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Prediction of popcorn hybrid and composite means

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ABSTRACT - *The objectives of this study were to evaluate the combining ability of 10 popcorn populations in a circulant diallel; to test the viability of superior hybrids; and to identify genetic composites for intrapopulation breeding. In four contrasting environments, 30 treatments were evaluated for grain yield (GY), plant height (PLH) and popping expansion (PE), in a random block design with four replications. Results indicated that the evaluation of treatments in a larger group of environments favors the expression of variability in genotypes. The additive effects for PE and the dominance effects for GY and PLH were highest. GY and PE of the combinations UNB2U-C1 x Angela and Braskalb x Angela were outstanding. The predicted mean PE and GY were highest for hybrid UNB2U-C1 x Angela and the composite formed by these parents (26.54 mL g^{-1} and 1,446.09 kg ha^{-1} respectively).*

Key words: Popcorn, circulant diallel, combining ability, popping expansion, composite estimates.

INTRODUCTION

Popcorn is a crop of high economic value and consumption in Brazil is on the rise (Brugnera et al. 2003). For being cheap and tasty, always freshly popped for clients and served hot, popcorn is very popular. For many people that work informally, popcorn is a direct source of family income. Until recently, the commercial planting of popcorn in Brazil was rather modest and significant grain importations, above all from the USA and Argentina, were necessary (Galvão et al. 2000). However, the market situation of the crop is changing. According to information of the packaging industry, grain importations have dropped markedly, mainly due to the large-scale use of the modified single hybrid IAC-112 (Sawazaki 2001) and of North American hybrids cultivated in the country (Sawazaki et al. 2003).

In spite of the progress, the low number of popcorn cultivars is still a constraint to further expansion of the crop in the country (Scapim et al. 2002). Consumers generally associate quality popcorn to imported grain, which implies that good popcorn must come from abroad. Sawazaki et al. (2000) and Galvão et al. (2000) demonstrated that this premise is not true, in an analysis of hybrids between the lines Guarani and IAC-64, in the states of São Paulo and Minas Gerais. The yield and popcorn quality were similar to the best North American hybrids.

To establish superior genotypes, the diallel analysis lends itself as viable alternative, even when the number of parents involved is high. In this situation, the circulant diallel is a particularly interesting methodology, for requiring only one sample of all possible parent combinations (Cruz et al. 2004).

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Veiga et al. (2000) demonstrated the efficiency of circulant in comparison with complete diallels, to classify parents as well as estimate parameters of general and specific combining ability. Ferreira et al. (2004) further verified the superior efficiency of the circulant over the complete diallel regarding the effects of general and specific combining ability. The authors evaluated maize ear yield in a circulant diallel and stated that a reduction of 30% in the number of crosses did not affect the choice of the best parents and hybrids.

This study was carried out to evaluate the combining ability of 10 popcorn populations in a circulant diallel, to check the feasibility of establishing commercial hybrids and identify genetic composites for intrapopulation breeding.

MATERIAL AND METHODS

Diallel crosses in a circulant scheme were performed between the populations Beija-flor, Branco-Viçosa, Viçosa-Viçosa, SE013-Maringá, PA038-Maringá, BRS Angela, Braskalb, Viçosa-UENF, UNB2U-C1 and UNB2U-C2, based on the algorithm of Kempthorne and Curnow (1961).

To create the hybrid combinations, the 10 populations were grown in 6.00 m long rows (row spacing 1.00 m and within-row plant spacing 0.40 m), and paired in all necessary combinations, in March 2003. The plants of the pairs of rows were crossed by hand. For this purpose, the mature tassels of a particular plant of a row were wrapped in kraft paper bag. Then the bag was used to cover an ear ready for pollination of a plant of the corresponding row-pair. Approximately 100 ears per row-pair were pollinated to generate a sufficient seed quantity for the follow-up procedures.

