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Original scientific paper

THE VARIATION OF YIELD COMPONENTS IN WHEAT (*Triticum aestivum L.*) IN RESPONSE TO STRESSFUL GROWING CONDITIONS OF ALKALINE SOIL

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The paper presents the results of experiments with 11 varieties of wheat grown in alkaline soil stressful conditions. The experiment was set up at the site in the Banat, on the non-ameliorated solonetz soil, as control variante, and with ameliorative measures using phosphogypsum. The phenotypic variability and genotype by environment interaction for the grain number and weight per spike, using AMMI model in three vegetation seasons were studied. The analysis of the results revealed that the tested varieties responded differently to external, stressful

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conditions and ameliorative measures. Based on the AMMI analysis results the significance of PCA axis was observed.

Key words: AMMI, solonetz, stability, wheat, yield components

INTRODUCTION

Constant striving to intensify agricultural production, using high quantities of chemicals has led to degradation of arable land, pollution of the environment and significant climate change, during the twentieth century. The result is stress cultivation conditions in crop production, such as drought, soil salinization, extreme temperatures, etc.Wheat crop is a crop that has great economic importance and requires favorable conditions of soil, both in terms of fertility, and in terms of physical properties and chemical reactions. In Vojvodina, beside the fertile chernozem soil, there is a low productive soil of solonetz type, with adverse physical and chemical properties, high content of adsorbed sodium and pH value above 9 (ŽIVKOVIĆ *et al.*, 1972; BELIĆ, 2005). Solonetz is mostly used as a natural pasture. Translation of solonetz to farmland fund could be possible by using reclamation measures including: the application of chemical ameliorations, disturbation of Bt horizon, laying drainage and open channel network, fertilization with organic and mineral fertilizers (BELIĆ *et al.*, 2006).The behavior of genotypes in different environmental conditions was caused by its genetic basis and interacting with the external environment. In modern wheat breeding programs, these sources of variation helps to select growing regions in which one genotype gave its best, moreover they are essential for the selection of genotypes that would best meet environmental, cultural practices and economic demands of some regions (DIMITRIJEVIĆ and PETROVIĆ, 2005; DIMITRIJEVIĆ *et al.*, 2009; SABAGHNIA *et al.*, 2008).The aim of this study was to examine, by the application of AMMI model, variation of number and weight of grains per spike of wheat genotypes and to study the impact of the genotype by environment interaction on alkaline soil of solonetz type.

MATERIAL AND METHOD

Ten varieties of hexaploid wheat (*Triticum aestivum ssp. vulgare* L. 2n = 6x = 42), from the Institute of Field and Vegetable Crops in Novi Sad: Renesansa, Pobeda, Evropa 90, NSR-5, Dragana, Ljiljana, Rapsodija, Simonida Cipovka, Nevesinjka and a variety Durumko of tetraploid wheat (*Triticum durum* L., 2n = 4x = 28), was chosen to be tested. The experiment was set up at the site of Kumane, in Banat (45.539^{o} North and 20.228^{o} East), on the solonetz soil. This type of soil has harsh chemical and physical properties, high content of clay and the presence of adsorbed sodium in the Bt horizon, which causes peptization of colloids and highly alkaline reaction. The solonetz at the site Kumane has pH = 9.86. Permeability is reduced, and water penetration into the deeper horizons is only possible through the cracks in the dry period (ŽIVKOVIĆ *et al.*, 1972). The experimental design was a randomized block design during the growing seasons 2004/05, 2005/06, 2006/07, with three replications and three treatments. Treatments were control (soil without repair) and soil with the use of phosphogypsum as ameliorative measure in the amount of 25t/ha and 50/ha. Amelioration led to the increment of humus content in the deeper layers and changes in chemical reactions (reducing alkalinity). The cultivars were sown in rows of 2m length, with a 20cm row spacing and spacing between plants in a row 10 cm, where with the seeding 50kg of NPK15: 15:15 fertilizers was given. In the phase of full maturity, we analyzed the number and yield of grains per spike (GNS and GYS, respectively). Genotype by environment interaction (GEI) was tested using AMMI (Additive Main Effects and Multiplicative Interaction) by ZOBEL *et al.* (1988). Data processing was performed in GenStat 8th Edition (trial ver.) VSN International Ltd (www. vsn-intl.com).

