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Genetic characterization of the 28 maize landraces in Paraná State

Caracterização genética de 28 populações de milho crioulo no Estado do Paraná

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Abstract

The characterization of maize landraces is extremely important in breeding programs for use of these genotypes as sources of genetic variability. The objective of this study was to quantitatively characterize 28 populations of maize landraces from the state of Paraná using the estimates of the effects of varieties and heterosis parents and the general combining ability, thereby assessing the main agronomic traits. In the crop of 2008/09, 56 inter-varietal hybrids, obtained through a topcross, 28 populations of maize landraces and three check varieties were evaluated for female flowering (FF), plant height (PH), ear height (EH) and grain mass (GY). The treatments were evaluated in a randomized block design, with two replications, at three Paraná State locations: the Experimental Center of the Agronomic Institute of Paraná in Londrina (IAPAR) and the experimental units of Pato Branco and Ponta Grossa. The data were submitted to an analysis of variance, considering a fixed model for genotypes and a random model for environments; the averages grouped by the Scott-Knott test, along with intersections of topcrosses, were analyzed according to a readapted model proposed by Oliveira et al. (1997). According to estimates of the parental effects, the GI 133 population showed the most promising estimates for all characteristics. The GI 088 and GI 173 populations stood out with promising estimates of the effects of heterosis. The conclusion is that the populations GI 133 and GI 173 may be indicated for recurrent selection programs or participation in obtaining composites.
Key words: Heterosis effects. Variety effects. Pre-breeding. *Zea mays* L.

Resumo

A caracterização de milho crioulo ou variedades locais de milho é de suma importância em programas de melhoramento, para utilização desses genótipos como fonte de variabilidade genética. O objetivo deste trabalho foi realizar a caracterização quantitativa de 28 populações de milho crioulo, oriundas do estado do Paraná, pelas estimativas dos efeitos de variedades e heterose de parentais e capacidade geral de combinação, avaliando as principais características agronômicas. Na safra de 2008/09, 56 híbridos intervarietais obtidos por meio de um cruzamento "topcross", 28 populações de milho crioulo e mais três testemunhas, foram avaliados quanto ao florescimento feminino (FF), altura de planta (PH) e de espiga (EH) e massa de grãos (GY). Os tratamentos foram avaliados em delineamento de blocos ao acaso, com duas repetições, em três locais do estado de Paraná: no Centro Experimental do Instituto Agronômico do

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Paraná em Londrina (IAPAR) e nas unidades experimentais de Pato Branco e Ponta Grossa. Os dados foram submetidos às análises de variância, considerando-se o modelo fixo para genótipos e aleatório para ambientes, sendo as médias agrupadas pelo Teste de Scott-Knott e os cruzamentos "topcrosses" foram analisados conforme o modelo readaptado proposto por Oliveira et al. (1997). Pelas estimativas dos efeitos de variedades, a população GI 133 apresentou as estimativas mais promissoras para todas as características. As populações GI 088 e GI 173 destacaram-se pelas estimativas promissoras dos efeitos de heterose. Conclui-se que as populações GI 133 e GI 173 podem ser indicadas para programas de seleção recorrente ou participação para formação de compostos.
Palavras-chave: Efeitos de variedade. Efeitos de heterose. Pré-melhoramento. *Zea mays* L.

Introduction

Maize landraces, or maize local varieties, were originated through the direct action of successive generations of family farmers and indigenous communities by crossing old and even recent genotypes, or simply through intrapopulation selection of plants adapted to their farming systems (FERREIRA et al., 2009). Although maize landraces are less productive than commercial cultivars, they have important specific characteristics that justify their evaluation for pre-breeding programs, such as the high potential for adaptation and cultivation in rural environments that have water deficiencies, nutrient shortages, and excess acidity or alkalinity in the soil. These populations are considered a source of genetic variability that can be exploited in the search for genes that are tolerant and/or resistant to biotic and abiotic factors (ARAÚJO; NASS, 2002).

The characterization of maize landraces access to germplasm banks through an evaluation of these variables encourages their use and contributes to the identification of divergent populations with genetic variability, which may be useful for the preliminary prediction of crosses that optimize heterosis (MIRANDA et al., 2003).

Topcrosses are generally used when there is no information available about the genotypes under study. These crosses also allow for the selection of populations for further research of recurrent intra- or inter-population selection (reciprocal recurrent selection), forming compounds or the commercial use of F_1 (GARBUGLIO; ARAÚJO, 2006; HALLAUER; MIRANDA FILHO, 1988). The topcrosses are easy to achieve, thus allowing the evaluation of a large number of genotypes and obtaining important parameters and genetic effects during selection (CRUZ et al., 2004).

