COMBINING ABILITY OF INBRED LINES DERIVED FROM A YELLOW DENT MAIZE SYNTHETIC CMS 61

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ABSTRACT - A breeding program based on heterosis exploitation needs the knowledgment of the germplasm to produce good combinations in superior hybrids. A study was conducted to evaluate inbred lines, derived from synthetic maize CMS 61, in a diallel mating design. The identified lines could be possible nominees for superior yielding hybrids combinations with a flint heterotic group. Ten inbred were crossed to form 45 single crosses. Parental inbred and crosses together with a single cross commercial hybrid were evaluated using a 7 x 8 simple rectangular lattice design at four locations during the 2000/01 crop season. Ear yield (kg ha^{-1}) is discussed. For this analysis, the Griffing´s method 2, model 1 was employed. The combining ability analysis of variance showed highly significant ($P < 0.01$) effects for locations, crosses and lines, general combining ability (GCA), specific combining ability (SCA) and GCA x L. Genotype x Locations and SCA x Locations were also significant ($P < 0.05$). Means of the crosses over the four locations ranged from 6113 kg ha^{-1} to 8924 kg ha^{-1}. Results showed that the non-additive gene effects were more important than the additive. The selected lines should prove useful germplasm to a breeding program in tropic.

Key words: *Zea mays* L., diallel, ear yield

CAPACIDADE DE COMBINAÇÃO DE LINHAGENS DERIVADAS DO SINTÉTICO DE MILHO DENTADO CMS 61

RESUMO - Um programa de melhoramento com sucesso, baseado na exploração da heterose, necessita do conhecimento do germoplasma, para selecionar linhagens promissoras capazes de produzir combinações híbridas superiores. Realizou-se um estudo para avaliar linhagens derivadas do sintético de milho (*Zea mays* L.) CMS 61, de grãos amarelos dentados, em cruzamentos dialélicos. Foram produzidos 45 híbridos simples dos cruzamentos entre dez linhagens elites extraídas do CMS 61. As linhagens parentais mais os híbridos simples e um híbrido simples comercial, usado como testemunha, foram avaliados através de um látice retangular 7 x 8, com duas repetições, em quatro locais, no ano agrícola 2000/01. Os dados da produtividade de espigas (kg ha^{-1}) dos quatro locais foram analisados utilizando-se o método 2, modelo 1 de Griffing. A análise de variância combinada mostrou efeitos altamente significativos ($P < 0.01$) para locais, cruzamentos, linhagens, CGC e CEC. As interações genótipos x locais e CEC x locais também foram significativas ($P < 0.05$). As médias dos cruzamentos nos quatro locais variaram de 6.113 kg ha^{-1} a 8924 kg ha^{-1}. Os resultados mostraram que os efeitos não aditivos foram mais importantes que os aditivos. As linhagens selecionadas representam materiais de grande valia para programas de melhoramento nas condições tropicais.

Palavras-chave: *Zea mays* L., dialelo, produção de espigas

Maize inbred lines derived from different germplasm can exhibit varying response patterns when grown at different environments. Heterosis has been used in maize breeding programs since Shull (1909) described the concept of single cross hybrids. The high yielding performance of hybrids depends on the combining ability of the lines involved in their development. In fact, breeders are interested in identifying lines that perform well in crosses.

The evaluation of genetic variation of lines proposed by Griffing (1956) is based in the concepts of general and specific combining abilities established by Sprague & Tatum (1942), who presented detailed methods for analyzing fixed set of lines or varieties in diallel crosses, which have been used extensively in breeding of several economic crops.

The diallel cross method have been utilized widely in maize breeding programs to evaluate the genetic potential of inbred lines and others genotypes, but its limitation is the increasing number of crosses in accordance with the increase in number of lines (Gonçalves, 1987; Hallauer & Miranda Filho, 1988; Kempthorne & Curnow, 1961; Martins & Miranda Filho, 1997; Miranda Filho & Vencovsky, 1999).

Sprague & Tatum (1942) found that general combining ability (GCA) was relatively more important than specific combining ability (SCA) for unselected inbred lines, but the opposite was observed for selected lines. Inheritance studies have shown that grain yield traits to be under quantitative genetic control (Hallauer & Miranda Filho, 1988). Therefore, with the magnitude of SCA effects comparatively larger than GCA effects, indicating of the greater importance of non-additive gene action.

Most of the works using measurements of GCA and SCA effects has been with temperate inbred lines rather than tropical lines. Additional studies are needed to examine similar parameters with lines derived from tropical synthetic germplasm.

Information on inbred lines derived from the same population is important in a breeding program. Lines with high GCA can be used to test selfed-progenies from a contrasting heterotic group to produce single crosses. Besides single cross lines derived from the same population can also be used for increasing uniformity in double cross hybrids.

