YIELD STABILITY OF NEW ZP MAIZE HYBRIDS

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Abstract

Six newly developed hybrids and four hybrids already widely grown during the last decade were observed in the present study. Grain yield stability parameters were estimated using methods developed by Eberhart and Russell (1966) and Lin and Binns (1988). The highest grain yield stability obtained by both parameters (b_i and P_i) was recorded in hybrids ZP 606 and ZP 600. Moreover, highest average grain yield was also detected in those two hybrids. The hybrids ZP 666 and ZP 560 will have highest adaptation to more favorable growing conditions. On the other hand, hybrids ZP 434 and ZP 341 are expected to show the best adaptability to less favorable environments. A high positive correlation was found between a superiority measure (P_i) and a grain yield.

Key words: *grain yield, maize hybrids, stability parameters*

1 Originalni naučni rad (Original scientific paper)

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Introduction

Many authors have shown the possibility of developing high yielding and stable hybrids. The assumption has been that commercial maize hybrids were characterized not only by the level of average yield but also by their stability. Numerous authors gave their definitions of stability and adaptability. Roemer (1917) described stability as the ability of a genotype to have always the uniform yield regardless of environmental effects. Adaptability is the ability of a variety to provide stable and high yield under different environmental conditions (Finlay and Wilkinson, 1963). In general, stability is defined as the practicable performance of genotypes under changing environmental conditions. In a biological sense, stability is fixed production efficiency of the species under different environmental conditions, while in the agricultural sense, it means whether species display the same production efficiency as predicted. Reliable stability of production efficiency under changing conditions of environment is very important. For this reason, plant breeders desire for the general adaptation capability in the species they develop (Kan et al., 2010). Adaptability and stability of a genotype is manifested through the interaction of genotype and the environment. Genotype x environment interaction is a source of variation that includes the influence of genotype and environmental factors. Individual consideration of these two factors doesn't give a realistic picture of either genotype or the environment. Only including interdependence of these two sources of variation can give reliable results. With the advent of intensive genotypes the sensitivity of genotypes to environmental conditions is increased (Dimitrijević and Petrović, 2000).

In the course of maize breeding it is important to select hybrids that are superior in all environments. Each deviation from such an ideal situation is a result of environmental effects on a genotype, i.e. a result of the genotype x environment interaction, which affects greater or lower stability of a genotype and its individual traits (Delić et al., 2009). Genotypes with a minimal variance for yield across environments are considered stable (Mohammadi et al., 2009). When a researcher starts the statistical analysis of the new experiment yields he has to choose the most appropriate model. Although the selection is based on previous experience and overall insight into the actual material, and certain research projects vary in their purpose and the questions that need to be answered, a good choice is not easy. Of course, experience tells us that the best model should be found among several leading models (Babić and Babić, 2006).

The aim of this study was to observe grain yield and yield stability of new ZP maize hybrids in different agroecological maize growing regions of Serbia. Although the use of multivariate statistical models is recently recommended, the most prevalent single factor most greatly affects the stability and adaptability of the genotype. By the conditions in Serbia this factor is commonly the available amount of rainfall during the growing season. Therefore, we assumed that the linear model should give reliable enough information on the stability of tested maize hybrids. It is expected that maize hybrids, with the lowest yield variation under changes of the environment, will show highest stability.

Material and methods

The following 10 ZP maize hybrids, from different maturity groups, were used in the present study: FAO 300 (ZP 341), FAO 400 (ZP 434), FAO 500 (ZP 505, ZP 544, ZP 555, ZP 560), FAO 600 (ZP 600, ZP 606, ZP 666 and ZP 684), with one hybrid (FAO 600) as a check. Out of them, the hybrids: ZP 505, ZP 555, ZP 560, ZP 600, ZP 606 and ZP 666 are recently developed.

The trials were set up as randomized block design at eight locations during 2009 and 2010. Each of the four main maize growing regions of Serbia was represented with two trial locations: Loznica and Šalinac in central Serbia, Žarkovac and Divoš in Srem, Sakule and Botoš in Banat, and Zmajevo and Bečej in Bačka. The elementary plot size amounted to 1,000
m^2. Planting and harvesting were mechanized. Samples for the moisture content were drawn at harvest. The plant density varied over hybrid maturity groups: 59000 plants·ha^{-1} in hybrids of FAO 600, 64000 plants·ha^{-1} in hybrids of FAO 500, and 69000 plants·ha^{-1} in hybrids of FAO 300-400.

