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EVALUATION OF YIELD AND SEED REQUIREMENTS STABILITY OF BREAD WHEAT(*Triticum aestivum* L.) *VIA* AMMI MODEL

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ABSTRACT

High quality seed of wheat is the key to successful agriculture. Improvement and evaluation of agronomic traits have been the primary objective of breeders for many years under variable environments. The objective of the present research was to determine influence of genotype, environment and their interaction on yield and randman of seed as a seed quality represent and to evaluate stability through AMMI model. Grain samples were obtained from ten winter wheat cultivars grown in 2009/10 and 2010/11 at three locations in Serbia: Novi Sad, Sremska Mitrovica and Pančevo. Yield and randman of seed were investigated and statistically analized via AMMI model which shows significant differences between genotypes at various locations. Best performer was Simonida with average yield 8.22 t·ha^{-1}. Analyses of randman of seed indicate at differences in the main effect and interaction.

Key words: AMMI model, randman of seed, stability, wheat (*Triticum aestivum* L.), yield.

INTRODUCTION

Wheat is a major crop contributing importantly to the nutrient supply of the global population and also a very versatile crop; it shows wide adaptation to diverse agro-ecological conditions and cropping technologies (Pena, 2007). High quality seed is the key to successful agriculture (Banu, 2004). Quality of seed is most often defined as a unifed sum of seed features that after sowing lead to a rapid and uniform germination, forming of a strong and healthy seedlings which will give the neccesary number of plants in favorable and unfavorable environmental conditions. The seed quality is also reflected in the final growth, maturation of plants, their uniformity and stability of yield (Molnar et al., 2005; Chloupek et al., 2003). It has long been recognized that wheat productivity and quality of seed vary considerably as a result of genotype, environment and their interaction (GEI). While wheat growers consider yield as a major issue, millers and bakers emphasize variability in the functional properties of flour as their biggest concern (Denčić et al., 2011). Precisely because of this situation it is necessary to include as many parameters into consideration. Improvement and evaluation of agronomic traits has been the primary objective of breeders for many years under variable environments. Breeders have also measured and selected for grain yield and most related traits such as thousand grain weight, test weight, randman of seed and other related traits (Rubio et al., 2004; Dimitrijević, 2011). All these traits are affected by the growing environment as well as by genetic factors, and numerous studies have described the GEI (Doehlert and McMullen, 2000; Doehlert et al., 2001). However, evaluation of genotypes across diverse environments and over several years is needed in order to identify spatially and temporally stable genotypes that could be recommended for release as new cultivars and/or for use in the breeding programs (Sharma et al., 2010). Large differential genotypic responses occur under varying environmental conditions (Mkumbira et al., 2003). This phenomenon is referred to as the GEI and is important in plant breeding programs (Mohammadi, 2010). An understanding of the cause of the GEI can help to identify superior genotypes based on traits. Usually a number of genotypes are tested over a number of sites and years and multiple traits are recorded and it is often difficult to determine the pattern of genotypic performance across environments. Numerous methods have been used to understand the causes of the interactions, although strategies may differ in overall appropriateness.

The objectives of the present research were two-fold (i) to determine influence of genotype, environment and their interaction on yield and randman of seed as a seed quality represent; (ii) to evaluate stability throught AMMI model.

MATERIALS AND METHODS

Samples

Grain samples were obtained from ten winter wheat cultivars grown in 2009/10 and 2010/11 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 Institute of Field and Vegetable Crops, Novi Sad so the fact that all cultivars were agronomically suitable for production in these locations was not questionable. The wheat cultivars were planted in a randomized complete block design with three replications. Plots of 5 m^2 with 10 rows spaced 12.5 cm apart were seeded at a rate of ≈230 $kg\cdot ha^{-1}$. Sowing in both growing seasons was completed by the end of October, while harvest was ended in 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***
NS rana 5	NS rana 1/Tisa x Partizanka/3/Mačvanka 1	1991		
Pobeda	Sremica x Balkan	1990	E1	Rimski Šančevi-2009/10
Renesansa	Jugoslavija x NS 55-25	1994	E2	Sremska Mitrovica-2009/10
Ljiljana	NS3287-3 x Rodna	2000	E3	Pančevo-2009/10
Cipovka	NS rana 5 x Rodna	2002	E4	Rimski Šančevi-2010/11
Dragana	Sremka 2 x Francuska	2002	E5	Sremska Mitrovica-2010/11
Simonida	NS 63-25/Rodna x NS-3288	2003	E6	Pančevo-2010/11
NS 40 S	NS 694 x NSA 88-3141	2005		
Zvezdana	NS 63-27/Stamena x NS rana 5	2006		

