	NS 40S	6 388^{c}	45.30^{c}	75.63^{c}
	G. Avenue	6 629^{ab}	43.89^{f}	75.13^{d}
	Agr. Apilco	6 732^{a}	44.66^{d}	77.10^{b}
$LSD_{0.05}$	A	197.8	0.28	0.39
	B	117.9	0.19	0.33
	AB	283.4	0.48	0.65

The average values in columns marked with the same lowercase letter do not differ significantly ($p > 0.05$) based on the LSD test.
*** F-test significant at the 0.001 level.

The thousand-kernel weight is a quantitative trait that depends on the genetic constitution of the variety, agroecological conditions, and applied agronomic practices. It is one of the components that significantly impacts the determination of wheat seed yield (Ferrante et al., 2017) and can be influenced by the environment and genotype-environment interactions (Krishnappa et al., 2022). The average values for thousand-kernel weight for all varieties were above 40 g. All varieties in the 2020/21 growing season had significantly higher thousand-kernel weights. The varieties Obala and Igra had the highest thousand-kernel weights significantly greater than all other varieties in both production years, while Galenika Avenue had the lowest. The variety Obala had the highest average value across all years (46.75 g) compared to Galenika Avenue (43.89 g). Table 2 shows that the variety Zvezdana had the highest average hectoliter weight, while the varieties Obala and Galenika Avenue had the lowest.

Conclusion

Agroecological conditions during the research years varied significantly and affected the grain yield of wheat varieties. Based on the analysis of average temperatures, distribution and amount of precipitation, the vegetation period of 2020/21 was more favorable for wheat production. The second year of the research, which had the highest yield, was characterized by a mild and long winter, cold spring and warm and dry summer, with the lowest but relatively well-distributed amount of precipitation. Significantly higher yields in the second year are primarily the result of growing crops on more fertile soil, as well as a more favorable distribution of precipitation during the vegetation period. In the entire three-year study, the highest average yields were obtained from the varieties Agrosava Apilco and NS Igra, while the variety Zvezdana had the lowest average yield but the highest hectoliter mass. In recent years, there has been a trend of climate change, which leads to disturbances in the amount and distribution of precipitation. Therefore, there is a need for a more detailed study of new wheat varieties and the selection of genotypes that show better properties under conditions of potential stress. This primarily refers to increased tolerance to water shortages and elevated temperatures during critical phases of plant development. In production, it is always recommended to cultivate several different varieties, not just one, because varieties react differently to different microclimates, soil conditions and localities.

Acknowledgement: The research is part of project number 451-03-66/2024-03/200088 supported by Ministry of Science, Technological Development and Innovation of R. Serbia

References

Đekić V., Milovanović M., Milivojević J., Staletić M., Popović V., Simić D., Mitrović M. (2015). Uticaj godine na prinos i kavalitet zrna ozime pšenice. Zbornik naučnih radova Instituta PKB Agroekonomik, 21(1-2): 79-85.

Denčić S., Kobiljski B., Mladenov N., Pržulj N. (2009). Wheat production, yields and Regression Analysis of morphological production traits of wheat warieties. Romanian Biotechnological Letters, 23(2): 13457-13465.

Djuric N., Prodanovic S., Brankovic G., DjekicV., Cvijanovic G., Zilic S., Dragicevic V., Zecevic V., Dozet, G. (2018): Correlation--Regression Analysis of morphological production traits of wheat warieties. Romanian Biotechnological Letters, 23(2): 13457-13465.

Dodig D., Zorić M., Jović M., Kandić V., Stanisavljević R., Šurlan-Momirović, G. (2015). Wheat seedlings growth response to water deficiency and how it correlates with adult plant tolerance to drought. Journal of Agricultural Science, 153: 466-480.

Đurić N., Cvijanović G., Dozet G., Rajičić V., Branković G., Poštić D. (2020). The influence of year and location on grain yield and yield components in winter wheat. Selekcija i semenarstvo, XXVI(1), 9-18. Doi: 10.5937/selsem2001009d

Ferrante A., Cartelle J., Savin R., Slafer G.A. (2017). Yield determination, interplay between major components and yield stability in a traditional and a contemporaryof awned/awnless isogenic lines and their response to source–sink manipulations. Field Crop Res. 254, 107827.

