

**BIPLOT ANALYSIS OF DIALLEL CROSSES OF NS MAIZE
INBRED LINES**

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Genetic markers, from morphological to molecular, in function with early Heterosis is a prerequisite for the successful commercial maize production. It does not appear in any cross of two inbred lines, and therefore, the determination of combining abilities of parental lines is essential. The most commonly used method for determining combining abilities is diallel analysis. Besides conventional methods for diallel analysis, a new biplot approach has been suggested. In this paper, we studied the combining ability for grain yield in a set of genotypes obtained by diallel crossing system of six inbred lines. Both, the Griffing's conventional

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method and the biplot approach have been used for diallel analysis. Comparing the GCA values from biplot analysis and Griffing's method, similar results can be observed, with the exception of NS L 1051 and NS L 1000 whose ranks are interchanged. Biplot analysis enables the SCA estimation of parent inbred, and the highest SCA has inbred B73D. Biplot analysis also allows the estimation of the best crosses. Inbred B73D shows the best results when crossed with testers Mo17Ht, NS L 1051 and N152, inbred N152 combines best with testers NS L 1001 and NS L 1000, whereas the cross of inbred NS L 1051 with tester B73D results with the highest grain yield per plant in comparison with other testers.

Key words: biplot, diallel, grain yield, maize

INTRODUCTION

Maize is one of the most important cereal crops in the world due to its very wide and variety utilisation (NASTASIĆ *et al.*, 2010). Most of the produced maize in industrialized countries is used as animal feed or for industrial purposes, but maize remains an important food source in many developing regions (SREČKOV, 2009). Therefore, the main goal of all maize breeding programs is to obtain new inbreds and hybrids that will outperform the existing hybrids with respect to a number of traits.

Discovery of heterosis has had a great impact on modern agriculture and was a milestone in maize breeding (LAMKEY and EDWARDS, 1998). Nowadays, heterosis is a prerequisite for the successful commercial maize production (STUBER, 1997). Heterosis, nonetheless, does not necessarily appear by crossing any two inbred lines. Thus, it is essential to determine the combining abilities of parental lines.

Diallel analysis has been often applied in genetic research to determine the inheritance of agronomically more important traits within a set of genotypes. It has been used especially for germplasm evaluation and estimation of combining abilities in order to make decision whether to include it in breeding programmes. General combining ability (GCA) is a breeding value of a genotype in terms of its performance ability. Its predominance can be useful to a breeder in increasing selection efficacy in segregating populations (BOCANSKI *et al.*, 2009). Special combining ability (SCA) is a cumulative effect of two genotypes in their hybrid. The predominance of SCA can facilitate detection of highly heterotic hybrids of economic importance.

There are several methods that can be used for diallel analysis. The mostly used one is the Griffing's method (1956), which partitions the total variance to GCA variance of parents and SCA variance of crosses. Beside the conventional methods for diallel analysis for evaluation of combining abilities, recently a new approach has been used. YAN and HUNT (2002) suggested the principal component biplot technique for diallel analysis. In the original application, two components of data matrix obtained from multilocation trials are used to visualize effects of genotype and genotype \times environment interaction, using a two-dimensional graph. Similarly to

multilocation trials, the first two components can be used to visualize GCA and SCA effects (BERTOIA *et al.*, 2006).

Grain yield is a complex quantitative trait that depends on a number of factors. It is within great influence of environmental conditions, has complex mode of inheritance and low heritability (BOCANSKI *et al.*, 2009). Also, it is the most economically important trait and therefore obtaining new elite inbred lines with good combining abilities is one of the goals of most maize breeding programs. The objective in this paper was to determine combining abilities for grain yield. Both, the Griffing's conventional method and the biplot approach have been used for diallel analysis of grain yield in maize.

MATERIALS AND METHODS

Genetic material evaluated in the research is obtain from diallel crosses of six inbred lines. N152, B73D and Mo17Ht, US derived inbreds, and NSL 1000, NSL 1001 and NSL 1051, domestic inbreds, were developed by pedigree selection in the Institute for Field and Vegetable Crops in Novi Sad, Serbia. Crosses were made during 2000, and the evaluation of genotypes (6 parents and 15 F₁ hybrids) in experimental trails are performed in 2001 and 2002 on experimental plots of the Institute for Field and Vegetable Crops, in Rimski Šančevi (45° 15' N, 19° 51' E). The experiment was planted as a completely random block system, with three replicates (without competition between parent and hybrid plants). The experimental plot consisted of two rows, 5m long, with 0,75m between rows and between plots, and 0,24m within rows. During the vegetation, the standard crop management practices were applied. The plots were harvested by hand. The grain yield per plant was measured on ten randomly chosen competitive plants in each replicate.