Sample Analyses

Yield YLD ($t\cdot ha^{-1}$) was determined in field. Randman of seed (RND) is defined as a ratio between natural and pure seed without any admixtures. RND was determined when the 4·100 g of natural seed was sifted through rectangular aperture size 2.2 mm. The rest of seeds on the sieve was measured and expressed as a percentage (%). Tests were performed on the harvested seed of each cultivar for each replication.

Statistical Analyses

Minimum, maximum, mean values, standard deviation and variance were calculated as indicators of trait variability. These statistical calculations were done using StatSoft, Inc. (2011), STATISTICA (data analysis software system), version 10 (www.statsoft.com). The sustainability index (SI) was estimated by the following formula (Babarmanzoor et al., 2009).

$$SI = [(Y-\sigma)/ Y_{max}] \times 100$$

where Y - average performance of a genotype, σ - standard deviation and Y_{max} – maximum value of a genotype in any year. The values of sustainability index were divided arbitrarily into 5 groups viz. very low (upto 20%), low (21-40%), moderate (41-60%), high (61-80%) and very high (above 80%). Genotype by environment interaction (GEI) was tested using AMMI (Additive Main Effects and Multiplicative Interaction) analysis by Zobel et al. (1998). Data processing was performed in GenStat 9th Edition VSN International Ltd (www. vsn-intl.com).

Growing Season Conditions

Reactions of genotypes were observed in two growing seasons (data not shown). Generally speaking, the weather conditions were very favourable for wheat production, the temperature on all locations across two years were higher than average, with more rainfall than usual and insulation much less than average. (Republic Hydro-meteorological Service of Serbia, 2011).

RESULTS AND DISCUSSION

The AMMI method is used for three main purposes. The first is model diagnoses, AMMI is more appropriate in the initial statistical analysis of yield trials, because it provides an analytical tool of diagnosing other models as sub cases when these are better for particular data sets (Gauch, 1988). Secondly, AMMI clarifies the G × E interaction and it summarizes patterns and relationships of genotypes and environments (Zobel et al., 1998; Crossa et al., 1990). The third use is to improve the accuracy of yield estimates (Ilker et al., 2011**)**.

Table 2. AMMI analysis for the yield of examined wheat cultivars

Source [1]	**df**	**SS**	**MS**	**F**	**p**	**The share of the total variation %**
Total	179	485,6	2,713	-	-	100
Treatments	59	448,3	7,599	32,88	$0,000^{**}$	92,32
Genotypes	9	29,1	3,236	14,00	$0,000^{**}$	5,99
Environments	5	374,1	74,812	72,61	$0,000^{**}$	77,04
Block	12	12,4	1,030	4,46	$0,000^{**}$	2,55
Interactions	45	45,1	1,003	4,34	$0,000^{**}$	9,29
$IPCA_1$	13	25,9	1,991	8,61	$0,000^{**}$	57,43
$IPCA_2$	11	11	1,000	4,33	$0,000^{**}$	24,39
$IPCA_3$	9	5,6	0,626	2,71	$0,007^{**}$	12,42
$IPCA_4$	7	1,8	0,257	1,11	$0,360^{ns}$	3,99
Residuals	5	0,8	0,163	0,71	$0,621^{ns}$	-
Error	108	25	0,231	-	-	-

[1] All sources were tested in relation to the error

AMMI analysis of variance for yield showed that the total sum of squares attributed to the impact of environments 77.04%, GEI was represented with 9.29% while 5.99% was the effect of genotype. Differences in soil and surface conditions of the site have caused a large sum of squares environments in total variation and precisely this fact was reflected with the axiom that environments was the most responsible for the variation in yield. The genetic constitution of cultivars is a precondition for expression of yield, nevertheless wheat is grown in the open field and the yield is quantitative trait so the environmental factors are crucial determinant of yield expression. There were significant differences between genotypes at various locations. It can be seen from the ratio of the sum of squares among interaction and genotype since the interaction was two times higher than the share of genotype (Table 2) .

