Analysis of diallel cross for the evaluation of maize populations across environments

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ABSTRACT

Eleven open-pollinated maize (*Zea mays* L.) populations were crossed in a diallel scheme and evaluated in five locations in the State of Paraná: [1] Ponta Grossa, [2] Pato Branco, [3] Palotina, [4] Londrina and [5] Guarapuava. Two commercial hybrids (P 3230 and BR 201) were included as checks in the experiments, thus completing 68 entries (11 parents, 55 hybrids and 2 checks). Plots were represented by single rows 5 m long spaced 0.9m with 25 plants per plot after thinning. The following traits were analyzed: GY- total plot grain yield expressed in kg/ha after adjustment to 14.5% grain moisture; PH- plant height (cm); EH- ear height (cm); and FF- days for female flowering. Plant height and EH were not included in location [2]; FF was not include in locations [2] and [3]. The joint analysis of variance showed significance for all traits, only for the variation among location, entries, variety effects and average heterosis. For yield the total heterosis in mid-parent percentage varied from –0.96% (PMI 8403 x PMI 9304) to 32.4% (PMI 9302 x PMI 9307). Variety effects (v_i) and general combining ability (g_i) effects were in the range of –1483 to 772 kg/ha and from –847 to 448 kg/ha, respectively. Both g_i (for yield) and v_i (for the other traits) were used to select two populations to be used in a reciprocal recurrent selection program. BR 106 showed the highest estimates for both g_i and v_i for yield but also showed undesirable traits (tall plants and late flowering). Some outstanding populations for yield potential *per se* did not show a good performance in crosses. Other populations with outstanding performance in crosses exhibited lower variety effects for yield or high variety effects for the other traits. Some introduced populations who showed shorter plants and earliness should be submitted to selection for yield, adaptation and other agronomic traits before being indicated for crossing. However, they should be recommended as source populations for short architecture and early flowering. An overall analysis led to the decision of choosing the population IAPAR 26 to be used as contrasting parent of BR 106 in a reciprocal recurrent selection program at IAPAR (Londrina, State of Paraná).

KEY WORDS: Diallel cross, maize population, heterosis.

INTRODUCTION

In hybrid maize breeding programs, recurrent selection for population improvement has been recognized as a useful strategy for the enhancement of the performance of inbred lines in hybrid crosses. The choice of base populations to be used as source of inbred lines for hybrid development is also an important aspect toward the maximization of genetic expression in hybrids (Miranda Filho and Vencovsky, 1984; Crossa et al., 1990). When a set of parental varieties is available, information on their genetic values, *per se* and in crosses, represent useful tools for choosing varieties for recurrent selection or for the synthesis of variety composites (Miranda Filho and Vencovsky, 1984; Araújo and Paterniani, 1999). The identification of heterotic patterns between populations allow the synthesis of divergent composites which can be used in reciprocal recurrent selection program (Hallauer and Miranda Filho, 1988).

Methods based on diallel crosses have been largely used in plant breeding, either to provide information on combining ability and/ or heterosis in crosses or to allow prediction of crosses that have not been directly evaluated (Miranda Filho and Chaves, 1992). Gardner and Eberhart (1966) suggested three ways for the analysis of diallel crosses of populations in equilibrium. Analysis I provides detailed information on the genetic effects but its use requires the inclusion of selfed parents besides the original parents and their crosses. Analyses II and III are based only on means of parent populations and their crosses. Analysis II provides a wide array of information including the effects of varieties and total heterosis and its components (average heterosis, variety heterosis and specific heterosis). Analysis III is a variation of Griffing (1956)'s Method 4, with partition of the sums of squares for hybrids into general and specific combining ability.

Short plant cultivars have long been recommended for the replacement of typically tropical varieties which are very tall with ears placed high in the stalk, bringing problems related to plant lodging and mechanical harvesting (Miranda Filho, 1974; Paterniani, 1993). On the other hand, early flowering cultivars have recently received special attention when short dry seasons may occur during the crop or they have also been recommended as second crop ("safrinha") in a double cropping system (Gama et al., 1995). The IAPAR maize breeding program aims the introduction or synthesis of maize populations which have high yield, short architecture and earliness. In the present work, eleven open pollinated populations were evaluated using the diallel mating scheme. The objective of this study was to obtain information about the performance *per se,* heterotic pattern and combining ability of these populations for the choice of the most promising for use in recurrent selection and hybrid development progams.

