HETEROTIC RESPONSES OF TROPICAL ELITE MAIZE ACCESSIONS FROM LATIN AMERICA WITH BRAZILIAN TESTERS

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ABSTRACT: Little emphasis has been placed on identifying new sources of tropical maize germplasm that can be used in breeding programs. Additional information on the performance and heterotic classification of tropical germplasm is needed. This study was conducted to identify elite maize accessions from Latin America that could contribute to increase the level of heterosis with the best heterotic patterns of Brazil. Seventy-two elite accessions from the Latin American Maize Project (LAMP) were crossed with the testers BR 105 (flint kernel Suwan background) and BR 106 (dent kernel Tuxpeño background). The 72 crosses plus 9 checks were evaluated using a simple 9 × 9 lattice in four locations that represent one tropical region. The combined analysis showed highly significant differences among treatments for ear weight and the interaction treatment × location was also significant. With both testers better crosses for ear weight were identified in relation to the double cross BR 201 (commercial check). With the tester BR 105, the high parent heterosis ranged from –28% to 26%, the accessions SE 032 and PE 001 were selected for further work. With the tester BR 106, the high parent heterosis ranged from –35% to 17% and the accessions PE 011 and Pasco 14 were selected for further work. The selected accessions will be improved through recurrent selection schemes to increase yield and improve agronomic traits. Afterwards they can be exploited, within and between heterotic groups, to produce highly productive hybrid combinations, or used per se as improved maize varieties.
Key words: germplasm, selected acessions, heterosis, genetic resources

RESPOSTAS HETERÓTICAS DE ACESSOS ELITES TROPICAIS DO PROGRAMA LATINO AMERICANO DE MILHO EM CRUZAMENTO COM TESTADORES BRASILEIROS

RESUMO: Pouca ênfase tem sido dada na identificação de novas fontes de germoplama tropical que podem ser usadas em programas de melhoramento de milho. São necessárias informações adicionais sobre a performance e classificação heterótica de germoplasmas tropicais. O objetivo deste estudo foi identificar acessos elite originados do Programa Latino Americano de Milho (LAMP) que poderiam contribuir para aumentar o nível de heterose com padrões heteróticos do Brasil. Setenta e dois acessos elites do LAMP foram cruzados com os testadores BR 105 (padrão heterótico flint) e BR 106 (padrão heterótico dentado). Os setenta e dois testcrosses, resultantes de cada cruzamento, e nove testemunhas foram avaliados em quatro locais. Utilizou-se o delineamento em látice simples 9 × 9. A análise combinada mostrou diferença significativa entre tratamentos para o caráter peso de espigas sendo também significativa a interação tratamentos × locais. Foram identificados, com ambos os testadores, cruzamentos mais produtivos que o híbrido duplo BR 201 (testemunha comercial). Com a variedade BR 105, a heterose em relação ao pai superior variou de –28% a 26% e os acessos SE 032 e PE 001 foram selecionados para melhoramento. Com a variedade BR 106, a heterose em relação ao pai superior variou de –35% a 17% e os acesses PE 011 e Pasco 14 foram selecionados para posteriores trabalhos de melhoramento. Os acessos selecionados serão melhorados através de esquemas de seleção recorrente para produção e características agronômicas. Estes acessos podem ser explorados, dentro e entre os grupos heteróticos, para produzir combinações híbridas ou para serem usados como variedades melhoradas de milho.
Palavras-chave: germoplasma, acessos selecionados, heterose, recursos genéticos

INTRODUCTION

The international scientific community has recently called attention to the need for more efficient conservation and utilization of plant genetic resources. Maize genetic biodiversity is great and the importance of genetic resources has long been emphasized for increasing the genetic base of cultivated maize and in maize breeding programs (Brown, 1953; Wellhausen, 1965; Brown & Goodman, 1977; Hallauer & Miranda

Filho, 1981; Duvick, 1984; Goodman, 1985; Salhuana et al., 1992). The use of maize genetic resources, however, is still limited due to the lack of agronomic information, poor adaptation, tendency for root and stalk lodging and time required to obtain improved cultivars (Brown, 1975; Hallauer, 1978; Stuber, 1986; Nass et al., 1993; Uhr & Goodman, 1995). Despite these problems a few breeders have worked with exotic populations and reported an increase in yield when crossing exotic with adapted populations due to the genetic diversity between the parental populations (Longquist & Gardner, 1961; Kauffman et al., 1982; Crossa et al., 1987 Becker et al., 1991; Michelini & Hallauer, 1993).

