Partially inbred maize lines in topcrosses and hybrid performance

Edésio Fialho dos Reis[1]*, *Willame dos Santos Candido*[1], *Maraiza Lima Costa*[1], *Angelita Lorrayne Soares Lima Ragagnin*[1], *Andreia Somera*[1]

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ABSTRACT

In plant breeding programs, the selection of potential progenies in early generations of inbreeding is an essential step. Considering that, the adoption of topcrosses helps the breeder in the selection, this study aimed to verify the potential of S_2 strains for synthesis of synthetic varieties and to obtain experimental information on yield and agronomic potential of topcross hybrids. As such, 75 topcross hybrids were generated from crossing 75 S_2 lines with F_2 generation of the commercial hybrid. The 75 hybrids were grown in a field, along with two commercial hybrids in a randomized complete block design with 4 replicates and in 4-meter plots. Flowering, plant height, height, diameter, length and weight in the ear, and grain yield traits were examined. Analysis of variance was performed, the combining ability was estimated, and, from the means, the Scott & Knott test was conducted. So, the topcross hybrids that distinguished themselves for grain yield were those composed by lines 67, 14, 44, and 69, presenting high CGA, therefore indicating good potential for producing synthetic or base population. For the other traits of agronomic interest that were assessed in maize, a potential for selection with different focuses was found: reduction of cycle and height and increase in length and diameter of the ear.

Keywords: *Zea mays*; general combining ability; synthetic variety; S_2 lines.

INTRODUCTION

In a breeding program, at least four steps are involved to obtain hybrids, namely: the selection of populations; the acquisition of lines; the evaluation of their combining ability; and extensive testing of the hybrid combinations achieved (Paterniani & Campos, 1999). Nevertheless, the selection of parental lines should be made according to methodologies that allow their evaluation in different combinations. It is important to point out that one of the main problems faced by maize breeders who work with line hybrids is the evaluation of the parent lines. For a high number of lines, the assessment of all possible crosses is impractical (Paterniani *et al*., 2010).

Various techniques and genetic designs can be employed in maize breeding, including diallel crosses, which is a methodology used to select genotypes with a high combining ability and allelic complementarity. Since breeding programs involve a high number of genotypes, partial diallels and topcrosses have been given preference in the evaluation of specific sets of crosses (Rodovalho *et al*., 2012).

The topcross method, though apparently simple, has a certain difficulty in defining the adequate tester for the group of lines to be evaluated and its interpretation (Paterniani & Miranda Filho, 1987). On this point, Hallauer *et al*. (2010) state that broad genetic base testers are helpful in obtaining the estimates of the general combining ability, while those of narrow genetic base are useful in estimating the specific combining ability.

The topcross hybrids of partially inbred lines are alternatives to reducing time and cost to obtain hybrids, because the production system needs a smaller number of successive self-fertilizations and a smaller area to obtain

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[1] Universidade Federal de Jataí, Jataí, Goiás, Brazil. edesiofr7@gmail.com; candidows.melhorista@gmail.com; maraiza-15@hotmail.com; angelita.angell@hotmail.com; andreia_somera@hotmail.com.

*Corresponding author: edesiofr7@gmail.com

and multiply the lines, reaching the market at a faster time, maintaining greater yield when compared with inbred lines (Ferreira *et al*., 2009; 2010).

Thus, the goals of this study were to verify the potential of S_2 strains for synthesis of synthetic varieties and to obtain experimental information on yield and agronomic potential of topcross hybrids.

MATERIAL AND METHODS

This work was carried out in two steps. The first step was to obtain topcross hybrids by crosses between the S_2 families and the tester, and the second one comprised the assessment of topcross hybrids in field trials.

The inbred progenies utilized in the study were from the population consisting of the "Creole" maize variety called *Movimento de Pequenos Agricultores*–MPA (Small Farmers Movement), which was self-fertilized in the first-crop corn 2012/2013, generating 95 S_1 families. In the second-crop corn 2012/2013, the inbred progenies were evaluated and the inbreeding depression of each of these progenies was estimated. Negative values of more than 80% of inbreeding depression were noticed for grain yield, with an average depression of 53.75% (Mendes *et al*., 2013).