The diallel crosses were based on the algorithm proposed by Kempthorne and Curnow (1961), where: p= number of parents under study; s= number of hybrid combinations of each parent, s < p-1 and s > 3 for diallels that include only F_1s and s > 2 when the parents are also included; ps/2= total number of crosses; and K=(p+1-s)/2: whole number. Three crosses of each population with the others were used for this purpose (s =3).

The hybrids, parents and controls (IAC-112, Produtor-Maringá, PR023-Maringá, UNB2U-C0 and Viçosa) were evaluated in two contrasting environments, in the State of Rio de Janeiro: Colégio Estadual Agrícola Antônio Sarlo, in Campos dos Goytacazes, at the Experimental Station of PESAGRO-RIO, Itaocara, planted on 09/12/2004 and 14/12/2004, respectively. In each environment, 30 treatments, corresponding to the 10 pre-selected parents, 15 hybrids and 5 controls were arranged in random blocks with four replications, planted in single rows of 10.00 m length, (row spacing 1.00 m and within-row plant spacing 0.20 m).

The following traits were evaluated: grain yield (GY), in kg ha^{-1}, measured by weighing the grains after shelling; plant height (PLH), in cm, measured after tasseling as the distance between the soil level to the insertion height of the flag leaf of 10 healthy plants; and popping expansion (PE), in mL g^{-1}. For this purpose, two 30g samples of each plot were popped for 2 minutes and 30 seconds at 270 ºC in an expansion measuring device developed by EMBRAPA-CNPDIA.

The individual and joint diallel analyses were carried out using the software package GENES (Cruz 2006) and the genetic-statistical model $Y_{ij} = \mu + g_i + g_j + s_{ij} + \xi_{ij}$ and $Y_{ij} = \mu + g_i + g_j + s_{ij} + l_k + gl_{ik} + gl_{jk} + sl_{ijk} + \xi_{ij}$, where: Y_{ij} = mean of the observation associated to the hybrid combination ij ($i \neq j$) or to the i^{th} parent (i = j); μ = general constant; g_i and g_j = effects of the general combining ability associated to the i^{th} and j^{th} parent, respectively; s_{ij} = effect of the Specific combining ability between the i^{th} and j^{th} parent; l_k = effect of the k^{th} environment or site; gl_{ik} and gl_{jk} = effects of the interaction between the general combining ability associated to the i^{th} and j^{th} parent and the k^{th} environment, respectively; sl_{ijk} = effect of the interaction between the specific combining ability between the i^{th} and j^{th} parent and the k^{th} environment; and $\xi_{ij.}$ = mean experimental error.

The estimators of the components of the general and specific combining ability, respectively ϕ_{gi} and ϕ_{si}, were expressed as: $\phi_{gi} = \frac{MSGCA - MSE}{\frac{bs(p+2)}{(p-1)}}$, and $\phi_{si} = \frac{MSSCA - MSE}{b}$, where: *MSGA*= mean square of the general combining ability; *MSGA*= mean square of the specific combining ability; *MSE* = mean square of the error; *b* = number of blocks; *s* = number of crosses; and *p* = number of parents. In the joint analysis, the estimators of the components of the general and specific combining ability in interaction with the environment were expressed by:

$$\phi_{giA} = \frac{MSGCAxE - MSE}{\frac{bs(p+2)}{(p-1)}} \quad \text{and} \quad \phi_{siA} = \frac{MSSCAxE - MSE}{b},$$

where: *MSGCAxE* and *MSCSAxE* = general and specific combining ability in interaction with the environment, respectively.

The number of composites was estimated by the expression: n = C_p^x , where x is the number of parents involved in the composite and p the number of parents involved in the diallel (Cruz 2006). The means of the biparental composites were estimated by the expression PV = $\frac{Y_{ii} + Y_{jj} + 2Y_{ij}}{4}$, where PV = Y_{ij} predicted value; and Y_{ij} = parent mean, when i = j, or of the hybrid, when i ≠ j, of the selected variable. The composites with three parents were estimated by the PV = $\frac{Y_{ii} + Y_{jj} + Y_{kk} + 2(Y_{ik} + Y_{ij} + Y_{jk})}{9}$.