Information about heterotic patterns, essential to maximize the use of genetic resources in breeding programs, has been increasing in recent years for tropical maize. Maize germplasm introductions from Mexico have shown good adaptation in Brazil. Their inclusion in breeding programs have resulted in commercial varieties that are good sources for extracting inbred lines in private or public research institutions (Naspolini et al., 1981; Gama et al., 1982; Santos et al., 1994). The Latin American Maize Project (LAMP) provided an excellent oportunity to select the best tropical accessions for participating countries (Salhuana et al., 1992), and now each country can utilize selected accessions as new gene pools for developing improved varieties and hybrids.

The objectives of this study were to: (i) identify among tropical elite maize accessions from the LAMP those that could contribute to increased levels of heterosis with the best heterotic pattern from Brazil; and (ii) incorporate the selected accessions into breeding programs.

MATERIAL AND METHODS

The Latin American Maize Project (LAMP) was an international project funded by Pioneer Hi-Bred International, Inc., to systematically evaluate maize genetic diversity for use in present and future breeding programs. The twelve countries involved evaluated more than 12,000 landrace accessions from the Americas (Salhuana et al., 1992). Because of differences in environments and growing seasons among the twelve countries the project was divided into five homologous areas (HA) according to altitude and latitude. Brazil was included in HA 1 which included tropical regions located between 0° to 23° N or S latitudes with altitudes below 1,200 meters above sea level (masl). The project was also divided into five stages of evaluation. Brazil evaluated 1,340 and 352 accessions, in the first and second stages, respectiveley. After the second stage the best 5% were selected for the third stage. The same protocol was used in the other countries, varying only the number of evaluated accessions. In the third stage, seeds of the best 5% were interchanged among countries with the same HA in order to make testcrosses. In this stage in Brazil, testcrosses using the testers BR 105 and BR 106 were made with five accessions from Bolivia, seven from Guatemala, fifteen from Mexico, two from Paraguay, fourteen from Peru, five from Venezuela, seven from the United States, and seventeen from Brazil.

The crosses were made in two isolated fields with different planting dates for accessions and testers. Accessions were detasseled and thus used as females. In 1991, the 72 crosses plus 9 checks were planted in a 9x9 simple lattice design at Sete Lagoas-MG (latitude 19°47’45"S and longitude 44°14’48"W), Goiânia-GO (latitude 16°40’43"S and longitude 49°15’14"W), Propriá-SE (latitude 10°12’40"S and longitude 36°50’25"W) and Janaúba-MG (latitude 15°48’09"S and 43°18’32"W). The common check in each experiment was the tester (BR 105 or BR 106) which was repeatedly interplanted in each incomplete lattice block. The means for these testers were considered as the superior parents for calculating heterosis estimates.

All experiments used fertilization and cultural practices of conventional maize farming systems. Data were recorded at four locations for plant height (cm), ear height (cm), number of broken stalks (B) and root lodging (R), ear number per plot, and yield measured as ear weight (Y) in t ha^{-1}. Data for 50% male and female flowering were only observed in Sete Lagoas-MG and Propriá-SE. Yield data were adjusted to 14.5% moisture based on grain moisture samples taken on the same day of harvest. Data for broken stalks and root lodging (B+R) were transformed to $\sqrt{B+R+1}$. Prolificacy was calculated using an ear index (EI, ear number per plot over final stand).