RESULTS AND DISCUSSION

Grain number per spike (GNS) belongs to traits directly highly correlated to grain yield. BOKAN and MALEŠEVIĆ (2004) stated that the highest yield was achieved in seasons where the highest grain number per spike was observed. Mean values, denoted in the experiment, varied within the range of 27 to 30 grains per spike. Somewhat lower GNS average was calculated for varieties Dragana, Simonida and Ljiljana ($\bar{x}$= 23, $\bar{x}$= 25 and $\bar{x}$ = 26, respectively). The effect of soil type, as well as, ameliorative measures could be noticed easily by comparing treatment means. The lack of significant average differences between treatments in 2004/2005 vegetation period, brings up the importance of environmental condition variation in effectiveness of ameliorative measures (tab. 1).

According to ANOVA, partitioning the total sum of squares for the trial revealed the complex nature of variation, especially genotype by environment interaction, where three explainable sources of variation were denoted. The first source of variation, quantified by IPCA1 axis held about 36% of GEI sum of squares, while two other axes, IPCA2 and IPCA3, brought out about 27% and 19%, respectively (tab. 2).

Multiplicative variation component was more expressive than additive variation component that was comparatively less pronounced, according to genotype grouping in all three biplots. In contrast, the treatment array indicates the complex conditions, where the variation of the experiment depended on the proportion of additive and multiplicative components. Vegetation periods 2004/2005, and 2005/2006 gave generally higher mean values of the observed traits. This is understandable considering that in 2005 was with a lot of precipitation and low temperature conditions, 2006 was quite variable, a 2007 dry with low humidity and very high temperatures. Thus the changing weather conditions influenced the effect of amelioration on the soil properties of the observed variation. The first source of variation (IPCA1), while incorporating the meteorological conditions, can be attributed to soil conditions. In addition, the minimum GEI showed varieties Europe 90 and Dragana. Variety Durumko reacted well to adverse conditions of soil, as well as, variety Nevesinjka, but in favorable weather conditions (Fig. 1).

Table 1. Grain number per spike mean values for 11 wheat varieties in 9 environments. Genotype and environmental means, variance (σ^2) and the first principal axis (IPCA1) are given

Varieties	Environment									$\bar{X}_G$	$PCA1_G$
	05-K	05-25	05-50	06-K	06-25	06-50	07-K	07-25	07-50*		
Renesansa	36	34	37	15	32	34	11	24	17	27	1,740
Pobeda	34	34	32	22	29	35	8	22	18	26	0,686
Evropa 90	32	40	36	31	37	31	12	24	25	30	-0,142
NSR-5	33	33	29	34	34	31	12	20	20	30	-1,358
Dragana	32	32	24	23	33	30	6	18	9	23	-0,064
Ljilljana	31	30	37	26	27	33	15	19	14	26	-0,835
Rapsodija	40	33	36	25	45	46	9	20	20	30	0,243
Simonida	30	35	31	17	30	34	10	21	20	25	0,867
Cipovka	36	38	41	24	37	30	19	24	24	30	0,599
Nevesinjka	38	43	36	25	30	31	8	24	30	30	1,837
Durumko	26	26	37	36	36	39	21	27	26	30	-3,573
$\bar{X}_E$	33	34	34	25	34	34	12	22	20	***28***	
σ^2	41,20	34,94	46,90	58,15	31,47	34,78	37,87	34,53	44,04		
$IPCA1_E$	2,030	2,537	0,499	-3,154	-0,462	-0,453	-1,447	0,195	0,256		

*Environmental labels where the first number represents harvest year, and the second label represents control (K), and 25t/ha or 50t/ha phosphogypsum applied. $LSD_{0.05}$=3.254 $LSD_{0.01}$=4.250

Table 2. ANOVA for grain number per spike mean values for 11 wheat varieties in 9 environments.

Sources of variation	Degree of freedom	Sum of squares	Mean square	F values	F – tab. 0,05	F – tab. 0,01
Total	296	29394	99,3			
Treatments	98	24032	245,5	**9,28	1,00	1,00
Genotypes	10	1691	169,1	**6,40	1,83	2,32
Environments	8	17750	2218,7	**65,77	1,94	2,41
Block	18	607	33,70	1,28	1,57	1,87
GE interaction	80	4591	57,4	**2,17	1,00	1,00
IPCA1	17	1639	96,4	**3,65	1,57	1,87
IPCA2	15	1221	81,4	**3,08	1,75	2,18
IPCA3	13	869	66,80	**2,53	1,75	2,18
Residue	35	862	24,60	0,93	1,46	1,69
Error	180	4755	26,4			