Theoretical and experimental evaluations of topcrosses have been presented with the objective of obtaining information about the frequency of favorable alleles, their genetic basis, their general or specific combining ability, the yield "per se," the number of testers and the genealogy between the evaluated genotypes (SEIFERT et al., 2006; FERREIRA et al., 2009; CARPENTIERI-PÍPOLO et al., 2010, CANCELLIER et al., 2011; CLOVIS et al., 2015). Furthermore, topcrosses are widely used in maize breeding programs, with the objective of studying the most diverse agronomic characteristics. Cancellier et al. (2011) evaluated the potential for 70 topcross hybrids selected for plant height, ear height, ear length and ear diameter, 100 seed weight, hectoliter weight and grain yield, observing that nineteen lines presented a set of characteristics that are favorable to the development of commercial genotypes in the production of grain in the southern Tocantins.

Ferreira et al. (2009) reported that few studies have been carried out to evaluate the potential of these maize landrace varieties in crosses. The same authors performed a topcrosses cross between 31 varieties of maize landraces with two hybrids and obtained high estimates of combining ability, allowing for the indication of these genotypes in the synthesis of compounds. Kostetzer et al. (2009) evaluated maize varieties using a partial diallel (11 x 5) and verified that the MC 45 and IAPAR 50 varieties presented promising genetic parameter estimates for all variables. The present work aimed to characterize 28 maize landrace populations for their estimates of variety and heterosis effects and their general combining ability in terms of their main agronomic characteristics.

Materials and Methods

In the growing season of 2007/2008, 56 topcross hybrids were obtained by a partial diallel (28 x 2) between 28 maize landrace populations and two maize tester populations (Table 1).

Table 1. Description of the 28 maize landrace populations, 2 tester populations and check varieties according to the origin, characteristics of the grain, days for female flowering (FF) and one-thousand grain weight (P 1000G).

Maize Landrace Populations					
Genotypes	Origin	Characteristics of the grain		FF	P 1000G
		Type	Color	(days)	(g)
GI 002	Amarilo Opaco Amiláceo	flint	yellow	76	161.38
GI 006	Asteca Lupionópolis	dentate	orange	72	293.44
GI 008	Asteca Nova Esperança	dentate	yellow	72	314.24
GI 018	Cravo n 1	dentate	orange	68	263.44
GI 028	Mato Grosso São João	dentate	orange	68	341.18
GI 036	Roxo asteca (G 5)	dentate	red	70	329.04
GI 045	Tupi Pytá Sopé	dentate	orange	68	298.02
GI 048	Composto Indonésia	flint	orange	64	223.08
GI 049	Palmeira (1)	dentate	yellow	64	287.10
GI 088	RGS III	dentate	yellow	64	314.40
GI 101	Cristal Paraguai	flint	white	75	210.94
GI 104	Peróla	semi- flint	white	68	249.16
GI 105	Tupi Moroti	dentate	white	76	190.12
GI 133	CIMMYT	dentate	orange	62	274.94
GI 135	Milho dos índios	dentate	red	75	322.64
GI 140	Astequinha	dentate	yellow	68	318.16
GI 148	General	dentate	orange	67	289.42
GI 149	Linha Paraná	dentate	yellow	69	337.46
GI 150	Linha Paraná	dentate	white	68	256.92
GI 151	Asteca Baixo	dentate	yellow	70	326.88
GI 152	Amarelão	dentate	yellow	68	254.42
GI 153	Macaco	dentate	yellow	68	363.52
GI 154	Tabuinha	dentate	yellow	70	303.76
GI 155	Dente de Rato	dentate	yellow	70	279.76
GI 156	Caiano Sobralia	dentate	yellow	68	321.92
GI 157	Asteca Branco	dentate	white	75	336.74
GI 158	Antigo Maia	dentate	yellow	69	340.26
GI 173	Palotina – PR	dentate	yellow	68	377.68
Check Varieties					
IPV 2122	IAPAR	dentate	orange	65	312.54
IPR 114	IAPAR	dentate	orange	71	331.81
IPR 115	IAPAR	dentate	orange	65	309.52
Testers					
PC 0201	IAPAR	dentate	yellow	65	319.44
PC 0202	IAPAR	dentate	orange	65	321.62

GI: germplasm introduced.

The performance of the 56 hybrids, the tester populations, the maize landrace populations *per se* and the three check varieties, IPV 2122, IPR 114 and IPR 115, were evaluated during the 2008/2009 harvest at three locations in the state of Paraná: Londrina, Pato Branco and Ponta Grossa. The following agronomic traits were evaluated: female flowering (FF) in days, from emergency to stigma style emission in 50% of the plants of the plot; plant height (PH) in centimeters, measured from the soil surface to the curvature of the flag leaf; ear height (EH) in centimeters, measured from the soil surface to the point of insertion of the upper ear; and grain yield (GY) resulting from the mechanical threshing of the plot ears, measured with an electronic scale in kg ha^{-1} (corrected for 14% humidity and ideal stand). For GY, only the data from Pato Branco and Ponta Grossa were considered, as those of Londrina were discarded due to the occurrence of drought.