RESULTS AND DISCUSSION

The analysis of variance for the combining ability of the environment in Campos dos Goytacazes (Table 1) indicated sufficient genetic variability in the parents and hybrids of the diallel, due to the genetic additive and non-additive effects.

The estimates of the quadratic components due to the GCA effects revealed superiority of the genetic additive over the non-additive effects for trait PE (12.6032). For GY and PLH the non-additive effects were higher. The predominance of genetic additive effects in popcorn for PE had also been described by Pacheco et al. (1998), Pereira and Amaral Júnior (2001) and Simon et al. (2004). With respect to GY, Andrade et al. (2002), Pereira and Amaral Júnior (2001) and Simon et al. (2004) also demonstrated the greater importance of non-additive effects.

The GCA effects ($\hat{g}_i$) for the environment of Campos dos Goytacazes expressed positive GY estimates for the parents UNB2U-C1, Viçosa-UENF, Angela, UNB2U-C2 and Viçosa-Viçosa, suggesting the suitability of these genotypes for breeding programs focused on the improvement of weight and grain yield (Table 2).

For plant height (PLH), the $\hat{g}_i$ estimates of the parents PA038-Maringá, SE013-Maringá and Viçosa-Viçosa were positive, for PE, the positive $\hat{g}_i$ magnitudes of the parents Angela, UNB2U-C1 and UNB2U-C2 were highest (6.1486; 2.5795; and 1.3271, respectively) (Table 2).

Due to the positive $\hat{g}_i$ values associated to the traits GY and PE, the parents UNB2U-C1, Angela and UNB2U-C2 can be included in intrapopulation breeding programs, with a view to the establishment of generations with superior grain yield and popping expansion.

When evaluating the same genotypes in Campos dos Goytacazes in the growing season 2003/2004, Freitas Júnior et al. (2006) confirmed the recommendation of UNB2U-C1, Angela and UNB2U-C2, besides Viçosa-Viçosa, for the development of superior progenies in intrapopulation breeding programs.

With respect to the $\hat{s}_{ij}$ estimates (Table 2) 10 combinations were promising regarding GY, above all the hybrids UNB2U-C1 x Angela and Viçosa-UENF x UNB2U-C2 (estimates of 17.25 and 143.68, respectively). These were not the highest $\hat{s}_{ij}$, values, but were the only pairs derived from parents with positive $\hat{g}_i$ estimates and are therefore considered superior when breeding for higher grain yields. The $\hat{s}_{ij}$ values alone do not identify the best combinations, but must be complemented by the evaluation of the $\hat{g}_i$ values, which must be of favorable effect for at least one of the parents (Cruz et al. 2004). The above hybrids obtained GY means of 1511.25 and 1608.75 kg ha^{-1}, respectively.

Table 1. Values and significances of the mean squares of popcorn genotypes, partitioned in general and specific combining ability as well as the mean square effects of the combining ability for three traits evaluated in a circulant diallel - Campos dos Goytacazes, RJ

SV	df	Mean squares[1]		
		GY	PLH	PE
Genotypes	24	596481.7708 **	283.1197 **	84.9479 **
GCA	9	628353.0421 **	340.3592 **	204.6025 **
SCA	15	577359.0084 **	248.7750 **	13.1555 **
Error	87	45880.4597	54.3960	2.9512
Mean square effects				
GCA		36404.5363	17.8726	12.6032
SCA		132869.6371	48.5947	2.5510

** = Significant at 1% probability by the F test; * = Significant at 5% probability by the F test

1/ GY = grain yield in Kg ha^{-1}; PLH = plant height in cm; and PE = grain popping expansion in mL g^{-1}

Table 2. Estimates of phenotypic means and effects of the general ($\hat{g}_i$) and specific combining ability ($\hat{s}_{ij}$) for three traits[1] evaluated in a circulant diallel