The stability parameters of grain yield were estimated after a method devised by Eberhart and Russell (1966), which is based on the linear regression analysis, and a method coined by Lin and Binns (1988), which is based on non parameteric statistics.

Eberhart and Russell (1966) model is presented with the equation:

$$Y_{ij} = m + b_i I_j + \delta_{ij} + e_{ij};$$

where Y_{ij} is an average yield of the i^{th} genotype in the j^{th} environment, m is an average yield of the i^{th} genotype in all environments, b_i is the regression coefficient to the environmental index indicating a genotypic response to environmental changes, I_j is the environmental index as a mean of all genotypes in the j^{th} environment reduced by a grand mean, δ_{ij} is the deviation from regression of the i^{th} genotype in the j^{th} environment, and e_{ij} is the effect of the mean experimental error. Cultivars with regression coefficients greater than unit would be more adapted to favorable growing conditions, those with regression coefficients below unit would be adapted to unfavorable environmental conditions, and those with regression coefficients equal to unit would have an average adaptation to all environments (Scapim et al., 2000).

Lin and Binns (1988) defined the superiority measure (*Pi*) of the i^{th} test cultivar as the mean square of the distance between the i^{th} test cultivar and the maximum response as:

$$Pi = [n(\bar{X}_i - \bar{M})^2 + \sum_{j=1}^{n}(X_j - \bar{X}_i - M_j + \bar{M})^2]/2,$$

where X_{ij} is the yield of the i^{th} cultivar in the j^{th} environment, M_j is the maximum response obtained among all the cultivars in the j^{th} environment, $\bar{X}_i$ is the yield mean of the i^{th} cultivar in the n environments and $\bar{M}$ is the mean of the maximum response in the n environments. The first term of the equation represents the genotype sum of squares and the second part is the G x E sum of squares. The smaller the value of *Pi* is, the less is the distance to the genotype with maximum yield (Alberts, 2004).

The comparison between the investigated estimators was calculated by the Spearman's rank correlation coefficient (r_s):

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)},$$

where d_i is the difference between two ranks of the investigated trait, and n is the number of correlated pairs (Maritz, 1981).

Complete statistical calculations were performed by Microsoft Office Excel 2003.

Results and discussion

The average two-year grain yield was 10,936 kg ha^{-1}(Tab. 1). It ranged from 9,947 kg ha^{-1} (ZP 341) to 11,859 kg ha^{-1}(ZP 600). Four hybrids (ZP 600, ZP 606, ZP 560 and ZP 666) had a higher mean yield during this period than the check (hybrid of FAO 600).

Table 1. Summary of the average grain yield and stability parameters of investigated hybrids
Tabela 1. Prosečan prinos i parametri stabilnosti ispitivanih hibrida

Hybrid	Grain yield (kg ha^{-1})	Rank	b_i (E&R)	Rank	P_i/10,000 (L&B)	Rank
ZP 684	10,719.9	7	0.9521	4	129.88	6
ZP 666	11,029.0	4	1.2026	10	110.45	4
ZP 606	11,594.8	2	1.0260	1	36.15	2
ZP 600	11,859.1	1	1.0381	2	22.13	1
ch. FAO 600	10,991.4	5	1.0449	3	113.29	5
ZP 560	11,537.0	3	1.1963	9	41.20	3
ZP 555	10,600.1	9	1.0780	7	160.72	8
ZP 544	10,684.1	8	0.9440	5	165.74	9
ZP 505	10,922.6	6	0.9413	6	138.53	7
ZP 434	10,406.4	10	0.7390	11	247.99	10
ZP 341	9,946.6	11	0.8378	8	389.83	11
Average	10,935.5		1.0000		141.45	