The experimental design was a randomized complete block design, with two replications in three environments. The plot consisted two 5m long rows, spaced 0.80 m apart between rows and 0.2 m between plants, totaling 25 plants per row after thinning.

At all locations, fertilization was performed using 350 kg ha^{-1} of NPK (8:28:16), and the topdressing fertilization was performed using 60 kg ha^{-1} of N supplied as urea.

The data were submitted to individual and joint analyses of variance, according to the simple factorial model with additional check varieties, with fixed genotypes and as random environments (CRUZ et al., 2004). The means were compared using the Scott-Knott test (1974) at 5% probability.

The topcross hybrids were evaluated according to the model readaptation of Miranda Filho and Geraldi (1984), proposed by Oliveira et al. (1987), applicable to partial diallels, considering several environments. The model for diallel crosses includes two population groups and the hybrids resulting from inter-varietal crosses of distinct groups. When the assays were repeated in several environments, the model was readjusted by Oliveira et al. (1987) as follows:

$$Y_{ij} = \bar{\mu} + \alpha d + \ell_i \tfrac{1}{2}\left(v_i + v_{j'}\right) + \theta\left(\bar{h} + h_i + h_j + s_{jj'}\right) +$$

$$+ \alpha \ell d_i + \tfrac{1}{2}\left(\ell v_{ij} + \ell v_{ij'}\right) + \theta\left(\ell\bar{h} + \ell h_i + \ell h_j + \ell s_{jj'}\right)\ \bar{\varepsilon}_{ijj'},$$

where Y_{ij}: = the average of hybrids resulting from crosses between the jth group 1 population and the J population of group 2 in the i-th environment; $\bar{\mu}$ = average of the averages of both groups for all environments; ℓ_i = the effect of the i-th environment; α= of value 0, and –1 and 1 for hybrids for the group of higher average genotypes and the lower average group, respectively; d = the difference between the two groups; v_i and v_j = the effect of the variety of groups (1) and (2), respectively; θ = the value 0 for variety and 1 for hybrids; $\bar{h}$ = effect of the mean heterosis of crosses; h_i and h_j = the effect of the heterosis of the variety of groups (1) and (2), respectively; s_{ij}: = the effect of the specific heterosis of the jj"-th hybrid; and $\bar{\varepsilon}_{ijj'}$ = experimental error associated with hybrids or parental traits.

Statistical analyses were performed using the packages GENES (CRUZ, 2006) and MAPGEN (FERREIRA, 1993).

The estimate of the general combining ability ($\hat{g}_i$) was calculated using the following expression (GRIFFING, 1956):

$$\hat{g}_i = \frac{v_i}{2} + h_i,$$

where v_i= variety effect and h_i = heterosis effect.

Results and Discussion

The joint analyses of variance detected significant differences ($p < 0.05$ and $p < 0.01$) for FF, PH and GY for treatments (T) and genotypes

(G), inferring the differences in performance among the evaluated genotypes (Table 2). The effects of T x E were significant ($p < 0.05$) only for PH, EH and GY, so their means are presented by location. When there is significance in this interaction, this indicates that there is a possibility of a genotype presenting excellent performance in one environment, while not being influenced by the recommendation of cultivars for wide adaptability in another (CLOVIS et al., 2015).

The coefficients of variation obtained in this study ranged from low to medium, indicating that the experimental design was satisfactory in controlling environmental variation, while allowing reliable data to be obtained (FRITSCHE-NETO et al., 2012; PIMENTEL-GOMES, 2000).

Table 2. Mean squares (MS) in the joining analysis for female flowering (FF), plant height (PH), ear height (EH) and grain yield (GY) of topcross hybrids and maize landrace populations. Londrina, Pato Branco and Ponta Grossa – PR. Season 2008/09.