MATERIAL AND METHODS

Eleven maize populations were chosen as parents in a diallel mating scheme for evaluation of their genetic potential as base germplasm for grain yield, short architecture and earliness. The origin and description of populations are shown in Table 1. All the populations were synthesized or introduced in the IAPAR maize breeding program. Populations designated as PMI (IAPAR maize population) were submitted to at least two cycles of stratified mass selection. The commercial varieties IAPAR 26 and IAPAR 51 were submitted to four cycles of stratified mass selection and two cycles of recurrent selection with half-sib families. BR 106 (EMBRAPA) is a commercial variety recommended for the state of Paraná and was not submitted to selection in the IAPAR program.

Crosses between populations were made in 1994/95 at the Experimental Station of IAPAR (Londrina, PR) in isolated blocks. In each isolated block one population was used as male parent and all other populations were planted as female parents (detasseled). Each population was represented by two rows 5 m long with 50 plants. Reciprocal crosses harvested in different crossing blocks were mixed to represent the same hybrid. The male rows in each isolated block were harvested to represent the respective parental population in the diallel scheme.

Experimental trials were conducted as randomized complete blocks with three replications in five locations in the State of Paraná in the year 1995/96: [1] Ponta Grossa, [2] Pato Branco, [3] Palotina, [4] Londrina and [5] Guarapuava. Two commercial hybrids (P 3230 and BR 201) were included as checks in the experiments, thus completing 68 entries. Plots were represented by single rows 5 m long spaced 0.9m apart with 25 plants per plot after thinning. The following traits were analyzed: GY- total plot grain yield expressed in kg/ha after adjustment to 14.5% grain moisture; PH- plant height (m); EH- ear height (m); and FF- days for female flowering. Plant height and EH were not included in location [2]; FF was not include in locations [2] and [3].

The analyses of variance were performed on each location and adjusted means were used in the analysis of variance across locations. Locations were considered as random effect and entries as fixed effect. The pooled error mean square was used to test the significance of entry by location interaction. Main effects were tested against their respective interactions with environment.

The diallel tables were analyzed according to Gardner and Eberhart (1966) model II. The model for each location is:

Table 1 – Origin and description of maize populations used in diallel crosses.

Population	Origin	Description
1 BR-106	CNPMS/EMBRAPA[1/]	Intermediate for plant height and flowering, yellow and semi-dent kernels
2 IAPAR 26	Synthesized in IAPAR by crossing two commercial hybrids recommended for the State of Paraná and two early experimental hybrids.	Intermediate to short plant height, early flowering, dent and semi-dent yellow kernels
3 IAPAR 51	Obtained from crosses between yellow and white kernel 'Tuxpeño' germplasm from CIMMYT, México.	Intermediate to short plant height, intermediate flowering, light yellow semi-dent kernels with segregating whites.
4 PMI 8403	Resulted from selection within the IPTT 8342 population introduced from CIMMYT, México	Short plants, early flowering, white kernels varying from semi-dent to flint endosperm
5 PMI 8701	Population 27 from CIMMYT, México: 'Amarillo Cristalino'; submitted to two cycles of stratified mass selection	Short plants, early flowering, yellow to orange and flint type kernels
6 PMI 9301	Population 'Mays Colorado' introduced from Paraguay and submitted to two cycles of stratified mass selection	Short plants, early flowering, yellow to orange and flint type kernels
7 PMI 9302	Population 26 from CIMMYT, México: 'Mezcla Amarilla'; submitted to two cycles of stratified mass selection	Short plants, early flowering, yellow to orange and flint type kernels
8 PMI 9303	Population 31 from CIMMYT, México: 'Amarillo Cristalino 2'; submitted to two cycles of stratified mass selection	Short plants, extra-early flowering, orange and semi-flint to flint type kernels
9 PMI 9304	Population ESALQ-PB1 E^{-} C5 (Araújo, 1992), submitted to two cycles of stratified mass selection	Short plants, extra-early flowering, yellow and semi-dent to dent type kernels
10 PMI 9306	Composite variety from IAPAR, obtained by intercrossing commercial hybrids from BRASKALB Seed Company	Short plants, early flowering, yellow and semi-dent type kernels
11 PMI 9307	Composite variety from IAPAR, obtained by intercrossing commercial hybrids from PIONEER Seed Company	Short plants, early flowering, yellow and semi-dent type kernels

