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PHENOTYPIC ANALYSIS OF AGRONOMIC TRAITS IN BREAD WHEAT

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Summary: *Components of yield and seed quality are traits of primary importance in bread wheat breeding programs. Yield components are obviously a major determinant of farmer's income, whereas seed quality is very important for breeding quality. In this paper, the thousand grain weight (TGW) was chosen as indicative of yield features and the shelling percentage (RND) as indicative of seed quality (although RND is not directly connected to the technological/seed quality, but rather indirectly and it greatly contributes to the wider picture of seed quality). The objectives of the present research were two-fold: to determine the influence of genotype, the environment and their interaction on the thousand grain weight and shelling percentage and to evaluate the stability via the AMMI model. The grain samples were obtained from ten winter wheat cultivars grown in 2009/10, 2010/11, 2011/12 at three locations in Serbia: Novi Sad, Sremska Mitrovica and Pančevo. The ten winter wheat cultivars used in this study were: Evropa 90, NSR-5, Pobeda, Renesansa, Ljiljana, Cipovka, Dragana, Simonida, NS 40 S and Zvezdana. The thousand grain weight and shelling percentage were investigated and statistically analyzed via the AMMI model, which showed significant differences between genotypes at various locations and ASV rankings. The most favorable cultivar in the experiment was Dragana in terms of all investigated traits.*

Key words: *AMMI model, bread wheat, quality of seed, stability.*

INTRODUCTION

Genetic studies of important traits in cereals have revealed that most of them are inherited quantitatively, rendering them difficult to detect within the genome. However, with the development of high density linkage maps, the discovery of such quantitative trait loci became possible in many species (Börner et al., 2002). Taking this into account and the fact that Brenchley et al. (2012) estimated the number of genes in wheat at about 96,000 by using shotgun sequencing, conventional breeding can be considered much harder than previously thought.

Components of yield and seed qualityfeaturesare traits of primary importance in bread wheat breeding programs (Groos et al., 2003).Yield components are obviously a major determinant of farmer's income, whereas seed quality is very important for breeding quality. In this paper, the thousand grain weight (TGW) was chosen as indicative of yield features and shelling percentage (RND) as indicative of seed quality (although RND is not directly connected to the technological/seed quality, but rather indirectly and it greatly contributes to the wider picture of seed quality). Seedquality is most often defined as a unified sum of seed features which, after sowing, lead to a rapid and uniform germination, forming strong and healthy seedlings which will give the necessary number of plants under favorable and unfavorable environmental conditions. Seed quality is also reflected in the final growth, maturation of plants, their uniformity and stability of yield (Mladenov et al., 2012).The accurate evaluation of these traits is made on the basis of the genotype x environment (GxE) interaction (Robert et al., 2001). Both of these traits are affected by different growing conditions at different locations as well as by genetic factors. Therefore, as Banjacet al. (2014)already stated, it is important to accurately determine the source of variation and their effects on the traits examined at different locations. The evaluation of different varieties in different environments and over longer

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periods of time are needed in order to identify the spatial and temporal stability of genotypes that could be recommended for new breeding programs and eventually new production (Sharma et al, 2010).

The objectives of the present research were two-fold: to determine the influence of genotype, the environment and their interaction on the thousand grain weight and shelling percentage and to evaluate the stability via the AMMI model.

MATERIAL AND METHODS

The grain samples were obtained from ten winter wheat cultivars grown in 2009/10, 2010/11, 2011/12 at three locations in Serbia: Novi Sad, Sremska Mitrovica and Pančevo. The ten winter wheat cultivars used in this study were: Evropa 90, NSR-5, Pobeda, Renesansa, Ljiljana, Cipovka, Dragana, Simonida, NS 40 S and Zvezdana (Table 1). All of these cultivars were designed in the Institute of Field and Vegetable Crops, Novi Sad. The wheat cultivars were planted in a randomized complete block design with three replications. The plots of 5 m2 with 10 rows spaced 12.5 cm apart were seeded at a rate of ≈230 kg·ha-1. The sowing in all three growing seasons was completed by the end of October, while the harvest was ended in the first ten-day period of July.