Source of variation	df	Mean Squares (MS)			df’	MS
		FF	PH	EH		GY
		(days)	(cm)			(kg ha^{-1})
Treatments (T)	88	42.26**	1025.61*	471.41 ^{ns}	88	11531242.21**
Genotypes (G)	85	39.41**	1056.22*	480.03 ^{ns}	85	11396954.9**
Check Varieties (C)	2	10.88^{ns}	236.16 ^{ns}	96.05 ^{ns}	2	6970549*
Groups (Gru)	1	347.57*	2.74 ^{ns}	489.48 ^{ns}	1	32067049.76*
Environments (E)	2	6360.20**	53882.72**	75054.76**	1	4454471.02*
T x E	176	16.03 ^{ns}	706.07*	448.28*	88	2677926.03*
G x E	170	16.33 ^{ns}	725.25 ^{ns}	457.37 ^{ns}	85	2764161.94 ^{ns}
C x E	4	2.55 ^{ns}	176.58 ^{ns}	208.55 ^{ns}	2	167510.33 ^{ns}
Gru x E	2	17.33 ^{ns}	134.18 ^{ns}	155.13 ^{ns}	1	368705.17 ^{ns}
Error	264	15.38	205.53	132.47	176	1053914.39
General means		75	219	122		5345
Genotype means		75	211	118		5289
C means		75	205	110		6952
CV (%)		5.00	6.78	9.72		19.20

df’: Degrees of freedom considering two environments.
**, *: significant at 5% and 1% probability by test F.
^{ns}: no significant at 5% and 1% probability by test F.

For female flowering (FF), most of the hybrids (92%) had averages similar to the commercial ones being considered as early genotypes (Table 3). Regarding plant height (PH) in Londrina, the test did not stratify the genotypes into groups. The averages presented in Pato Branco were divided into two groups (a and b), whereas in Ponta Grossa, the genotypes had very different PH means and were separated into 11 groups. For AE, three groups (a, b and c) were observed in Londrina, two groups in Pato Branco (a and b), and five groups in Ponta Grossa (a-e). For grain yield (GY), the hybrids in Pato Branco were divided into four groups, and only 19 hybrids did not differ from the means presented by the evaluated varieties. In Ponta Grossa, the hybrids were divided into three groups (a, b and c) and some hybrids, such as GI 088 x TC1, GI 133 x TC1, GI 045 x TC2, GI 148 x TC2 and GI173 x TC2, were shown to have similar performance to check variety IPR 115 (group a). GI 088 x TC1, GI 133 x TC1, GI 148 x TC2 and GI 173 x TC2 hybrids exhibited satisfactory performance for GY in both environments. All these results indicate that these genotypes of maize landraces exhibit a performance different from the traits in environments where testing was done and that this fact informs selection.

Table 3. Means for female flowering (FF), plant height (PH), ear height (EH) and grain yield (GY) of topcross hybrids and of check varieties in three environments of Paraná state, Londrina (LD), Pato Branco (PB) and Ponta Grossa (PG). Season 2008/09.