The values of the estimated regression coefficient b_i (Tab. 1) show best yield stability of later maturity hybrids (ZP 606 and ZP 600). The stated hybrids also had the highest average grain yield in this trails. These results are not in agreement with results obtained by Carvalho et al. (1983), Delić et al. (2009) and Stevanović et al. (2011), where hybrids with the highest grain yield, in most of cases, were not the most stable. Adaptability and stability of genotypes may be due to various factors. Therefore, the values determined from one set of genotypes and environments can not be generalized. The established stability of genotype is in most cases adaptability and stability of genotype on prevalent stress factor during the trails. Some recent studies indicate that the yield potential and the stability are defined by the different set of genes (Babic, 2011, Via et al., 1995). Therefore, it is possible to create a stable genotype with high yield potential. Later maturity hybrids, especially hybrids ZP 666 and ZP 560, indicate the highest adaptation to more favorable growing conditions. Early to medium early maturity hybrids (ZP 341 and ZP 434), will be best adapted to less favorable environments. Similar results, where later maturity hybrids had regression coefficient value greater than unit and earlier maturity hybrids had b_i value below unit, have been gained by Loffler et al. (1986) and Babić et al. (2006).

According to the superiority measure parameter (P_i) (Lin and Binns, 1988), the highest yielding hybrid (ZP 600) had the lowest P_i value, thus it might be considered to be the most desirable genotype. That is in concordance with the results achieved by Alberts (2004) and Pavlov et al. (2011).

Table 2. Rank correlation coefficients of stability measures of maize grain yield
Tabela 2. Koeficijenti korelacije između rangova parametara stabilnostiprinosa zrna kukuruza

	b_i	P_i
grain yield	0.500	0.982**
b_i		0.500

**P < 0.01

Results obtained on the rank correlation coefficients presented in Table 2 show that the mean difference among ranks over the grain yield and the superiority measure (P_i) shows a complete mutual relation (r_s =0.982**). There was no significant relation between the mean difference among ranks over the grain yield and the regression coefficient (b_i), on one hand, and the regression coefficient in relation to the superiority measure, on the other hand (r_s =0.500 in both cases).

Conclusion

Values of the stability measures showed that hybrids with the highest grain yield in the majority of cases were considered to be the most stable ones. Also, in this study, late to medium late maturity hybrids were, in most cases, the most stable. Four top yielding hybrids in this study belonged to the group of new hybrids (ZP 600, ZP 606, ZP 560 and ZP 666). They also had the lowest superiority measure parameter.

Hybrids ZP 600 and ZP 606 had the highest mean yield and best stability by both stability parameters, b_i and P_i.

By the regression coefficient from Eberhart and Russell (1966) model, the highest adaptation to more favorable growing conditions could be expected for hybrids ZP 666 and ZP 560. Early to medium early maturity hybrids (ZP 341 and ZP 434), are recommendable for growing in less favorable environments.

References

ALBERTS, M.J.A. (2004): A comparison of statistical methods to describe genotype x environment interaction and yield stability in multi-location maize trials. Phd thesis. University of the Free State, Bloemfontein, South Africa

BABIĆ V., BABIĆ, M. (2005): Identifikacija specifičnih interakcija u ogledu prinosa kukuruza. Selekcija i semenarstvo, Vol. XI No. 1-4:13-18.

BABIĆ, V., BABIĆ, M., DELIĆ, N. (2006): Stability parameters of commercial maize (*Zea mays* L.) hybrids. Genetika, Vol. 38, No. 3, 235-240.

BABIĆ, V. (2011): Genetičke komponente stabilnosti hibrida kukuruza. Doktorska disertacija. Univerzitet u Beogradu, Poljoprivredni fakultet. Pp: 86-94.

CARVALHO, F.I.F., FEDERIZZI, L.C., NODARI, R.O., STORCK, L. (1983): Comparison among stability models in evaluating genotypes. Rev. Brasil. Genet. Vol. VI, 4, 667-691.

DELIĆ, N., STANKOVIĆ, G., KONSTANTINOV, K. (2009): Use of non parametric statistics in estimation of genotypes stability. Maydica, Vol. 54, 155-160.

DIMITRIJEVIĆ M., PETROVIĆ, S. (2000): Adaptabilnost i stabilnost genotipa. Selekcija i semenarstvo VII (1-2): 21-28.

