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Original Article

Differences in the relationship of the most important traits of bread wheat depending on the different agro-ecological conditions

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Abstract:

Different agro-ecological conditions have a great influence on the phenotypical expression of yield components and grain yield. Besides this, their relationships are changed, too. In extreme wet conditions of the year, with large amounts of precipitations during the most important development stages, phenotypic differences and the relationship between the most important yield components and grain yield are less pronounced. Coefficients of variation, correlation analysis, and cluster analysis were used to determine the performances of advanced wheat genotypes under different agro-climatic conditions of research locations. In this research, the highest degree of variation, i.e. coefficients of variation for spikes mass and grain mass per plant from localities Kragujevac, Kruševac, and Sombor were expressed. Compared with the other two localities, the locality Sombor is distinguished by a strong and positive degree of correlations between yield components and grain yield.

Key words:
wheat, yield components, grain yield, correlations

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Apstrakt:

Međuzavisnost najvažnijih osobina hlebne pšenice u različitim agroekološkim uslovima

Različiti agroekološki uslovi, u velikoj meri, utiču na fenotipsku ekspresiju komponenti rodnosti i prinosa zrna. Pored toga, odnosi između njih se menjaju, takođe. U godini sa velikim količinama padavina i ekstremno vlažnim uslovima tokom najvažnijih faza razvoja, fenotipske razlike i odnosi između najznačajnijih komponenti rodnosti i prinosa zrna su manje izraženi. Koeficijent varijacije, korelaciona analiza i klaster analiza su korišćene u cilju određivanja ponašanja perspektivnih genotipova pšenice u različitim agroklimatskim uslovima ispitivanih lokaliteta. U ovom istraživanju, najviši stepen varijacije, tj. koeficijent varijacije, utvrđen je za masu klasa i masu zrna po biljci na lokalitetima Kragujevac, Kruševac i Sombor. U poređenju sa ostala dva lokaliteta, lokalitet Sombor se odlikovao najvećim brojem pozitivnih i negativnih korelacija između komponenti rodnosti i prinosa zrna.

Ključne reči:
pšenica, komponente rodnosti, prinos zrna, korelacije

Introduction

Compared to other plant species, bread wheat (*Triticum aestivum* L.) is characterized by a genetically complex constitution, composed of three homologous genomes (ABD), with a high number of repetitive sequences and homologous DNA copies (Guan et al., 2020). The hexaploid genomic nature of wheat with expressed multiple allelism for the most quantitative traits distinguishes a high degree of interactions between homoeologous genes and chromosomes. The result is a wide range in the degree of gene expression, which provides wide adaptability of production features in different agroecological conditions (Dubcovsky & Dvorak, 2007).

The wheat breeding process is usually focused on genetic gain responsible for grain yield and yield components (spike number per surface unit, spike length, spikelets number per spike, kernel number per spike, 1000 grain weight, etc.). Future selection is mostly determined by current and upcoming climatic changes, where the drought represents one of the key factors. On the other hand, an extreme amount of precipitation in certain years, during intensive wheat development, can represent a limiting factor for yield and technological quality of grain (Luković et al., 2020).

The wheat yield is a complex character representing a function of several component features and their interaction with the environment. Examination of yield structure involves the assessment of relationship among various characters contributing to the yield (Kadam et al., 2022). Analysis of correlations among traits with a potential impact on grain yield is of great importance for the process of selection that takes place within a breeding program. Among the many methods potentially utilized for this purpose, the analysis of correlation coefficients is one of the most widely used ones (Hristov et al., 2011; Nukasani et al. 2013).

A study was conducted to estimate the relationship between the most important yield components and grain yield of advanced wheat genotypes under different agro-climatic conditions of research locations and the degree of their variability. The wheat genotypes chosen during the experiment would be used as initial material for further improvement of grain yield.

