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# Yield potential of green maize from partially inbred lines in top crosses

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**Abstract**

Selecting potential progenies in early inbred generations is an essential step towards the success of breeding programs. Given this, the use of top crosses assists breeders in selecting progenies to generate lines with the potential for hybrid yield. Thus, the purpose of this study was to assess the behavior of partially inbred progenies ($S_1$) of maize with potential for green maize yield in top crosses and to evaluate the hybrid performance. Seventy-five top cross hybrids were generated from the cross between 75 $S_1$ progenies and the $F_2$ generation of the hybrid AG 1051. The 75 hybrids, the male tester ($F_2$ generation of the hybrid AG 1051 as a broad genetic base tester), and the hybrid AG 1051 were sown in a block design with four replicates. The following traits were evaluated: husked ear yield; commercial ear yield; flowering; plant height; strawing; mean weight of grain mass in green maize stage; tassel branch number; ear row number; ear length; and ear diameter. The analysis of variance was performed estimating the general combining ability, and, from the means, the Scott & Knott test was conducted. The top cross hybrids that were prominent for commercial ear yield were those composed of partially inbred progenies 19, 48, 6, 28, and 42 with high GCA, suggesting a potential for the production of open pollination population or synthetic production as well.

**Keywords:** $S_1$ lines; yield; early selection; plant breeding; *Zea mays.*
**Abbreviations**: CEYIELD_commercial ear yield; ED_ear diameter; EH_ear height; EL_ear length; ERN_ear row number; FF_female flowering; gi's_ general combining ability; MF_male flowering; MWG_ mean weight of grain mass; PH_plant height; ESYIELD_ ear with straw yield; STRAW_straw; TBN_tassel branch number.

## Introduction

At a global level, maize (*Zea mays* L.) has become one of the most widely consumed and cultivated cereals, a demand that is explained by its numerous applications in the agricultural and industrial sector (Shiferaw et al., 2011). Regarded as one of the most produced grains worldwide, 1,098.95 million tons is the estimate of world production for 2018/19 harvest year. The United States ranks as the world's largest producer with 371.52 million tons, followed by China with a production of 256 million tons, and Brazil with 94.5 million tons (USDA, 2018).

This culture stands out as one of the most important in the world, because of its yield, chemical composition, and nutritional value, making it the most studied allogamous species for its high economic relevance (Grigulo et al., 2011).

Among the many commercial alternatives for maize, green maize yield is of great relevance. Green maize can be used in the food industry or for fresh consumption, increasing the economic value of the final product and encouraging farmers to improve their incomes (Dovale et al., 2011).

The growing need for high-quality green maize requires public-private research entities to develop maize cultivars that meet the demands of the green maize consumer market. Pereira Filho et al. (2002) points out that attention should be paid to some traits to select genotypes with potential for green maize, such as yellow toothed grains, large, cylindrical, and well ears with straw, white cob, good graining, smooth pericarp, with long harvest and post-harvest longevity.

The great breakthrough in maize yield was the discovery of heterosis manifested in hybrids. Obtaining them in a breeding program implies the following steps: choosing the population, obtaining lines, evaluating the combining ability and extensive tests of the hybrids obtained (Paterniani and Campos, 1999).

Nevertheless, the process of obtaining simple hybrid maize is very costly, which makes the seeds more expensive and difficult to access, mainly for small producers. Thus, new alternatives for hybrids have been proposed to reduce production costs. One of these alternatives is the use of hybrids of partially inbred lines and top cross hybrids. The partially inbred lines require less time to achieve, are easier to handle when compared to inbred lines, and present satisfactory yield. In this way, they can generate hybrids with high yield within a reduced time and lower costs (Ferreira et al. 2009; Paterniani et al. 2010; Guedes et al. 2011; Silva et al. 2017).

Once the lines have been obtained, the evaluation of their combining ability can be carried out by the top cross method

proposed by Davis (1927), which consists of crossing a large number of partially inbred lines with a common tester. The top cross method seeks to assess the relative merit of crossbred lines with a tester, removing lines with inferior agronomic performance in the initial stages of production, making the breeding program more rational and efficient (Nurmberg et al., 2000).
There have been very few studies in the literature that focus on the evaluation of partially inbred lines in crosses with testers and the agronomic performance of top cross hybrids with emphasis on traits for green maize consumption. This emphasize the importance of choosing genotypes that combine high commercial yield of green ears and green grain mass.
Therefore, this study aims at (a) evaluating the behavior of partially inbred $S_1$ progenies of maize in top crosses, obtained from $S_0$ progenies with the high potential of green yield; (b) to produce synthetic varieties and (c) to collect experimental information on the yield and agronomic potential of hybrid combinations.

**Results and Discussion**

***Analysis of variance***

Based on the analysis of variance (Table 1), there was a significant difference (F-test) for the traits evaluated, except for plant height (PH) and commercial ear yield (CEYIELD) traits. Therefore, most traits were adequate to distinguish the genotypes with high variability among the top cross hybrids assessed, allowing selection of material with better agronomic performance to proceed with the genetic breeding program. In general, the coefficients of experimental variation were low for all traits, except CEYIELD, PH, and ear height (EH) traits (Table 1), where the values ranged from 1.56 to 26.94. Such results are in line with what has been reported in the literature for maize cultivation (Cancellier et al. 2011; Mendes et al. 2013).