[1/] IAPAR: Instituto Agronômico do Paraná; CNPMS/EMBRAPA: Centro Nacional de Pesquisa de Milho e Sorgo, Empresa Brasileira de Pesquisa Agropecuária; CIMMYT: Centro Internacional de Mejoramiento de Mays y Trigo, México; ESALQ: Escola Superior de Agricultura Luiz de Queiroz , USP.

$$Y_{ii'} = \mu + \tfrac{1}{2}(v_i + v_{i'}) + \theta\,(\bar{h} + h_i + h_{i'} + s_{ii'}) + \bar{e}_{ii'}$$

Where $Y_{ii'}$ is the mean (over three replications) representing the cross i x i'; u is the mean of parent varieties or populations; v_i is the effect of varieties or populations; $\bar{h}$ is the average mid-parent heterosis; h_i is the variety heterosis; $s_{ii'}$ is the specific heterosis or specific combining ability; and $\bar{e}_{ii}$ is the error term associated with the observed mean. The model can be applied to represent both variety or population mean (i = i'; q = 0) and hybrid mean (i ≠ i'; q = 1). The combined analysis over environments was performed according to the methodology given by Morais et al. (1991).

RESULTS AND DISCUSSION

Means were obtained for four traits over three replications, across five locations (Table 2). Grain yield (GY), varied from 4959 to 7373 kg/ha for varieties and from 5820 to 8505 kg/ha for hybrid crosses; the highest yield was for the BR 106 x PMI 9307 cross which was practically equal to the best check (P 3230) and 6.9% higher than the average of the two checks. For the other traits, the total means range was from 185 to 244 cm for plant height, from 90 to 132 cm for ear height and from 67 to 81 days for female flowering.

In the analysis of variance (Table 3), for grain yield, a highly significant variation P<0.01 was detected for locations, entries, varieties, heterosis, average heterosis, and interactions of varieties and heterosis effects with environments (locations). Similar patterns of significance for the same sources of variation were reported by Santos et al. (1994), Gama et al. (1995), Sinobas and Monteagudo (1996) and San Vicente et al. (1998). Variety heterosis and specific heterosis were non significant as source of variation, as also reported by Miranda Filho and Vencovsky (1984) for one set of open-pollinated varieties.

From the total sum of squares in the analysis of variance for yield, a proportion of 61% resulted from the effects of varieties and 39% resulted from the total heterosis. A similar proportion of the sums of squares was reported by Gardner and Paterniani (1967), Parentoni et al. (1990), Gama et al. (1995), and Sinobas and Monteagudo (1996). However, a more expressive effect of heterosis as source of variation was found by Santos et al. (1994) and San Vicente et al. (1998).

From the components of the total heterosis, the highly significant average heterosis for yield is indicative of an expressive superiority of hybrid mean over the variety mean; in fact an average heterosis of 14.3% over all crosses was considered fairly high for variety crosses. Hallauer and Miranda Filho (1988) reported a 19.5% average heterosis in a set of 1,394 crosses, including highly heterotic crosses between old races of maize. A high average heterosis (33%) including crosses with heterotic effects as high as 101% were reported by Paterniani and Lonnquist (1963) in crosses between South-American races. On the other hand, lower estimates of the average heterosis, ranging from 8 to 10%, was reported by Vasal et al. (1992), Beck et al. (1990) and Crossa et al. (1990) in diallel crosses between Mexican populations or “pools”. The effect of variety heterosis and specific heterosis for grain yield

Table 2 – Observed means for grain yield (Kg/ha), plant height (cm), ear eight (cm) and female flowering (days) in eleven populations and their crosses (diallel scheme).