Table 1. Genotype, pedigree and year of release of 10 winter wheat cultivars and environments description

Genotype	**Pedigree**	**Year of release**	**Environment**	
Evropa 90	Talent x NS rana 2	1990	***Code***	***Location-Veg. season***
NSR-5	NS rana 1/Tisa x Partizanka/3/Mačvanka 1	1991	E1	Rimski Šančevi-2009/10
Pobeda	Sremica x Balkan	1990	E2	Rimski Šančevi-2010/11
Renesansa	Jugoslavija x NS 55-25	1994	E3	Rimski Šančevi-2011/12
Ljiljana	NS3287-3 x Rodna	2000	E4	Sremska Mitrovica-2009/10
Cipovka	NS rana 5 x Rodna	2002	E5	Sremska Mitrovica-2010/11
Dragana	Sremka 2 x Francuska	2002	E6	Sremska Mitrovica-2011/12
Simonida	NS 63-25/Rodna x NS-3288	2003	E7	Pančevo-2009/10
NS 40 S	NS 694 x NSA 88-3141	2005	E8	Pančevo-2010/11
Zvezdana	NS 63-27/Stamena x NS rana 5	2006	E9	Pančevo-2011/12

The thousand grain weight (TGW) was calculated from the weight (g) of 4 lots of 100 seeds, multiplying by 10.The shelling percentage RND (%) was determined when the 4x100g of natural seed was sifted through a 2.2 mm rectangular aperture. The rest of seeds on the sieve were measured and expressed as a percentage (%).All the tests were performed on the harvested seed of each cultivar for each replication. The genotype by environment interaction (GxE) was tested using the AMMI (Additive Main Effects and Multiplicative Interaction) analysis given by Zobelet al. (1998). The data processing was performed in the GenStat 9th Edition VSN International Ltd. (www. vsn-intl.com), trial version.

Since the AMMI model does not make provision for a quantitative stability measure, and as such a measure is essential in order to quantify and rank genotypes in terms of yield stability, the following parameter ASV (AMMI Stability Value) was introduced:

$$ASV = \sqrt{\left[\frac{IPCA1\ SumofSquars}{IPCA2\ SumofSquars} x IPCA1\ score\right]^2 + [IPCA2score]^2}$$

Weather conditions (data not shown) were favourable for wheat production, especially in the first two years of this experiment. The temperatures were higher than average, with more rainfall than usual, and the insulation was much less than average. The year 2012 was dry with the precipitation less than average (the Republic Hydro-Meteorological Service of Serbia, 2013).

RESULTS

The AMMI analysis of variance for TGW showed that the total sum of squares attributed to the impact of environments was 50.48%, the GxE was represented with 23.83% while 19.56% was the effect of genotype (Table 2).

Table 2. AMMI analysis of variance for thousand grain weightof 10 wheat cultivars examined across 9 environments

Source	*df*	*SS*	*MS*	*F calculated*	*F table 0.05*	*0.01*	*The share of the total variation %*
Total	269	4018.4	14.94	-	-	-	100
Treatments	89	3772.0	42.38	29.14^{**}	1.00	1.00	93.87
Genotypes	9	785.9	87.33	60.04^{**}	1.88	2.41	19.56
Environments	8	2028.6	253.58	22.55^{**}	1.94	2.51	50.48
Block	18	10.8	0.60	0.41^{ns}	1.57	1.87	0.27
Interactions	72	957.4	13.30	9.14^{**}	1.00	1.00	23.83
$IPCA_1$	16	368.6	23.04	15.84^{**}	1.57	1.87	38.50
$IPCA_2$	14	232.7	16.62	11.43^{**}	1.75	2.18	24.31
$IPCA_3$	12	159.2	13.26	$^{**}9.12$	1.75	2.18	16.63
$IPCA_4$	10	103.2	10.32	$^{**}7.10$	1.83	2.32	10.78
$IPCA_5$	8	51.9	6.49	$^{**}4.46$	1.94	2.51	5.42
$IPCA_6$	6	26.1	4.34	$^{**}2.99$	2.09	2.80	2.73
Residuals	6	15.9	2.65	$^{ns}1.82$	2.09	2.80	-
Error	162	235.6	1.45	-	-	-	-