Genotypes	Traits	Estimates of $\hat{g}_i$ effects									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	GY	269.00	-210.08	98.35	-69.29	-221.11	21.99	-142.64	163.71	-23.27	113.34
	PLH	-0.18	-5.00	0.04	1.21	-1.37	-0.90	0.69	-4.78	4.92	5.36
	PE	2.57	-1.66	-1.23	-2.68	-1.74	6.14	-0.52	1.32	-1.86	-0.32
	Traits	Estimates of the $\hat{S}_{ij}$ effects (above the diagonal) of the phenotypic means of the parents (along the diagonal) and of the hybrids (below the diagonal)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	GY	1703.75				96.61	17.25	-39.35			
1	PLH	157.87				-3.26	0.51	0.66			
	PE	24.20				2.59	-0.87	-2.07			
	GY		563.75				553.83	-99.02	-16.63		
2	PLH		188.50				5.57	10.05	2.53		
	PE		13.92				2.77	-0.65	1.11		
	GY			1038.75				181.29	143.68	396.92	
3	PLH			150.62				-1.94	-0.45	15.70	
	PE			15.32				1.79	1.16	-0.83	
	GY				436.25				466.32	179.56	610.44
4	PLH				153.75				4.74	5.15	1.84
	PE				12.85				0.01	0.43	0.86
	GY	1347.50				635.00				231.39	-76.47
5	PLH	152.37				152.62				8.99	-2.06
	PE	22.30				14.45				-0.87	0.13
	GY	1511.25	1568.75				1063.75				-204.59
6	PLH	156.62	153.50				149.00				10.08
	PE	26.72	26.12				31.95				-3.46
7	GY		1290.00	751.25	1340.00			896.25			
	PLH		158.37	158.37	156.00			156.50			
	PE		18.85	16.02	18.90			18.27			
8	GY		1140.00	1608.75	1763.75				1233.75		
	PLH		147.62	152.00	158.37				145.37		
	PE		19.65	20.12	17.52				20.37		
	GY			1675.00	1290.00	1190.00				752.50	
9	PLH			177.87	168.50	169.75				152.12	
	PE			14.92	14.75	14.37				15.77	
	GY				1857.50	1018.75	1133.75				1265.00
10	PLH				165.62	159.12	171.75				163.00
	PE				16.72	16.92	21.22				19.45

[1] GY = grain yield in Kg ha^{-1}; PLH = plant height in cm; and PE = grain popping expansion in mL g^{-1}
1 = UNB2U-C1; 2 = Braskalb; 3 = Viçosa-UENF; 4 = PA038-Maringá; 5 = Branco-Viçosa; 6 = Angela; 7 = Beija-flor; 8 = UNB2U-C2; 9 = SE013-Maringá; and 10 = Viçosa-Viçosa

For the trait plant height (PLH), owing to the strong winds that generally blow in Campos dos Goytacazes, combinations with negative and high $\hat{s}_{ij}$ values are ideal. From this viewpoint, the combinations UNB2U-C1 x Branco-Viçosa, Viçosa-UENF x Beija-flor, Viçosa-UENF x UNB2U-C2 and Branco-Viçosa x Viçosa-Viçosa were superior, above all the first pair, with negative $\hat{g}_i$ values in both parents and a phenotypic value of 152.37 cm.

For mean popping expansion (PE), the combinations UNB2U-C1 x Angela and Braskalb x Angela, in this order, performed best in the environment of Campos dos Goytacazes (26.72 mL g^{-1} and 26.12 mL g^{-1}, respectively). Angela is one of the parents in both combinations. Considering that Angela was also the parent with the highest positive $\hat{g}_i$ value, the absence of the pair UNB2U-C1 x Angela among the superior hybrids, based on $\hat{s}_{ij}$ is evidence of the need to select the most promising hybrids more accurately.

For Ferrão et al. (1985), this absence is justified when $\hat{g}_i$ and $\hat{g}_j$ estimates are highly discrepant and, consequently, recommend that an indication of superior hybrids must be based on estimates of the phenotypic means. It was concluded that the best hybrids for PE in Campos dos Goytacazes were UNB2U-C1 x Angela and Braskalb x Angela.