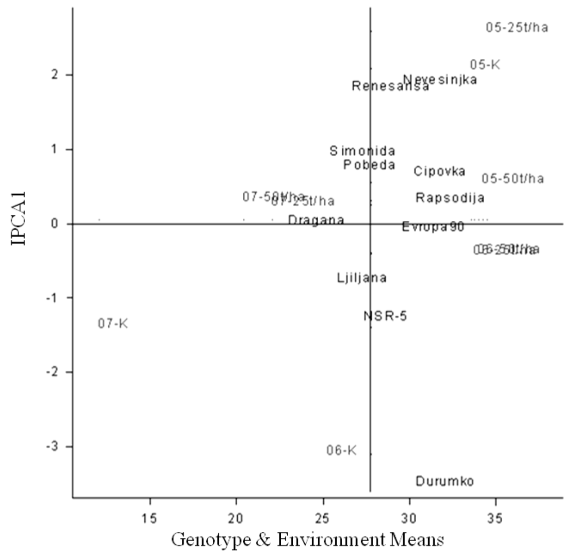

Figure 1. Biplot of the grain number per spike for 11 varieties of wheat in 9 environments

Grain weight per spike (GWS) is an important component of plant yield, as well as the number of grains per spike, can be included in the indirect indicators of grain yield (Asfaq et al., 2003; Petrović et al., 2009; Knežević et al., 2008). Weight and number of grains per spike Zečević et al. (2010) are among the criteria in the selection process in wheat breeding. According to the results, a greater sensitivity of that mass property to the meteorological conditions, could be observed, as the general average was the lowest in the control variant (solonetz without ameliorative measures) in dry growing conditions of 2006/2007 vegetation period. More favorable 2004/2005 season exhibited more significant impact on minimizing the differences between the averages per treatment. In terms of 2005/2006, that was characterized by increased rainfall in March and April, less rainfall in May with the temperature at the level of multi-annual average, and then cooling and stronger precipitation during June, the effects ameliorative measures were the most obvious (Table 3).

Analysis of variance identified and demonstrated the importance of sources of variation in the experiment. Significance of genotype x environment interaction indicates the presence of cross-over interaction, in which the impact of two significant sources of variation was quantified in the first and second axis (IPCA1 and IPCA2, respectively). In doing so, the first source of variation had a share of around 44%, and the second around 21% of the GE interaction sum of squares (Table 4).

Table 3. Mean values of grain weight per spike (g) 11 wheat varieties in 9 agroecological environments. Genotypic and environmental values, the variance (σ2), and the first axis of variation (IPCA1), are given

Varieties	Environments									$\bar{X}_G$	PCAg1
	05-K	05-25	05-50	06-K	06-25	06-50	07-K	07-25	07-50		
Renesansa	1,46	1,39	1,56	0,39	1,37	1,33	0,47	1,05	0,57	1,07	0,050
Pobeda	1,35	1,32	1,34	0,68	1,22	1,54	0,32	0,93	0,75	1,05	-0,105
Evropa 90	1,31	1,50	1,33	1,19	1,53	1,25	0,42	0,97	0,96	1,16	-0,183
NSR-5	1,39	1,26	1,24	1,26	1,50	1,19	0,49	0,82	0,87	1,11	-0,232
Dragana	1,37	1,26	1,02	0,81	1,60	1,25	0,29	0,83	0,36	0,98	-0,575
Ljilljana	1,18	1,15	1,60	0,96	1,20	1,25	0,54	0,79	0,57	1,03	0,085
Rapsodija	1,63	1,21	1,47	0,79	1,51	1,40	0,41	0,81	0,79	1,11	-0,206
Simonida	1,09	1,27	1,28	0,65	1,20	1,23	0,36	0,93	0,79	0,98	0,049
Cipovka	1,42	1,37	1,57	0,89	1,48	1,12	0,68	0,89	0,86	1,14	0,049
Nevesinjka	1,44	1,56	1,43	0,69	1,07	1,08	0,31	1,07	1,32	1,11	0,290
Durumko	1,20	1,05	1,99	0,93	1,05	1,16	0,96	1,22	1,16	1,19	0,778
$\bar{X}_E$	1,35	1,30	1,44	0,84	1,34	1,25	0,48	0,94	0,82	1,08	
σ^2	0,090	0,053	0,124	0,084	0,063	0,059	0,075	0,072	0,950		
IPCAe1	-0,263	-0,192	0,544	-0,193	-0,571	-0,284	0,315	0,214	0,431		

$LSD_{0.05}$=0.155 $LSD_{0.01}$=0.202

Table 4. Analysis of variance for grain weight per spike (g) 11 wheat varieties in 9 agroecological environment