Entry[1/]	Grain yield kg/ha	Plant height cm	Ear height cm	Flowering day	Entry[1/]	Grain yield Kg/ha	Plant height cm	Ear height cm	Flowering days
1	7214	242	132	81	3x7	7148	230	117	75
2	6612	239	120	74	3x8	7479	218	111	73
3	7373	228	121	78	3x9	7065	217	115	73
4	7159	220	110	72	3x10	7991	238	128	77
5	6343	224	108	75	3x11	7679	231	116	77
6	6065	207	104	76	4x5	7508	230	114	74
7	5666	208	102	73	4x6	7525	220	108	74
8	4959	185	90	67	4x7	7029	221	108	72
9	5978	205	97	70	4x8	6023	202	103	70
10	6660	225	119	75	4x9	6506	213	106	72
11	6837	224	116	76	4x10	7828	220	112	72
1x2	8099	238	124	75	4x11	7708	225	108	74
1x3	8311	238	126	81	5x6	6588	227	115	73
1x4	8391	234	122	76	5x7	6949	215	107	74
1x5	8185	227	114	77	5x8	6508	206	98	69
1x6	7976	227	123	76	5x9	6754	199	101	71
1x7	7607	228	115	76	5x10	7679	228	115	74
1x8	7259	226	112	73	5x11	8001	228	108	73
1x9	7453	225	114	76	6x7	6843	221	112	74
1x10	8289	237	126	76	6x8	6928	210	111	71
1x11	8505	239	124	76	6x9	6507	215	107	72
2x3	7784	233	119	77	6x10	7867	234	123	73
2x4	7457	230	119	73	6x11	7634	224	107	73
2x5	7606	231	116	74	7x8	6026	196	93	69
2x6	7890	235	123	75	7x9	6364	203	95	71
2x7	7438	234	115	73	7x10	7297	217	110	73
2x8	7071	217	111	71	7x11	8279	235	119	72
2x9	6533	227	117	71	8x9	5820	194	99	68
2x10	8263	221	114	73	8x10	6805	207	101	72
2x11	7660	230	115	75	8x11	6088	205	101	70
3x4	7413	223	118	74	9x10	7447	215	110	71
3x5	7580	233	120	76	9x11	7471	219	108	72
3x6	6767	231	119	77	10x11	8203	244	125	75

[1/] See table one for pedigree and cross designation

(Table 3) was not significant. Overall results are indicative that high yield in hybrid crosses depends essentially on the average heterosis rather than variety heterosis or specific heterosis.

For PH, EH and FF, the variation of locations, populations and varieties effects showed to be highly significant ($P<0.01$). A less significant effect ($P<0.05$) for average heterosis. Heterosis and specific heterosis was significant only for PH. The interactions between location with entries and varieties were highly significant for EH and FF and the interactions of total heterosis and variety heterosis were highly significant for FF. However, a higher possibility to detect significance of effects occur under a low magnitude of the interaction between some genetic effects and random environmental effects, as verified for the traits listed above. It may also occur as reported by Gama et al. (1995) for all sources of variation for PH and EH.

Table 3 – Analysis of variance, means and coefficients of variation (CV) for four traits over five locations following Model II of Gardner and Eberhart (1966) for variety diallel crosses.

Sources of variation	Grain yield		Plant height		Ear height		Flowering	
	df	MS[1/]	df	MS	df	MS	df	MS
Locations (L)	4	37.5444**	3	$3.68x10^{4}$**	3	$1.87x10^{4}$**	2	$1.65x10^{3}$**
Entries (E)	65	2.8999**	65	651.99**	65	376.11**	65	21.58**
Varieties	10	11.5354**	10	3524.76**	10	2081.27**	10	125.01**
Heterosis	55	1.3298**	55	129.66*	55	66.07	55	2.77
Average heterosis	1	38.8722**	1	271.82*	1	251.35*	1	16.04*
Variety heterosis	10	0.9561	10	106.94	10	44.17	10	3.12
Specific heterosis	44	0.5615	44	131.60*	44	66.84	44	2.39
E x L	260	0.5908**	195	117.61**	195	61.24	130	2.58**
Varieties x L	40	0.9861**	30	287.84**	30	76.91	20	5.54**
Heterosis x L	220	0.5189	165	86.86	165	58.39	110	2.04**
Average het. x L	4	1.1139	3	13.96	3	23.14	2	0.61
Variety het. x L	40	0.4780	30	90.04	30	61.01	20	3.26**
Specific het. x L	176	0.5147	132	87.54	132	58.60	88	1.79
Pooled error	650	0.4889	520	91.25	520	60.07	390	1.41
CV%		13.73		4.28		9.46		2.27
Observed means:								
Complete diallel		7210		223.4		115.7		73.8
Checks: Pioneer 3230		8433		233		107		73
BR 201		7495		232		125		80

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

[1/] kg/ha x 10^{-6}

The partition of the sums of squares showed that the larger portion was due to the variation among populations, with values of 83.2%, 85.1% and 89.1% for PH, EH and FF, respectively, thus indicating a less pronounced effect of dominance for those traits as compared to grain yield. Similar proportions were found by Miranda Filho and Vencovsky (1984),), Gama et al. (1995), and Sinobas and Monteagudo (1996). The low heterosis observed in the expression of PH, EH and FF in the hybrid means are indicative that prediction of means should be made based on the variety effects only.