The objective of this study was to use diallel crosses to evaluate a set of ten inbred lines from the tropical yellow dent type synthetic CMS 61, tested across four locations.

Material and Methods

One hundred and eighty S_2 maize progenies, from a synthetic population (CMS 61) of early cycle with yellow dent kernel type, developed by the Embrapa Maize and Sorghum Research Center, were topcrossed with a contrasting heterotic flint type synthetic (CMS 53) and the hybrids were evaluated for yield and others traits, at four locations: Sete Lagoas (MG)- longitude 44°15’W, latitude 19°28’S, altitude 723 m; Janaúba (MG)- longitude 43°30’W, latitude 15°80’S, altitude 533 m; Goiânia (GO)- longitude 49°15’W, latitude 16º40’S, altitude 741 m, and Londrina (PR)- longitude 51°11’W, latitude 23°23’S, altitude 630 m, in 1998/99. The ten selected lines with high yield potential and excellent agronomic characteristics, resulted from the best crosses were selfed for a more advance generation inbreeding (S6) and their seeds were increased. Then, these lines were crossed in a 10 x10 diallel scheme.

The possible 45 single crosses, the 10 inbred parents, and a commercial single cross hybrid as a check (C 901) were evaluated using a 7 x 8 lattice design with two replications. The experiments were evaluated at four locations, in Sete Lagoas (MG), Janaúba (MG), Goiânia (GO) and Londrina (PR), in 2000/2001 crop season. Each plot consisted of two 4 m rows, spaced at 0.80 m x 0.20 m between and within rows, respectively. Data were collected for several traits, but only ear yield (unhusked ear) is presented in this study.

The analyses of variance were performed using Griffing´s method 2, model I, diallel analyses (Griffing, 1956). Location was considered as random effect. The parameters were estimated considering the parametric restriction $\Sigma_j s_{ij} = 0$, for all i, according to Cruz & Regazzi, 2001.

Results and Discussion

The mean ear yield of the single crosses over the four locations (Table 1) ranged from 8924 kg ha^{-1} (L 4 x L 6) to 6113 kg ha^{-1} (L 6 x L 10). The hybrid check out yielded the best single cross by 32.94%. This check mean yield greater than the means of the single crosses can be explained because they were produced with lines extracted from the same synthetic population.

The lower yielding inbred line (L10) produced 1426 kg ha^{-1}, and the higher yielding line (L2) 2832 kg ha^{-1}. The individual analysis of variance (data not shown) for yield permited to verify significant differences among treatments ($P < 0.01$) at all locations.

For mean ear yield over locations the coefficient of variation of 16.22% was considered of median magnitude (Scapim et al., 1995). The ratio between the highest and the lowest error mean square values of the individuals analysis of variance was 1.74, evidencing the condition of homogeneity of the variance (Pimentel-Gomes & Garcia, 2002).

Highly significant differences ($P < 0.01$) were detected in the combined analysis of variance (Table 2) for environments, genotypes (single crosses and inbreds lines), single crosses *vs* inbred lines contrast, and for inbred lines and single crosses. Genotype x

TABLE 1 - Ear yield means (kg ha^{-1}) for the 10 lines (diagonal) derived from the synthetic CMS 61, for the 45 single crosses (above diagonal), and for the commercial hybrid (last line in this table), evaluated over four environments.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**1905**	8279	6944	7518	7304	7522	8162	6951	7528	8386
2		**2832**	7695	8488	7477	7757	7133	7915	8003	8683
3			**2600**	8593	6554	7676	6704	7666	6965	7770
4				**2150**	6742	8924	7100	6958	7700	7810
5					**1610**	7512	7494	6801	6348	8148
6						**2665**	7098	7343	7020	6113
7							**1671**	7378	6375	7313
8								**2074**	6718	8803
9									**1703**	8073
10										**1426**
Single cross check (C 901) = 11864 kg ha^{-1}										

environments interaction was also significant ($P < 0.05$). The single crosses did not have the same performance in the tested environments, indicating genetic differences and behavior among the single crosses, even though they were from the same germplasm. As pointed out by Troyer (1996) and Hallauer & Miranda Filho (1988), single crosses are more influenced by external environmental factors than other hybrids types. These results agree with Sprague & Eberhart (1977) and Gama et al. (1995), who confirms the results found that single cross with a narrow genetic base have a greater environmental interaction than germplasm from a broad genetic base.

Joint analysis of variance of diallel data across environments for GCA and SCA effects permited to verify highly significant differences for environments, GCA, SCA and GCA x environments (P < 0.01) , and SCA x environments interaction (P < 0.05) (Table 3).