Analysis of variance was done using average years values, where hybrids were treated as fixed factors, and years as random factor. Griffing's method 4 (without parents and reciprocal crosses; GRIFFING 1956), model 1 (fixed effect of parents) was applied to estimate GCA and SCA. The significance of hybrids, GCA and SCA mean squares were estimated using F test.

The concept of GGE originates from analysis of multi-environment trials of crop cultivars. The yield (or any other measure of cultivar performance) of cultivar in an environment is mixed effect of genotype main effect (G), environmental main effect (E) and genotype × environment interaction (GE). To extend the application of GGE biplot to the other types of two-way data with similar data structure, the cultivars can be generalised as entries and environments as testers (YAN *et al.* 2001).

When GGE biplot is used for diallel cross analysis, the average yield and genotype stability correspond to GCA and SCA of parents, respectively. In conventional diallel analysis SCA relates to a cross, not parental lines.

GGE biplot analysis is expressed as:

$$Y_{ij} - \beta_j = \lambda_1 \varepsilon_{i1} \eta_{j1} + \lambda_2 \varepsilon_{i2} \eta_{j2} + \varepsilon_{ij}$$

where Y_{ij} is genotypic values of the combination (pure inbred lines or F₁ hybrids) between inbred i and tester j for a given trait; β_j average value of all combinations with tester j , λ_1 and λ_2 are singular values for PC1 and PC2. ε_{i1} and ε_{i2} are PC1 and

PC2 eigenvectors for inbred i (entry), respectively; η_{ij1} and η_{ij2} are PC1 and PC2 eigenvectors for tester j , respectively; ε_{ij} is the residual of model for inbred i and tester j . In diallel crosses, a parent is both an entry and a tester. This analysis is done using GGE biplot software (YAN, 2001).

RESULTS AND DISCUSSION

The analysis of variance of combining abilities showed highly significant both additive and nonadditive gene effects on grain yield per plant (Table 1), with predominant impact of nonadditive gene effect (GCA/SCA=0,684).

Table 1. Analysis of variance of combining abilities for grain yield per plant

Source	df	MS
OKS	5	1469,428**
PKS	9	538,886**
Error	70	2,660
OKS/PKS		0,684

**₁, p<0.01

The greater nonadditive effect on the examined traits have been corroborated by many authors (UNAY *et al.*, 2004; SOFI and RATHER, 2006; BELLO and OLAOYE, 2009; ABDEL-MONLEAM *et al.*, 2009; AKBAR *et al.*, 2009; BOĆANSKI *et al.*, 2010).

A few authors (PSWARAYI and VIVEK, 2008 and OJO *et al.*, 2007), however, determined greater additive effect on grain yield. This discrepancy can be explained by the difference in genetic material estimated i.e. by the different genetic background of the tested genetic material, the effect of inbreeding, as well as the environmental factors (OJO *et al.*, 2007; AKBAR *et al.*, 2009).

GCA and SCA values calculated by conventional diallel analysis are presented in table 2. According to the results, it can be concluded that inbred N152 was the parent line with the best GCA effect. Positive, highly significant GCA was found for inbred B73D. The GCA values for the other inbreds were also highly significant, albeit negative.

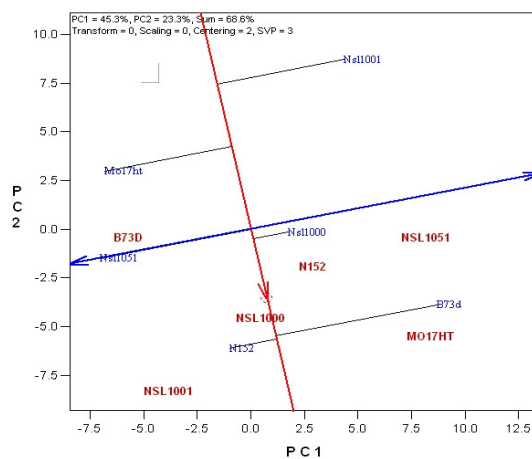
Almost all SCA values, except for the hybrid combinations N152 × NSL 1000 and NS L 1000 × B73D, were highly significant, which is possibly due to a high value of nonadditive genetic variance that has been determined for the trait. The hybrid combination NSL 1051 × Mo17Ht proved to be with the greatest, although negative, SCA.