In the further course of analyses, four components were separated from the interaction sum of squares, of which the first one ($IPCA_1$) accounts for38.50% of the structure. Due to the high proportion of the first principal component, a graphical display of the AMMI analyses is provided in the form of AMMI 1 bi plot (Figure 1).

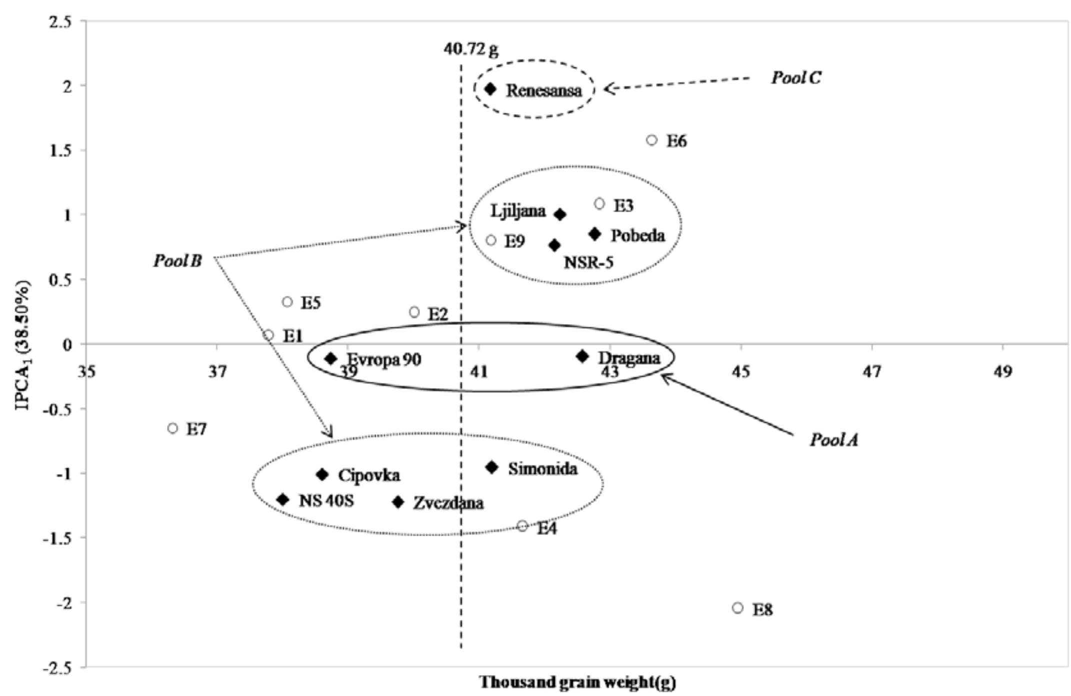

Figure 1. Biplot of the AMMI model for the thousand grain weight of 10 examined wheat cultivars grown in 9 environments

The biplot shows that most genotypes achieved yields which slightly deviate from the grand mean of the experiment (40.72g). The best performance was recorded in Pobeda, while the largest contribution to the GxE interaction was determined in E6 and E8, since they were the most distant from the axis of stability. In relation to the value of interaction, the genotypes were grouped in three pools according to stability:

pool A-stable genotypes: Evropa 90 and Dragana.

pool B-medium stable genotypes: Simonida, Zvezdana, Cipovka, NS40S, Ljiljana, Pobeda and NSR-5.

pool C- minimum stable genotypes: Renesansa.