The interaction GCA x environments indicated that the general combining ability of the lines varied across locations, suggesting different parental lines selection for hybrid production at specific locations. The significant SCA x environments interaction allows to infer that differential response has occurred in the hybrid combinations in each location. There are instances in the literature where the relative sizes of means squares have been used to assess the relative importance of general and specific combining ability. Baker (1978) suggested an expression of the ration between GCA and SCA component of variance, to explain the relative importance of general and specific combining abilities in determine progenies performance. The close the ratio to unity, the greater the predictability based on general combining ability. Because the analysis were based on a model with fixed effects, it was used the components of

TABLE 2 - Mean squares for the combined analysis of variance for ear yield (kg ha^{-1}), of 45 crosses and 10 parents of the synthetic CMS 61.

Source of Variation	d.f.		Mean Squares
Environments (E)	3		154416069.65**
Genotypes (G)	54		39149538.55**
Single-crosses (SC)		44	3706027.20**
Inbred lines (IL)		9	1928624.05**
SC vs. IL		1	1933652268.00**
E x G	162		1507350.69*
Combined Errors	164		1114859.75
Mean = 6510.59	CV% = 16.22		

**, * = Significant at 0.01 and at 0.05 probability levels, respectively.

TABLE 3 - Combined diallel analysis of variance for ear yield (kg ha^{-1}) of the 10 lines and 45 crosses from the synthetic CMS 61.

Source of Variation	d. f.	Mean Squares
Environments (E)	3	154416069.65**
GCA	9	6253392.74**
SCA	45	45728768.71**
GCA vs E	27	1735814.77**
SCA vs E	135	1461657.88*
Combined Error	164	1114859.75

**, * = Significant at 0.01 and at 0.05 probability levels, respectively.

mean squares and the calculated ratio was approximately 0.14. Also, the results of the analysis presented in Table 3, indicated that the variation among the SCA effects had greater contribution to the total variation for ear yield than GCA effects indicating significant non-additive effects. This result is in accordance with the results found by Aguiar et al. (2004), in their study with maize lines for second crop season. According to Hallauer & Miranda Filho (1988), dominance effects for grain yield are more relevant than for other maize traits. Different results were found by Paterniani et al. (2000), using a set of selected lines from CIMMYT, indicating that the additive effects were more important than the non-additive effects.

Line L2 and line L5 had the largest positive and negative GCA effects, respectively (Table 4). Six out of ten lines presented positive GCA effects. Similar results were obtained by Nass et al. (2000). The largest positive and negative SCA effects were found for the crosses line L8 x line L10 and line L10 x line L6, respectively. The results found for SCA effects were more positive than negative. Vasal et al. (1992) and Gama et al. (1995) reported that single crosses produced by crossing lines extracted from different source populations had more positive SCA effects than those involving crossing lines from a specific population.

For hybrid production through a diallel analysis must be chosen the best hybrids with the highest SCA in which one of the lines presents the highest GCA value (Cruz & Regazzi, 2001). The results found with this set of inbred lines used in this study indicated that the best lines likely to be useful in crosses in a breeding program are L2, L4 and L10, since present high positive GCA for ear yield. Those lines can also be used as a tester for lines selection derived from CMS 53, synthetic population from a contrasting heterotic group, aiming single-cross production. Some high yielding single crosses, principally (L 4 x L 6) and (L 2 x L 10), can be considered promising for hybrid development when crossing with contrasting heterotic group of lines.

TABLE 4 – Estimates of SCA effects and GCA effects of the 10 lines and 45 crosses from the synthetic CMS 61, across environments.

Parents	1	2	3	4	5	6	7	8	9	10	GCA
1	-4736.73	1245.67	355.77	731.78	1062.10	889.62	1878.75	452.89	1241.55	1615.34	**65.63**
2		-595.73	714.94	1311.10	844.36	733.34	458.62	1027.94	1325.90	1521.59	**456.80**
3			-3935.48	1861.01	365.75	1096.21	473.84	1220.50	731.97	1051.97	**12.44**
4				-4780.42	356.58	2147.20	672.71	315.78	1270.07	895.61	**209.70**
5					-4231.14	1279.53	1611.15	703.26	461.79	1777.76	**-334.67**
6						-3958.74	823.87	853.34	742.53	-648.18	**56.54**
7							-4253.18	1238.58	448.07	900.75	**-293.12**
8								-4281.41	575.14	2175.38	**-77.75**
9									-4227.39	1657.76	**-290.09**
10										-5473.99	**194.53**

Conclusions

The diallel analysis using yield data was useful to choose single crosses with good yields compared with the check hybrid over the four locations, indicating the good potential of the selected lines for hybrid development.

SCA effects played a greater role than GCA effects, indicating the importance of non-additive effects for this set of lines.

The line L2 had the highest GCA effect, while lines L5 had lowest GCA effects for ear yield.

The lines L2, L4 and L10 were identified as the best promising lines to be used in hybrid combinations.

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