***Scott and Knott test***

Table 2 shows the Scott and Knott test and the grouping of the means of the 75 top cross hybrids, control (AG 1051), and tester, that nearly 50% of the top cross hybrids were grouped with the control (hybrid AG 1051) for the traits related to the yield (ESYIELD and CEYIELD). It shows the potential of the inbred lines that generated the top cross hybrids for implementation in breeding programs, as the hybrid AG 1051 is mostly used for green maize yield. For the flowering traits (male flowering - MF and female flowering - FF), we verified that some of the materials were equal while others inferiority. A fact that can be positive, considering that it is a cycle, indicating hybrids with better earliness. Regarding the ear traits (ear length - EL, ear diameter - ED, ear row number - ERN, mean weight of grain mass – MWG, and ear with straw yield - ESYIELD), we noted that approximately 50% of the top cross hybrids were clustered in the same control group for the EL and ED traits, while for ERN, there was only one cluster. For MWG, around 66% of the top cross hybrids matched the mean weight of the grain mass of the AG 1051 hybrid, while for the ESYIELD trait, nearly 62% of the top cross hybrids were clustered in the group with the lowest mean, suggesting that ears with better straws had lower mean of a scale of grades. In this work, top cross hybrids with high yield potential were achieved, with yields similar to or higher than the commercial control (AG 1051). These findings show the high yield potential of hybrids from partially inbred $S_1$ lines, confirming the results achieved by Souza Júnior (1995); Ferreira et al. (2009); Marcondes et al. (2015); and Marcondes et al. (2016), who reported the feasibility of yielding maize hybrids using partially inbred lines.
The five top cross hybrids that had the highest yield of ears with straw were 10, 19, 5, 6, and 25, while for commercial ears they were 19, 48, 6, 28, and 42. As Rodrigues et al. (2009) stated in the green maize yield system, the ears normally are transported to the processing or sale place in straw form for fresh consumption. This process reduces the physical damage by transport. In this way, the ear with straw yield (ESYIELD) proves to be an important trait that should be taken into account in the assessment of cultivars to this end. It is also desirable, for the green maize yield, a higher commercial ear yield (CEYIELD) since they are the ones that will be commercialized (Albuquerque et al. 2008).
For earlier cycles, the five selected ones were 12, 17, 19, 4, and 52, with a mean of approximately two days less than the total mean of the hybrids for the male flowering trait. The ones with the largest ear diameter were 8, 6, 57, 18, and 61. Those with the largest ear length were 5, 21, 69, 2, and 10. These progenies can be of interest in the breeding process as the length and diameter of the ears are generally well connected to yield. In accordance with Albuquerque et al. (2008), it is worth mentioning that the consumer prefers larger diameter and longer length ears, because thinner and shorter ears are generally rejected, remaining for a more extended time in commercial establishments, favoring their deterioration.
These results highlight the relevance of evaluating the importance of each partially inbred line by means of the use of top crosses, as already reported by Arnhold et al. (2009), who studying the performance association between $S_3$ families and their top cross hybrids of popcorn. They found that it is not possible to recommend replacing the selection in top cross by selection *per se* of inbred families in popcorn. Regarding the mean weight of grain mass trait, hybrids 8, 42, 61, 48, and 25 were the ones that presented the highest means, pointing out they have the potential to be used by a *pamonha* (maize-paste wrapped in husks) factory to obtain green maize by-products.

***Effects of the general combining ability***

Table 3 provides estimates of the effects of the general combining ability (gi's) for the assessed traits of the 75 top cross maize hybrids. Assuming that the partially inbred lines were crossed with a tester considered to be of a broad genetic basis (AG 1051), the effects of the general combining ability were estimated (Vencovsky and Barriga, 1992).
It can be seen that the values of gi's for male flowering (MF) ranged from -2.45 days (Lines 12) to 2.55 days (Line 9) and, for female flowering (FF), the scores ranged from -2.94 days (Line 12) to 2.56 days (Line 63). Similar results were obtained

**Table 1.** Analysis of variance for ear with straw yield (ESYIELD), commercial ear yield (CEYIELD), plant height (PH), tassel branch number (TBN), male flowering (MF), female flowering (FF), ear length (EL), ear diameter (ED), ear row number (ERN), ear height (EH), mean weight of grain mass (MWG), and strawing (STRAW) of 75 top cross hybrids of green maize, commercial hybrid AG 1051, and the broad genetic base tester ($F_2$ of the AG 1051). Jataí Municipality, Goiás State, Brazil, 2018.

| SV | DF | Mean Squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ESYIELD | CEYIELD | PH | TBN | MF | FF | EL | ED | ERN | EH | MWG | STRAW |
| Blocks | 3 | 48235249.73 | 117610882.79 | 438.52 | 23.34 | 63.63 | 51.96 | 3.61 | 1.87 | 0.90 | 138.93 | 35127.41 | 0.60 |
| Hybrids | 76 | 10305857.17** | 6027977.74 ** | 2868.72$^{ns}$ | 7.89** | 3.70** | 3.75** | 2.43** | 0.10** | 2.96** | 1319.40$^{ns}$ | 766.60 ** | 0.01 * |
| Residue | 228 | 2587176.19 | 2041268.65 | 2783.80 | 2.26 | 0.94 | 1.15 | 1.05 | 0.05 | 1.88 | 1148.57 | 454.80 | 0.01 |
| Mean | | 14625.19 | 5302.96 | 240.73 | 11.59 | 62.23 | 63.72 | 18.03 | 4.61 | 15.04 | 143.00 | 130.22 | 1.53 |
| CV% | | 11.00 | 26.94 | 21.92 | 12.97 | 1.56 | 1.69 | 5.69 | 5.10 | 9.13 | 23.7 | 16.38 | 7.21 |