Materials and Methods

The experimental part of the study was performed during 2018/2019 in three localities: Institute of Forage Crops Kruševac, Agroinstitute in Sombor, and Centre for Small Grains Kragujevac. The plant material consisted of 14 perspective lines of winter wheat created in the Center from Kragujevac (1 - KG-27/6; 2 - KG-244/4; 3 - KG-199/4; 4 - KG-307/4; 5 - KG-331/4; 6 - KG-28/6; 7 - KG-162/7; 8 - KG-191/5-13; 9 - KG-40-39/3; 10 - KG-52/23; 11 - KG-60-3/3; 12 - KG-1/6; 13 - KG-52/3; 14 - KG-47/21 and 15 - cultivar „Pobeda"). The experiment was conducted in field conditions with the application of a completely random block system, in three replications with the size of the basic plot of 5 m^2 (5 x 1 m). The machine sowing was conducted with 600-650 germinated grains per m^2 depending on the characteristics of the genotype.

A total of 45 plants (three replications with 15 plants) was selected from each examined genotype per locality, in order to analyze the following morphological and productive traits: number of productive spikes per m^2 (NPS), plant height (PH), spike length (SL), number of spikelets per spike (NSS), spike mass (SM), spikes mass per plant (SMP), grain number per spike (GNS), grain mass per spike (GMS), grain mass per plant (GMP), hectoliter mass (HM), thousand-grain weight (TW), and grain yield (Y). After the harvest, grain yield (Y) was measured for each plot in three replications and then converted to t/ha.

Specificities of all three localities used in the research were represented by the most important climatic characteristics - average air temperatures and precipitation values during the period of investigation, as well as in the period of 15 years (**Fig. 1**). Temperature degrees were not a limiting factor during the development of examined genotypes, since small differences in their average values were recorded between the investigation period and multi-year period.

The main climate characteristic was an uneven arrangement of precipitation amounts during different months. During February, March and April, low values were recorded in all three locations, while extremely large precipitation values, compared with 15-year average ones, were noticed in Kragujevac and Sombor during May and June.

Coefficients of variation of examined traits were calculated in Microsoft Excel representing a percentage relationship between the average and standard deviation value of the analyzed trait. Relative dependencies between yield components and grain yield were defined through correlation analysis (Pearson's correlation coefficient), while the obtained coefficients were tested at the 5% and 1% levels of significance. In order to group similar genotypes, the Euclidean distance was used as a measure of the similarity of potential clusters. Data were standardized (reduced to zero mean and unit deviation) and statistically processed by Minitab 20 and SPSS 20 software packages.

Results and discussion

Between examined genotypes from the different localities, wheat genotype KG-331/4 achieved the highest value of average grain yield in Kragujevac, ranging from 3.870 t/ha to 5.250 t/ha. The highest average grain yield values of the genotype KG-199-4 were found in Kruševac, with a yield range of 3.130 - 5.400 t/ha. The best wheat genotype in Sombor was KG-60-3/3 with grain yield values ranging from 4.100 t/ha to 7.200 t/ha.

Average values and coefficients of variation (%) of examined yield components and grain yield in investigated locations (Kragujevac – 1, Kruševac – 2, and Sombor – 3) are represented in **Tab. 1**. Most yield components had the highest average values in Kragujevac (spike length, spike mass, spikes mass per plant, grain number per spike, grain mass per spike, grain mass per plant). This statement can be explained by the fact that Kragujevac represents the