Analyses of variance were carried out for each location according to Cochran & Cox (1957). Adjusted treatments means were used for the combined analysis over the four locations. This analysis was done based on a randomized complete block design since lattice efficiency of each experiment was low. Location was considered as a random model effect and treatments were considered as fixed effects. Adjusted mean yield values were used for estimating heterosis in relation to the superior parent. LSD was calculated as $t_{5\%}\sqrt{2MS(TxL)/r}$.

RESULTS AND DISCUSSION

Analysis of variance of the means from the crosses with the tester BR 105, combined across four locations (TABLE 1), showed highly significant differences among treatments for all traits (P≤0.01). For treatments x locations interaction, significant differences were found (P≤0.01) for yield (YI), ear height (EH) and square root of broken stalks + root lodging (B+R), but no significant differences were detected for the plant height (PH) and ear index (IE). The crosses with the tester BR 106 (TABLE 2) also showed significant differences among treatments (P≤0.01) for all traits, but for treatments x locations interaction significant differences were only found for YI(P≤0.05) and B+R (P≤0.01). The four environments where the treatments were evaluated fall could be

TABLE 1 - Mean squares of the combined analysis of variance for trials with tester BR 105 over four environments for yield (Y), plant height (PH), ear height (EH), ear index (EI) and square root of broken stalks + root lodging + 1 (B+R).

Source	MEAN SQUARES					
	d.f.	Y	PH	EH	EI	B + R
Locations (L)	3	209.80	54,856	53,113	0.94	184.79
Treatments (T)	80	3.72**	1,358**	903**	0.02**	1.49**
T x L	246	1.24**	379	206**	0.01	0.56**
Mean effective error	256	0.52	298	142	0.01	0.36
CV%		11.25	6.88	8.06	9.49	20.90
Overall mean		6.50	250	148	1.04	2.89

** Significant at 0.01.

TABLE 2 - Mean squares of the combined analysis of variance for trials with tester BR 106 over four environments for yield (Y), plant height (PH), ear height (EH), ear index (EI) and square root of broken stalks + root lodging+ 1 (B+R).

Source	MEAN SQUARES					
	d.f.	Y	PH	EH	EI	B + R
Locations(L)	3	340.80	70,477	68,635	1.43	236.42
Treatments(T)	80	4.42**	1,515**	1,302**	0.02**	0.78**
T x L	246	1.24*	262	231	0.01	0.59**
Mean effective error	256	0.90	250	216	0.01	0.45
CV%		15.41	6.10	6.46	245	10.28
Overall mean		143	10.08	0.96	24.60	2.74

*,** Significant at the 0.05 and 0.01 level, respectiveley.

classified as HA 1 despite the distance of 1,500 miles between the two furthest locations. Within HA 1, Propriá-SE and Janaúba-MG could represent one subregion, while Sete Lagoas-MG and Goiânia-GO could be included in another subregion. Within these subregions there are large differences in soil type, altitude, and climatic conditions. The first subregion has hot days and high night temperatures with irregularly distributed rainfall, while the second has more moderate climatic conditions and lower night temperatures. Thus, a treatments x locations interaction should be expected for traits that are affected by environment. Even for analysis by grouping subregions, significative differences were found due to treatments x locations interactions for traits Y and B+R (data not shown). Similar results have been shown in tropical regions within environments that are considered more uniform with adapted, improved maize populations (Naspolini et al., 1981; Gama et al., 1982; Santos et al., 1994). Large climatic variability is a problem in tropical regions. For this reason, it is usually recommended to select genotypes for specific environmental conditions to avoid losses in time and to more efficiently use limited financial resources.