** e * significant at 1% and 5% probability, respectively, by the F test.

**Table 2.** Means of ear with straw yield (ESYIELD), commercial ear yield (CEYIELD), tassel branch number (TBN), male flowering (MF), female flowering (FF), ear length (EL), ear diameter (ED), ear row number (ERN), mean weight of grain mass (MWG), and strawing (STRAW) of 75 top cross hybrids of green maize, commercial hybrid AG 1051, and broad genetic base tester ($F_2$ of the AG 1051). Jataí Municipality, Goiás State, Brazil, 2018. *The means were compared with each other using the Scott & Knott test at 5% probability.*

| HYBRIDS | ESYIELD | | CEYIELD | | TBN | | MF | | FF | | EL | | ED | | ERN | | MWG | | STRAW | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13474.86 | b | 3667.51 | b | 11.85 | b | 61.25 | d | 63.75 | a | 17.15 | b | 4.50 | b | 14.20 | a | 120.55 | b | 1.90 | a |
| 2 | 16912.49 | a | 6491.83 | a | 12.65 | b | 62.25 | c | 63.75 | a | 19.20 | a | 4.60 | b | 14.50 | a | 131.45 | a | 1.10 | b |
| 3 | 15931.68 | a | 5119.58 | b | 11.60 | c | 61.25 | d | 62.25 | c | 17.60 | b | 4.25 | b | 15.60 | a | 146.35 | a | 1.30 | b |
| 4 | 13787.73 | b | 5164.70 | b | 12.50 | b | 60.75 | d | 62.50 | c | 15.95 | b | 4.55 | b | 14.30 | a | 111.00 | b | 1.35 | b |
| 5 | 17543.34 | a | 6634.40 | a | 14.15 | a | 62.00 | c | 64.00 | a | 19.75 | a | 4.85 | a | 15.10 | a | 151.45 | a | 1.50 | a |
| 6 | 17368.04 | a | 7261.97 | a | 11.50 | c | 63.75 | a | 64.75 | a | 18.75 | a | 4.95 | a | 14.90 | a | 129.00 | a | 1.35 | b |
| 7 | 15396.42 | a | 4907.53 | b | 11.40 | c | 61.75 | c | 63.25 | b | 17.30 | b | 4.65 | a | 14.20 | a | 134.40 | a | 1.70 | a |
| 8 | 15387.73 | a | 5562.00 | a | 15.75 | a | 61.00 | d | 61.75 | c | 17.75 | b | 5.00 | a | 16.70 | a | 164.70 | a | 1.20 | b |
| 9 | 15704.75 | a | 6094.34 | a | 12.45 | b | 64.75 | a | 65.50 | a | 17.90 | b | 4.70 | a | 15.15 | a | 138.95 | a | 1.15 | b |
| 10 | 17726.50 | a | 6034.90 | a | 9.60 | c | 63.00 | b | 63.75 | a | 19.15 | a | 4.75 | a | 15.10 | a | 151.95 | a | 1.35 | b |
| 11 | 15740.91 | a | 5843.34 | a | 10.50 | c | 61.25 | d | 62.00 | c | 19.02 | a | 4.69 | a | 14.39 | a | 145.08 | a | 1.46 | a |
| 12 | 13414.47 | b | 5140.86 | b | 15.25 | a | 59.75 | d | 60.75 | c | 18.50 | a | 4.75 | a | 14.80 | a | 136.60 | a | 1.30 | b |
| 13 | 13245.82 | b | 4059.88 | b | 12.00 | b | 62.25 | c | 63.75 | a | 17.80 | b | 4.60 | b | 14.00 | a | 122.55 | b | 1.05 | b |
| 14 | 16228.21 | a | 6533.47 | a | 11.70 | c | 62.00 | c | 63.00 | b | 18.65 | a | 4.45 | b | 15.00 | a | 134.80 | a | 1.60 | a |
| 15 | 13794.18 | b | 5869.58 | a | 10.10 | c | 61.75 | c | 64.00 | a | 18.15 | a | 4.65 | a | 15.30 | a | 123.20 | b | 1.35 | b |
| 16 | 13949.61 | b | 4438.31 | b | 13.25 | b | 63.50 | a | 65.00 | a | 17.55 | b | 4.00 | b | 16.30 | a | 123.55 | b | 1.35 | b |
| 17 | 15831.53 | a | 6346.90 | a | 12.80 | b | 60.25 | d | 61.50 | c | 18.10 | a | 4.65 | a | 14.50 | a | 132.90 | a | 1.20 | b |
| 18 | 16189.64 | a | 5634.72 | a | 9.20 | c | 62.75 | b | 63.50 | b | 18.80 | a | 4.90 | a | 15.60 | a | 143.55 | a | 1.50 | a |
| 19 | 17651.80 | a | 8630.95 | a | 11.00 | c | 60.50 | d | 63.25 | b | 18.55 | a | 4.75 | a | 15.90 | a | 138.45 | a | 1.35 | b |
| 20 | 15523.60 | a | 4850.16 | b | 9.75 | c | 63.25 | b | 64.75 | a | 18.30 | a | 4.45 | b | 14.70 | a | 112.48 | b | 1.25 | b |
| 21 | 13261.22 | b | 5700.87 | a | 12.80 | b | 63.25 | b | 63.75 | a | 19.35 | a | 4.55 | b | 14.30 | a | 127.45 | a | 1.25 | b |
| 22 | 15817.37 | a | 5090.19 | b | 10.60 | c | 61.00 | d | 62.50 | c | 17.80 | b | 4.60 | b | 15.10 | a | 133.20 | a | 1.20 | b |
| 23 | 15102.91 | a | 6028.39 | a | 13.75 | a | 62.00 | c | 63.25 | b | 18.75 | a | 4.55 | b | 14.90 | a | 145.25 | a | 1.30 | b |
| 24 | 15372.88 | a | 6404.59 | a | 11.55 | c | 61.00 | d | 63.00 | b | 19.05 | a | 4.50 | b | 14.90 | a | 114.60 | b | 1.00 | b |
| 25 | 17323.62 | a | 6667.96 | a | 11.40 | c | 61.75 | c | 62.50 | c | 18.25 | a | 4.85 | a | 14.80 | a | 153.70 | a | 1.15 | b |
| 26 | 14523.00 | b | 5626.13 | a | 12.90 | b | 62.00 | c | 63,00 | b | 18.35 | a | 4.80 | a | 15.50 | a | 143.45 | a | 1.30 | b |
| 27 | 11960.01 | b | 5510.80 | a | 14.35 | a | 61.00 | d | 62.50 | c | 18.05 | a | 4.80 | a | 14.70 | a | 151.20 | a | 1.40 | b |
| 28 | 15982.38 | a | 7135.55 | a | 12.85 | b | 63.50 | a | 64.25 | a | 18.25 | a | 4.50 | b | 15.30 | a | 125.85 | b | 1.25 | b |
| 29 | 14325.16 | b | 5589.25 | a | 12.25 | b | 62.25 | c | 64.75 | a | 17.85 | b | 4.70 | a | 15.20 | a | 133.05 | a | 1.20 | b |
| 30 | 12258.62 | b | 4631.63 | b | 11.70 | c | 62.50 | b | 64.00 | a | 18.35 | a | 4.35 | b | 14.20 | a | 121.45 | b | 1.20 | b |
| 31 | 13741.31 | b | 5562.28 | a | 11.00 | c | 62.75 | b | 63.75 | a | 18.05 | a | 4.60 | b | 14.50 | a | 131.00 | a | 1.20 | b |
| 32 | 14106.90 | b | 4596.26 | b | 11.75 | c | 62.00 | c | 63.00 | b | 18.45 | a | 4.55 | b | 16.10 | a | 138.50 | a | 1.00 | b |
| 33 | 14225.95 | b | 4374.94 | b | 10.25 | c | 62.00 | c | 63.25 | b | 17.75 | b | 4.50 | b | 13.30 | a | 127.90 | a | 1.10 | b |
| 34 | 14781.83 | a | 6318.64 | a | 11.90 | b | 62.00 | c | 64.75 | a | 18.55 | a | 4.60 | b | 15.30 | a | 121.80 | b | 1.10 | b |
| 35 | 14982.90 | a | 5781.19 | a | 10.75 | c | 62.50 | b | 64.00 | a | 16.50 | b | 4.60 | b | 15.20 | a | 96.20 | b | 1.35 | b |
| 36 | 13868.59 | b | 4612.21 | b | 12.60 | b | 61.50 | c | 63.50 | b | 17.75 | b | 4.55 | b | 14.30 | a | 135.50 | a | 1.40 | b |

