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Original scientific paper

STABILITY OF YIELD AND YIELD COMPONENTS IN MAIZE HYBRIDS

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Two-year grain yield and 1000-grains mass data of 24 maize hybrids of FAO maturity groups 400, 500, 600, 700 were analyzed. Investigations were performed at the two environments in two years. Nonparametric methods of the Kubinger and the van der Laan–de Kroon showed genotype x environment interaction for both investigated features, and method of Hildebrand showed interaction for 1000-grains mass. Maize hybrids stability was estimated with stability parameters: $Si^{(1)}$- the mean of the absolute rank differences over environments, $Si^{(2)}$- the common variance of the ranks, $Si^{(3)}$.and $Si^{(6)}$: the sum of the absolute deviations and sum of squares of rank for each genotype relative to the

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mean of ranks, respectively. On the basis of the stability parametar values, the most stable and the most unstable hybrids were estimated for each FAO maturity group, for both investigated features. Correlation coefficients between both investigated features and stability parameters and for all pairs of stability parameters were computed. In spite of the positive correlations estimated between all four stability parameters, we can make two groups: the first group formed: $Si^{(1)}$- the mean of the absolute rank differences over environments and $Si^{(2)}$- the common variance of the ranks and the second group formed: $Si^{(3)}$ and $Si^{(6)}$- the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks respectively.

Key words: GE interaction, maize hybrids, nonparametric methods, stability analysis

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INTRODUCTION

The expression of quantitative traits, as is the yield and the yield components, is the sum of the effect of genotype, environmental effect and genotype x environment interaction effect (*GEI*). Genotype x environment interaction is the result of different genotype response on environment changes. (BAKER, 1990). Differential genotypic responses on changeable environmental conditions, especially when they are connected with modified genotype ranks in different environments (c*rossover GEI*), represent an obstacle in the identification of the superior and stable hybrids (EPINAT *et al.,* 2001). Genotype x environment interaction, as a component of the trait phenotypic variability, decreases heritability, and hinders complex trait breeding (KELLY *et al.,*1998). Third, unfavorable effect of the *GEI* includes concealing potential usefulness of egzotic germplasm (GIAUFFRET *et al*., 2000).

Hybrid high yield performance depends on genetic potential, realized in breeding program and yield stability depends on hybrid ability to confront limiting environmental conditions. Stability of expected grain yield is one of the most desirable properties, in order to recommend hybrid for use.

The aim of this study, on the basis of measured stability parameters values, was to select the most stable and the most unstable maize hybrids for each investigated FAO maturity group, for the grain yield and the yield component-1000 grains mass.

MATERIAL AND METHODS

Investigation of the yield and the yield component stability, was performed during 2004. and 2005. year at the Maize Research Institute - Zemun Polje. The trial was conducted according to random complete block design, in three replications, at the two locations: Zemun Polje and Pančevo. Analyzed material represented 24 maize hybrids of FAO maturity groups: 400, 500, 600, 700. One raw elementary plot was the 3,22 m^2 area, what is adequate to planting density of 62 112 plants ha^{-1}. Between hybrids of different FAO maturity groups two raws for isolation purpose were sowed and has not been taken into account during measurments. Grain yield evaluation was performed by measurment of ears mass for each elementary plot, and then average sample of six ears from each replication was taken, in order to calculate grain yield with 14% moisture ha^{-1}. It was performed ears shelling, on the basis of the four random subsamples, of the 100 grains on each genotype, in order to calculate 1000-grains mass.