Table 2. GCA (diagonal line) and SCA values for grain yield per plant

Parents	N152	NSL 1001	NSL 1000	B73D	NSL 1051	Mo17Ht
N152	23.625**	7.995**	-1.559	10.149**	-7.030**	-9.555**
NSL 1001		-21.967**	-23.484**	-27.959**	20.995**	22.453**
NSL 1000			-9.446**	-3.647*	19.641**	9.049**
B73D				23.579**	4.899**	16.558**
NSL 1051					-4.275**	-38.505**
Mo17Ht						-11.517**

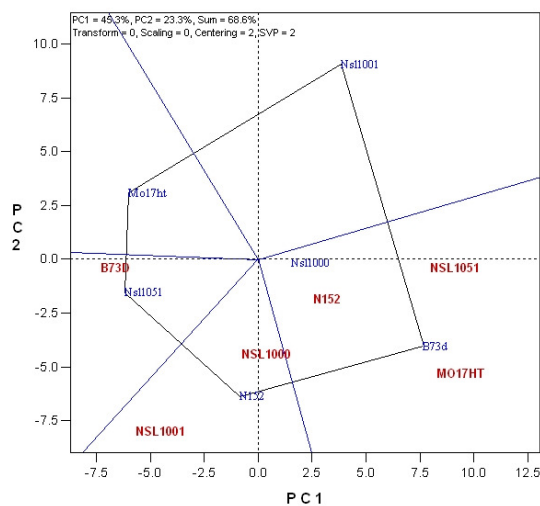
*, p<0.05, **, p<0.01

Graph 1. shows GCA and SCA inbred lines. Biplot explains of 68,6% (PCA1=45,3%; PCA2=23,3%) the total variance, which is partitioned, according to conventional analysis by Griffing, to GCA of parent inbreds and SCA of its crosses. General combining abilities of inbreds (entries) increase in the direction of the arrow on ATC (Average Tester Coordinate) abscissa, ranking the inbreds by their GCA in descending order, as follows: N152, B73D, NS L 1000, NS L 1051, Mo17Ht and NS L 1001. Inbreds on the right from the ATC ordinate (N152, B73D and NS L 1001) have positive GCA, where inbreds Mo17Ht and NS L 1001 have negative GCA for grain yield per plant. Inbred line NS L 1051 is placed on the ordinate itself and has the average GCA value. Comparing the GCA values from Biplot analysis and Griffing's method (Tab. 2.) similar results can be observed, with the exception of NS L 1051 and NS L 1000 whose ranks are swapped.



Graph 1. GCA and SCA

Unlike the conventional methods of diallel analysis, which give an insight only into SCA of crosses, biplot analysis enables the SCA estimation of parent inbreds. SCA are presented by the inbred label projections on the ATC ordinate. The highest SCA relates to inbred B73D, followed by: NS L 1051, NS L 1001, Mo17Ht, N152 and NS L 1000.



Graph 2. Best crosses

The estimations of the best crosses of inbred lines are presented on the graph 2. Inbreds that are the furthest away from the origin are connected with straight lines forming a polygon, leaving the labels of the other inbreds within the polygon. Lines that are perpendicular on the sides of the polygon divide biplot into several sectors, with every tester belonging to one sector. All testers within a sector produce the best cross for the grain yield with a common inbred (YAN *et al.*, 2000).

Inbred B73D shows the best results when crossed with testers Mo17Ht, NS L 1051 and N152, inbred N152 combines best with testers NS L 1001 and NS L 1000, whereas the cross of inbred NS L 1051 with tester B73D results with the highest grain yield per plant in comparison with other testers. The prediction of good performance of the crosses of testers NS L 1051 and Mo17Ht with B73D is in agreement with the BSSS × nonBSSS heterotic pattern, given that the lines NS L 1051 and Mo17Ht belong to Lancaster Sure Crop and B73 D to the BSSS heterotic group.

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ANALIZA NS INBRED LINIJA KUKURUZA

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I z v o d

Određivanje kombinacionih sposobnosti roditeljskih inbred linija, radi iskorištavanja heterozisa, je od suštinske važnosti. Najčešće korišćen metod je dialelna analiza. Pored konvencionalnih metoda dialelne analize za procenu kombinacionih sposobnosti, u poslednje vreme prisutan je i novi pristup analize kombinacionih sposobnosti. U ovom radu smo proučavali kombinacione sposobnosti za prinos zrna u setu genotipova dobijenih dialelnim sistemom ukrštanja šest linija. Pored primene konvencionalne metode analize po Griffingu, korišten je i biplot pristup za sagledavanje podataka. Upoređujući vrednosti OKS dobijenih biplot analizom i primenom Griffing-ovog metoda, dobijeni su slični rezultati, sa izuzetkom NS L 1051 i NS L 1000 čiji su rangovi zamenjeni. Biplot analiza omogućava i procenu PKS samih roditeljskih linija. Najveća vrednost PKS zapažena je kod linije B73D, a zatim slede: NS L 1051, NS L 1001, Mo17Ht, N152 i NS L 1000. Biplot analiza takođe omogućava i procenu najboljih ukrštanja. Inbred linija B73D pokazala je najbolje rezultate u ukrštanju sa linijama Mo17Ht, NS L 1051 i N152, N152 sa NS L 1001 i NS L 1000, dok se linija NS L 1051 najbolje kombinuje sa testerom B73D.

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