Table 2 (continued)

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37 | 12897.13 | b | 4469.77 | b | 12.80 | b | 62.25 | c | 64.25 | a | 17.55 | b | 4.50 | b | 15.50 | a | 129.75 | a | 1.55 | a |
| 38 | 15481.56 | a | 6420.26 | a | 12.60 | b | 62.50 | b | 64.25 | a | 18.75 | a | 4.75 | a | 14.50 | a | 128.05 | a | 1.40 | b |
| 39 | 14601.25 | a | 4689.73 | b | 10.95 | c | 61.75 | c | 63.25 | b | 18.10 | a | 4.60 | b | 14.30 | a | 131.15 | a | 1.45 | a |
| 40 | 16476.67 | a | 6630.24 | a | 11.40 | c | 62.25 | c | 64.00 | a | 19.00 | a | 4.65 | a | 14.40 | a | 138.15 | a | 1.55 | a |
| 41 | 12962.66 | b | 4230.92 | b | 13.15 | b | 61.00 | d | 62.25 | c | 16.65 | b | 4.60 | b | 15.30 | a | 120.55 | b | 1.65 | a |
| 42 | 16517.44 | a | 6916.41 | a | 11.90 | b | 62.25 | c | 63.75 | a | 18.45 | a | 4.80 | a | 16.20 | a | 156.70 | a | 1.20 | b |
| 43 | 14833.52 | a | 5810.43 | a | 13.35 | b | 62.25 | c | 6375 | a | 18.20 | a | 4.55 | b | 14.45 | a | 147.10 | a | 1.55 | a |
| 44 | 12293.21 | b | 4689.95 | b | 11.70 | c | 62.25 | c | 64.25 | a | 17.05 | b | 4.65 | a | 15.90 | a | 124.25 | b | 1.10 | b |
| 45 | 13267,.82 | b | 2442.93 | b | 10.35 | c | 63.25 | b | 65.00 | a | 17.25 | b | 4.40 | b | 19.60 | a | 108.80 | b | 1.35 | b |
| 46 | 13888.35 | b | 4644.81 | b | 12.20 | b | 61.50 | c | 62.50 | c | 18.20 | a | 4.60 | b | 14.60 | a | 119.15 | b | 1.95 | a |
| 47 | 14894.69 | a | 3536.40 | b | 10.50 | c | 63.50 | a | 64.75 | a | 17.69 | b | 4.36 | b | 14.52 | a | 111.42 | b | 1.73 | a |
| 48 | 16478.21 | a | 7857.08 | a | 9.60 | c | 62.50 | b | 63.50 | b | 18.70 | a | 4.65 | a | 14.10 | a | 153.70 | a | 1.50 | a |
| 49 | 14485.43 | b | 3765.19 | b | 11..40 | c | 61.75 | c | 64.00 | a | 16.80 | b | 4.55 | b | 15.00 | a | 114.50 | b | 1.45 | a |
| 50 | 13450.13 | b | 3965.89 | b | 12.15 | b | 62.25 | c | 63.50 | b | 18.00 | a | 4.65 | a | 15.20 | a | 128.85 | a | 1.25 | b |
| 51 | 15601.77 | a | 5004.82 | b | 9.40 | c | 62.00 | c | 64.50 | a | 17.95 | b | 4.65 | a | 15.60 | a | 138.70 | a | 1.05 | b |
| 52 | 9965.98 | c | 2502.38 | b | 11.55 | c | 60.75 | d | 62.75 | b | 16.00 | b | 4.50 | b | 15.40 | a | 107.80 | b | 1.70 | a |
| 53 | 14330.99 | b | 4652.91 | b | 11.15 | c | 62.75 | b | 63.25 | b | 18.25 | a | 4.55 | b | 15.90 | a | 140.15 | a | 1.45 | a |
| 54 | 13809.28 | b | 4273.55 | b | 9.60 | c | 62.75 | b | 63.75 | a | 18.40 | a | 4.60 | b | 15.00 | a | 131.40 | a | 1.30 | b |
| 55 | 15310.05 | a | 5030.33 | b | 12.40 | b | 63.00 | b | 65.25 | a | 18.40 | a | 4.75 | a | 15.20 | a | 141.05 | a | 1.30 | b |
| 56 | 14341.40 | b | 4427.91 | b | 11.30 | c | 63.25 | b | 64.25 | a | 17.85 | b | 4.75 | a | 15.00 | a | 137.65 | a | 1.85 | a |
| 57 | 14795.42 | a | 5233.02 | b | 11.90 | b | 62.50 | b | 63.75 | a | 17.40 | b | 4.90 | a | 16.70 | a | 119.25 | b | 1.60 | a |