The AMMI analyses showed that the variation of the shelling percentage was mainly determined by the influence of the environment (82.84%), while the GxE interaction and genotype accounted for 9.10% and5.63% respectively, Table 3.

Table 3. AMMI analysis of the variance of the shelling percentage for 10 wheat cultivars examined across 9 environments

Source	*df*	*SS*	*MS*	*F calculated*	*F table 0.05*	*0.01*	*The share of the total variation %*
Total	269	6603	24.55	-	-	-	100
Treatments	89	6443	72.39	89.67^{**}	1.00	1.00	97.58
Genotypes	9	372	41.33	51.20^{**}	1.88	2.41	5.63
Environments	8	5470	683.71	419.35^{**}	1.94	2.51	82.84
Block	18	29	1.63	2.02^{**}	1.57	1.87	0.44
Interactions	72	601	8.35	10.34^{**}	1.00	1.00	9.10
$IPCA_1$	16	328	20.48	25.37^{**}	1.57	1.87	54.58
$IPCA_2$	14	139	9.95	12.33^{**}	1.75	2.18	23.13
$IPCA_3$	12	52	4.37	5.42^{**}	1.75	2.18	8.65
$IPCA_4$	10	38	3.76	4.66^{**}	1.83	2.32	6.32
$IPCA_5$	8	26	3.19	3.96^{**}	1.94	2.51	4.33
$IPCA_6$	6	13	2.21	2.73^{*}	2.09	2.80	2.16
Residuals	6	5	0.86	1.07^{ns}	2.09	2.80	-
Error	162	131	0.81	-	-	-	-

Due to the solid share of the first principal component in the total variation of interaction (54.58%),the stability of genotypes and the environment was presented in the form of AMMI1 biplot (Figure 2). The biplot shows that the most genotypes achieved a greater shelling percentage in comparison with the grand mean of the experiment (92.16%). The best performance was recorded in Dragana and while the largest contribution to the GxE interaction was determined in E1 and E3, since they were the most distant from the axis of stability. In relation to the value of interaction, the genotypes were grouped in three pools according to stability:

pool A-stable genotypes: Dragana, Ljiljana and NSR-5

pool B-medium stable genotypes: Simonida, Pobeda, Zvezdana, NS40S, Cipovka and Renesansa

pool C- minimum stable genotypes: Evropa 90.

