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WHEAT YIELD STABILITY ACROSS YEARS WITH VARYING CLIMATE CONDITIONS

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Abstract: This paper aimed to investigate the yield stability of 19 wheat winter varieties using the AMMI model. The experiment was carried out in the experimental field of the Center for Small Grains and Rural Development in Kragujevac during a three-year period (2019/2020, 2020/2021, 2021/2022). The Perfekta, and Javorka varieties stood out as the most stable varieties for grain yield. At the same time, the Perfecta variety achieved the highest grain yield at the level of the entire experiment indicating that this variety maintains its superiority even in less favorable climatic conditions, on soils of poorer fertility. This significantly contributes to safe and sustainable agricultural production.

Keywords: wheat, AMMI model, stability, climate change

Introduction

Wheat genotypes with high genetic potential for grain yield and quality perform exceptionally well on fertile land when intensive production techniques are applied. However, the true value of these genotypes is determined by their ability to maintain these traits across various agroecological conditions, as well as in the presence of biotic and abiotic stresses. Important traits, such as yield stability and broad adaptability, when combined with a high genetic potential for grain yield, highlight the superiority of specific varieties (Luković et al., 2020; Martínez-Peña et al., 2022). Varieties possessing these characteristics not only achieve high yields in favorable climatic environments but also mitigate the risk of losses during years with significant climatic fluctuations (Ebadi et al., 2020; Perišić et al., 2022), which is essential for successful and sustainable agricultural production.

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This research aimed to investigate the stability of the yield of different wheat varieties in years with different climatic conditions.

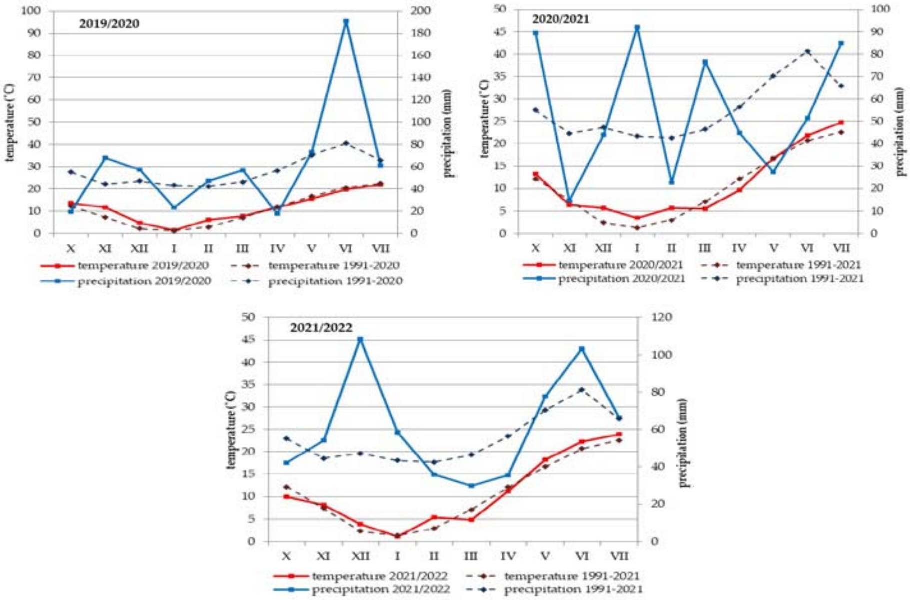
Materials and methods

The research involved 19 genotypes of winter wheat selected from three breeding institutions in Serbia: Center for Small Grains and Village Development in Kragujevac (Aleksandra, Perfekta, Takovčanka, Kruna, and KG-52/3), the Institute of PKB Agroeconomics in Belgrade (Merkur, Vizeljka, Talas, Ratarica, and Carica), and the Institute of Field and Vegetable Crops in Novi Sad (NS 40S, Obala, Ilina, Futura, Vlajna, Zvedana, Javorka, Renaissance, and Pobeda). The research was conducted over three growing seasons: 2019/2020, 2020/2021, and 2021/2022. The experiments took place in Kragujevac on Vertisol-type land, using a completely random block system design with three repetitions. The basic plot size was 5 m^2 (5 m × 1 m). Within the plot, 10 rows were sown with a spacing of 10 to 12 cm between each row. Basic soil preparation and pre-sowing treatments were conducted in the autumn by applying 300 kg ha^{-1} of NPK fertilizer (16:16:8). The sowing was performed mechanically, using 600 to 650 germinating seeds per m^2, depending on the genotype characteristics. At the beginning of March, a top dressing of 200 kg ha^{-1} of KAN fertilizer was applied. The harvest was performed with a combine harvester in the wheat full maturity stage. The grain yield, measured in kg per plot, was converted to t ha^{-1}, with the moisture content adjusted to 13%.

The AMMI model (Gauch and Zobel, 1996) was utilized to evaluate the interaction between genotype and environment, which involves both analysis of variance (ANOVA) and principal components analysis (PCA). The statistical data processing was performed using SPSS software version 22.0 (IBM Corporation, New York, NY, USA) and GenStat version 12.

Graphs 1-3 illustrate the average air temperature and total precipitation values for each month during the experiment period as well as a long period time (1991-2021)

During the first year of the experiment, there was a significant deficit of precipitation in October and April, while the amount of precipitation was twice



as high as the multi-year average in June (Graph 1). In the 2020/2021 period, November, February, and May were characterized by a dry spell with extremely low precipitation levels. In contrast, the 2021/2022 period recorded significantly lower precipitation in February, March, and April compared to the multi-year average (Graphs 2 and 3).