Hybrids	FF (days)	PH (cm)			EH (cm)			GY (kg ha^{-1})	
	Means	LD	PB	PG	LD	PB	PG	PB	PG
GI 002 x TC1	76 c	208 a	193 b	205 i	118 c	93 b	120 d	5652 b	4412 c
GI 006 x TC1	73 c	235 a	178 b	243 e	123 b	90 b	158 b	6091 b	6903 b
GI 008 x TC1	76 c	240 a	200 a	251 d	140 a	103 b	140 c	6756 a	6401 b
GI 018 x TC1	75 c	253 a	205 a	245 e	160 a	125 a	136 c	6109 b	9178 a
GI 028 x TC1	76 c	233 a	180 b	226 g	143 a	90 b	123 d	5779 b	6954 b
GI 036 x TC1	76 c	235 a	208 a	250 d	135 a	100 b	153 b	7019 a	7465 b
GI 045 x TC1	74 c	233 a	180 b	206 i	138 a	90 b	108 e	5991 b	6329 b
GI 048 x TC1	75 c	220 a	195 b	231 f	128 b	110 a	138 c	5079 c	9329 a
GI 049 x TC1	75 c	250 a	203 a	233 f	138 a	105 a	140 c	5064 c	7419 b
GI 088 x TC1	75 c	130 a	195 b	238 e	135 a	103 b	123 d	6589 a	8289 a
GI 101 x TC1	77 c	215 a	208 a	234 f	133 b	133 a	130 d	5886 b	5089 c
GI 104 x TC1	76 c	243 a	215 a	242 e	145 a	118 a	139 c	5323 b	6103 b
GI 105 x TC1	81 b	223 a	180 b	239 e	143 a	93 b	146 c	5630 b	8633 a
GI 133 x TC1	73 c	220 a	185 b	215 h	108 c	98 b	113 e	6522 a	7860 a
GI 135 x TC1	77 c	245 a	208 a	267 b	143 a	118 a	161 b	6280 b	5150 c
GI 140 x TC1	76 c	215 a	225 a	241 e	133 b	115 a	140 c	6187 b	6672 b
GI 148 x TC1	74 c	233 a	218 a	239 e	133 b	120 a	131 d	6824 a	9271 a
GI 149 x TC1	75 c	245 a	233 a	226 g	145 a	130 a	125 d	7104 a	7061 b
GI 150 x TC1	79 b	243 a	208 a	210 i	130 b	108 a	126 d	5774 b	7067 b
GI 151 x TC1	73 c	235 a	188 b	246 e	130 b	98 b	143 c	3670 d	6503 b
GI 152 x TC1	73 c	248 a	198 b	244 e	143 a	85 b	126 d	7040 a	7441 b
GI 153 x TC1	75 c	238 a	200 a	240 e	138 a	110 a	130 d	5710 b	9283 a
GI 154 x TC1	79 b	245 a	208 a	247 e	148 a	113 a	126 d	6832 a	6532 b
GI 155 x TC1	78 c	223 a	213 a	233 f	130 b	120 a	121 d	6390 b	6981 b
GI 156 x TC1	74 c	225 a	208 a	219 h	130 b	98 b	121 d	6647 a	6620 b
GI 157 x TC1	79 b	238 a	183 b	217 h	140 a	93 b	118 d	6014 b	4563 c
GI 158 x TC1	76 c	233 a	193 b	219 h	130 b	85 b	119 d	6742 a	7378 b
GI 173 x TC1	74 c	243 a	190 b	215 h	140 a	100 b	164 b	5443 b	6775 b
GI 002 x TC2	76 c	243 a	180 b	219 h	158 a	85 b	138 c	3008 d	6452 b
GI 006 x TC2	78 c	235 a	200 a	221 h	140 a	100 b	121 d	7546 a	4502 c
GI 008 x TC2	76 c	258 a	198 b	240 e	163 a	98 b	133 d	6661 a	5961 b
GI 018 x TC2	73 c	253 a	188 b	219 h	160 a	88 b	115 e	7623 a	6316 b
GI 028 x TC2	74 c	233 a	173 b	236 f	133 b	88 b	133 d	5883 b	8520 a
GI 036 x TC2	75 c	258 a	185 b	223 g	140 a	80 b	124 d	5385 b	6444 b
GI 045 x TC2	75 c	240 a	210 a	223 g	143 a	105 a	126 d	6295 b	8338 a
GI 048 x TC2	71 c	238 a	198 b	200 j	148 a	93 b	108 e	3812 d	5585 c
GI 049 x TC2	74 c	223 a	178 b	219 h	138 a	93 b	119 d	6734 a	7432 b
GI 088 x TC2	74 c	223 a	183 b	226 g	133 b	88 b	163 b	5152 c	7304 b
GI 101 x TC2	77 c	230 a	185 b	236 f	148 a	90 b	133 d	4516 c	5720 b
GI 104 x TC2	73 c	248 a	190 b	209 i	148 a	90 b	110 e	5790 b	5550 c
GI 105 x TC2	77 c	228 a	203 a	223 g	138 a	103 b	131 d	6017 b	6727 b
GI 133 x TC2	70 c	243 a	185 b	195 j	138 a	95 b	110 e	5477 b	10188 a
GI 135 x TC2	77 c	265 a	188 b	243 e	150 a	93 b	140 c	5987 b	7945 a

continue

continuation

GI 140 x TC2	75	c	238	a	203	a	205	i	135	a	108	a	105	e	7463	a	4242	c
GI 148 x TC2	73	c	253	a	183	b	238	e	150	a	88	b	138	c	7129	a	8770	a
GI 149 x TC2	74	c	248	a	195	b	219	h	148	a	90	b	111	e	6399	b	8246	a
GI 150 x TC2	73	c	238	a	195	b	225	g	145	a	93	b	125	d	5174	c	8558	a
GI 151 x TC2	75	c	245	a	188	b	230	f	140	a	98	b	128	d	6328	b	8694	a
GI 152 x TC2	72	c	258	a	183	b	225	g	158	a	85	b	122	d	4452	c	7549	b
GI 153 x TC2	72	c	263	a	193	b	238	e	160	a	93	b	145	c	6602	a	7624	b
GI 154 x TC2	75	c	240	a	173	b	237	f	145	a	75	b	140	c	6300	b	7538	b
GI 155 x TC2	76	c	233	a	193	b	231	f	135	a	108	a	128	d	4722	c	6003	b
GI 156 x TC2	72	c	233	a	183	b	227	g	135	a	85	b	118	d	5992	b	8418	a
GI 157 x TC2	78	c	258	a	190	b	230	f	148	a	95	b	128	d	4744	c	7202	b
GI 158 x TC2	75	c	240	a	180	b	225	g	148	a	88	b	124	d	6680	a	5819	b
GI 173 x TC2	74	c	235	a	180	b	232	f	140	a	85	b	134	c	6438	a	10104	a
Check Varieties	FF (days)		PH (cm)						EH (cm)						GY (kg ha^{-1})			
	Means		LD		PB		PG		LD		PB		PG		PB		PG	
IPV 2122	75	c	206	a	180	b	206	i	113	c	75	b	113	e	8989	a	7901	a
IPR 114	74	c	234	a	168	b	234	f	125	b	90	b	125	d	6713	a	7640	b
IPR 115	74	c	226	a	170	b	226	g	130	b	88	b	130	d	6946	a	8967	a
General Means	75		236		193		228		139		98		129		6052		7185	
CV (%)			9,2		7,6		1,5		7,9		13,4		7,7		10,5		19,8	

Means followed by the same letter do not differ by the Scott-Knott test ($p < 0.05$).