Table 1. Names of 24 maize hybrids used in investigation

FAO 400	FAO 500	FAO 600	FAO 700
ZP4-1	ZP5-1	ZP6-1	ZP7-1
Us.ch1-400	ZP5-2	ZP6-2	ZP7-2
Us.ch2-400	ZP5-3	ZP6-3	ZP7-3
	ZP5-4	ZP6-4	ZP7-4
	NS5-1	NS6-1	Us.ch-700
	Cecilia	NS6-2	Constanca
	Us.ch-500	NS6-3	
		Us.ch-600	

Biometrical procedure included application of nonparametric methods in the genotype x environment interaction analysis. Investigation can be divided into three stages:

1. Testing of the genotype x environment interaction existance with four nonparametric methods according to HÜHN (1996): Bradenkamp; Hilderbrand; Kubinger; and van der Laan de Kroon method.
2. Evaluation of genotype stability was performed using four nonparametric stability parameters: ($Si^{(1)}$) - the mean of the absolute rank differences of a genotype over environments; ($Si^{(2)}$) - the common variance of the ranks; ($Si^{(3)}$ and $Si^{(6)}$) - the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks, respectively.
3. Estimation of the relationship between stability parameters, and between investigated features and stability parameters, was calculated using Spearman rank correlation coefficient.

RESULTS AND DISCUSSION

Results of the genotype x environment interaction testing of the 24 maize hybrids for grain yield and 1000-grains mass, after methods of Hilderbrand, Cubinger and van der Laan-de Kroon were applied, is shown (Table 2).

Table 2. Genotype x environment interaction testing of 24 maize hybrids

Trait	Hilderbrand	Kubinger	v.d. Laan-de Kroon
Grain yield	88.25	91.70*	185.16**
1000 kernal weight	239.74**	245.84**	266.98**

$^{*}P<0.05$; $^{**}P<0.01$

Outcomes of the genotype x environment interaction testing by applying method of Bradenkamp has not been shown, because this method didn't show interaction existance neither for one of the investigated features. This is compatible with the results of HÜHN *et al.* (1995), KNEZOVIĆ (2001), KNEZOVIĆ *et al.* (2002) and indicates relative uncertainty of this method.

For the investigated feature of grain yield, method of Hilderbrand didn't show significant interaction, method of Kubinger showed significant genotype x environment interaction and method of van der Laan-de Kroon showed highly significant interaction. All three methods for the 1000-grains mass showed highly significant genotype x environment interaction.

Relation of numerical significance values after applying nonparametric methods wasn't in accordance with the results of the HÜHN (1996), because in this study van der Laan de Kroon method showed the highest numerical values. This outcome was compatible with the KNEZOVIĆ (2001) study of genotype x environment interaction of the spring oat.

Grain yield -Grain yield mean value of the tested genotypes was in the range of 4.9-7.3 t/ha^{-1}. The lowest mean value was expressed by the genotype Us.ch1-400 (4.9 t/ha^{-1}), and the highest mean value was accomlished by genotypes ZP7-2 and Us.ch-700 (7.3 t/ha^{-1}). Grain yield mean values of 24 maize hybrids tested and stability assessment was shown (Table 3).

Stability parameters used were: ($Si^{(1)}$) - the mean of the absolute rank differences of a genotype over environments; ($Si^{(2)}$) - the common variance of the ranks; ($Si^{(3)}$ and $Si^{(6)}$) - the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks, respectively. ($Si^{(1)}$) values were in the range of: 2.33-14.83, ($Si^{(2)}$) values were in the range of: 3.33-154.92, ($Si^{(3)}$) values were in the range of: 0.12-15.53, ($Si^{(6)}$)- values were in the range of: 0.13-2.62. Test of significance ($Zi^{(1)}$) for ($Si^{(1)}$) wasn't significant, and ($Zi^{(2)}$) for ($Si^{(2)}$) was significant for ZP6-4 (13.64).