Eighteen S_1 families were selected, which showed less inbreeding depression for grain yield, which were sown in the second-crop corn 2013/2014 for the second cycle of self-fertilization, generating the S_2 progenies. In accordance with the seed production, 75 S_2 progenies were selected to compose the group of partially inbred lines (75%).

The tester used was the F_2 generation of commercial hybrid AG6040, considered to have a broad genetic base. The seeds of the 75 S_2 progenies used were sown in a five-meter row for the crosses. One line of the tester was sown every three lines. Planting was done in an isolated field and, at the time of male flowering, the detasseling of the S_2 family was done, so that there was pollen only of the tester, which was the male parent. The seeds of the 75 topcross hybrids were harvested individually, for the experimental evaluation.

For the second stage, the experiment to assess topcross hybrids was conducted in the second crop 2014/2015, in a randomized complete block design with four replicates. The plots were four-meter rows spaced 0.90 m between rows and 0.20 m between plants. Two commercial hybrids, planted in the region, were interspersed as controls (AG7098 PRO and SHS5050). The experiment was sown in February 2015, and the recommended cultural management for the maize culture were adopted to conduct the experiment. The following traits were assessed in each plot: the number of days for male flowering (MF) and for female flowering (FF), and for a sample of five plants, the plant height (PH) and the ear height (EH) were measured in meters. After cropping, five ears randomly obtained from each plot were used to assess the ear length (EL) in centimeters and the ear diameter (ED) in centimeters. The ear yield, in $kg.ha^{-1}$ (EY), and the grain yield (GY), in $kg.ha^{-1}$, were evaluated by the total weight of the plot corrected for 13% humidity and adjusted for stand variation. Stand correction was using the covariance method described by Vencovsky & Barriga, (1992). The analysis of variance, for the measured traits (PH, EH, EL, ED), was performed with means of plots and, for EY and GY, with the total of the plot.

The general combining ability (g_i) based on the statistical genetic model was also estimated, as mentioned by Ferreira *et al*. (2009):

$$Y_{ij} = m + g_i + e_{ij}$$

which,

m = overall mean;

g_i = effect of the general combining ability of i line;

e_{ij} = medium experimental error.

The g_i was obtained according to the following expression:

$g_i = c_i - c$, being,

g_i = effect of the general combining ability of the lines;

c_i = mean of each hybrid;

c = overall mean of topcross hybrids.

Scott & Knott test was used to group the means with at 5% probability. The statistical analyses carried out at all stages were made with the Genes program (Cruz, 2013).

RESULTS AND DISCUSSION

The coefficients of experimental variation (Table 1) were, in general, of low magnitude for all traits, ranging from 1.89 to 16.91. Thus, it is deduced that there was good experimental accuracy for the traits evaluated. These results are in line with what has been reported in the literature for the maize crop (Guimarães *et al*. 2011; Mendes *et al*., 2013). For the source of variation hybrids, a relevant difference was seen for all the traits assessed. It is concluded, then, that there was variability among the assessed hybrids, which allows selecting topcross hybrids with the best agronomic performance. Table 2, referring to the means of the 75 topcross hybrids and the two controls, displays that, regarding control 1, hybrid AG7098, the traits related to yield (ear yield and grain yield) showed, for all topcross hybrids, magnitudes below the referred hybrid, while in the other traits there is equality for some of the topcross hybrids compared and inferiority for

others, which can be favorable, as it is the cycle and height of the plant. Concerning control 2, hybrid SHS 5050, topcross hybrids presented equality in means or even superiority. For the plant height trait, the results agree with the ones verified by Ferreira *et al*. (2009), who noticed that, in general, the plant height of topcross hybrids was low compared to that of control hybrids, which may be due to the smaller size of the tester. For the yield trait, the results do not match those obtained by Ferreira *et al*. (2009) and Marcondes *et al*. (2015), in which the topcross hybrids were classified in the group of the most productive, possibly because they were using lines with higher levels of inbreeding (S_3 and S_4), respectively. Nonetheless, the comparison with commercial hybrids should be treated with caution, as it only indicates a reference of the topcross hybrids to be tested with the one that is being marketed.