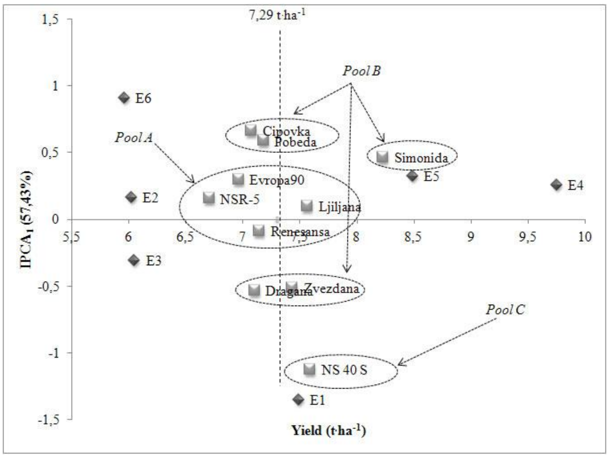

Figure 1. Biplot of the AMMI model for yield for 10 examined wheat varieties grown across six environments

In further course of analyses from the interaction sum of squares four main components were separated, of which the first one ($IPCA_1$) explains 57.43% of the structure. Due to the high proportion of first principal component graphical display of AMMI analyses is provided in form of AMMI 1 biplot (Figure 1).

Biplot shows that the most genotypes achived yield that slighly deviate from the grand mean of the experiment (7.29 t·ha^{-1}). Best performer was Simonida with average yield 8.22 t·ha^{-1} and also achived good interaction with the E5 environment. Largest contribution to the GEI gave E1 and E6, since they were most distant from the axis of stability. In relation to the value of interaction, genotypes were grouped in three pools according to stability:

pool A-stable genotypes: Renesansa, Ljiljana, NSR5 and Evropa 90

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

pool C- minimum stable genotypes: NS 40S.

For achiving highest yield most suitable environments were E4 and E5, while the lowest values od yield were recorded at environments E6, E2 and E3.

High sustainability index (%) was estimated in the cases of Simonida (69.03) and Zvezdana (64.69), while the rest of genotypes showed moderate sustainability index (41-60), Table 3. These results prove that SI is not a suitable stability index for discriminating stable genotypes with high grain yield.

Table 3. Basic statistics parameters for yield (t·ha^{-1}) of 10 winter wheat genotypes across two seasons: minimum, maximum and mean values, standard deviation, variance with sustainability index in six environments

Genotype	Minimum value	Maximum value	Mean value	Standard deviation	Variance	Sustainability index (SI) %
Evropa 90	5.47	9.48	6.96	1.74	3.03	55.01
NS rana 5	4.89	9.19	6.70	1.56	2.43	55.98
Pobeda	5.08	10.38	7.18	1.97	3.89	50.14
Renesansa	5.68	9.79	7.14	1.64	2.67	56.21
Ljiljana	5.97	10.34	7.56	1.66	2.74	57.10
Cipovka	5.27	9.76	7.07	1.70	2.87	55.01
Dragana	5.03	9.24	7.10	1.57	2.45	59.93
Simonida	6.83	10.01	8.22	1.31	1.72	69.03
NS 40 S	5.03	10.09	7.57	2.01	4.04	55.17
Zvezdana	5.99	9.25	7.43	1.44	2.08	64.69

AMMI analyses showed that the variation of randman was mainly determined by the influence of environment (60.39%), GEI (20.43%) and finally genotype (15.34%), Table 4.

Minor proportion of genotype indicates that randman of seed is trait to which the genotype effect is under expression of 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. Due to the very high share of the first principal component of the total variation of interaction (72.55%) stability of genotypes and environment was presented in the form of AMMI1 biplot (Figure 2).