TABLE 3 shows mean values for all traits for BR 105 crosses across the four locations, along with the high-parent heterosis (HPH) estimates for yield (Y). For Y means of crosses ranged from 4.4 t ha^{-1} to 7.7 t ha^{-1}, while these means for the checks ranged from 5.7 t ha^{-1} to 8.0 t ha^{-1}. The best cross (SE 032 x BR 105) produced 7.7 t ha^{-1} while the double cross commercial check BR 201 produced 6.8 t ha^{-1}. There was large variability for PH (231 to 267 cm) and EH (119 to 162 cm). Among this group of elite accessions from Latin America, the lowest means for PH and EH were observed from crosses with accessions from Guatemala. For root lodging (B+R), the crosses with accessions from Mexico and Peru gave highest means for PH and EH while crosses with Bolivian accessions showed a trend to having better tolerance to broken stalks and root lodging. Prolificacy, measured by ear index, can serve as an indicator of the adaptability level of the elite accessions from other countries of Latin America. The crosses with lower EI values were from Mexico and showed the poorest nicking of female and male flowering while making crosses TABLE 3). Although the data for male and female flowering were taken in two locations, results indicate that the groups of accessions from Guatemala and from Mexico were the earliest and latest, respectively, confirming the level of adaptability.

The means combined over four environments with tester BR 106, the checks and the high-parent heterosis estimates for Y are shown in TABLE 4. The range of variation for yield was from 4.1 t ha^{-1} to 7.4 t ha^{-1} while the commercial check BR 201 produced 6.6 t ha^{-1}. For the other traits the crosses with BR 106 showed similar trends as the crosses with BR 105, but means were lower with tester BR 106 due to having a lower mean values for these traits or due to the elite accessions having a dent endosperm.

TABLE 3 - Mean values over four environments considering maize elite accessions x tester BR 105 and high parent heterosis estimates for yield in (HPH%).

Elite accessionsx Tester BR 105	Origin	50% days tassel&	50% days silk &	Plant height	Ear height	Ear Index	(B + R)	Yield	HPH
				------- cm -------				t ha $^{-1}$	%
Yer 147	Mexico	74	78	267	162	1.00	3.30	6.3	3
Col 71	Mexico	64	69	246	146	0.98	3.26	5.7	-6
Son 72	Mexico	68	75	252	152	1.00	3.34	6.3	3
Chis 740	Mexico	74	77	261	164	0.99	3.26	7.6	24
Tams 103	Mexico	70	75	250	146	1.03	3.09	5.9	-3
Chis 644	Mexico	74	78	262	159	1.02	2.59	7.3	20
Dgo 86	Mexico	64	67	236	134	0.98	2.69	5.4	-11
Chis 462	Mexico	72	76	264	155	1.02	2.66	6.7	10
Sin 117	Mexico	65	68	241	139	0.96	2.93	5.5	-10
Col 38	Mexico	70	75	263	161	0.97	3.01	6.0	-1
BC 12	Mexico	66	68	248	145	0.99	3.46	5.7	-6
Chis 775	Mexico	69	72	254	149	1.08	2.83	7.3	20
Dgo 102	Mexico	63	66	248	145	0.99	3.56	5.8	-5
Chis 553	Mexico	64	67	242	147	1.07	3.11	6.0	-1
Chis 645	Mexico	68	72	261	161	1.04	3.31	6.3	3
Piura 163	Peru	61	64	231	138	1.00	3.35	4.4	-28
Piura 229	Peru	60	63	237	137	1.01	3.55	5.0	-18
Piura 196	Peru	62	64	232	133	1.09	3.55	5.0	-18
LBQU 46	Peru	67	71	249	151	1.00	3.23	5.3	-13
Lim 86	Peru	72	76	265	157	1.02	3.13	6.2	1
Lim 36	Peru	67	70	251	152	0.99	3.16	5.6	-8
Lim 13	Peru	70	75	258	152	1.08	3.08	7.2	18
Loreto 21	Peru	70	74	259	153	1.07	3.28	7.2	18
Madre de Dios 22	Peru	71	75	266	160	1.05	3.04	6.9	13
San Martin 126	Peru	72	76	266	160	0.99	2.90	6.9	13
Madre de Dios 46	Peru	71	76	266	159	1.05	2.97	6.8	11
Ucayali 12	Peru	69	73	256	151	1.10	2.82	7.2	18
Pasco 14	Peru	70	75	259	158	1.07	3.30	7.5	23
San Martin 111	Peru	70	73	254	159	1.04	3.38	6.8	11
Guate GPO 4-1A	Guatemala	60	62	214	119	1.10	3.50	5.3	-13
Guate GPO 5-1A	Guatemala	61	63	231	123	1.13	3.80	5.5	-10
Guate GPO 13-2A	Guatemala	65	69	242	144	1.02	3.30	6.6	8
Guate GPO 21-18A	Guatemala	68	71	249	142	1.04	2.23	6.2	1
Guate 110	Guatemala	62	64	241	137	0.99	3.18	5.2	-15
Guate 209	Guatemala	69	72	259	150	1.01	2.88	6.8	11
Guate 740	Guatemala	66	68	248	145	1.01	2.88	6.5	6
BG 070403	Venezuela	66	69	255	148	1.03	3.05	6.3	3
BG 002	Venezuela	66	69	246	144	1.12	2.82	6.3	3
BG 070809	Venezuela	66	68	254	144	1.04	2.42	6.6	8
BG 070404	Venezuela	68	72	251	154	1.07	3.36	6.7	10
BG 070422	Venezuela	68	71	246	144	1.04	2.70	6.3	3
Per GP 3	USA	71	74	257	152	1.02	3.32	6.8	11
Bavi 155	USA	71	75	264	160	1.02	2.94	6.5	6