Among the topcross hybrids, the progenies that had reduction in the number of days for male and female flowering simultaneously were 2, 20, 31, 41, 43, 47 and 66, with a mean of approximately two days less than the overall

Table 1: Analysis of variance for male flowering (MF), female flowering (FF), ear height (EH), plant height (PH), ear diameter (ED), ear length (EL), ear yield (EY), and grain yield (GY) of 75 topcross hybrids and two controls. Jataí-GO, 2015

Source	Mean Squares								
	d.f.	MF	FF	PH	EH	ED	EL	EY	GY
Blocks	3	48.65	38.50	0.97	0.676	0.084	1.48	2290894.6	5443671.7
Hybrids	76	6.64**	3.38**	0.06**	0.029**	0.170**	2.43**	7940584.8**	3881943.7**
Residue	228	1.72	1.15	0.01	0.006	0.052	1.21	1278549.1	919752.9
Mean		56.32	56.76	1.97	1.130	4.490	16.76	7055.6	5666.7
CV%		2.33	1.89	5.37	7.120	5.090	6.57	16.00	16.91

** significant at 1% probability by the F test.

Table 2: Means of male flowering (MF), female flowering (FF), plant height (PH), ear height (EH), ear diameter (ED), ear length (EL), ear yield (EY), and grain yield (GY) of 75 topcross hybrids of maize and two controls. Jataí-GO, 2015

Hybrids	MF days	FF days	PH m	EH M	ED cm	EL cm	EY $kg.ha^{-1}$	GY $kg.ha^{-1}$
1	54.00 b	56.00 c	1.95 c	1.11 c	4.70 b	16.20 b	6727.23 c	5341.11 c
2	54.50 b	55.75 c	1.98 b	1.093 c	4.35 c	16.00 b	6799.45 c	5647.23 c
3	57.50 a	56.75 c	1.89 c	1.10 c	4.70 b	15.90 b	7034.17 c	5602.23 c
4	55.50 b	57.00 b	1.81 c	1.05 c	4.35 c	16.05 b	6673.62 c	5075.84 c
5	57.75 a	57.75 b	1.81 c	0.976 d	4.55 b	16.60 b	7287.51 c	5852.23 c
6	57.50 a	56.75 c	1.93 c	1.08 c	4.55 b	17.10 a	6398.06 c	4975.00 c
7	55.25 b	56.25 c	1.84 c	1.11 c	4.55 b	16.60 b	8483.34 b	6918.89 b
8	54.75 b	56.25 c	2.24 a	1.27 a	4.45 c	16.50 b	6686.95 c	5442.50 c
9	55.50 b	56.50 c	2.08 a	1.15 b	4.60 b	16.15 b	7016.67 c	5559.17 c
10	57.00 a	57.75 b	2.02 b	1.19 b	4.50 b	15.70 b	6007.78 c	4779.17 c
11	55.70 b	56.25 c	2.08 a	1.17 b	3.80 c	17.40 a	6037.50 c	4761.11 c
12	57.50 a	57.75 b	2.12 a	1.26 a	4.65 b	16.25 b	6991.12 c	5456.95 c
13	55.50 b	56.50 c	2.02 b	1.16 b	4.50 b	15.85 b	6261.95 c	5402.78 c
14	55.50 b	56.25 c	2.13 a	1.20 b	4.60 b	17.50 a	9270.84 b	7443.06 b
15	56.75 a	57.25 b	1.84 c	1.03 d	4.45 c	15.95 b	6045.84 c	4789.73 c
16	57.75 a	58.00 b	2.11 a	1.13 c	4.50 b	16.10 b	5973.62 c	4727.23 c
17	56.75 a	56.25 c	1.80 c	1.07 c	4.30 c	17.00 a	6495.28 c	5166.67 c
18	58.00 a	57.75 b	2.03 b	1.18 b	4.65 b	16.55 b	6950.84 c	5604.17 c
19	56.25 b	56.75 c	1.95 c	1.09 c	4.55 b	15.85 b	5743.89 c	4568.06 c
20	54.25 b	55.50 c	2.00 b	1.17 b	4.60 b	17.40 a	7257.78 c	5822.23 c
21	57.25 a	57.00 b	2.14 a	1.24 a	4.75 b	17.05 a	7954.17 b	6257.78 b
22	54.75 b	56.75 c	1.98 b	1.10 c	4.65 b	17.20 a	6835.56 c	5326.39 c
23	54.75 b	56.25 c	1.97 b	1.07 c	4.55 b	16.05 b	6476.39 c	5291.11 c
24	55.75 b	55.75 c	1.95 c	1.01 d	4.40 c	17.00 a	6360.56 c	5333.34 c
25	57.00 a	57.75 b	2.02 b	1.11 c	4.75 b	15.90 b	6628.62 c	5416.67 c
26	56.25 b	56.00 c	1.81 c	1.07 c	4.35 c	15.85 b	5677.23 c	4527.23 c
27	54.50 b	56.25 c	1.91 c	1.13 c	4.65 b	15.85 b	6811.95 c	5423.06 c
28	56.25 b	56.25 c	2.00 b	1.15 b	4.60 b	17.60 a	7350.84 c	5736,95 c