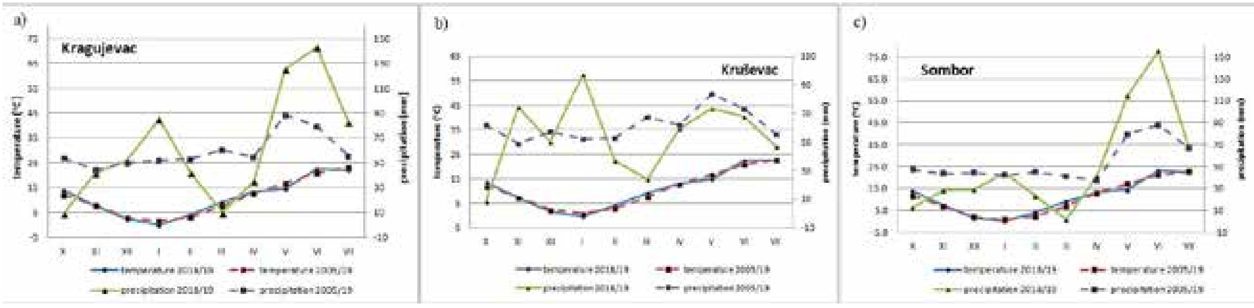

Fig. 1. Average values of air temperatures and precipitations during 2018/2019 and 15-year period (2005-2019) in Kragujevac (**a**), Kruševac (**b**), and Sombor (**c**)

place of selection of all examined wheat genotypes. Since environmental factors (soil especially) had the most limited influence in this locality (Luković et al., 2020), examined genotypes stabilized their expression of yield components and grain yield at similar levels. On the contrary, in the other two localities, where the conditions were nearest to the optimal ones, a high degree of differentiation of the wheat genotypes was noticed, especially in a grain yield domain. Sombor genotype was distinguished by the highest average values of the number of productive spikes per m^2 (626) and grain yield (5.111 t/ha), influenced by optimal fertility and better water regimes of the soil. The highest value of the plant height (93.06 cm) is measured in plants from the locality of Kruševac. Unlike the other two localities with large amounts of precipitation, in this locality, wheat genotypes had optimal conditions of soil humidity during the phase of stem elongation, in April and May especially.

Besides having an impact on ecological adaptation, the dynamics of plant development also contribute to the realization of genetically determined yield potentials in various environments. Revealing of genetic determinants of plant development becomes urgent, due to global climate change, which can seriously affect and even disrupt the locally adapted developmental patterns (Horvath et al., 2023). The polygenic nature of grain yields as well as the large influence of the environment and the complex relationship among yield component traits represent challenges in wheat selection (Cao et al., 2020). The impact of different management practices on yield components and their role in yield modulation are not well understood (Jaenisch et al., 2022).

The highest degree of variation, i.e. coefficients of variation (CV) for spikes mass per plant (16.81, 23.87, and 17.10, respectively) and grain mass per plant (16.38, 22.17, and 18.02, respectively) on localities Kragujevac, Kruševac, and Sombor were expressed since a large amount of precipitation was recorded during grain filling phase. Similar findings were pointed out by Sokoto et al. (2012), Nukasani et al. (2013), and Haydar et al. (2020), while Kozdój et al. (2015) recorded higher values for coefficients of variation. As a consequence of large soil heterogeneity and differences in the water

Table 1. Average values and coefficient of variation (%) of examined yield components and grain yield in investigated locations

Location	NPS*	PH (cm)	SL (cm)	NSS	SM (g)	SMP (g)	GNS	GMS (g)	GMP (g)	HM (kg/ hl)	TW (g)	Y (t/ha)
Average values ($\bar{x}$)												
1	580	91.01	10.23	21.58	2.41	7.66	47.67	1.82	5.33	75.67	40.57	4.438
2	594	93.06	9.99	21.60	1.82	5.51	41.75	1.36	3.97	75.67	39.44	4.449
3	626	88.22	9.92	20.68	1.91	5.84	44.21	1.52	4.48	75.61	40.51	5.111
Coefficient of variation												
1	10.80	9.57	10.67	8.06	13.34	16.81	17.44	21.04	16.38	1.87	4.58	12.61
2	9.00	9.55	10.39	5.09	12.36	23.87	9.94	13.34	22.17	2.68	3.96	14.51
3	10.78	9.96	10.86	6.12	13.22	17.10	9.90	14.56	18.02	3.33	4.97	17.57