Cuba 164	USA	68	71	253	154	1.04	2.91	7.1	16
Scro GP 1	USA	66	70	258	158	1.07	3.36	6.9	13
Rep. Domin. 150	USA	69	72	257	153	1.15	3.20	6.5	6
Scro GP 3	USA	66	70	262	156	1.04	3.41	6.9	13
Barbados GP 2	USA	71	74	263	158	1.10	3.32	6.7	10
Av. Moroti 03002	Paraguai	67	72	249	147	1.04	2.84	6.6	8
Av. Moroti 14003	Paraguai	68	71	249	145	1.09	3.36	5.8	-5
CMS 0508 III	Brazil	67	70	237	143	1.05	2.54	6.4	5
CMS 06	Brazil	68	71	244	141	1.04	2.10	7.3	20
Tuxpeno 1	Brazil	69	73	241	137	0.99	2.24	6.5	6
PE 011	Brazil	69	74	254	152	1.00	2.47	6.5	6
094 R2	Brazil	69	71	291	150	1.01	2.41	7.2	18
BA 038	Brazil	71	74	254	157	1.03	2.78	7.3	20
Flint. Comp. Ne.	Brazil	69	73	254	151	1.09	3.21	6.8	11
Comp. Manaus	Brazil	67	70	251	149	1.00	2.85	7.4	21
PE 001	Brazil	70	74	253	152	1.12	2.61	7.5	23
Comp. Jaiba III	Brazil	70	74	256	149	1.06	2.10	6.7	10
AL 015	Brazil	71	75	254	150	1.05	2.54	6.6	8
PE 027	Brazil	70	75	258	156	1.06	2.81	6.1	0
SE 003	Brazil	69	74	262	155	1.01	2.45	6.6	8
RN 007	Brazil	70	74	258	154	1.09	2.63	7.1	16
SE 003	Brazil	70	74	259	155	0.99	3.18	6.3	3
SE 028	Brazil	71	73	251	151	1.05	2.87	7.3	20
SE 032	Brazil	69	72	254	151	1.09	2.82	7.7	26
Bozm 093- C. Blanco	Bolivia	70	75	269	161	1.00	2.62	6.5	6
Bozm 0082- C. Ama.	Bolivia	70	74	256	152	1.06	2.64	6.0	-1
Bozm 0303-C. Ama.	Bolivia	69	73	259	156	1.04	1.91	6.9	13
Bozm 1168-C. Ama.	Bolivia	71	76	253	150	1.07	2.28	6.8	11
Bozm 1155-Perola	Bolivia	71	76	267	162	1.04	2.54	6.8	11
BR 105 - Int. check [a]	Brazil	69	72	238	136	1.12	1.12	6.1	-
Checks									
BR 201	Brazil	69	71	218	113	0.98	2.74	6.8	-
Sintetico 06	Brazil	70	74	231	133	0.99	3.21	6.2	-
Nitroflint	Brazil	69	71	234	135	0.96	2.80	6.2	-
Nitrodent	Brazil	67	70	239	134	0.98	3.18	6.5	-
106 x Cravo	Brazil	70	73	249	146	0.97	2.48	6.2	-
Crasel	Brazil	67	71	211	115	1.03	2.39	6.0	-
06 x 05 SRR	Brazil	68	71	245	145	1.20	2.28	8.0	-
Sintetico Elite	Brazil	68	71	225	130	0.97	1.90	5.7	-
Comp. Vega Precoce	Brazil	68	71	237	133	0.97	1.80	6.3	-
LSD0.05		3.6	3.7	19	14	0.74	0.10	1.1	-