In the analysis of the set of evaluated traits, the hybrids UNB2U-C1 x Angela and Braskalb x Angela outmatched the other combinations in the growing season 2004/2005. For Freitas Júnior et al. (2006), these hybrids were also superior in the growing season 2003/2004; Braskalb x Angela stood out particularly for PE.

The analysis of variance for combining ability for the environment of Itaocara (Table 3), ratified the predominance of the additive genetic effects on PE, due to the non-significance of SCA at 5% probability, while GY and PLH were significant at a level of 1% for SCA.

For GY, the effects for the general combining ability of the parents UNB2U-C1, Viçosa-UENF, Angela, UNB2U-C2, and Viçosa-Viçosa were positive (Table 4), indicating these as genotypes of interest when focusing on higher grain yields.

In relation to PE, the $\hat{g}_i$ values of the parents Angela, UNB2U-C1, UNB2U-C2, Beija-flor, and Viçosa-Viçosa were positive (6.2514; 1.9294; 1.8021; 1.0850; and 0.2759) (Table 4). The $\hat{g}_i$ estimates of the parents Angela, UNB2U-C1, UNB2U-C2 and Viçosa-Viçosa were also positive for grain yield. It is noteworthy that, with exception of parent Viçosa-Viçosa, these genotypes were the ones recommended for intrapopulation breeding in the environment of Campos dos Goytacazes (Table 2), i.e., a single breeding program can be implemented for the environments studied.

The GY values were positive for all combinations, with exception of Branco-Viçosa x Viçosa-Viçosa, which had a negative value and is therefore uninteresting (Table 4). Especially interesting were the hybrids UNB2U-C1 x Angela, Viçosa-UENF x UNB2U-C2 and Angela x Viçosa-Viçosa, with $\hat{s}_{ij}$ values of 542.34, 415.68, and 175.17, respectively, besides positive $\hat{g}_i$ estimates. It is worth pointing out that the first, third and fourth highest phenotypic means for GY were found for the hybrids UNB2U-C1 x Angela, Viçosa-UENF x UNB2U-C2 and Angela x Viçosa-Viçosa, which confirms that they are in fact superior.

With respect to PLH, the combinations Viçosa-UENF x Beija-flor, PA038-Maringá x UNB2U-C2 and Branco-Viçosa x Viçosa-Viçosa are indicated for

Table 3. Values and significances of the mean squares of popcorn genotypes, partitioned in general and specific combining ability, as well as the mean square effects of the combining ability for three traits evaluated in a circulant diallel - Itaocara, RJ

SV	df	Mean squares[1]		
		GY	PLH	PE
Genotypes	24	1468965.4583 **	422.6479 **	117.1242 **
GCA	9	1202721.5332 **	452.9005 **	305.5664 **
SCA	15	1628711.8018 **	404.4900 **	4.0588 ns
Error	87	221856.2045	67.1904	3.6667
Mean square effects				
GCA		61304.0830	24.1068	18.8687
SCA		351713.8993	84.3248	0.0980

** = Significant at 1% probability by the F test; * = Significant at 5% probability by the F test
[1] GY = grain yield in Kg ha^{-1}; PLH = plant height in cm; and PE = popping expansion in mL g^{-1}

Table 4. Estimates of the phenotypic means and effects of the general ($\hat{g}_i$) and specific combining ability ($\hat{s}_{ij}$) for three traits[1/] evaluated in a circulant diallel