Continued Table 2:

Hybrids	MF days	FF days	PH m	EH M	ED cm	EL cm	EY kg.ha^{-1}	GY kg.ha^{-1}
29	55.25 b	56.00 c	1.88 c	1.05 c	4.35 c	17.20 a	7343.90 c	5920.28 c
30	56.25 b	56.50 c	2.01 b	1.11 c	4.50 b	16.45 b	6373.06 c	5059.73 c
31	54.75 b	55.00 c	1.80 c	1.02 d	4.15 c	17.20 a	6004.17 c	4846.67 c
32	54.75 b	55.75 c	1.79 c	1.03 d	4.25 c	17.55 a	5175.84 c	4115.28 c
33	57.00 a	57.00 b	1.87 c	1.11 c	4.35 c	17.15 a	6856.95 c	5427.23 c
34	56.75 a	57.25 b	2.08 a	1.23 a	4.50 b	16.50 b	7354.17 c	5853.62 c
35	55.00 b	55.50 c	1.64 c	0.94 d	4.15 c	15.85 b	5709.17 c	4684.73 c
36	55.75 b	56.25 c	1.89 c	1.03 d	4.30 c	16.60 b	6442.50 c	5266.67 c
37	56.00 b	56.75 c	1.88 c	1.04 d	4.40 c	16.70 b	6263.89 c	5093.89 c
38	56.25 b	56.75 c	2.05 b	1.25 a	4.40 c	17.65 a	7896.67 b	6326.39 b
39	57.50 a	57.50 b	2.00 b	1.12 c	4.35 c	17.05 a	6525.84 c	5021.67 c
40	56.50 a	57.75 b	2.10 a	1.19 b	4.30 c	16.30 b	5423.06 c	4364.73 c
41	54.25 b	55.50 c	1.90 c	1.12 c	4.40 c	16.80 a	6645.28 c	5544.45 c
42	57.00 a	57.00 b	2.15 a	1.27 a	4.60 b	17.55 a	8155.01 b	6581.39 b
43	54.75 b	55.00 c	1.92 c	1.07 c	4.30 c	15.90 b	7041.67 c	5631.95 c
44	58.00 a	56.50 c	2.00 b	1.21 b	4.60 b	17.30 a	9361.95 b	7316.12 b
45	55.50 b	56.75 c	1.83 c	0.98 d	4.05 c	16.35 b	4996.67 c	4202.78 c
46	56.75 a	56.50 c	1.87 c	1.08 c	4.45 c	15.80 b	5842.50 c	4722.23 c
47	54.00 b	54.25 c	1.98 b	1.13 c	4.45 c	16.55 b	6955.56 c	5750.84 c
48	57.25 a	57.25 b	1.86 c	1.00 d	4.65 b	16.30 b	8591.67 b	7140.28 b
49	56.75 a	57.00 b	1.89 c	1.10 c	4.55 b	16.20 b	6075.00 c	5227.78 c
50	56.25 b	56.75 c	2.13 a	1.25 a	4.40 c	18.60 a	7881.39 b	6460.56 b
51	57.00 a	57.00 b	2.00 b	1.19 b	4.55 b	18.20 a	7588.89 b	6377.23 b
52	58.25 a	57.75 b	2.08 a	1.23 a	4.60 b	16.00 b	7171.67 c	5571.67 c
53	56.75 a	56.75 c	2.13 a	1.20 b	4.60 b	16.85 a	6865.28 c	5587.50 c