The effects of varieties (v_i) and general combining ability (g_i) were used directly in choosing the most promising varieties, for the formation of superior hybrid or composite population mainly in relation to yield potential. The most promising populations for yield were BR 106, IAPAR 26, PMI 9306 and PMI 9307. IAPAR 51 was not included because, despite its high v_i estimate, it showed a negative h_i estimate (variety heterosis effect), leading to a positive but low g_i value (general combining ability effect). Miranda Filho and Vencovsky (1984) emphasized that the v_i are very important when h_i's are not significant. Otherwise, g_i effects are useful for selection among populations because of the relation $g_i = v_i + h_i$ (Miranda Filho and Chaves, 1992). In this sense, the most promising variety in the set is unquestionably BR 106.

For the other traits (PH, EH and FF), the interest is for populations with lower effects of v_i , as determined by the objectives of the program; i.e., identification of populations with lower architecture and early flowering. Population PMI 9303 showed the lowest v_i estimates for the mentioned traits. On the other hand, the highest effects were observed for BR 106 and IAPAR 26.

When considering the whole set of hybrids, for yield, total mid-parent heterosis varied from –0.96% (PMI 8403 x PMI 9304) to 32,43% (PMI 9302 x PMI 9307). The later also showed a high and positive estimate for specific combining ability ($s_{ii'}$) and high grain yield mean (8279 kg/ha). Estimates of specific combining ability (data not shown) varied from –904 (PMI 9303 x PMI 9307) to 788 kg/ha (IAPAR 51 x PMI 9303). Vencovsky (1970) emphasized that higher specific combining ability estimates result from large differences in allele frequencies. One cross that showed high negative estimate for $s_{ii'}$ (-611 kh/ha) was PMI 8701 x PMI 9301. Although PMI 9301 has been introduced from Paraguay, from a region close to the border with the State of Paraná, it exhibited morphological characteristics that are very similar to PMI 8701. Therefore, the possibility that PMI 9301 has been introduced from CIMMYT and thus have a genetic base similar to PMI 8701 cannot be ruled out.

Table 4 – Estimates of variety effects ($\hat{v}_i$), general combining ability ($\hat{g}_i$), variety mean (m), and average heterosis ($\bar{h}$) for four traits following Model II of Gardner and Eberhart (1966) for variety diallel cross.

Populations	GY (kg/ha)		PH (cm)		EH (cm)		FF (days)	
	$\hat{v}_i$	$\hat{g}_i$	$\hat{v}_i$	$\hat{g}_i$	$\hat{v}_i$	$\hat{g}_i$	$\hat{v}_i$	$\hat{g}_i$
1. BR 106	772	705	23,2	9,8	21,2	7,7	6,7	3,0
2. IAPAR 26	170	241	20,2	7,2	9,2	4,7	-0,3	0,2
3. IAPAR 51	931	176	9,2	6,8	10,2	6,5	3,7	2,7
4. PMI 8403	717	-27	1,2	-1,5	-0,8	-1,4	-2,3	-0,5
5. PMI 8701	-99	-31	5,2	-0,8	-2,8	-2,5	0,7	0,0
6. PMI 9301	-377	-134	-11,8	1,4	-6,8	2,0	1,7	0,3
7. PMI 9302	-776	-295	-10,8	-3,5	-8,8	-4,4	-1,3	-0,7
8. PMI 9303	-1483	-847	-33,8	-16,7	-20,8	-10,0	-7,3	-3,3
9. PMI 9304	-464	-635	-13,8	-11,6	-13,8	-6,5	-4,3	-2,0
10. PMI 9306	218	448	6,2	3,3	8,2	3,7	0,7	0,1
11. PMI 9307	395	399	5,2	5,4	5,2	0,1	1,7	0,2
μ	6442,4		218,8		110,8		74	
$\bar{h}$	921,0		4,3		2,2		-0,7	
$\bar{h}$ %	14,3		2,0		2,0		-1,0	

As mentioned above, some intervarietal hybrids showed an yield expression of the same level as the checks, which showed by themselves a fairly high yield potential for the conditions of the State of Paraná. Hallauer and Miranda Filho (1988) emphasized that the general use of variety crosses is not recommended due to their lack of uniformity for several important traits, which contributes to a lower yield when compared to more uniform types of hybrids. In addition, the lack of uniformity may also raise difficulties for detasseling in the seed production fields and compromise uniform patterns of the harvested hybrid seeds.