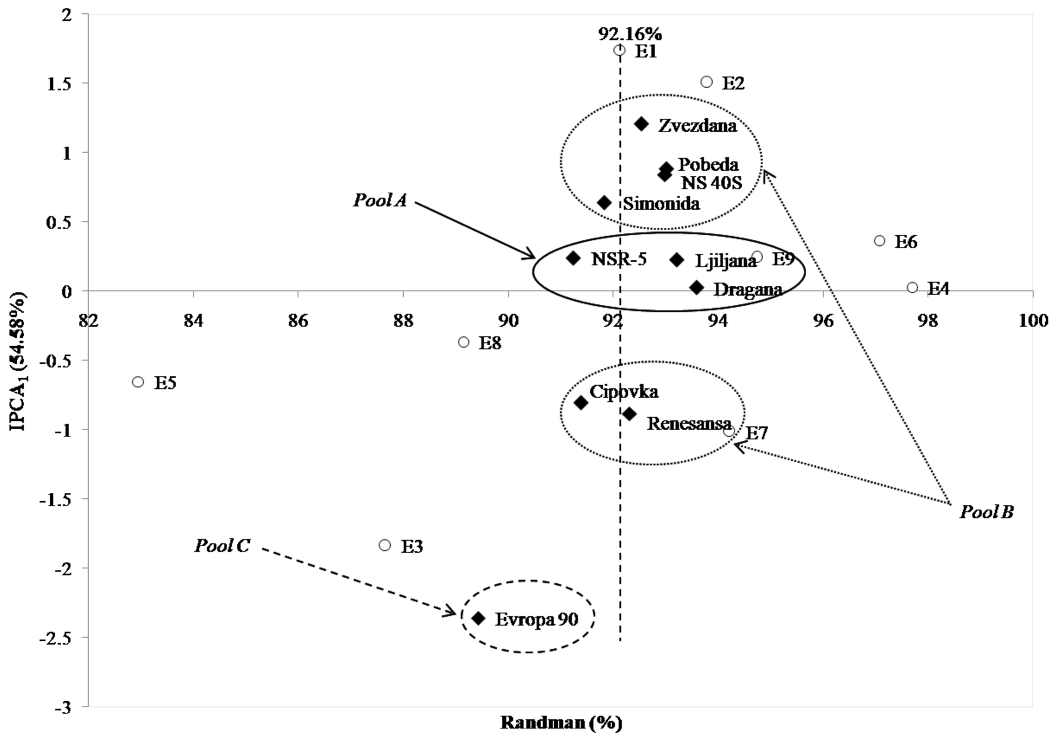

Figure 2. Biplot of the AMMI model for the shelling percentage of 10 examined wheat cultivars grown in 9 environments

Table 4 presents the mean value, AMMI model IPCA1 and IPCA2 scores of the examined traits for each genotype and the AMMI stability value (ASV). According to the ASV ranking for TGW, Dragana had the lowest value which shows that it was the most stable, while Renesansa was unstable. In terms of the shelling percentage, Evropa 90 had the lowest stability, while Dragana again had the highest stability.

Table 4. Mean values for examined traits and ranking order by the AMMI stability value (ASV) across 9 environments

	TGW				RND			
Genotype								
	Mean Value	$IPCA_1$	$IPCA_2$	ASV	Mean Value	$IPCA_1$	$IPCA_2$	ASV
Evropa 90	38.74	-0.11	-2.35	2.35	89.43	-2.36	-0.74	5.62
NS rana 5	42.15	0.76	0.14	1.21	91.24	0.24	0.63	0.85
Pobeda	42.77	0.85	0.16	1.36	93.02	0.88	-1.28	2.44
Renesansa	41.17	1.97	-0.12	3.13	92.31	-0.88	0.42	2.13
Ljiljana	42.24	1.01	0.87	1.82	93.22	0.23	0.31	0.62
Cipovka	38.61	-1.01	-0.67	1.73	91.39	-0.81	0.60	2.00
Dragana	42.58	-0.10	0.50	0.52	93.59	0.02	0.09	0.11
Simonida	41.20	-0.95	0.01	1.51	91.84	0.64	0.92	1.77
NS 40 S	38.00	-1.20	1.33	2.32	92.99	0.84	-1.54	2.51
Zvezdana	39.76	-1.22	0.14	1.94	92.54	1.20	0.59	2.90

DISCUSSION

Depending on objectives, there are two different concepts of stability: the static concept of stability and the dynamic concept of stability (Becker and Leon, 1985). Both concepts are very valuable, but their application depends on the traits considered. In terms of the static concept, a stable genotype possess an unchanged performance regardless of any variation of environmental conditions. It shows no deviation from the expected character level, which means that the variance among environments is zero (which is preferred, but totally impossible). Where as the impacts of environments for TGW is 50.48%, the idea remains theoretical. Conversely, the dynamic concept permits a predictable response to the environment and a stable genotype has no deviations. Therefore, stable genotypes will correspond completely to the estimated level or prediction and it should not be the same for all genotypes. The fact that 19.56% of total variation is explained by the genotype is in accordance with the dynamic concept of stability and shows how strong was the genetic response of these cultivars for the TGW.

The AMMI method is used for three main purposes. The first is model diagnosis, the AMMI is more appropriate in the initial statistical analysis of yield trials because it provides the analytical tool of diagnosing other models as sub cases when these are better for particular data sets (Gauch, 1988). Secondly, the AMMI clarifies the GxE interaction and it summarizes patterns and relationships of genotypes and environments (Zobel et al., 1988; Crossa et al., 1990). The third use is to improve the accuracy of yield estimates (Farshadfar et al., 2011**)**.