54	57.50 a	58.00 b	2.08 a	1.14 b	4.50 b	15.30 b	6303.62 c	5120.84 c
55	56.25 b	56.75 c	2.08 a	1.25 a	4.75 b	15.80 b	7183.34 c	6011.95 c
56	58.00 a	58.00 b	1.98 b	1.09 c	4.70 b	16.90 a	7149.45 c	5756.39 c
57	55.25 b	57.00 b	2.01 b	1.18 b	4.70 b	16.35 b	8002.78 b	6725.84 b
58	55.75 b	57.25 b	2.00 b	1.16 b	4.40 c	17.65 a	6843.89 c	5457.78 c
59	55.25 b	57.00 b	2.06 b	1.10 c	4.55 b	17.20 a	6780.00 c	5462.50 c
60	57.75 a	57.50 b	1.79 c	1.07 c	4.15 c	17.15 a	5643.06 c	4490.28 c
61	55.50 b	57.00 b	1.86 c	1.02 d	4.45 c	17.10 a	7305.56 c	5280.56 c
62	55.25 b	56.25 c	1.83 c	0.98 d	4.30 c	17.90 a	7196.67 c	5698.62 c
63	56.25 b	56.75 c	1.80 c	0.97 d	4.15 c	16.85 a	6909.73 c	5543.90 c
64	57.25 a	57.25 b	1.95 c	1.14 b	4.25 c	16.45 b	6598.62 c	5402.23 c
65	57.50 a	58.00 b	2.13 a	1.26 a	4.30 c	15.95 b	5950.84 c	4861.11 c
66	54.5 b	55.75 c	1.92 c	1.10 c	4.50 b	16.30 b	6114.73 c	4943.06 c
67	57.00 a	57.50 b	2.21 a	1.26 a	4.60 b	17.90 a	8989.73 b	7463.89 b
68	57.50 a	58.25 b	2.19 a	1.30 a	4.70 b	18.05 a	8436.12 b	7090.28 b
69	55.50 b	56.50 c	2.25 a	1.28 a	4.55 b	17.60 a	8923.06 b	7281.95 b
70	56.25 b	56.25 c	1.86 c	1.07 c	4.55 b	16.25 b	7768.06 b	6626.39 b
71	56.50 a	56.25 c	1.85 c	1.07 c	4.35 c	15.30 b	5463.34 c	4371.67 c
72	56.75 a	56.75 c	2.08 a	1.23 a	4.80 b	17.55 a	8649.45 b	6675.84 b
73	57.75 a	57.00 b	1.99 b	1.15 b	4.45 c	18.60 a	7854.17 b	6394.45 b
74	58.75 a	57.50 b	2.04 b	1.18 b	4.45 c	18.05 a	7145.84 c	5813.34 c
75	59.00 a	57.25 b	1.90 c	1.09 c	4.45 c	17.80 a	7131.95 c	5839.73 c
MEAN	56.30	56.75	1.97	1.13	4.47	16.74	6921.66	5582.08
Control1*	60.50 a	60.75 a	2.09 a	1.23 a	5.35 a	17.95 a	15866.68 a	10488.90 a
Control2**	55.25 b	55.25 c	1.85 c	1.09 c	4.7 b	17.05 a	9170.84 b	7545.84 b

Means followed by the same letter, in the columns, belong to the same group and do not differ statistically by the Scott – Knott test (P<0.05).