However, the identification of outstanding varieties and variety crosses may indicate outstanding sources of inbred lines to be used in crosses toward the development of more uniform hybrid crosses. In this sense, the population BR 106 was identified as outstanding for yield, based on estimates of the general combining ability effects (g_i). Other outstanding populations were PMI 9307, PMI 9306, and IAPAR 26. As undesirable characteristics, BR 106 exhibited high v_i estimates for PH, EH and FF. In other words, it is the tallest and latest population in the set under study. PMI 9306 and PMI 9307 were recently introduced in selection program and more information about their performance *per-se* is needed. IAPAR 51 and PMI 8403 showed high v_i but low h_i effects for yield, thus resulting in lower g_i effects. Therefore, their potential to produce outstanding crosses depends largely on specific combining ability, as occur when they were are crossed with BR 106. Other populations with lower architecture and early flowering were recently introduced and were not submitted to intense selection for either adaptation or yielding potential, as inferred from their relatively lower yields under the conditions of the experiments. Therefore, their potential to produce good hybrids depends largely on the specific combining ability, as observed in the cross PMI 9302 x PMI 9307. Nevertheless, those less adapted populations can be used as excellent sources of short plants and earliness in the synthesis of new composite varieties. Overall results and number of cycles of selection led to the decision of choosing the population IAPAR 26 to be used as contrasting parent to BR 106 in a reciprocal recurrent selection program at IAPAR (Londrina, State of Paraná).

RESUMO

Análise dialélica na avaliação de populações de milho em diferentes ambientes

Onze populações de milho (*Zea mays* L.) foram cruzadas no esquema dialélico e avaliados em cinco locais do Estado do Paraná: : [1] Ponta Grossa, [2] Pato Branco, [3] Palotina, [4] Londrina and [5] Guarapuava. Dois híbridos comerciais (P 3230 and BR 201) foram incluídos como testemunhas nos experimentos, assim completando 68 tratamentos (11 pais, 55 híbridos e 2 testemunhas). As parcelas foram constituídas de linhas simples de 5 m de comprimento espaçadas de 0,9 m entre linhas com 25 plantas por parcela após o desbaste. Os seguintes caracteres foram analisados : peso total de grãos na parcela (GY) após ajuste para kg/ha a 14,5% de umidade; altura da planta, cm (PH); altura da espiga, cm (EH); e florescimento feminino, dias (FF). PH e EH não foram incluídos no local [2]; FF não foi incluído nos locais [2] e [3]. A análise da variância conjunta mostrou significância para todos os caracteres, somente para a variação entre locais, entradas, efeitos de variedades e heterose média. . Para produção, a heterose total em percentagem da média dos pais variou de –0,96% (PMI 8403 x PMI 9304) a 32,4% (PMI 9302 x PMI 9307). Os efeitos de variedades (v_i) e de capacidade geral de combinação (g_i) variaram de –1483 a 772 kg/ha e de –847 a 448 kg/ha, respectivamente. . Ambos g_i (para produção) e v_i (para os demais caracteres) foram usados para selecionar duas populações para serem usadas em um programa de seleção recorrente recíproca. BR 106 mostrou as maiores estimativas de g_i e v_i para produção mas também exibiu caracteres indesejáveis (plantas altas e florescimento tardio). Algumas populações que se destacaram para o potencial de produção *per se* não mostraram bom comportamento em cruzamento. Outras populações com bom comportamento nos híbridos mostraram valores baixos no efeitos de variedades para produção ou altos para outros caracteres. Porém, elas podem ser recomendadas como fontes de genes para arquitetura baixa ou florescimento precoce. Uma análise geral dos resultados levaram à decisão de escolher a população IAPAR 26 para ser usada como parental contrastante de BR 106 em um programa de seleção recorrente recíproca no IAPAR (Londrina, Paraná).

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