*NPS - number of productive spikes per m^2; PH - plant height; SL - spike length; NSS - number of spikelets per spike; SM - spike mass; SMP - spike mass per plant; GNS - grain number per spike; GMS - grain mass per spike; GMP - grain mass per plant; HM - hectoliter mass; TW – thousand-grain weight; Y - grain yield regime, grain mass per spike and grain number per spike expressed higher CV values in the locality of Kragujevac. Besides this, the highest CV for grain yield is recorded in Sombor, while the smallest variation was noticed in Kragujevac. Hectoliter mass was the character that showed the lowest value of coefficients of variations. Matković et al. (2022) examined the variability of grain yield and its components on different soil types, and they recorded the lowest values for the coefficient of variation for thousand-grain weight and number of grains per spike. On the other hand, coefficient of variation values were higher for the number of grains per spike on the less fertile soil, due to the more pronounced influence of ecological variance. Amin et al. (2015) pointed out that phenotypic selection of the number of grains per spike may be unsuccessful due to the pronounced influence of the non-additive source of variation.

In the locality of Kragujevac (**Tab. 2**), none of the examined yield components showed a statistically significant degree of correlation with grain yields. The primary effect of precipitation change on grain yield is expressed through growth limitations, with a positive relationship between average yields and precipitation at all sites (Pirttioja et al., 2015). This phenomenon was strongly emphasized at temperature levels close to the baseline and progressively reduced under the conditions of increased warming. Compared to the other examined localities, soil represented the most limiting factor in Kragujevac. Spike mass was expressed with spike mass per plant (0.78), grain mass per spike (0.76), and grain mass per plant (0.77). Plant height revealed a modest, statistically significant, positive correlation with spike mass and hectoliter mass (0.57 and 0.52, respectively). A statistically highly significant coefficient of correlation (0.98) was confirmed between the characters - spike mass per plant and grain mass per plant.

In the locality of Kruševac, grain yield expressed a statistically significant positive correlation with the number of productive spikes per m^2 (0.53). The highest coefficient of correlation (0.97), statistically very significant, is recorded between spike mass and grain mass per spike, as well as between spike mass per plant and grain mass per plant. The results of the investigation are in accordance with those published by Mohammadi et al. (2012), Philipp et al. (2018), and Baye et al. (2020).

Hectoliter mass and thousand-grain weight showed moderate positive correlation with spike mass, spike mass per plant, grain mass per spike, and grain mass per plant. Thousand-grain weight expressed a modest, statistically significant, positive correlation with spike mass, spike mass per plant, grain mass per spike, and grain mass per plant. The number of spikelets per spike revealed a similar, statistically significant correlation with spike length and grain mass per plant. Stressful environmental conditions reduced values of all traits in all analyzed genotypes, at the same time reducing their genetic potential. In favorable environmental conditions, grain weight per spike, followed by the number of grains per spike and spike weight, had the greatest and most direct positive effect on grain yield (Matković Stojšin et al., 2022).

Compared with the other two localities, Sombor is distinguished by a great number of strong and positive degrees of correlation between yield components and grain yield. It can be explained by the fact that in the optimal environmental conditions as in the locality of Sombor, examined wheat genotypes expressed the maximum of their genetic potential. Grain yield showed a statistically very significant, positive correlation with grain mass per plant (0.89), spike mass per plant (0.87), grain mass per spike (0.75), number of spikelets per spike (0.68), number of productive spikes per m^2 (0.67), and spike mass (0.67). Thousand-grain weight revealed a very significant positive linkage compared to spike mass and grain mass per spike (0.79), grain mass per plant (0.61), spike mass per plant (0.59), and plant height. At the same locality, the highest degree of correlation (0.99) is recorded between spike mass and grain mass per spike, as well as between spike mass per plant and grain mass per plant. Similar results were published by Ayer et al. (2017), Ullah et al. (2021) and Matković et al. (2022) as well.

Correlative dependence between traits showed large variation depending on the investigated year, resulting from the interaction within the genetic background of each genotype, as well as their interactions with environmental factors (Terzić et al., 2018). The authors found a more positive, stronger, and statistically significant correlation during the year with optimal monthly temperature and more proper arrangements of precipitation. This data is in accordance with our findings in the locality of Sombor, where yield components expressed a strong and positive correlation with grain yield in the majority of cases.