Grčak M., Grčak D., Župunski V., Jevtić R., Lalošević M., Radosavac A., Kondić D., Živić J., Paunović A., Zećević V., Mićanović D., Knežević D. (2019). Effect of cereals pea intercropping on spike index of spring wheat, triticale, oat and pods index of pea. Acta Agriculturae Serbica, 24(48):167-180.

https://www.stat.gov.rs/sr-latn/vesti/statisticalrelease/?p=8841 (accessed on 28.05.2024).

Kaya Y., Akcura M. (2014). Effects of genotype and environment on grain yield and quality traits in bread wheat (*T. aestivum* L.). Food Science and Technology, 34(2): 386-393.

Kovačević V., Rastija M. (2014). Žitarice. Udžbenik. Sveučilište Josipa Jurja Strossmayera u Osijeku, Poljoprivredni fakultet u Osijeku, Osijek.

Knežević D., Laze A., Paunović A., Djurović V., Đukić N., Valjarević D., Kondić D., Mićanović D., Živić J., Zečević V. (2020). Approaches in cereal breeding. Acta Agriculturae Serbica, 25 (50): 179- 186.

Knežević D., Paunović A., Djurović V., Roljević Nikolić S., Mićanović D., Madić M., Menkovska M., Zečević V. (2022). Improving the quality of wheat for human consumption. Zbornik radova, "XXVII Savetovanje o Biotehnologiji", Agronomski fakultet Čačak, 11-20.

Krishnappa G., Khan H., Krishna H., Kumar S., et al (2022). Genetic dissection of grain iron and zinc. and thousand kernel weight in wheat (*Triticum aestivum* L.) using genome-wide association study. Sci. Rep. 12 (1): 1–14. doi: 10.1038/s41598-022-15992-z

Madić M., Đurović D., Stevović V., Tomić D., Biberdžić M., Pavlović N., Marjanović M. (2024). Grain yield and yield components of prospective homozygous winter wheat genotypes. 2nd International Symposium On Biotechnology (2024**)** 35-40.

Madić M., Knežrvić D., Paunović A., Đurović D. (2016). Plant height and internode length as components of lodging resistance in barley. Acta Agriculturae Serbica, XXI, 42: 99-106.

Matković Stojšin M., Petrović S., Banjac B., Roljević Nikolić S., Zečević V., Bačić J., Đorđević, R. Knežević, D. (2022). Development of selection criteria for improving grain yield in wheat grown in different agro-ecological environments. Acta Agriculturae Serbica 27 (53): 79-87.

Matković Stojšin M., Zečevć V., Petrović S., Dimitrijević M., Mićanović D., Banjac B., Knežević D. (2018). Variability, correlation, path analysis and stepwise regression for yield components of different wheat genotypes, Genetika, 50(3): 817-828.

Mian M.A.K., Begum A.A., Sahe R.R. (2019). Functional relationship between grain yield and spikes per square meter of wheat as influenced by seed rate under late sown condition. Bangladesh Agron. J., 22 (1): 105-113.

Miao L., Mao X., Wang J., Liu Z., et al. (2017). Elite haplotypes of a protein kinase gene TaSnRK2. 3 associated with important agronomic traits in common wheat. F. Plant Sci 8:368

Urošević D., Knežević D., Đurić N., Matković Stojšin M., Kandić V., Mićanović D., Stojiljković, J., Zečević V. (2023). Assessment the Potential of Old and Modern Wheat Genotypes: Yield Components and Nutritional Profiles in a Comprehensive Study. Agronomy 13, 2426.

Urošević D., Knežević D., Matković Stojšin M., Živić J., Đurović V., Radosavac,A., Mićanović D. (2022). Phenotypic variability and similarity of number of productive tillers in wheat varieties (*Triticum aestivum* L.). Book of proceedings of the XIII International Scientific Agriculture Symposium "Agrosym 2022", Jahorina, October 06-09, 415-422.

Zhang Z.G., Lv G.D., Li B., Wang J.J., Zhao Y., Kong F.M., Guo Y., Li, S.S. (2017). Isolation and characterization of the TaSnRK2. 10 gene and its association with agronomic traits in wheat (*Triticum aestivum* L.). PLoS One 12(3):e0174425

Zuo Q., Kuai J., Zhao L., Hu Z., Wu J., Zhou G. (2017). The effect of sowing depth and soil compaction on the growth and yield of rapeseed in rice straw returning field. Field Crops Research, 203: 47–54. doi: 10.1016/j.fcr.2016.12.016.