Table 3. Grain yield stability parameters values of 24 maize hybrids

GENOTYPE	GY(t/ha^{-1})	$S_i^{(1)}$	$Z_i^{(1)}$	$S_i^{(2)}$	$Z_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$
ZP4-1	5,2	11,33	1,50	78,67	1,13	0,40	0,23
Us.ch-600	5.7	11,33	1,50	78,67	1.13	0.40	0.23
ZP5-1	5,7	8,58	0,05	46,23	0,00	0,47	0,26
ZP5-2	6,1	4,67	1,48	16,67	1,16	0,81	0,38
ZP5-3	5,3	10,67	0,96	73,67	0,79	1,20	0,40
ZP5-4	6,3	9,00	0,14	54,00	0,04	2,67	0,78
NS5-1	6,3	9,17	0,19	58,25	0,13	6,12	1,25
Cecilia	6,4	3,67	2,50	9,67	1,74	0,35	0,29
Us.ch-500	6,2	7,67	0,01	38,33	0,11	2,92	0,83
ZP6-1	6,3	9,00	0,14	52,67	0,03	2,77	0,72
ZP6-2	7,1	10,08	0,59	63,40	0,29	6,20	2,27
ZP6-3	6,9	13,00	3,37	107,00	4,16	15,04	2,28
NS6-1	7,0	9,50	0,31	58,25	0,13	3,00	1,33
NS6-2	6,9	2,33	4,28	3,33	2,37	1,68	0,86
NS-640	5,7	9,00	0,14	50,00	0,01	2,13	0,56
Us.ch1-400	4,9	7,67	0,01	35,33	0,19	0,12	0,13
Us.ch2-400	5,3	9,67	0,38	81,67	1,36	1,80	0,50
ZP6-4	6,0	14,83	6,28	154,92	13,64	10,84	1,59
ZP7-1	6,8	7,00	0,13	30,33	0,37	7,52	1,63
ZP7-2	7,3	9,67	0,38	72,33	0,71	2,67	1,33
ZP7-3	6,5	11,50	1,65	86,25	1,75	7,13	1,43
ZP7-4	6,4	10,17	0,64	66,92	0,43	7,11	1,42
Us.ch-700	7,3	7,67	0,01	38,00	0,12	2,39	1,89
Constanca	6,9	14,17	5,11	131,58	8,34	15,55	2,62
			Σ=32,755		Σ=41,361		

($Si^{(1)}$) - the mean of the absolute rank differences of a genotype over environments; ($Si^{(2)}$) - the common variance of the ranks; ($Si^{(3)}$ and $Si^{(6)}$) - the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks, respectively. Test of significance ($Zi^{(1)}$) and ($Zi^{(2)}$) for ($Si^{(1)}$) and ($Si^{(2)}$). GY-Grain yield.

The most stable hybrid of **FAO 400 maturity group** was Us.ch1-400 ($Si^{(1)}$=7.67; $Si^{(2)}$=35.33; $Si^{(3)}$=0.12; $Si^{(6)}$=0.13), the most unstable hybrid was Us.ch2-400 ($Si^{(1)}$=9.67; $Si^{(2)}$=81.67; $Si^{(3)}$=1.80; $Si^{(6)}$=0.50). The most stable hybrids of **FAO 500 maturity group** were: Cecilia ($Si^{(1)}$=3.67; $Si^{(2)}$=9.67; $Si^{(3)}$=0.35) and

ZP5-1 ($Si^{(6)}$=0.26). The most unstable hybrids were: ZP5-3 ($Si^{(1)}$=10.67; $Si^{(2)}$=73.67) , Us.ch-500 ($Si^{(3)}$=2.92) and NS5-1 ($Si^{(6)}$=1.25). The most stable hybrids of **FAO 600 maturity group** were: NS6-2 ($Si^{(1)}$=2.33; $Si^{(2)}$=3.33; $Si^{(3)}$=1.68) and NS6-3 ($Si^{(6)}$=0.56). The most unstable hybrids were: ZP6-4 ($Si^{(1)}$ =14.83; $Si^{(2)}$=154.92) and ZP6-3 ($Si^{(3)}$=15.04; $Si^{(6)}$=2.28). The most stable hybrids of **FAO 700 maturity group** were: ZP7-1 ($Si^{(1)}$=7.00; $Si^{(2)}$=30.33), Us.ch-700 ($Si^{(3)}$=2.39) and ZP7-2 ($Si^{(6)}$=1.33). The most unstable hybrid was Constanca ($Si^{(1)}$=14.17; $Si^{(2)}$=131.58; $Si^{(3)}$=15.55; $Si^{(6)}$=2.62).