| 58 | 14256.98 | b | 4525.03 | b | 10.05 | c | 61.50 | c | 63.00 | b | 17.98 | a | 4.59 | b | 15.27 | a | 138.91 | a | 1.60 | a |
| 59 | 14881.88 | a | 6477.76 | a | 11.10 | c | 64.25 | a | 65.00 | a | 19.10 | a | 4.55 | b | 15.80 | a | 119.40 | b | 1.50 | a |
| 60 | 14641.90 | a | 6239.08 | a | 9.60 | c | 62.75 | b | 65.00 | a | 17.90 | b | 4.85 | a | 15.70 | a | 135.55 | a | 1.40 | b |
| 61 | 16318.21 | a | 5022.58 | b | 12.20 | b | 61.50 | c | 64.00 | a | 18.60 | a | 4.85 | a | 14.90 | a | 156.55 | a | 1.30 | b |
| 62 | 13056.01 | b | 4526.27 | b | 9.55 | c | 62.50 | b | 64.50 | a | 17.10 | b | 4.45 | b | 14.90 | a | 121.30 | b | 1.50 | a |
| 63 | 14938.03 | a | 5445.55 | a | 10.75 | c | 64,50 | a | 66,25 | a | 17.15 | b | 4.70 | a | 14.80 | a | 111.70 | b | 1.65 | a |
| 64 | 14058.32 | b | 3793.22 | b | 10.30 | c | 62.25 | c | 63.50 | b | 17.20 | b | 4.80 | a | 16.50 | a | 129.35 | a | 1.40 | b |
| 65 | 14216.95 | b | 4914.96 | b | 14.45 | a | 62.00 | c | 63.50 | b | 19.00 | a | 4.60 | b | 14.50 | a | 135.80 | a | 1.40 | b |
| 66 | 13846.78 | b | 5908.27 | a | 13.00 | b | 62.00 | c | 64.25 | a | 18.55 | a | 4.40 | b | 14.50 | a | 117.25 | b | 1.20 | b |
| 67 | 15556.39 | a | 3667.28 | b | 9.90 | c | 61.50 | c | 63.50 | b | 17.35 | b | 4.65 | a | 13.90 | a | 104.65 | b | 1.25 | b |
| 68 | 14223.30 | b | 5077.04 | b | 10.90 | c | 62.50 | b | 63.00 | b | 17.50 | b | 4.60 | b | 15.60 | a | 130.15 | a | 1.55 | a |
| 69 | 13975.88 | b | 5753.49 | a | 10.00 | c | 63.25 | b | 64.25 | a | 19.30 | a | 4.50 | b | 14.20 | a | 131.05 | a | 1.60 | a |
| 70 | 14834.21 | a | 6401.50 | a | 11.35 | c | 62.25 | c | 63.50 | b | 18.60 | a | 4.45 | b | 14.00 | a | 128.15 | a | 1.25 | b |
| 71 | 12106.63 | b | 4692.32 | b | 10.70 | c | 62.25 | c | 64.00 | a | 17.50 | b | 4.65 | a | 14.60 | a | 129.60 | a | 1.75 | a |
| 72 | 12727.37 | b | 3644.13 | b | 11.55 | c | 61.00 | d | 64.00 | a | 17.30 | b | 4.50 | b | 15.20 | a | 108.35 | b | 1.40 | b |
| 73 | 15310.43 | a | 5797.13 | a | 12.90 | b | 63.50 | a | 64.75 | a | 17.30 | b | 4.55 | b | 14.48 | a | 133.70 | a | 1.25 | b |
| 74 | 14917.65 | a | 5816.35 | a | 9.65 | c | 62.50 | b | 63.50 | b | 17.70 | b | 4.55 | b | 15.10 | a | 130.60 | a | 1.30 | b |
| 75 | 13331.44 | b | 5807.05 | a | 11.90 | b | 63.00 | b | 64.25 | a | 18.60 | a | 4.35 | b | 14.10 | a | 124.35 | b | 1.45 | a |
| MÉAN | 14625.19 | | 5302.96 | | 11.59 | | 62.23 | | 63.72 | | 18.03 | | 4.61 | | 15.04 | | 130.22 | | 1.38 | |
| TESTER | 8898.47 | c | 1727.98 | b | 9.90 | c | 64.00 | a | 65.75 | a | 16.50 | b | 4.50 | b | 14.30 | a | 103.05 | b | 1.70 | a |
| AG 1051 | 16921.71 | a | 7978.57 | a | 10.30 | c | 62.75 | b | 63.75 | a | 18.75 | a | 4.70 | a | 15.30 | a | 116.15 | b | 1.25 | b |