Purchase et al. (2000) developed a quantitative stability value to rank genotypes via the AMMI model, named the AMMI stability value (ASV). This model was considered to be the most appropriate single method of describing the stability of genotypes. For all of the examined features, the AMMI analysis and ASV ranking were in accordance and had exactly the same results. The presented results indicate that the two analyzed characteristics of bread wheat have changed under the influence of locality – this was reflected through a significant GxE interaction. The calculated values of GxE interaction showed that there were differences in the stability of genotype in terms of the two investigated traits. The genotypes were grouped differently according to stability, expressed through interaction scores (AMMI model).

In breeding programs, it is much easier to achieve low and stable values of individual cultivars, but much more knowledge and work is needed for high and stable values of any traits. The correlation between the investigated traits is an irrefutable fact. It is well known that Evropa 90 and Cipovka unstable TGW values own fine grain with a large percentage of waste, what indicates a small random number, which is in accordance with previous research of Mladenov et al., 2012. A minor proportion of genotype indicates that the random number is a trait of the morphological properties of grain (size of a seed), while everything else is under the influence of living conditions through different phenological stages, but mostly during grain filling. Therefore, it is logical to allocate a total opposite and label it the ideal genotype for the examined features. Dragana has a big and large seed and because of that it will have small waste, presented through a small shelling percentage, but a lower test weight, which is in line with Jocković, 2014. The cultivar NS40S points to a paradoxical situation where the shelling percentage is high and TGW is small. The explanation arises from the fact that the size of the sieve on which the random number was determined is 2.2 mm, and the seed of this cultivar is larger and extremely uniform so it could not pass easily through it. The stability calculated as ASV are in accordance with the AMMI model and indicates that Dragana is the most stable cultivar for the traits investigated in this study.

CONCLUSION

Based on the results obtained, it can be concluded that genetic variability was determined for the two investigated properties in the material used for this study. The most suitable environments for achieving the highest TGWwere E6 and E8, while the lowest values ofTGW were recorded in the environments E7 and E1. In E2 environment, the genotypes exhibited the most stable reaction to TGW as indicative of yield. The environment E4 was the most suitable for the realization of a high shelling percentage.

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ANALIZA FENOTIPSKIH OSOBINA HLEBNE PŠENICE

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Izvod: Komponente prinosa i kvaliteta semena hlebne pšenice su osobine, koje imaju primarni značaj u oplemenjivanju ove biljne vrste. Komponente prinosa su glavna odrednica ekonomske dobiti proizvođača, dok je kvalitet semena presudan za kvalitet hleba. Za ovo istraživanje, kao predstavnik komponenti prinosa pšenice, je odabrana masa hiljadu masu zrna (TGW), dok je randman semena (RND), indirektno, značajan za kvalitet semena. Istraživanje je imalo dva cilja (i) da se utvrdi uticaj genotipa, životne sredine i njihove interakcije na masu hiljadu zrna i randman, kao predstavnike kvaliteta semena; (ii) da se oceni stabilnost kroz AMMI model. Analizirano je deset sorti hlebne pšenice, gajenih u 2009/10, 2010/11, 2011/12 godini, na tri lokaliteta u Srbiji: Novi Sad, Sremska Mitrovica i Pančevo. Ispitivane sorte su: Evropa 90, NSR-5, Pobeda, Renesansa, Ljiljana, Cipovka, Dragana, Simonida NS 40 S i Zvezdana. AMMI analiza i rangiranje preko ASV za masu hiljadu zrna i randman su pokazali značajne razlike između genotipova na različitim lokalitetima. U pogledu oba ispitivana svojstva, na nivou celog ogleda, najveću stabilnost ispoljila je sorta Dragana.

Ključne reči*: *AMMI model, hlebna pšenica, kvalitet semena, stabilnost

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