Great stability for grain yield have shown hybrids of FAO 500 maturity group during two year investigation. Hybrids of FAO 600 and FAO 700 maturity group have shown great instability with single exceptions. FAO 400 maturity group hasn't been taken into account for comparison because of little number of tested hybrids.

Table 4. Correlation coefficients of stability parameters for grain yield

	GY	$S_i^{(1)}$	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$
GY	1,000	-0,054	-0,071	0,527**	0,767**
$S_i^{(1)}$		1,000	0,984**	0,503*	0,375
$S_i^{(2)}$			1,000	0,492*	0,358
$S_i^{(3)}$				1,000	0,899**
$S_i^{(6)}$					1,000

*P < 0.05; **P < 0.01

GY-Grain yield

Grain yield of 24 maize hybrids used in the investigation was negatively unsignificantly correlated with $Si^{(1)}$ and $Si^{(2)}$, while there was highly significant medium correlation with $Si^{(3)}$(r=0.527**) and highly significant high correlation with $Si^{(6)}$(r=0.767**). Almost functional dependance was observed between $Si^{(1)}$ and $Si^{(2)}$ (r=0.984**) and between $Si^{(3)}$ and $Si^{(6)}$ was observed high correlation (r=0.899**), and this was in accordance with the results of KAYA *et al.* (2003); ABARA *et al.* (2006); MOHAMMADI *et al.* (2007) and SOLOMON *et al.* (2007). Neither $Si^{(1)}$ nor $Si^{(2)}$ weren't correlated with $Si^{(6)}$, while the correlation coefficients of $Si^{(1)}$ and $Si^{(2)}$; with $Si^{(3)}$ were medium (0.503*; 0.492* respectively). AKCURE et al. (2008) found small and insignificant correlation of $Si^{(1)}$ and $Si^{(2)}$; with $Si^{(3)}$.

1000-grains mass - Mean values of the 1000-grains mass was in the range of 35.2-46.6 g. The lowest 1000-grains mass mean value was expressed by the genotype ZP7-3 (35.2 g) and the highest mean value for this trait accomplished genotype Constanca (46.6 g). 1000-grains mass mean values and stability assessment of 24 maize hybrids was shown (Table 5).

Table 5. 1000-grains mass stability parameters values of 24 maize hybrids

Genotype	GW (g)	$S_i^{(1)}$	$Z_i^{(1)}$	$S_i^{(2)}$	$Z_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$
ZP4-1	37,8	9,83	0,457	72,25	0,705	2,41	0,59
Us.ch-600	43,2	10,17	0,637	71,58	0,667	13,69	2,77
ZP5-1	46,5	12,17	2,340	107,58	4,241	1,63	1,30
ZP5-2	40,2	4,50	1,627	17,58	1,096	1,37	0,51
ZP5-3	36,8	5,83	0,620	24,50	0,653	0,20	0,16
ZP5-4	41,1	7,33	0,057	36,00	0,169	1,63	0,71
NS5-1	39,1	5,33	0,942	19,42	0,968	0,15	0,16
Cecilia	42,8	7,33	0,057	45,33	0,008	5,06	1,29
Us.ch-500	37,9	10,50	0,846	80,25	1,245	7,95	1,14
ZP6-1	39,9	12,42	2,628	111,40	4,800	8,90	1,47
ZP6-2	43,6	10,17	0,637	68,92	0,525	6,41	1,89
ZP6-3	41,3	6,33	0,366	27,67	0,488	2,04	0,80
NS6-1	42,4	12,33	2,530	102,00	3,484	15,40	2,40
NS6-2	42,5	6,50	0,296	28,92	0,430	4,37	1,05
NS6-3	42,3	10,33	0,738	94,33	2,567	17,10	2,25
Us.ch1-400	44,9	7,92	0,001	43,23	0,026	3,00	1,65
Us.ch2-400	40,6	4,50	1,627	14,25	1,350	1,70	0,57
ZP6-4	42,0	8,33	0,016	48,67	0,001	5,34	1,19
ZP7-1	39,2	11,33	1,500	85,67	1,698	1,90	0,65
ZP7-2	42,2	12,17	2,340	103,58	3,691	10,40	1,93
ZP7-3	35,2	9,50	0,307	62,25	0,245	2,48	0,58
ZP7-4	40,4	11,50	1,653	90,25	2,135	14,09	1,62
Us.ch-700	38,3	10,00	0,543	67,00	0,434	5,60	0,92
Constanca	46,6	1,50	5,632	2,25	2,484	0,60	1,20
			Σ=28,391		Σ=34,111		