Genotypes	Traits	Estimates of $\hat{g}_i$ effects									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	GY	171.10	-277.30	95.14	-326.59	-222.43	153.84	-40.17	248.96	-102.08	299.52
	PLH	2.01	-9.21	-0.98	-2.42	-4.54	0.49	3.52	1.16	4.08	5.87
	PE	1.92	-0.69	-1.20	-5.01	-0.24	6.25	1.08	1.80	-4.17	0.27
	Traits	Estimates of the $\hat{S}_{ij}$ effects (above the diagonal) of the phenotypic means of the parents (along the diagonal) and of the hybrids (below the diagonal)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	GY	1703.75				316.12	542.34	351.36			
	PLH	209.50				1.75	14.21	5.13			
	PE	24.20				1.44	-1.02	-0.01			
2	GY		957.50				148.25	384.77	375.64		
	PLH		188.50				5.57	10.05	2.53		
	PE		19.75				0.87	-0.28	-0.97		
3	GY			1611.25				173.57	415.68	501.73	
	PLH			208.62				-1.06	5.92	6.00	
	PE			19.15				0.52	0.26	-2.03	
4	GY				476.25				189.92	650.98	833.11
	PLH				202.87				-6.75	10.94	12.40
	PE				11.40				-0.93	-0.07	0.04
5	GY	2231.25				1123.75				564.32	-84.79
	PLH	215.25				207.12				5.94	-8.09
	PE	24.07				20.45				-0.39	-1.04
6	GY	2833.75	1991.25				1841.25				175.17
	PLH	232.75	212.87				205.00				4.23
	PE	28.10	27.37				33.15				0.75
7	GY		2448.75	2033.75	2195.00				1431.25		
	PLH		226.70	220.37	217.50				216.00		
	PE		23.95	21.05	21.35				23.00		
8	GY		2313.75	2726.25	2078.75				1973.75		
	PLH		210.50	222.12	208.00				217.50		
	PE		21.07	21.80	16.80				25.37		
9	GY			2461.25	2188.75	2206.25				903.75	
	PLH			225.12	228.62	221.50				212.75	
	PE			13.52	11.67	16.12				13.85	
10	GY					1958.75	2595.00				2103.75
	PLH					209.25	226.62				223.50
	PE					19.92	28.22				21.62

[1] GY = grain yield in Kg ha^{-1}; PLH = plant height in cm; and PE = grain popping expansion in mL g^{-1}

1 = UNB2U-C1; 2 = Braskalb; 3 = Viçosa-UENF; 4 = PA038-Maringá; 5 = Branco-Viçosa; 6 = Angela; 7 = Beija-flor; 8 = UNB2U-C2; 9 = SE013-Maringá; and 10 = Viçosa-Viçosa

breeding for reduced plant size, since these are the only pairs with negative $\hat{S}_{ij}$ estimates that were derived from at least one parent with negative $\hat{g}_i$ value.

For PE, the $\hat{S}_{ij}$ values were positive for the hybrids UNB2U-C1 x Branco-Viçosa, Braskalb x Angela, Viçosa-UENF x Beija-flor, Viçosa-UENF x UNB2U-C2, PA038-Maringá x Viçosa-Viçosa, and Angela x Viçosa-Viçosa. The best one was Angela x Viçosa-Viçosa, due to the parents with positive $\hat{g}_i$ estimates. However, the highest estimates of phenotypic means for PE were observed, hierarchically, for the hybrids: Angela x Viçosa-Viçosa, UNB2U-C1 x Angela and Braskalb x Angela. According to Ferrão et al. (1985), this can be explained by the deviations between $\hat{g}_i$ and $\hat{g}_j$, that were discrepant enough to attain a negative $\hat{S}_{ij}$ value for the pair UNB2U-C1 x Angela, which indicates the cited hybrids based only on the mean. The best combinations were therefore UNB2U-C1 x Angela, Braskalb x Angela and Angela x Viçosa-Viçosa.

For the environment of Itaocara, the best hybrids were UNB2U-C1 x Angela, Braskalb x Angela and Angela x Viçosa-Viçosa. The second stood out mainly for popping expansion and the others for grain yield as well.

The significance for the combining abilities revealed the existence of variability due to the additive and non-additive genetic effects (Table 5). It was therefore inferred that the evaluation in four environments favored the expression of variability among the genotypes for the evaluated traits, as a result of the effects of combining ability.

Freitas Júnior et al. (2006) observed no significant effect of the environment on PE in an evaluation of the diallel components in the growing season 2003/2004. In our study however, the evaluation in trials in four environments, in the growing seasons 2003/2004 and 2004/2005, detected significance of the environmental effect (1% probability). This corroborates the idea that a larger number of environments is favorable for the identification of variability in the genotypes.