Cluster analysis was used for grouping the examined genotypes of winter wheat according to phenotypic similarity of grain components and grain yield (**Fig. 2**). The additional objective of cluster analysis was to provide a general picture of the genotype's interaction with their environment, while selecting those with a high average value of an analyzed trait (Hristov et al., 2011).

Examined genotypes of winter wheat from all investigated localities were grouped into four major

Table 2. Coefficients of correlation of examined yield components and grain yield in Kragujevac, Kruševac, and Sombor

Traits	Kragujevac										
	NPS	PH	SL	NSS	SM	SMP	GNS	GMS	GMP	HM	TW
PH	0.45										
SL	-0.06	0.03									
NSS	-0.19	-0.08	0.47								
SM	0.38	0.57*	-0.01	0.02							
SMP	0.45	0.34	-0.32	-0.26	0.78**						
GNS	0.26	-0.18	0.16	0.46	0.27	0.40					
GMS	0.03	0.44	-0.10	-0.05	0.76**	0.43	-0.26				
GMP	0.29	0.30	-0.35	-0.29	0.77**	0.98**	0.33	0.52*			
HM	0.26	0.52*	0.25	-0.33	0.57*	0.54*	0.06	0.25	0.50		
TW	-0.10	0.24	-0.26	-0.43	-0.10	-0.12	-0.61*	0.24	-0.01	-0.14	
Y	0.01	0.17	-0.19	-0.01	0.36	0.31	0.08	0.30	0.34	0.20	0.22
	Kruševac										
	NPS	PH	SL	NSS	SM	SMP	GNS	GMS	GMP	HM	TW
PH	-0.05										
SL	-0.34	0.05									
NSS	-0.35	-0.08	0.65**								
SM	0.14	0.48	0.08	-0.24							
SMP	0.23	0.63*	-0.34	-0.51	0.55*						
GNS	0.40	-0.22	0.073	0.17	0.40	-0.22					
GMS	0.19	0.43	-0.07	-0.39	0.97**	0.54*	0.36				
GMP	0.27	0.52*	-0.43	-0.67**	0.53*	0.97**	-0.24	0.57*			
HM	0.07	0.40	0.08	-0.19	0.50	0.48	-0.15	0.44	0.46		
TW	0.24	0.23	-0.22	-0.25	0.53*	0.53*	0.28	0.56*	0.53*	0.06	
Y	0.53*	-0.05	-0.35	-0.21	0.34	0.15	0.42	0.38	0.14	0.18	0.46
	Sombor										
	NPS	PH	SL	NSS	SM	SMP	GNS	GMS	GMP	HM	TW
PH	0.15										
SL	-0.63*	0.02									
NSS	-0.50	0.02	0.71**								
SM	0.32	0.36	-0.12	-0.47							
SMP	0.52*	0.40	-0.43	-0.56*	0.84**						
GNS	0.04	-0.33	0.25	0.23	0.22	0.10					
GMS	0.37	0.32	-0.22	-0.56*	0.99**	0.88**	0.16				
GMP	0.53*	0.35	-0.49	-0.63*	0.83**	0.99**	0.06	0.88**			
HM	-0.12	-0.10	0.03	-0.37	0.30	0.22	-0.33	0.36	0.27		
TW	0.32	0.52*	-0.15	-0.45	0.79**	0.59*	-0.07	0.79**	0.61*	0.30	
Y	0.67**	0.06	-0.56*	-0.68**	0.67**	0.87**	0.17	0.75**	0.89**	0.36	0.42

*NPS - number of productive spikes per m^2; PH - plant height; SL - spike length; NSS - number of spikelets per spike; SM - spike mass; SMP - spike mass per plant; GNS - grain number per spike; GMS - grain mass per spike; GMP - grain mass per plant; HM - hectoliter mass; TW – thousand-grain weight; Y - grain yield