In the joint partial diallel analysis (Table 4), we observed that there were significant differences between the QM's for the sources of variation (SV), treatments (T) and the parents 2 (P2) for all of the variables analyzed, indicating that there is genetic variability among the evaluated populations. For Parental 1 (P1), a group composed of the test populations, there was no significance ($p > 0.05$) of any traits. The Parents 2 (P2), a group composed of 28 maize landraces, exhibited significant differences for all traits, inferring that the maize landrace populations differ in their average allelic frequencies, contributing differently at intersections where they are involved. The groups (Gru) presented significant differences for the PH and GY, indicating that there was different behavior among them. In relation to the split of the QM's of the effects of heterosis in medium heterosis ($\bar{h}$), a significant difference occurred for the PH and EH, evidencing that the populations in crossbreeding obtained averages higher than the populations *per se*. Parental heterosis 2 (HP2) presented significant differences only for female flowering (FF). The absence of significance for heterosis of parents presented by PH, EH and GY indicated that groups of Parental 1 (P1), testers, Parents (P2) and maize landraces populations when crossbreed do not present heterotic potential (s_{ij}). Araújo and Miranda Filho (2001) also did not find significant differences for heterosis of varieties and total heterosis for the same traits analyzed in this work.

Table 4. Mean squares (MS) in the diallel analysis for female flowering (FF), plant height (PH), ear height (EH) and grain yield (GY) applicable to partial diallels in several environments (Oliveira et al., 1987) Pato Branco, Ponta Grossa and Londrina-PR. Season 2008/2009.

Source of Variation	df	Mean squares (MS)			df[(a)]	MS
		FF	PH	EH		GY
		(Days)	(cm)			(kg ha^{-1})
Environments (E)	2	1819.27 **	25784.76 **	38147.49 **	1	33982.03 **
Treatments (T)	85	38.17 **	527.43 **	250.29 **	85	3713.50 **
Parental 1 (P1)	1	0.02 ns	225.33 ns	261.33 ns	1	1007.31 ns
Parental 2 (P2)	27	36.24 **	607.54 **	431.66 **	27	3385.59 **
Groups (Gru)	1	8.37 ns	11992.03 **	257.19 ns	1	164125.59 **
Heterosis (H)	56	40.31 **	289.47 ns	162.52 ns	56	1055.42 ns
Means heterosis (MH)	1	14.32 ns	6975.03 **	2246.28 **	1	2878.92 ns
Parental heterosis 1 (PH1)	1	3.24 ns	48.76 ns	0.76 ns	1	1883.72 ns
Parental heterosis 2 (PH2)	27	34.92 **	205.50 ns	140.56 ns	27	1010.14 ns
Specific heterosis (SH)	27	48.04 ns	134.74 ns	113.29 ns	27	1002.49 ns
E x T	170	39.72 **	364.34 ns	277.68 **	85	1360.19 ns
E x P1	2	14.85 ns	1513.13 **	796.91 **	1	2519.73 ns
E x P2	54	26.20 **	133.56 ns	151.80 ns	27	672.54 ns
E x Gru	2	274.18 **	14422.70 **	7972.58 **	1	1702.16 ns
E x H	112	42.49 **	204.06 ns	191.69 **	56	1664.93 *
E x MH	2	105.02 **	2306.66 **	1054.26 **	1	342.00 ns
E x PH1	2	7.40 ns	98.38 ns	71.77 ns	1	1806.40 ns
E x PH2	54	36.63 **	178.47 ns	182.27 ns	27	1710.75 *
E x SH	54	47.34 ns	155.69 ns	173.60 ns	27	1662.86 ns
Error	255	15.85	212.43	133.00	170	1088.42
Means		73	199	109		5716

[1]; QM x 10^3

**, *: significant at 5% and 1% probability by test F.

ns: no significant at 5% and 1% probability by test F.