Sources of variation	Degree of freedom	Sum of squares	Mean square	F values	F – tab. 0,05	F – tab. 0,01
Total	296	50,82	0,1717			
Treatments	98	38,68	0,3947	**6,57	1,00	1,00
Genotypes	10	1,39	0,1385	*2,30	1,83	2,32
Environments	8	27,96	3,4944	**47,99	1,94	2,41
Block	18	1,31	0,0728	1,21	1,57	1,87
GE interaction	80	9,34	0,1168	**1,94	1,00	1,00
IPCA1	17	4,15	0,2441	**4,06	1,57	1,87
IPCA2	15	1,95	0,1303	*2,17	1,75	2,18
Residue	48	3,24	0,0675	1,12	1,35	1,52
Error	180	10,82	0,0601			

Screening the average distribution of the treatment in respect to overall trial mean value, i.e. analyzing the additive component of variation the influence of more favorable weather conditions of 2004/2005 and 2005/2006, compared to the dry 2006/2007, on grain weight per spike average variation, was observable. The array of varieties indicates multiplicative factors of variation influence on the GWS variation, while the additive component was significantly reduced, which reduces the repeatability of the experiment. Effect of treatment is less evident, because of the more complex nature of GEI and it was notable that weather conditions corrected treatment effect and influenced the reaction of varieties to amelioration measures. Varieties Simonida and Ljiljana exhibited a stable response to the first, predominant source of variation (Fig. 2).

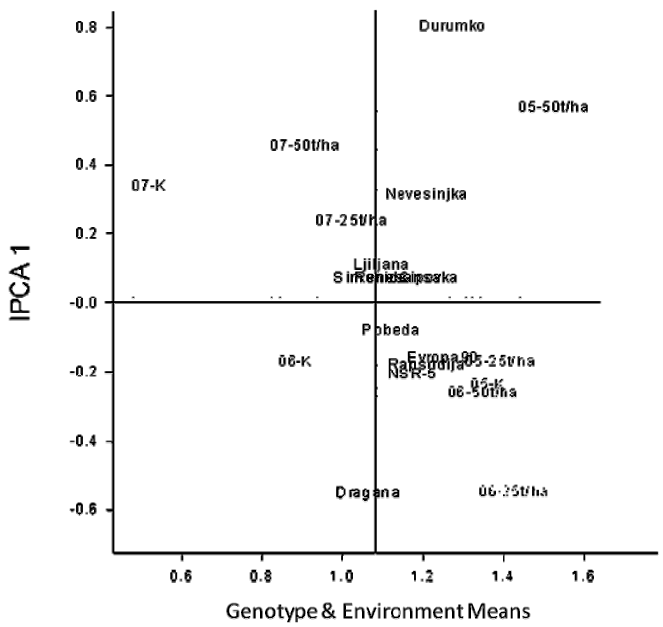

Figure 2. Biplot of grain weight / spike (g) 11 wheat varieties in 9 environments

CONCLUSION

The experiment showed a complex variation of the GE interaction in the given conditions. Varieties Europe 90 and Dragana were recorded as the most stable for the grain numberper spike, and Simonida, Ljiljana, as well as, Ljiljana for grain weight per spike. For the traits in study, varieties Durumko and Nevesinjka well endured the most stressful conditions on the control. Varieties responded to ameliorated measures enhancing the level of GNS and GWS, at the most, especially in favorable agro-ecological conditions.

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VARIJACIJA KOMPONENTI PRINOSA HLEBNE PŠENICE U STRESNIM USLOVIMA GAJENJA NA ALKALIZOVANOM ZEMLJIŠTU

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I z v o d

U radu su prikazani rezultati ogleda sa 11 sorti pšenice gajenih u stresnim uslovima, na alkalizovanom zemljištu. Ogled je postavljen na lokalitetu u Banatu, na tlu tipa solonjec, na prirodnom pašnjaku, kao kontrolnoj varijanti i sa merama popravke zemljišta uz primenu fosforgipsa, kao meliorativnog sredstva. Ispitana je fenotipska varijabilnost i interakcija genotip/spoljna sredina za broj i masu zrna po klasu, uz primenu AMMI modela, u tri vegetaciona perioda. Analizom dobijenih rezultata može da se primeti da su ispitane sorte različito reagovale na stresne uslove i na meliorativne mere. Na osnovu rezultata AMMI analize je uočena značajnost izvora varijacije i sorte sa manjom GE interakcijom, kao i one koje su dobro reagovale na meliorativne mere.

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