& Mean values from two locations.
[a]Check interplanted in each incompleted lattice block.

Mean values obtained in this study were indicative that there are accessions with desirable performance to be introduced into breeding programs. However, in these agronomically unimproved accessions it is impossible to select for all traits simultaneously, because there will be very little gain from selection for any single trait. The best alternative, according to Eberhart et al. (1995), would be to select initially for the principal trait (yield) since most of the other traits have high heritabilities.

Because yield is the primary agronomic trait of interest, and since these elite accessions have never been improved in their native countries, heterosis will be

TABLE 4 - Mean values over four environments considering maize elite accessions x tester BR 106 and high - parent heterosis estimates for yield in (HPH%).

Elite accessionsx Tester BR 105	Origin	50% days tassel&	50% days silk &	Plant height	Ear height	Ear Index	(B + R)	Yield	HPH
				------- cm -------				t ha $^{-1}$	%
Yer 147	Mexico	74	78	258	161	0.98	2.55	7.0	11
Col 71	Mexico	68	70	237	138	0.97	2.76	5.6	-11
Son 72	Mexico	69	75	242	139	0.90	3.36	6.0	- 5
Chis 740	Mexico	73	76	263	156	0.91	2.93	6.5	3
Tams 103	Mexico	71	74	246	145	0.92	3.01	6.0	- 5
Chis 644	Mexico	74	78	261	156	0.90	2.73	6.6	5
Dgo 86	Mexico	64	68	240	132	0.80	2.57	4.2	-33
Chis 462	Mexico	73	77	271	165	0.88	2.87	5.0	-21
Sin 117	Mexico	65	69	224	130	0.89	2.22	5.3	-16
Col 38	Mexico	73	77	256	156	0.96	2.58	6.3	0
BC 12	Mexico	67	70	229	127	0.90	2.79	4.7	-25
Chis 775	Mexico	72	77	247	141	0.98	2.93	6.9	9
Dgo 102	Mexico	65	67	231	127	0.97	2.42	6.0	-5
Chis 553	Mexico	65	68	228	125	1.02	2.46	5.5	-13
Chis 645	Mexico	71	77	267	167	0.90	2.65	6.2	-1
Piura 163	Peru	64	69	225	132	0.93	3.30	4.2	-33
Piura 229	Peru	65	68	235	137	1.00	2.94	4.1	-35
Piura 196	Peru	66	68	232	126	0.90	2.87	4.3	-32
LBQU 46	Peru	65	68	234	130	0.97	3.06	5.1	-19
Lim 86	Peru	72	76	244	145	0.91	3.07	5.6	-11
Lim 36	Peru	69	74	248	149	0.90	2.76	5.4	-14
Lim 13	Peru	71	76	257	151	0.91	2.90	6.5	3
Loreto 21	Peru	70	75	252	149	0.94	3.32	6.1	-3
Madre de Dios 22	Peru	72	76	258	154	0.98	2.69	6.9	9
San Martin 126	Peru	72	75	265	158	0.95	2.55	6.5	3
Madre de Dios 46	Peru	71	76	257	155	0.92	2.64	5.4	-14
Ucayali 12	Peru	71	76	258	155	0.98	2.24	6.8	8
Pasco 14	Peru	70	73	252	152	0.96	3.00	7.2	14
San Martin 111	Peru	70	75	249	156	0.99	3.06	6.9	9
Guate GPO 4-1A	Guatemala	64	66	220	124	1.06	3.46	6.0	5
Guate GPO 5-1A	Guatemala	66	68	233	137	1.03	3.33	5.3	-16
Guate GPO 13-2A	Guatemala	68	71	235	134	0.97	2.91	6.3	0
Guate GPO 21-18A	Guatemala	70	75	249	147	0.97	2.91	6.1	-3
Guate 110	Guatemala	64	67	225	125	0.95	2.47	5.5	-13
Guate 209	Guatemala	69	73	239	138	0.95	2.49	6.0	-3
Guate 740	Guatemala	67	72	236	139	0.95	2.41	5.5	-13
BG 070403	Venezuela	68	71	243	140	0.95	2.73	6.2	-1
BG 002	Venezuela	68	71	240	136	0.93	2.52	6.3	0
BG 070809	Venezuela	69	71	257	154	0.91	2.93	6.4	1
BG 070404	Venezuela	70	73	254	150	0.95	2.96	6.4	1
BG 070422	Venezuela	68	70	250	142	1.01	3.29	6.4	1
Per GP 3	USA	70	75	255	146	0.84	2.97	6.0	-5
Bavi 155	USA	72	76	271	168	0.97	2.71	6.9	9