Table 4. AMMI analysis for the randman of seed in examined wheat cultivars

Source [1]	df	SS	MS	F	p	The share of the Total Variation %
Total	179	2115,4	11,82	-	-	100
Treatments	59	2034,2	34,48	62,39	$0,000^{**}$	96,16
Genotypes	9	324,6	36,06	65,26	$0,000^{**}$	15,34
Environments	5	1277,5	255,50	142,24	$0,000^{**}$	60,39
Block	12	21,6	1,80	3,25	$0,001^{**}$	1,02
Interactions	45	432,1	9,60	17,38	$0,000^{**}$	20,43
$IPCA_1$	13	313,5	24,11	43,63	$0,000^{**}$	72,55
$IPCA_2$	11	45,4	4,13	7,47	$0,000^{**}$	10,51
$IPCA_3$	9	34,7	3,86	6,98	$0,000^{**}$	8,03
$IPCA_4$	7	32,3	4,62	8,36	$0,000^{**}$	7,48
Residuals	5	6,2	1,24	2,24	$0,060^{ns}$	-
Error	108	59,7	0,55	-	-	-

[1] All sources were tested in relation to the error

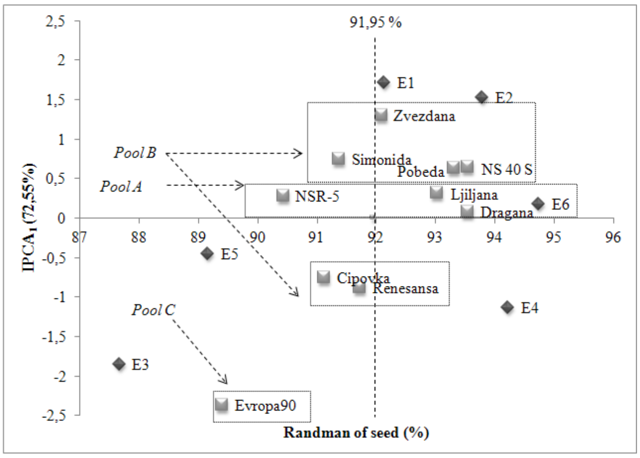

Figure 2. Biplot of the AMMI model for randman of seed for 10 examined wheat varieties grown across six environments

The position of environment points indicates at differences among main effect and interaction. Cultivars recorded largest randman of seed in the E6, which was at the same time the most stable environment for the expression of this trait. For the achievement of stable randman of seed after E6, E5 was most suitable. Nevertheless, this environment has not showned to be suitable for high randman of seed values, considering that the lowest main has been achieved here (89.15%). Environments E3 and E1 had the highest scores of interaction and that fact distinguished them as the unfavourable for stable randman of seed. Similar to yield and for randman of seed three groups in relation to stability were allocated:

pool A- stable genotypes: Ljiljana, NSR5 and Dragana

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

pool C- minimum stable genotypes: Evropa 90.

Zvezdana has been classifed in *pool B* although its interaction deviates from the values of other genotypes in that group. But the deviation is less than the least stable genotype from the *pool C*. Zvezdana achieved the value of randman of seed at the average level of two-year experiment and also had a positive interaction with E2 and E1 and negative with E4. These facts indicates that its stability is conditioned by the terms of year and not by locality.

Very high sustainability index (above 90%) was estimated in the all cases (Table 5). These results prove that SI was not a suitable stability index for discriminating stable genotypes with high randman of seed.

Table 5. Basic statistics parameters for randman of seed (%) of 10 winter wheat genotypes across two seasons: minimum, maximum and mean values, standard deviation, variance with sustainability index in six environments

Genotype	Minimum value	Maximum value	Mean value	Standard deviation	Variance	Sustainability index (SI) %
Evropa 90	85.90	95.27	89.39	3.61	13.01	90.04
NS rana 5	85.03	93.27	90.42	2.99	8.96	93.74
Pobeda	86.80	96.60	93.30	3.77	14.18	92.69
Renesansa	89.50	94.73	91.71	2.10	4.41	94.59
Ljiljana	89.05	96.47	93.04	3.00	9.00	93.34
Cipovka	88.13	93.90	91.11	2.98	8.88	93.85
Dragana	89.93	95.87	93.53	2.75	7.55	94.69
Simonida	86.77	94.23	91.36	3.13	9.81	93.63
NS 40 S	86.80	97.03	93.54	3.98	15.87	92.30
Zvezdana	85.33	96.57	92.08	4.70	22.10	90.49

In the presented results, all characteristics of wheat have changed under the influence of locality – this was reflected through significant GEI. Calculated values of GEI showed that there were differences in a stability of genotype across both investigated traits. Genotypes were grouped differently according to stability, expressed throught interaction scores (AMMI model) and SI index. Nevertheless, AMMI model is more comprehensive and results of this analysis are considered as plausible. Since that AMMI analysis fully explained sum of squares it provides a good estimation of genotypes on the observed locations.

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