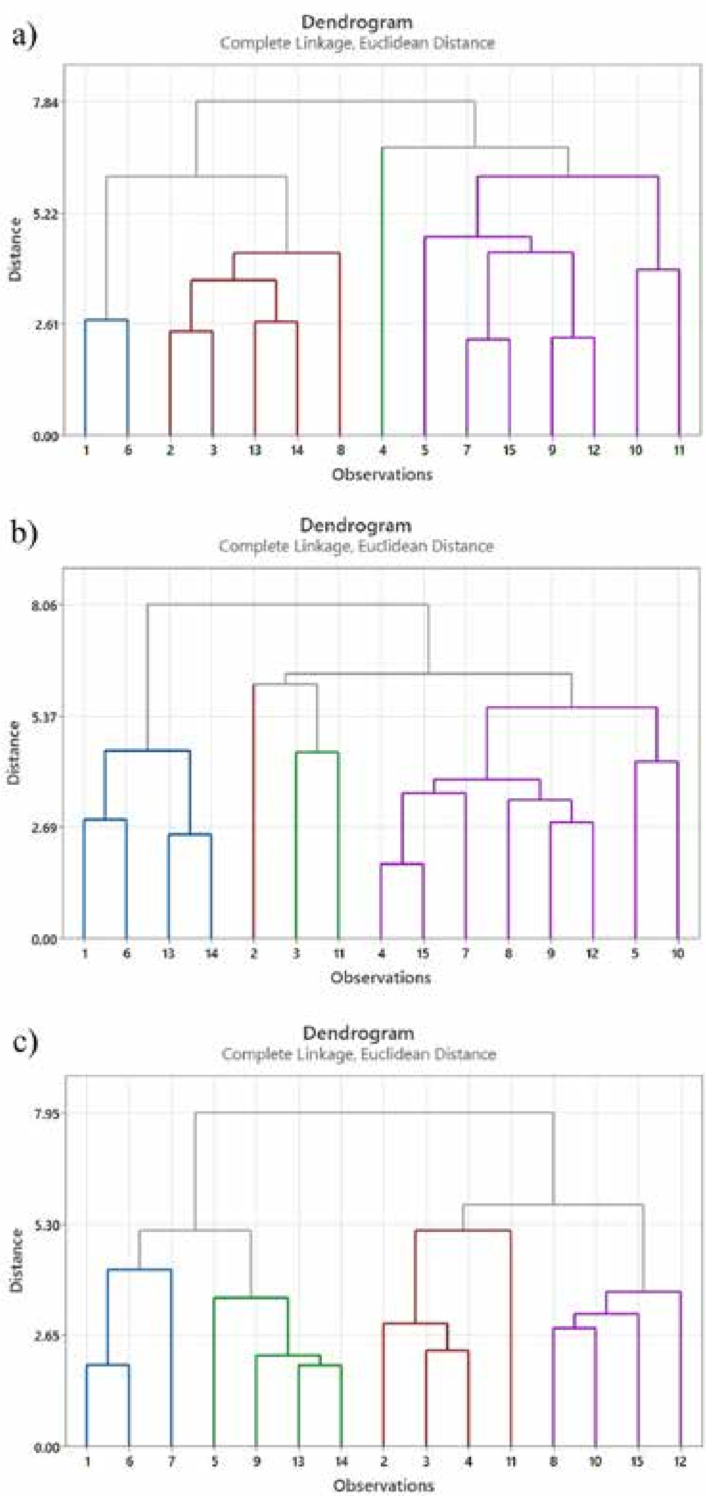

Fig. 2. Cluster analysis of examined wheat genotypes in the investigated localities - Kragujevac (a), Kruševac (b), and Sombor (c) (*Genotypes: 1 - KG-27/6; 2 - KG-244/4; 3 - KG-199/4; 4 - KG-307/4; 5 - KG-331/4; 6 - KG-28/6; 7 - KG-162/7; 8 - KG-191/5-13; 9 - KG-40-39/3; 10 - KG-52/23; 11 - KG-60-3/3; 12 - KG-1/6; 13 - KG-52/3; 14 - KG-47/21; 15 - Pobeda)