Control1* and Control2*: commercial hybrids AG7088 and SHS5050, respectively.

Table 3: Estimates of the effects of the general combining ability (g_i's) for male flowering (MF), female flowering (FF), plant height (PH), ear height (EH), ear diameter (ED), ear length (EL), ear yield (EY), and grain yield (GY), of 75 lines of maize. Jataí, GO – 2015

Lines	MF(days)	FF(days)	PH(m)	EH(m)	ED(cm)	EL(cm)	EY(kg.ha^{-1})	GY(kg.ha^{-1})
1	-2.280	-0.730	-0.020	-0.021	0.228	-0.543	-194.433	-240.967
2	-1.780	-0.980	0.011	-0.034	-0.122	-0.743	-122.211	65.144
3	1.220	0.020	-0.084	-0.031	0.228	-0.843	112.511	20.144
4	-0.780	0.270	-0.163	-0.072	-0.122	-0.693	-248.044	-506.244
5	1.470	1.020	-0.164	-0.161	0.078	-0.143	365.844	270.144
6	1.220	0.020	-0.043	-0.047	0.078	0.357	-523.600	-607.078
7	-1.030	-0.480	-0.129	-0.021	0.078	-0.143	1561.678	1336.811
8	-1.530	-0.480	0.267	0.143	-0.022	-0.243	-234.711	-139.578
9	-0.780	-0.230	0.105	0.025	0.128	-0.593	95.011	-22.911
10	0.720	1.020	0.043	0.067	0.028	-1.043	-913.878	-802.911
11	-0.530	-0.480	0.107	0.041	-0.672	0.657	-884.156	-820.967
12	1.220	1.020	0.152	0.136	0.178	-0.493	69.456	-125.133
13	-0.780	-0.230	0.049	0.034	0.028	-0.893	-659.711	-179.300
14	-0.780	-0.480	0.153	0.077	0.128	0.757	2349.178	1860.978
15	0.470	0.520	-0.138	-0.095	-0.022	-0.793	-875.822	-792.356
16	1.470	1.270	0.140	0.006	0.028	-0.643	-948.045	-854.856
17	0.470	-0.480	-0.174	-0.055	-0.172	0.257	-426.378	-415.411
18	1.720	1.020	0.055	0.055	0.178	-0.193	29.178	22.089
19	-0.030	0.020	-0.018	-0.041	0.078	-0.893	-1177.767	-1014.022
20	-2.030	-1.230	0.027	0.046	0.128	0.657	336.122	240.144
21	0.970	0.270	0.166	0.117	0.278	0.307	1032.511	675.700
22	-1.530	0.020	0.008	-0.031	0.178	0.457	-86.100	-255.689
23	-1.530	-0.480	-0.008	-0.053	0.078	-0.693	-445.267	-290.967
24	-0.530	-0.980	-0.024	-0.119	-0.072	0.257	-561.100	-248.744
25	0.720	1.020	0.051	-0.015	0.278	-0.843	-293.044	-165.411
26	-0.030	-0.730	-0.161	-0.057	-0.122	-0.893	-1244.433	-1054.856
27	-1.780	-0.480	-0.059	0.001	0.178	-0.893	-109.711	-159.022
28	-0.030	-0.480	0.025	0.020	0.128	0.857	429.178	154.867
29	-1.030	-0.730	-0.100	-0.072	-0.122	0.457	422.233	338.200
30	-0.030	-0.230	0.037	-0.018	0.028	-0.293	-548.600	-522.356
31	-1.530	-1.730	-0.172	-0.103	-0.322	0..457	-917.489	-735.411
32	-1.530	-0.980	-0.185	-0.097	-0.222	0.807	-1745.822	-1466.800
33	0.720	0.270	-0.108	-0.012	-0.122	0.407	-64.711	-154.856
34	0.470	0.520	0.106	0.100	0.028	-0.243	432.511	271.533
35	-1.280	-1.230	-0.329	-0.183	-0.322	-0.893	-1212.489	-897.356
36	-0.530	-0.480	-0.080	-0.099	-0.172	-0.143	-479.156	-315.411
37	-0.280	0.020	-0.094	-0.087	-0.072	-0.043	-657.767	-488.189
38	-0.030	0.020	0.074	0.120	-0.072	0.907	975.011	744.311
39	1.220	0.770	0.029	-0.003	-0.122	0.307	-395.822	-560.411
40	0.220	1.020	0.127	0.060	-0.172	-0.443	-1498.600	-1217.356
41	-2.030	-1.230	-0.068	-0.008	-0.072	0.057	-276.378	-37.633
42	0.720	0.270	0.175	0.139	0.128	0.807	1233.345	999.311
43	-1.530	-1.730	-0.050	-0.055	-0.172	-0.843	120.011	49.867
44	1.720	-0.230	0.022	0.083	0.128	0.557	2440.289	1734.033
45	-0.780	0.020	-0.139	-0.147	-0.422	-0.393	-1924.989	-1379.300
46	0.470	-0.230	-0.102	-0.042	-0.022	-0.943	-1079.156	-859.856
47	-2.280	-2.480	0.007	0.003	-0.022	-0.193	33.900	168.756
48	0.970	0.520	-0.118	-0.128	0.178	-0.443	1670.11	1558.200
49	0.470	0.270	-0.084	-0.023	0.078	-0.543	-846.656	-354.300
50	-0.030	0.020	0.155	0.119	-0.072	1.857	959.733	878.478
51	0.720	0.270	0.031	0.060	0.078	1.457	667.233	795.145
52	1.970	1.020	0.111	0.102	0.128	-0.743	250.011	-10.411
53	0.470	0.020	0.155	0.078	0.128	0.107	-56.378	5.422