**Table 3**.Estimates of the effects of the general combining ability (gi's) for ear with straw yield (ESYIELD), commercial ear yield (CEYIELD), plant height (PH), tassel branch number (TBN), male flowering (MF), female flowering (FF), ear length (EL), ear diameter (ED), ear row number (ERN), ear height (EH), mean weight of grain mass (MWG), and straw (STRAW) of 75 topcross hybrids of green maize. Jataí Municipality, Goiás State, Brazil, 2018.

| HYBRIDS | ESYIELD | CEYIELD | PH | TBN | MF | FF | EL | ED | ERN | EH | MWG | STRAW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1196.06 | -1647.45 | -3.38 | 0.22 | -0.95 | 0.06 | -0.90 | -0.11 | -0.84 | 66.97 | -10.22 | 0.52 |
| 2 | 2241.56 | 1176.87 | 9.97 | 1.02 | 0.05 | 0.06 | 1.15 | -0.01 | -0.54 | 5.77 | 0.68 | -0.28 |
| 3 | 1260.76 | -195.38 | -6.38 | -0.03 | -0.95 | -1.44 | -0.45 | -0.36 | 0.56 | -8.03 | 15.58 | -0.08 |
| 4 | -883.19 | -150.26 | -32.38 | 0.87 | -1.45 | -1.19 | -2.10 | -0.06 | -0.74 | -15.08 | -19.77 | -0.03 |
| 5 | 2872.41 | 1319.45 | 11.67 | 2.52 | -0.20 | 0.31 | 1.70 | 0.24 | 0.06 | -0.33 | 20.68 | 0.12 |
| 6 | 2697.12 | 1947.01 | 11.52 | -0.13 | 1.55 | 1.06 | 0.70 | 0.34 | -0.14 | 10.72 | -1.77 | -0.03 |
| 7 | 725.49 | -407.43 | -7.73 | -0.23 | -0.45 | -0.44 | -0.75 | 0.04 | -0.84 | -11.28 | 3.63 | 0.32 |
| 8 | 716.81 | 247.04 | 0.27 | 4.12 | -1.20 | -1.94 | -0.30 | 0.39 | 1.66 | 4.77 | 33.93 | -0.18 |
| 9 | 1033.82 | 779.38 | 5.72 | 0.82 | 2.55 | 1.81 | -0.15 | 0.09 | 0.11 | 2.82 | 8.18 | -0.23 |
| 10 | 3055.57 | 719.95 | 7.62 | -2.03 | 0.80 | 0.06 | 1.10 | 0.14 | 0.06 | 9.52 | 21.18 | -0.03 |
| 11 | 1069.98 | 528.38 | -10.43 | -1.13 | -0.95 | -1.69 | 0.97 | 0.08 | -0.66 | -11.93 | 14.31 | 0.07 |
| 12 | -1256.45 | -174.10 | -10.68 | 3.62 | -2.45 | -2.94 | 0.45 | 0.14 | -0.24 | -10.23 | 5.83 | -0.08 |
| 13 | -1425.11 | -1255.07 | -19.93 | 0.37 | 0.05 | 0.06 | -0.25 | -0.01 | -1.04 | -25.13 | -8.22 | -0.33 |
| 14 | 1557.29 | 1218.51 | -4.38 | 0.07 | -0.20 | -0.69 | 0.60 | -0.16 | -0.04 | -2.58 | 4.03 | 0.22 |
| 15 | -876.74 | 554.62 | -13.88 | -1.53 | -0.45 | 0.31 | 0.10 | 0.04 | 0.26 | -12.03 | -7.57 | -0.03 |
| 16 | -721.31 | -876.64 | -2.23 | 1.62 | 1.30 | 1.31 | -0.50 | -0.61 | 1.26 | -8.43 | -7.22 | -0.03 |
| 17 | 1160.61 | 1031.95 | -13.68 | 1.17 | -1.95 | -2.19 | 0.05 | 0.04 | -0.54 | -13.08 | 2.13 | -0.18 |
| 18 | 1518.72 | 319.77 | -1.33 | -2.43 | 0.55 | -0.19 | 0.75 | 0.29 | 0.56 | -10.33 | 12.78 | 0.12 |
| 19 | 2980.87 | 3315.99 | -4.58 | -0.63 | -1.70 | -0.44 | 0.50 | 0.14 | 0.86 | 35.32 | 7.68 | -0.03 |
| 20 | 852.67 | -464.79 | -6.93 | -1.88 | 1.05 | 1.06 | 0.25 | -0.16 | -0.34 | -22.13 | -18.29 | -0.13 |
| 21 | -1409.71 | 385.92 | 12.17 | 1.17 | 1.05 | 0.06 | 1.30 | -0.06 | -0.74 | 5.27 | -3.32 | -0.13 |