clusters, showing the significant genetic diversity among them for all analyzed traits. In the localities of Kragujevac and Kruševac, most of the high-yielding genotypes, followed by the highest trait values, are located in the fourth cluster; on the other hand, the dispersion of genotypes throughout different clusters was more equal in Sombor. Genotypes 1 and 6 as low-yielding genotypes were grouped into the same cluster in all examined localities, pointing out their great similarity and stability in phenotypic expression. The most yielding perspective genotypes of bread wheat were mostly positioned in the third and fourth clusters (KG-60-3/3, Pobeda, KG-199/4, and KG-40-39/3).

Conclusion

Genetic background determines phenotypic expression of yield components and grain yield as well as interactions between genotype and environmental conditions. Wheat genotype KG-331/4 achieved the highest value of average grain yield in Kragujevac, ranging from 3.870 t/ha to 5.250 t/ha. Genotype KG-199-4 expressed the highest average grain yield in Kruševac, with a yield range between genotypes 3.130 - 5.400 t/ha. Most of the yield components had the highest average values in Kragujevac (spike length, spike mass, spike mass per plant, grain number per spike, grain mass per spike, grain mass per plant). Since Kragujevac represents the place of selection, examined genotypes stabilized their expression of yield components and grain yield on similar levels. The highest degree of variation, i.e. coefficients of variation (CV), was confirmed for the characters - spike mass per plant (16.81, 23.87, and 17.10, respectively) and grain mass per plant (16.38, 22.17, and 18.02, respectively) in investigated localities (Kragujevac, Kruševac, and Sombor, respectively). Compared with the other two localities, Sombor wheat is distinguished by a great number of strong and positive degrees of correlation between yield components and grain yield.

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References

Amin, M.F., Hasan, M., Barma, N.C.D., Rahman, M.M., & Hasan, M.M. (2015). Variability and heritability analysis in spring wheat (*Triticum aestivum* L.) genotypes. *Bangladesh Journal of Agricultural Research*, *40*(3), 435-450.

Ayer, D.K., Sharma, A., Ojha, B.R., Paudel, A., & Dhakal, K. (2017). Correlation and Path Coefficient Analysis in Advanced Wheat Genotypes. *SAARC Journal of Agriculture*, *15*(1), 1-12.

Baye, A., Berihun, B., Bantayehu, M., & Derebe, B. (2020). Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. *Cogent Food & Agriculture*, *6*(1), 1752603.

Cao, S., Xu, D., Hanif, M., Xia, X., & He, Z. (2020). Genetic architecture underpinning yield component traits in wheat. *Theoretical and Applied Genetics*, *133*, 1811–1823.

Dubcovsky, J. & Dvorak, J. (2007). Genome Plasticity a Key Factor in the Success of Polyploid Wheat Under Domestication. *Science*, *5833*(316), 1862-1866.

Guan, J., Garcia, D.F., Zhou, Y., Appels, R., Li, A., & Mao, L. (2020). The Battle to Sequence the Bread Wheat Genome: A Tale of the Three Kingdoms. *Genomics Proteomics & Bioinformatics*, *18*, 221–229.

Haydar, F.M.A., Ahamed, M.S., Siddique, A.B., Uddin, G.M., Biswas, K.L., & Alam, M.F. (2020). Estimation of Genetic Variability, Heritability and Correlation for some Quantitative Traits in Wheat (*Triticum aestivum* L.). *Journal of Biological Sciences*, *8*, 81-86.

Horvath, A., Kiss, T., Berki, Z., Horvath, A., Balla, K., Cseh, A., Veisz, O., & Karsai, I. (2023). Effects of genetic components of plant development on yield-related traits in wheat (*Triticum aestivum* L.) under stress-free conditions. *Frontiers in Plant Science*, *13*, 1070410.