Continued Table 3:

Lines	MF(days)	FF(days)	PH(m)	EH(m)	ED(cm)	EL(cm)	EY(kg.ha^{-1})	GY(kg.ha^{-1})
54	1.220	1.270	0.109	0.015	0.028	-1.443	-618.044	-461.244
55	-0.030	0.020	0.103	0.123	0.278	-0.943	261.678	429.867
56	1.720	1.270	0.010	-0.038	0.228	0.157	227.789	174.311
57	-1.030	0.270	0.039	0.052	0.228	-0.393	1081.122	1143.756
58	-0.530	0.520	0.031	0.034	-0.072	0.907	-77.767	-124.300
59	-1.030	0.270	0.083	-0.029	0.078	0.457	-141.656	-119.578
60	1.470	0.770	-0.182	-0.061	-0.322	0.407	-1278.600	-1091.800
61	-0.780	0.270	-0.117	-0.107	-0.022	0.357	383.900	-301.522
62	-1.030	-0.480	-0.146	-0.151	-0.172	1.157	275.011	116.533
63	-0.030	0.020	-0.175	-0.156	-0.322	0.107	-11.933	-38189
64	0.970	0.520	-0.028	0.016	-0.222	-0.293	-323.044	-179.856
65	1.220	1.270	0.157	0.135	-0.172	-0.793	-970.822	-720.967
66	-1.780	-0.980	-0.055	-0.023	0.028	-0.443	-806.933	-639.022
67	0.720	0.770	0.241	0.132	0.128	1.157	2068.067	1881.811
68	1.220	1.520	0.214	0.171	0.228	1.307	1514.456	1508.200
69	-0.780	-0.230	0.275	0.152	0.078	0.857	2001.400	1699.867
70	-0.030	-0.480	-0.114	-0.057	0.078	-0.493	846.400	1044.311
71	0.220	-0.480	-0.125	-0.056	-0.122	-1.443	-1458.322	-1210.411
72	0.470	0.020	0.107	0.103	0.328	0.807	1727.789	1093.756
73	1.470	0.270	0.022	0.019	-0.022	1.857	932.511	812.367
74	2.470	0.770	0.069	0.058	-0.022	1.307	224.178	231.256
75	2.720	0.520	-0.078	-0.034	-0.022	1.057	210.289	257.644

mean of the progenies. With respect to the ratio between plant height and ear, the topcross hybrids with the lowest ratio were 5, 24, and 45, meaning that these progenies have the lowest ear height in relation to the total plant height, and, in general, the lower the ear height, the lower the probability of the plant breaking below the ear.