In relation to the estimates of varietal effects ($\hat{v}_j$), the GI 018 population was highlighted because it presented the lowest $\hat{v}_i$ estimate for FF, contributing to the reduction of the cycle by up to 6 days (Table 5). For PH, the populations GI 150 and GI 133 stood out with negative $\hat{v}_i$ estimates of 20 cm, indicating that these populations, on average, contributed to the reduction in plant height. The lowest $\hat{v}_i$ estimate for EH was observed once again in the GI 150 population (-23 cm). The highest $\hat{v}_i$ estimates for GY were observed for the GI 148, GI 049 and GI 155 populations. The GI 133 stood out for the purpose of varietal estimates of most promising varieties for all traits, negatives estimates for FF (-4 days), PH (-20 cm), EH (-21 cm) and positives estimates for GY (1,015 kg ha^{-1}), allowing its indication for recurrent selection programs or obtaining compounds. The effect of varieties is the performance of the “i” population, performance *per se*, in relation to the average of the other populations, which is related to the additive components of the averages (GARDNER; EBERHART, 1966). According to HALLAUER et al. (1988), for the PH and FF, negative and smaller values for parameter estimates are highly desirable, since they contribute to the additive model, reducing the mean PH and FF of the populations. Thus, it is valuable to select genotypes with negative estimates that contribute to the reduction of FF, PH and EH (SOLALINDE et al., 2014). For PH and EH, there is a predominance of additive effects and only partial dominance (GORGULHO; MIRANDA FILHO 2001).

The parental heterosis parameter ($\hat{h}_i$) to FF oscillated between –13 days (GI 036) to 4 days (GI 018), wherein the GI 036 population stood out by having the lower estimate. For PH and EH, the GI 088 (-22 cm) and GI 036 (-14 cm) populations were outstanding, with the most negative values. The highest estimates of the effects of heterosis on GY were presented by the GI 018 (1121 kg ha^{-1}) and GI 105 (775.32 kg ha^{-1}) populations. Two populations, GI 088 and GI 173, stood out as having promising estimates for all variables, low and negative for FF, PH and EH, and high and positive for GY (Table 5), inferring that these populations in crossing will result in more heterotic hybrid combinations (CRUZ et al., 2004). According to Bernini and Paterniani (2012), the parental heterosis parameter is the difference between the mean of the heterosis of the hybrids and the mean heterosis.

For general combining ability ($\hat{g}_i$), the GI 088, GI 133 and GI 156 populations revealed promising negative estimates, contributing to a reduction in FF, PH and EH (Table 5). These same populations exhibited promising and significant $\hat{g}_i$ estimates toward increasing GY as GI 133 (963 kg ha^{-1}), GI 156 (439 kg ha^{-1}) and GI 088 (373 kg ha^{-1}). The general combining ability is a genetic parameter obtained due to the genetic differences in the parents and the average effects of an allelic substitution being associated with additive effects (HALAUER; MIRANDA FILHO, 1988). Kostetzer et al. (2009), evaluating local varieties of Paraná and synthetic maize varieties, identified promising $\hat{g}_i$ estimates in the following varieties: MC45 (0,33 kg ha^{-1}) in São João do Triunfo and IAPAR 50 (0,59 kg ha^{-1}) in Londrina. Ferreira et al. (2009), evaluated 31 maize landrace populations in two locations in the state of Paraná, obtained from Londrina, and their estimates ranged from –0,670 kg ha^{-1} (MC 13) to 980 kg ha^{-1} (MC 31). Senhorinho et al. (2015) evaluated common maize cultivars and found that $\hat{g}_i$ affects the promise for increasing GY in 30B39, 30K64 and 30B30, indicating the difference in the vigor of the maize landrace populations in comparison with modern maize cultivars. Oliboni et al. (2013) evaluated maize commercial cultivars and selected the hybrids P30F44 and 2B688 for the potential confirmed by the high $\hat{g}_i$ estimates obtained for grain yield and plant height.

In pre-breeding, it is difficult to gather genotypes that present promising genetic parameters for all evaluated traits, thus requiring selection. This is even more true when working with maize landrace populations that present very different traits. However, the $\hat{g}_i$ estimates are associated with the frequency of favorable alleles for traits of agronomic interest (VENCOVSKY; BARRIGA, 1992), emphasizing that the positive estimates reflect the genotype for the contribution to an increase or a negative reduction in the trait. Thus, the maize landrace population GI 133 brought together the best effects of varieties ($\hat{v}_i$) and general ability combining ($\hat{g}_i$), allowing for use in recurrent selection programs or in obtaining hybrids and composites. The GI 088 population has collected the best estimates that can also be used in recurrent selection programs and for incorporation into hybrid combinations.

Table 5. Estimates of the effects of population (v_i and v_j), parental heterosis (h_i and h_j) and general combining ability GCA (g_i and g_j) on 28 maize landrace populations evaluated in Londrina, Pato Branco and Ponta Grossa-PR. Season 2008/09.