Cuba 164	USA	70	73	251	147	0.90	2.54	6.3	0
Scro GP 1	USA	69	73	245	139	0.95	3.31	6.3	0
Rep. Domin. 150	USA	69	72	253	152	1.09	2.83	6.0	-5
Scro GP 3	USA	68	70	249	150	0.97	3.23	6.4	1
Barbados GP 2	USA	71	75	260	159	0.96	3.15	5.9	- 6
Av. Moroti 03002	Paraguay	71	75	247	145	1.01	3.05	6.0	-5
Av. Moroti 14003	Paraguay	71	76	257	159	0.90	3.22	5.3	-16
CMS 0508 III	Brazil	69	73	231	130	1.01	2.66	6.7	6
CMS 06	Brazil	72	75	241	142	1.02	2.44	6.5	3
Tuxpeno 1	Brazil	70	73	245	139	0.92	2.20	6.2	-1
PE 011	Brazil	70	75	258	156	0.97	2.67	7.4	17
094 R2	Brazil	72	75	251	149	0.99	2.16	6.9	9
BA 038	Brazil	72	76	246	146	1.02	2.43	7.2	14
Flint. Comp. Ne.	Brazil	71	74	256	152	0.99	2.75	6.7	6
Comp. Manaus	Brazil	70	73	234	135	0.94	2.69	6.7	6
PE 001	Brazil	72	74	252	149	0.96	2.23	7.4	17
Comp. Jaiba III	Brazil	71	74	254	150	1.03	2.81	6.7	6
AL 015	Brazil	71	74	262	156	0.94	2.78	6.5	3
PE 027	Brazil	71	76	258	151	1.01	2.61	6.4	1
SE 003	Brazil	72	75	248	147	0.98	2.46	6.9	9
RN 007	Brazil	70	73	255	152	1.00	2.53	7.2	14
SE 003	Brazil	72	76	256	156	1.01	2.61	6.7	6
SE 028	Brazil	72	76	248	149	1.01	2.67	6.6	5
SE 032	Brazil	72	75	241	143	0.97	2.31	6.6	5
Bozm 093- C. Blanco	Bolivia	71	74	254	148	0.91	2.38	7.2	14
Bozm 0082- C. Ama.	Bolivia	71	76	249	148	0.94	2.74	6.1	-3
Bozm 0303-C. Ama.	Bolivia	74	78	248	146	0.94	2.62	5.4	-14
Bozm 1168-C. Ama.	Bolivia	74	78	245	145	0.95	2.57	5.9	-6
Bozm 1155-Perola	Bolivia	74	77	252	151	0.98	2.56	6.7	6
BR 106 - Int. check [a]	Brazil	68	72	232	133	1.05	2.05	6.3	-
Checks									
BR 201	Brazil	69	72	214	110	0.98	3.02	6.6	-
Sintetico 06	Brazil	72	75	217	115	0.97	3.00	6.0	-
Nitroflint	Brazil	68	71	224	124	0.97	2.57	6.1	-
Nitrodent	Brazil	67	70	223	130	0.89	2.74	6.0	-
106 x Cravo	Brazil	70	74	240	140	0.96	2.71	5.4	-
Crasel	Brazil	68	71	205	108	0.95	2.62	5.3	-
06 x 05 SRR	Brazil	69	71	224	131	1.11	2.39	7.0	-
Sintetico Elite	Brazil	70	73	220	125	0.87	2.57	5.2	-
Comp. Vega Precoce	Brazil	69	73	230	122	0.95	1.97	6.2	-
$LSD_{0.05}$		3.7	4.0	16	15	0.09	0.76	1.1	-