EBERHART, S.A., RUSSEL, W.A. (1966): Stability parameters for comparing varieties. Crop Science, Vol. 6, 36-40.

FINLAY, K.W., WILKINSON, G.N. (1963): The analysis of adaptation in a plant breeding programme. Australian Journal of Agricultural Research, Vol. 14, 742-754.

KAN, A., KAYA, M., GURBUZ, A., SANLI, A., OZCAN, K., CIFTCI, C.Y. (2010): A study on genotype x environment interaction in chickpea cultivars (*Cicer arietinum* L.) grown in arid and semi-arid conditions. Scientific Research and Essays Vol. 5(10), 1164-1171.

LIN C.S., BINNS M.R. (1988): A superiority measure of cultivar performance for cultivar x location data. Canadian Journal of Plant Science, Vol. 68, 193-198.

LOFFLER, C.M., SALABERRY, M.T., MAGGIO, J.C. (1986): Stability and genetic improvement of maize yield in Argentina. Euphytica, Vol. 35, 449-458.

MARITZ, J.S. (1981): Distribution-Free Statistical Methods. Chapman and Hall, 217.

MOHAMMADI, R., AGHAEE, M., HAGHPARAST, R., POURDAD, S.S., ROSTAII, M., ANSARI, Y., ABDOLAHI, A., AMRI, A. (2009): Association among Non-parametric Measures of Phenotypic Stability in Four Annual Crops. Middle Eastern and Russian Journal of Plant Science and Biotechnology 3 (Special Issue 1), Global Science Books, 20-24.

PAVLOV, J., DELIĆ, N., STEVANOVIĆ, M., ČAMDŽIJA, Z., GRČIĆ, N., CREVAR, M. (2011): Grain yield of ZP maize hybrids in the maize growing areas in Serbia. 46th Croatian and 6th International symposium on agriculture, Opatija. Book of proceedings, 395-398.

ROEMER, J. (1917): Sinde die ertagsreichen sorten ertagissicherer. Mitt DLG, Vol. 32, 87–89.

SCAPIM, C.A., OLIVEIRA, V.R., BRACCINI, A.L., CRUZ, C.D., ANDRADE, C.A.B., VIDIGAL, M.C.G. (2000): Yield Stability in Maize (*Zea mays L.*) and Correlations Among the Parameters of the Eberhart and Russel, Lin and Binns and Huehn Models. Genetics and Molecular Biology, Vol. 23, 2, 387-393.

STEVANOVIĆ, M., PAVLOV J., GRČIĆ N., ČAMDŽIJA Z., MLADENOVIĆ-DRINIĆ, S., STANKOVIĆ G. (2011): Grain yield and stability parameters of ZP maize hybrids. 4th international scientific/professional conference - Agriculture in Nature and Environment Protection, Vukovar, 84-87.

VIA S., GOMULKIEWICZ R., DE JONG G., SCHEINER S.M., SCHLICHTING C.D. (1995): Adaptive phenotypic plasticity; consensus and controversy. Trends Ecol. Evol. 10: 212-217.

STABILNOST PRINOSA NOVIH ZP HIBRIDA KUKURUZA

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Rezime

U ovom radu je korišćeno šest novih hibrida, kao i četiri hibrida koji već zauzimaju velike površine u proizvodnji u zadnjih deset godina. Parametri stabilnosti prinosa su izračunati korišćenjem metoda koje su razvili Eberhart i Rasel (1966) i Lin i Bins (1988). Najviša stabilnost prinosa, na osnovu oba parametra (b_i i P_i) je utvrđena kod hibrida ZP 606 i ZP 600. Najviši prosečan prinos je takođe zabeležen kod ova dva hibrida. Hibridi ZP 666 i ZP 560 pokazuju najvišu adaptabilnost na povoljnije uslove gajenja. Sa druge strane, hibridi ZP 434 i ZP 341 su pokazali bolju adaptabilnost u manje povoljnim uslovima gajenja. Visoka pozitivna korelacija je zabeležena između parametra stabilnosti P_i i prinosa zrna.

Ključne reči: hibridi kukuruza, prinos zrna, parametri stabilnosti

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