($Si^{(1)}$) - the mean of the absolute rank differences of a genotype over environments; ($Si^{(2)}$) - the common variance of the ranks; ($Si^{(3)}$ and $Si^{(6)}$) - the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks, respectively. Test of significance ($Zi^{(1)}$) and ($Zi^{(2)}$) for ($Si^{(1)}$) and ($Si^{(2)}$). GW-1000 grains mass.

Stability parameters used were: ($Si^{(1)}$) - the mean of the absolute rank differences of a genotype over environments; ($Si^{(2)}$) - the common variance of the ranks; ($Si^{(3)}$ and $Si^{(6)}$) - the sum of the absolute deviations and sum of squares of rank for each genotype relative to the mean of ranks, respectively.

($Si^{(1)}$) values were in the range of: 1.50-12.42, ($Si^{(2)}$) values were in the range of: 2.25-111.40, ($Si^{(3)}$) values were in the range of: 0.15-17.10, ($Si^{(6)}$) - values were in the range of: 0.16-2.77. Tests of significance $Zi^{(1)}$ for $Si^{(1)}$ and $Zi^{(2)}$ for $Si^{(2)}$ didn't showed significant values.

The most stable hybrid of **FAO 400 maturity group** was Us.ch2-400 ($Si^{(1)}$=4.50; $Si^{(2)}$=14.25; $Si^{(3)}$=1.70; $Si^{(6)}$=0.57). The most unstable hybrids were:

ZP4-1 ($Si^{(1)}$=9.83; $Si^{(2)}$=72.25) and Us.ch1-400 ($Si^{(3)}$=3.00; $Si^{(6)}$=1.65). The most stable hybrids of **FAO 500 maturity group** were: ZP5-2 ($Si^{(1)}$= 4.50; $Si^{(2)}$=17.58) and NS5-1 ($Si^{(3)}$=0.15; $Si^{(6)}$=0.16). The most unstable were: ZP5-1 ($Si^{(1)}$=12.07; $Si^{(2)}$=107.58; $Si^{(6)}$=1.30) and Us.ch-500 ($Si^{(3)}$=7.95). The most stable hybrid of **FAO 600 maturity group** was ZP6-3 ($Si^{(1)}$=6.33; $Si^{(2)}$=27.67; $Si^{(3)}$=2.04; $Si^{(6)}$=0.80). The most unstable were: ZP6-1 ($Si^{(1)}$=12.42; $Si^{(2)}$=111.40), NS6-3 ($Si^{(3)}$=17.00) and Us.ch-600 ($Si^{(6)}$=2.77). The most stable hybrids of **FAO 700 maturity group** were: Constanca ($Si^{(1)}$=1.50; $Si^{(2)}$=2.25; $Si^{(3)}$=0.60) and ZP7-3 ($Si^{(6)}$=0.58). The most unstable were: ZP7-2 ($Si^{(1)}$=12.17; $Si^{(2)}$=103.58; $Si^{(6)}$=1.93) and ZP7-4 ($Si^{(3)}$=14.09).

Great stability for 1000-grains mass showed hybrids of FAO 500 maturity group during two year investigation. Hybrids of FAO 600 and FAO 700 maturity group showed great instability, with single exceptions. FAO 400 maturity group has not been taken into account for comparison because of small number of hybrids tested.

Table 6. Correlation coefficients of stability parameters for 1000-grains mass.