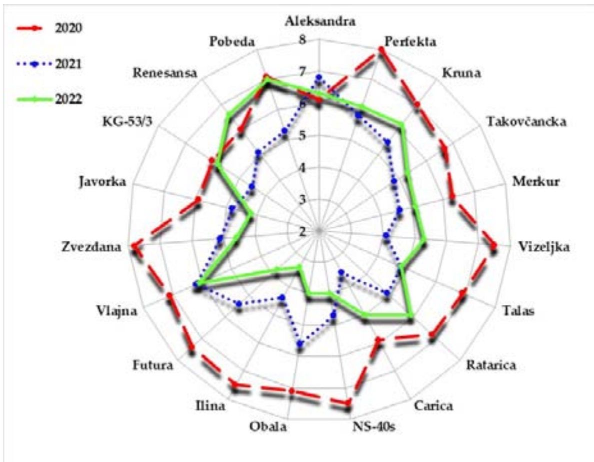
Graph 1-3. Average monthly air temperatures and the total precipitation in the production year: 2019/2020, 2020/2021, and 2021/2022

Results and discussion

Wheat yield was significantly influenced by the year, the genotype, and the interaction between genotype and year (Table 1). In 2019/2020, the Perfekta variety achieved the highest average grain yield of 8.0 t ha^{-1}, while the Carica and Javorka varieties recorded the lowest yield at 5.9 t ha^{-1}. Nine varieties produced yields exceeding 7.0 t ha^{-1}. In the second year of the study, the Aleksandra variety emerged as the most productive, with a yield of 6.8 t ha^{-1}. In the third year, the Pobeda variety led with a yield of 7.0 t ha^{-1} (Graph 4).

Differences between years were the most important factor affecting grain yield with 47.9% of the explained square root. The portion of variation due to genotype was significantly lower and amounted to 18.86% (Table 1). Similar results were obtained by Mohammadi et al. (2017), Aktas (2020), and Gupta et al. (2022). These authors emphasize the predominant influence of the external environment on grain yield variability.

In the total sum of squares for the comparison, the interaction contributed 28.80% and demonstrated high statistical significance and its breakdown into main components was necessary. Upon analyzing the interaction, two main components were identified. The first principal component accounted for 75.21% of the variation, while the second principal component explained 24.79% of the variation caused by the genotype × year interaction (Table 1).



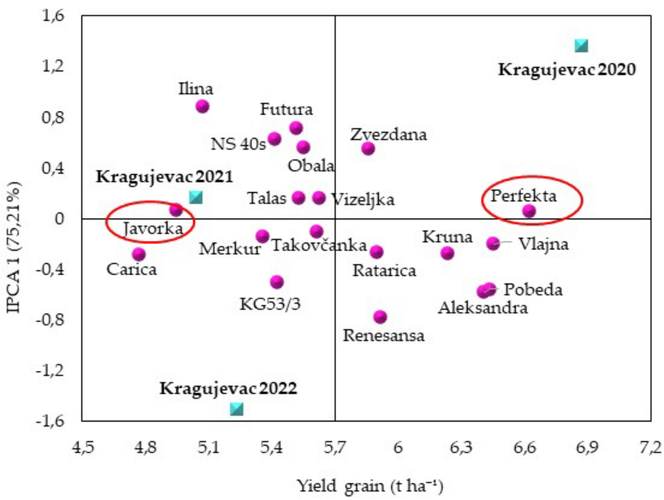
Graph 4. Average grain yield of investigated wheat varieties

Table 1. Analysis of variance of the AMMI model for wheat grain yield

Source	df	SS	MS	F	SS %
Total	170	241.4	1.42	-	-
Treatments	56	230.69	4.119	45.16^{**}	95.56
Genotypes	18	45.53	2.53	27.73^{**}	18.86
Year	2	115.6	57.802	402.54^{**}	47.89
Block	6	0.86	0.144	1.57^{ns}	0.36
Interactions	36	69.55	1.932	21.18^{**}	28.8
IPCA1	19	52.31	2.753	30.18^{**}	75.21
IPCA2	17	17.24	1.014	11.12^{**}	24.79
Residuals	-15	0	0	0	-
Error	108	9.85	0.091	-	4.08

In all the observed years, the Perfekta and Javorka varieties exhibited the greatest stability concerning the first principal component. Furthermore, Perfekta emerged as the most productive variety, achieving the highest grain yield across the entire trial. In contrast, Javorka's average yield was significantly lower than the overall average of the trial.

The group of moderately stable wheat varieties included Takovčanka, Kruna, Talas, Vizeljka, Vlajna, Ratarica, Merkur, and Carica. Among these, only Kruna, Vlajna, and Ratarica achieved above-average values for the observed trait. The varieties Ilina and Renesansa exhibited the highest interaction values, indicating that they are very unstable. Considering the studied years, it is evident that 2021 had the smallest interaction effect, which suggests the greatest stability among the varieties. However, this year also recorded the lowest average grain yield, at 5.04 t ha^{-1}. In contrast, the years 2020 and 2022 were characterized by significant instability, with 2022 being a more productive year—during which the analysed wheat varieties achieved their highest average grain yield (Graph 5).



Graph 5. AMMI 1 biplot analysis of stability of grain yield

Conclusion

The analysis of variance using the AMMI model showed a statistically significant effect from all sources of variation, including both additive factors (such as genotype and external environment) and non-additive factors (involving G × E interactions) on grain yield. The most stable varieties, which also produced above-average grain yields, were Perfekta, Kruna, and Vlajna. In central Serbia, where the soils are heterogeneous and of poor fertility, these varieties should be prioritized as they consistently yield excellent results under varying climate conditions.

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