V(1)	FF	PH	EH	GY	V(1)	FF	AP	AE	MG	V(1)	FF	PH	EH	GY
	$\hat{v}_i$					$\hat{h}_i$					$\hat{g}_i$			
	days	cm		kg ha^{-1}		days	cm		kg ha^{-1}		days	cm		kg ha^{-1}
PC 0201	0,67	-4,83	-2	-464,5	PC 0201	-0,39	1,52	-0,19	366,81	PC 0201	-0,06	-0,89	-1,19	134,56
PC 0202	-0,67	4,83	2	464,5	PC 0202	0,39	-1,52	0,19	-366,81	PC 0202	0,06	0,89	1,19	-134,56
V(2)	$\hat{v}_j$				V(2)	$\hat{h}_j$				V(2)	$\hat{g}_j$			
GI 002	3	-10	-7	-488	GI 002	1	-7	2	-1278	GI 002	2**	-12**	-2	-1522**
GI 006	3	19	14	656	GI 006	0	-6	-5	-409	GI 006	1**	4**	1	-81
GI 008	1	9	6	316	GI 008	2	7	5	-75	GI 008	2**	12**	8**	83
GI 018	-6	3	4	-414	GI 018	4	5	4	1121	GI 018	1*	6**	5**	914**
GI 028	4	-20	-7	246	GI 028	-2	7	3	189	GI 028	-1	-3*	-1	312*
GI 036	-1	-5	-1	-822	GI 036	-13	8	-14	-1155	GI 036	-13**	5**	-15**	-1566**
GI 045	-3	-7	-9	207	GI 045	3	2	1	205	GI 045	1**	-2	-3**	309*
GI 048	-2	-13	-19	-2117	GI 048	-1	-3	7	-134	GI 048	-2**	-10**	-2*	-1192**
GI 049	-2	0	3	1400	GI 049	1	-5	-6	-487	GI 049	0	-5**	-5**	213
GI 088	-1	1	1	-726	GI 088	0	-22	1	737	GI 088	-1*	-21**	2*	373**
GI 101	1	-6	-2	-1269	GI 101	1	0	5	-446	GI 101	1*	-2*	4**	-1080**
GI 104	-1	-13	-10	-606	GI 104	1	10	8	-377	GI 104	1	4**	3**	-680**
GI 105	-1	-11	-9	-2019	GI 105	2	4	9	775	GI 105	1**	-1	5**	-234*
GI 133	-4	-20	-21	1015	GI 133	1	-2	-2	456	GI 133	-1*	-12**	-12**	963**
GI 135	0	19	27	-936	GI 135	0	8	-4	365	GI 135	1	17**	9**	-103
GI 140	2	9	10	900	GI 140	1	-9	-8	-611	GI 140	3**	-4**	-3**	-161
GI 148	4	4	3	2122	GI 148	-2	3	-1	471	GI 148	0	6**	1	1531**
GI 149	2	23	20	989	GI 149	-1	-9	-12	247	GI 149	0	3*	-2**	742**
GI 150	-3	-21	-23	-789	GI 150	1	6	8	524	GI 150	-1	-4**	-4**	129
GI 151	2	9	7	604	GI 151	-1	1	0	-481	GI 151	0	5**	3**	-179
GI 152	-1	8	8	-61	GI 152	0	3	-3	149	GI 152	0	7**	0	119
GI 153	-1	10	11	849	GI 153	-1	3	1	424	GI 153	-2**	8**	7**	848**
GI 154	1	-1	-7	-1402	GI 154	0	7	8	668	GI 154	1	7**	4**	-33
GI 155	2	-11	-4	1218	GI 155	0	4	2	-960	GI 155	2**	-2	-1	-351**
GI 156	-3	2	-5	679	GI 156	1	-6	-5	99	GI 156	-1*	-5**	-8**	439**
GI 157	2	7	2	35	GI 157	0	0	0	-793	GI 157	2**	3**	0	-776**
GI 158	-3	9	4	-149	GI 158	3	-9	-3	373	GI 158	2**	-4**	-1	298*
GI 173	4	6	5	563	GI 173	-1	-5	2	404	GI 173	1	-2	5**	686**
Means	73	199.1	109.52	5716.19										
D	-1.01	-0.92	-6.18	1567.81										
Heterosis	0.85	18.78	10.66	467.43										

Conclusions

Topcross hybrids exhibited productive potential and differential performance in the environments in which they were evaluated.

Maize landrace GI 133 and GI 173 populations presented *per se* positive potential for indication in recurrent selection programs or for participation in obtaining composites.

The GI 088 and GI 173 populations stood out in terms of the effects of heterosis ($\hat{h}_i$), indicating that they are promising populations for maize breeding programs.

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