| 22 | 1146.45 | -224.77 | 1.22 | -1.03 | -1.20 | -1.19 | -0.25 | -0.01 | 0.06 | -5.68 | 2.43 | -0.18 |
| 23 | 431.99 | 713.44 | -5.28 | 2.12 | -0.20 | -0.44 | 0.70 | -0.06 | -0.14 | -5.03 | 14.48 | -0.08 |
| 24 | 701.95 | 1089.63 | -19.03 | -0.08 | -1.20 | -0.69 | 1.00 | -0.11 | -0.14 | -19.08 | -16.17 | -0.38 |
| 25 | 2652.70 | 1353.01 | 2.57 | -0.23 | -0.45 | -1.19 | 0.20 | 0.24 | -0.24 | -4.53 | 22.93 | -0.23 |
| 26 | -147.92 | 311.17 | -12.48 | 1.27 | -0.20 | -0.69 | 0.30 | 0.19 | 0.46 | -0.38 | 12.68 | -0.08 |
| 27 | -2710.92 | 195.84 | -2.98 | 2.72 | -1.20 | -1.19 | 0.00 | 0.19 | -0.34 | -1.43 | 20.43 | 0.02 |
| 28 | 1311.45 | 1820.59 | 6.02 | 1.22 | 1.30 | 0.56 | 0.20 | -0.11 | 0.26 | 1.77 | -4.92 | -0.13 |
| 29 | -345.77 | 274.29 | 4.82 | 0.62 | 0.05 | 1.06 | -0.20 | 0.09 | 0.16 | 8.57 | 2.28 | -0.18 |
| 30 | -2412.31 | -683.33 | -5.28 | 0.07 | 0.30 | 0.31 | 0.30 | -0.26 | -0.84 | -7.08 | -9.32 | -0.18 |
| 31 | -929.62 | 247.32 | -13.03 | -0.63 | 0.55 | 0.06 | 0.00 | -0.01 | -0.54 | -7.23 | 0.23 | -0.18 |
| 32 | -564.02 | -718.70 | 0.47 | 0.12 | -0.20 | -0.69 | 0.40 | -0.06 | 1.06 | -6.88 | 7.73 | -0.38 |
| 33 | -444.97 | -940.02 | -19.18 | -1.38 | -0.20 | -0.44 | -0.30 | -0.11 | -1.74 | -6.43 | -2.87 | -0.28 |
| 34 | 110.91 | 1003.69 | -10.98 | 0.27 | -0.20 | 1.06 | 0.50 | -0.01 | 0.26 | -16.33 | -8.97 | -0.28 |
| 35 | 311.97 | 466.23 | 9.27 | -0.88 | 0.30 | 0.31 | -1.55 | -0.01 | 0.16 | 9.82 | -34.57 | -0.03 |
| 36 | -802.34 | -702.75 | 4.67 | 0.97 | -0.70 | -0.19 | -0.30 | -0.06 | -0.74 | 71.07 | 4.73 | 0.02 |
| 37 | -1773.79 | -845.18 | -10.23 | 1.17 | 0.05 | 0.56 | -0.50 | -0.11 | 0.46 | 65.12 | -1.02 | 0.17 |
| 38 | 810.63 | 1105.30 | -1.83 | 0.97 | 0.30 | 0.56 | 0.70 | 0.14 | -0.54 | -1.78 | -2.72 | 0.02 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | -69.67 | -625.22 | 2.92 | -0.68 | -0.45 | -0.44 | 0.05 | -0.01 | -0.74 | -2.73 | 0.38 | 0.07 |
| 40 | 1805.75 | 1315.28 | 12.92 | -0.23 | 0.05 | 0.31 | 0.95 | 0.04 | -0.64 | 14.67 | 7.38 | 0.17 |
| 41 | -1708.26 | -1084.04 | -22.73 | 1.52 | -1.20 | -1.44 | -1.40 | -0.01 | 0.26 | -12.88 | -10.22 | 0.27 |
| 42 | 1846.52 | 1601.45 | -10.53 | 0.27 | 0.05 | 0.06 | 0.40 | 0.19 | 1.16 | -8.03 | 25.93 | -0.18 |
| 43 | 162.59 | 495.48 | -11.08 | 1.72 | 0.05 | 0.06 | 0.15 | -0.06 | -0.59 | -7.03 | 16.33 | 0.17 |
| 44 | -2377.71 | -625.01 | -14.43 | 0.07 | 0.05 | 0.56 | -1.00 | 0.04 | 0.86 | -16.28 | -6.52 | -0.28 |
| 45 | -1403.10 | -2872.02 | -4.43 | -1.28 | 1.05 | 1.31 | -0.80 | -0.21 | 4.56 | -6.98 | -21.97 | -0.03 |
| 46 | -782.57 | -670.15 | -19.63 | 0.57 | -0.70 | -1.19 | 0.15 | -0.01 | -0.44 | -8.83 | -11.62 | 0.57 |
| 47 | 223.77 | -1778.55 | 14.67 | -1.13 | 1.30 | 1.06 | -0.36 | -0.25 | -0.52 | 4.82 | -19.35 | 0.35 |