& Mean values from two locations.
[a]Check interplanted in each incompleted lattice block.

discussed only for yield. The high-parent heterosis with the tester BR 105 showed estimates that ranged from -28% to 26%. In crosses with BR 106, the high-parent heterosis ranged from -35% to 17% (TABLES 3 and 4). The differences among these heterotic responses with the testers can be partially explained because of endosperm types of the accessions. More than 90% of the elite accessions had dent endosperm and crosses with dent x flint have shown higher heterosis than dent x dent (Gama et al., 1982; Pollak et al., 1991; Vasal et al., 1993; Santos et al., 1994). Other studies using crosses with tropical maize populations have also shown high parent heterosis ranging from negative values to high and positive values. Gama et al. (1982) found values from –17% to 117%, but the greatest high-parent heterosis was 20.7%. Naspolini et al. (1981) found a heterosis of 35% for the best cross. Similar values were shown by Santos et al. (1994) where results of a diallel study with twenty-eight tropical maize populations showed great variation in heterosis. The best cross (8.4 t ha^{-1}) showed a heterosis of 14% relative to the superior parent and 73% relative to mid-parent. Depending on the improvement level and genotypes tested, heterosis can vary and have low or high values. Low values for heterosis were reported by Beck et al. (1991) and Crossa et al. (1990) with cultivars from the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). On the other hand, crosses among tropical or subtropical germplasms with temperate accessions showed higher heterosis perhaps because of larger genetic divergence among populations (Gerrish, 1983; Mungoma & Pollak, 1988; Pollak et al. 1991; Vasal et al. 1993).

According to Pandey & Gardner (1992) the populations that were developed from broad genetic resources without regard to heterotic pattern, generally show low heterosis, but in some specific instances high values can be observed. Populations like these generally show poor performance with almost no heterosis, but can perform very well in a specific environment. For this reason, it is important to maintain the elite accession per se for its use in forming two or more breeding populations to which recurrent selection could be applied. Such improved populations can serve as useful resources for development of new varieties and will be used far more often for developing inbreds or hybrids.

In this study, some elite maize accessions were judged to have performed well in crosses with testers BR 105 and BR 106 (TABLES 3 and 4) because they showed higher yields than a commercial check BR 201. From a practical point of view and considering the limited financial resources for maize breeding programs in public institutions, among the elite accessions the following were selected for further work in Brazil: SE 032 and PE 001 with the tester BR 105, and PE 011 and Pasco 014 with tester BR 106. It is important to emphasize that with more financial resources it would be possible to select elite accessions for each specific ecological region, since significative treatments x locations interactions occurred. These accessions, belonging to two different groups, could enhance heterosis and could be used to develop new varieties for small farmers. By initially improving the elite accessions through recurrent selection, allelic frequencies of desirabele genes will be increased; consequently, accessions will have higher yield with better agronomic traits. The probability of identifying superior lines will be increased (Hallauer and Miranda Filho, 1981) and the two divergent populations will show high cross performance with each other.

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