For grain yield, the significance at 1% probability by the F test for GCA x environment and SCA x environment interaction (Table 5) allows the conclusion that parents as well as hybrids revealed differences in the evaluated environments. However, the mean-square analysis of the effects showed a difference between the GCAxE and SCAxE values (8130.4869 and 43545.0214, respectively) which indicates a greater differentiation in the hybrids than the parents.

A significance at 1% probability by the F test regarding PE, for genotypes x environment, can be associated to the significance at 1% probability for the GCA x environment interaction. Although the values for GCAxE and SCAxE are equal when observing the mean square effects, it is assumed that genes with additive effect prevail in the trait expression, based on

Table 5. Values and significances of the mean squares of popcorn genotypes, general and specific combining ability, and their interactions with the environment, as well as the mean square effects of the combining ability for three traits evaluated in a circulant diallel in four environments

SV	df	Mean squares[1]		
		GY	PLH	PE
Genotypes	24	1879863.7656 **	924.0285 **	302.2309 **
GCA	9	1773191.8931 **	1109.7318 **	777.9206 **
SCA	15	1943866.8891 **	812.6066 **	16.8170 **
Environments (E)	3	27613517.7291 **	70649.3538 **	116.9652 **
Genotypes x E	72	259986.1753 **	134.4705 ns	12.8757 **
GCA x E	27	232428.4915 **	104.0195 ns	20.0224 **
SCA x E	45	276520.7856 **	152.7411 ns	8.5877 ns
Error	348	102340.7000	107.0912	5.4761
Mean squares of the effects				
GCA		26107.0498	15.6662	12.0694
SCA		115095.3868	44.0947	0.7088
GCAxE		8130.4869	-0.1919	0.9091
SCAxE		43545.0214	11.4124	0.7779

** = Significant at 1% probability by the F test; * = Significant at 5% probability by the F test
[1] GY = grain yield in Kg ha^{-1}; PLH = plant height in cm; and PE = grain popping expansion in mL g^{-1}

the GCA and SCA values (12.0694 and 0.7088, respectively).

The mean square analysis of the effects for PE shows that the best option for the use of the parents in intrapopulation breeding programs is by the formation of genetic composites. For GY and PLH, breeding for superior genotypes requires hybridizations, based on the manifestation of the heterotic effect of these combinations (Cruz et al. 2004).

Of the predicted composites, the best GY and PE expressions were found for the biparental composite, in particular the one derived from the parents UNB2U-C1 and Angela. This combination performed best in all four evaluated environments (1446.09 kg ha^{-1} and 26.54 mL g^{-1}).

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Predição de médias de híbridos e compostos de milho pipoca

RESUMO - *O intento deste trabalho foi avaliar a capacidade combinatória de dez populações de milho pipoca, por meio de dialelo circulante; averiguar a viabilidade de obtenção de híbridos superiores; e identificar compostos genéticos para o melhoramento intrapopulacional. Trinta tratamentos foram avaliados para rendimento de grãos (RG), altura de planta (ALTP) e capacidade de expansão (CE), em quatro ambientes contrastantes, utilizando o delineamento em blocos ao acaso com quatro repetições. Os resultados indicaram que a avaliação dos tratamentos em um grupo maior de ambientes favoreceu a expressão da variabilidade entre genótipos. Houve superioridade dos efeitos aditivos para CE e de dominância para RG e ALTP. As combinações UNB2U-C1 x Angela e Braskalb x Angela destacaram-se para RG e CE. O híbrido UNB2U-C1 x Angela e o composto formado por estes genitores revelaram-se superiores, simultaneamente, para CE e RG, com respectivas médias preditas de 26,54 mL g^{-1} e 1.446,09 kg ha^{-1}.*

Palavras-chave: milho pipoca, dialelo circulante, capacidade combinatória, capacidade de expansão, predição de composto.

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