Hristov, N., Mladenov, N., Kondic-Špika, A., Marijanovic Jernomela, A., Jockovic, B., & Jacimovic, G. (2011). Effect of environmental and genetic factors on the correlation and stability of grain yield components in wheat. *Genetika*, *43*(1), 141 -152.

IBM SPSS Statistics for Windows (2011). *Version 20.0. Armonk, NY: IBM Corp.*

Jaenisch, B., Munaro, L., Jagadish, K., & Lollato, R. (2022). Modulation of Wheat Yield Components in Response to Management Intensification to Reduce Yield Gaps. *Frontiers in Plant Science*, *13*, 772232.

Kadam, D.J., Karwar, S.H., & Jadhav, P.S. (2022). Correlation analysis for different characteristics in wheat. *The Pharma Innovation Journal*, *11*(1), 98-100.

Luković, K., Prodanović, S., Perišić, V., Milovanović, M., Perišić, V., Rajičić, V., & Zečević, V. (2020). Multivariate analysis of morphological traits and the most important productive traits of wheat in extreme wet conditions. *Applied Ecology and Environmental Research*, *18*(4), 5857-5871.

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.

Minitab, LLC. 2021. *Minitab.* Retrieved from https://www.minitab.com

Mohammadi, M., Sharifi, P., Karimizadeh, R., & Shefazadeh, M.K. (2012). Relationships between Grain Yield and Yield Components in Bread Wheat under Different Water Availability (Dryland and Supplemental Irrigation Conditions). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *40*(1), 195-200.

Nukasani, V., Potdukhe, N.R., Bharad, S., Deshmukh, S., & Shinde, S.M. (2013). Genetic variability, correlation and path analysis in wheat. *Journal of Wheat Research*, *5*(2), 48-51.

Philipp, N., Weichert, H., Bohra, U., Weschke, W., Schulthess, A.W., & Weber, H. (2018). Grain number and grain yield distribution along the spike remain stable despite breeding for high yield in winter wheat. *PLoS ONE*, *13*(10), e0205452.

Pirttioja, N., Carter, T.R., Fronzek, S., Bindi, M., Hoffmann, H., Palosuo, T., Ruiz-Ramos, M., Tao, F., Trnka, M., Acutis, M., Asseng, S., Baranowski, P., Basso, B., Bodin, P., Buis, S., Cammarano, D., Deligios, P., Destain, M.F., Dumont, B., Ewert, F., Ferrise, R., François, L., Gaiser, T., Hlavinka, P., Jacquemin, I., Kersebaum, K.C., Kollas, C., Krzyszczak, J., Lorite, I.J., Minet, J., Minguez, M.I., Montesino, M., Moriondo, M., Müller, C., Nendel, C., Öztürk, I., Perego, A., Rodríguez, A., Ruane, A.C., Ruget, F., Sanna, M., Semenov, M.A., Slawinski, C., Stratonovitch, P., Supit, I., Waha, K., Wang, E., Wu, L., Zhao, Z., & Rötter, R.P. (2015). Temperature and precipitation effects on wheat yield across a European transect: a crop model ensemble analysis using impact response surfaces. *Climate Research*, *65*, 87–105.

Sokoto, M.B., Abubakar, I.U., & Dikko, A.U. (2012). Correlation Analysis of some Growth, Yield, Yield Components and Grain Quality of Wheat (*Triticum aestivum* L.). *Nigerian Journal of Basic and Applied Science*, *20*(4), 349-356.

Terzić, D., Đekić, V., Milivojević, J., Branković, S., Perišić, V., Perišić, V., & Đokić, D. (2018). Yield components and yield of winter wheat in different years of research. *Biologica Nyssana*, *9*(2), 119-131.

Ullah, M., Mahpara, S., Bibi, R., Shah, R., Ullah, R., Abbas, S., Ullah, M.I., Hassan, A., El-Shehawi, A., Brestic, M., Zivcak, M., & Khan, M. (2021). Grain yield and correlated traits of bread wheat lines: Implications for yield improvement. *Saudi Journal of Biological Sciences*, *28*, 5714–5719.