	GW	$S_i^{(1)}$	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$
GW	1,000	0,029	0,026	0,180	0,674**
$S_i^{(1)}$		1,000	0,985**	0,721**	0,636**
$S_i^{(2)}$			1,000	0,703**	0,620**
$S_i^{(3)}$				1,000	0,797**
$S_i^{(6)}$					1,000

*P < 0.05; **P < 0.01
GW-1000 grains mass

1000-grains mass of 24 maize hybrids didn't show significant correlation with stability parametars $Si^{(1)}$ and $Si^{(2)}$, with $Si^{(3)}$ showed small significant correlation, while there was strong highly significant correlation with $Si^{(6)}$ (r=0.674**). Very high correlation coefficients, almost close to functional dependence, were observed between $Si^{(1)}$ and $Si^{(2)}$ (r=0.985**). $Si^{(3)}$ and $Si^{(6)}$ showed very strong correlation (r=0.797**).

$Si^{(1)}$ and $Si^{(3)}$, $Si^{(1)}$ and $Si^{(6)}$, $Si^{(2)}$ and $Si^{(3)}$, $Si^{(2)}$ and $Si^{(6)}$ correlation coefficients values showed strong and highly significant correlation.

Two groups of similiar parameters can be made: the first group formed $Si^{(1)}$ and $Si^{(2)}$, and the second group formed $Si^{(3)}$ and $Si^{(6)}$, what is in accordance with the results of NASSAR *et al.* (1987), HÜHN (1990), MIRANDA (1993), TANER *et al.* (2003), SABAGHNIA *et al.* (2006).

CONCLUSION

Application of the nonparametric methods in genotype x environment interaction testing, confirmed its existance for both investigated features. Method of Bredenkamp didn't show existance of genotype x environment interaction, neither for grain yield nor for 1000-grains mass, and this indicates relative uncertainty of this particular method. On the basis of numerical values of applied methods assessed series was: van der Laan and de Kroon> Kubinger~ Hilderbrand>Bredenkemp.

Stability parameters values showed that hybrids with best perfomances for investigated features didn't show in the most cases stability, which indicated that researchers should pay special attention to the investigation of stability for grain yield and yield components in breeding programs.

Great stability for grain yield and 1000-grains mass showed hybrids of FAO 500 maturity group, while hybrids of FAO 600 and FAO 700 maturity group showed great instability for both investigated features, with single exceptions. FAO 400 maturity group has not been taken into account for comparison because of small number of hybrids tested.

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STABILNOST PRINOSA I KOMPONENTI PRINOSA HIBRIDA KUKURUZA

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Izvod

Analizirani su dvogodišnji podaci prinosa i mase 1000 semena kod 24 hibrida kukuruza FAO grupe zrenja 400, 500, 600 i 700. Istraživanja su izvršena na dva lokaliteta tokom dvogošnjeg perioda. Primenom neparametrijskih metoda: Kubingerove i van der Laana i de Kroona, utvrđeno je postojanje interakcije genotip × spoljašnja sredina za obe ispitivane osobine a metoda Hildebranda je utvrdila postojanje interakcije za masu 1000 zrna. Stabilnost hibrida procenjena je pomoću neparametrijskih parametara stabilnosti: $Si^{(1)}$- prosečne razlike rangova u različitim sredinama; $Si^{(2)}$- varijanse rangova; $Si^{(3)}$ i $Si^{(6)}$- relativnog odstupanja u odnosu na prosečan rang. Na osnovu izračunatih vrednosti parametara stabilnosti utvrđeni su najstabilniji i najnestabilniji hibridi za svaku FAO grupu zrenja, kod obe ispitivane osobine. Izračunati su koeficijenti korelacije između obe ispitivane osobine i parametara stabilnosti kao i između samih parametara stabilnosti. Iako je između sva četiri parametra stabilnosti utvrđena jaka povezanost, ipak se može govoriti o dve grupe parametara stabilnosti: u prvu grupu spadaju prosečna razlika rangova u različitim sredinama i varijansa rangova, a u drugu grupu relativno odstupanje u odnosu na prosečan rang.

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