The topcross hybrids that presented the highest ear diameter were 21, 25, 55, and 72; those that showed the highest ear length were 50, 51, 68, and 74. These progenies may be interesting in the breeding process, as the length and diameter of the ear is generally well related to yield. These results underline the significance of evaluating the value of each partially inbreeding line by using the topcrosses, as already related by Arnhold *et al.* (2009). These authors, by studying the performance association between S_3 families and their topcross hybrids of pop corn, observed that it is not possible to recommend the replacement of the topcross selection by the selection per se of inbreeding families in pop corn, since, for the grain yield and expansion capacity traits assessed, the low correlation does not justify the selection only by the performance *per s*e.

In relation to the grain yield of 16 higher yielding topcross hybrids, they were statistically equal to the SHS 5050 hybrid, which is used in the market. There are some topcross hybrids with a yield above 7,000 kg.ha^{-1}.

Table 3 provides estimates of the effects of the general combining ability (GCA) for the assessed traits of the 75 maize S_2 lines. Given that the lines were crossed with a tester considered to have a broad genetic base (AG 6040), the effects of general combining ability were estimated (Vencovsky & Barriga, 1992).

The values of GCA for male flowering ranged from -2.28 days (lines 1 and 47) to 2.72 days (line 75) and, for female flowering, the scores ranged from -2.48 days (line 47) to 1.52 days (line 68). Similar results were found by Clovis *et al.* (2015), who selected promising lines with negative GCA for male and female flowering, suggesting that the selected lines provided an improvement in the hybrid earliness. Considering the cycle and the greater importance in the formation of the ear, closely related to the production of the stigma-style, priority should be given to the reduction for female flowering; in this way, the best lines were 47, 31, and 43. For plant height, the GCA ranged from -0.329 m (line 35) to 0.275 m (line 69) and, for ear height, from - 0.183 m (line 35) to 0.171 days (line 68). Prioritizing the reduction of the plant and ear height, line 35 would be the most suitable, followed by lines 5, 63, and 62. For the ear diameter, the GCA ranged from -0.672 cm (line 11) to 0.328 cm (line 72) and, for the ear length, the GCA was from -1.443 cm (lines 71 and 54) to 1.857 cm (lines 73 and 50), which enables the recommendation of larger diameter lines or longer ear lengths if it is worthwhile.

For the hulled ears yield, a trait that has a strong relationship with the grain yield, it was observed values of general combining ability (GCA) ranging from -1924.98 kg.ha-^{1} (line 45) to 2440.28 kg.ha-^{1} (line 44), and, for grain yield in kg.ha-^{1}, the GCA was observed ranging from -

1466.80 (line 32) to 1881.81 (line 67), demonstrating successful possibilities in selecting lines for the synthetic production. Thus, for grain yield the following lines should be recommended: 67, 14, 44, 69 indicating a GCA higher than 1700.00 kg.ha- [1]. These same genotypes could be used, in their hybrid form, with the AG6040 for base population yield for selection purposes, and they could be used both for future yielding of an open pollinated variety and for extraction of lines to obtain hybrids. Estimating the effects of the general combining ability for grain yield in maize, Scapim *et al*. (2008) and Clovis *et al*. (2015) also identified high and positive values, suggesting the feasibility of selecting inbreeding lines with yield potential by means of topcrosses. Barreto *et al*. (2012), also assessing the ability to combine maize S_2 families by using testers, found significant effects of GCA. Both studies confirm the results found in this study.

CONCLUSIONS

It is concluded that topcross hybrids of partially inbreeding maize lines have good yield potential, being equivalent to one of the commercial hybrids used in the trial, and may be an alternative for the production of synthetic or base populations for selection purposes.

The 67, 14, 44, and 69 lines stand out for presenting the best grain yields. It was also possible to identify good agronomic behavior of the other traits evaluated.

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