| 48 | 1807.29 | 2542.12 | 118.72 | -2.03 | 0.30 | -0.19 | 0.65 | 0.04 | -0.94 | 4.77 | 22.93 | 0.12 |
| 49 | -185.50 | -1549.77 | -8.73 | -0.23 | -0.45 | 0.31 | -1.25 | -0.06 | -0.04 | -3.13 | -16.27 | 0.07 |
| 50 | -1220.79 | -1349.06 | -1.53 | 0.52 | 0.05 | -0.19 | -0.05 | 0.04 | 0.16 | -4.98 | -1.92 | -0.13 |
| 51 | 930.85 | -310.14 | -12.43 | -2.23 | -0.20 | 0.81 | -0.10 | 0.04 | 0.56 | 0.57 | 7.93 | -0.33 |
| 52 | -4704.94 | -2812.58 | -19.18 | -0.08 | -1.45 | -0.94 | -2.05 | -0.11 | 0.36 | -6.38 | -22.97 | 0.32 |
| 53 | -339.94 | -662.04 | -15.78 | -0.48 | 0.55 | -0.44 | 0.20 | -0.06 | 0.86 | -11.38 | 9.38 | 0.07 |
| 54 | -861.64 | -1041.41 | 96.57 | -2.03 | 0.55 | 0.06 | 0.35 | -0.01 | -0.04 | -6.23 | 0.63 | -0.08 |
| 55 | 639.13 | -284.63 | 0.32 | 0.77 | 0.80 | 1.56 | 0.35 | 0.14 | 0.16 | -1.83 | 10.28 | -0.08 |
| 56 | -329.52 | -887.05 | -10.03 | -0.33 | 1.05 | 0.56 | -0.20 | 0.14 | -0.04 | 11.47 | 6.88 | 0.47 |
| 57 | 124.50 | -81.94 | -11.08 | 0.27 | 0.30 | 0.06 | -0.65 | 0.29 | 1.66 | -3.03 | -11.52 | 0.22 |
| 58 | -413.94 | -789.93 | 4.72 | -1.58 | -0.70 | -0.69 | -0.06 | -0.02 | 0.22 | -8.63 | 8.14 | 0.22 |
| 59 | 210.95 | 1162.81 | 12.77 | -0.53 | 2.05 | 1.31 | 1.05 | -0.06 | 0.76 | -0.38 | -11.37 | 0.12 |
| 60 | -29.03 | 924.13 | 0.27 | -2.03 | 0.55 | 1.31 | -0.15 | 0.24 | 0.66 | -6.58 | 4.78 | 0.02 |
| 61 | 1647.29 | -292.38 | -10.93 | 0.57 | -0.70 | 0.31 | 0.55 | 0.24 | -0.14 | -0.93 | 25.78 | -0.08 |
| 62 | -1614.91 | -788.69 | -9.93 | -2.08 | 0.30 | 0.81 | -0.95 | -0.16 | -0.14 | -6.03 | -9.47 | 0.12 |
| 63 | 267.11 | 130.59 | 16.32 | -0.88 | 2.30 | 2.56 | -0.90 | 0.09 | -0.24 | 9.37 | -19.07 | 0.27 |
| 64 | -612.61 | -1521.74 | -1.93 | -1.33 | 0.05 | -0.19 | -0.85 | 0.19 | 1.46 | 3.62 | -1.42 | 0.02 |
| 65 | -453.97 | -400.00 | -1.13 | 2.82 | -0.20 | -0.19 | 0.95 | -0.01 | -0.54 | 1.12 | 5.03 | 0.02 |
| 66 | -824.14 | 593.32 | -5.08 | 1.37 | -0.20 | 0.56 | 0.50 | -0.21 | -0.54 | -9.23 | -13.52 | -0.18 |
| 67 | 885.46 | -1647.67 | -3.38 | -1.73 | -0.70 | -0.19 | -0.70 | 0.04 | -1.14 | -3.43 | -26.12 | -0.13 |
| 68 | -447.63 | -237.92 | -5.63 | -0.73 | 0.30 | -0.69 | -0.55 | -0.01 | 0.56 | -4.18 | -0.62 | 0.17 |
| 69 | -695.05 | 438.53 | -4.68 | -1.63 | 1.05 | 0.56 | 1.25 | -0.11 | -0.84 | -10.38 | 0.28 | 0.22 |
| 70 | 163.29 | 1086.54 | 9.07 | -0.28 | 0.05 | -0.19 | 0.55 | -0.16 | -1.04 | 4.27 | -2.62 | -0.13 |
| 71 | -2564.29 | -622.64 | -16.93 | -0.93 | 0.05 | 0.31 | -0.55 | 0.04 | -0.44 | -15.58 | -1.17 | 0.37 |
| 72 | -1943.56 | -1670.83 | 96.72 | -0.08 | -1.20 | 0.31 | -0.75 | -0.11 | 0.16 | -12.43 | -22.42 | 0.02 |
| 73 | 639.50 | 482.17 | 1.67 | 1.27 | 1.30 | 1.06 | -0.75 | -0.06 | -0.56 | 2.82 | 2.93 | -0.13 |
| 74 | 246.72 | 501.39 | -7.88 | -1.98 | 0.30 | -0.19 | -0.35 | -0.06 | 0.06 | -8.03 | -0.17 | -0.08 |
| 75 | -1339.49 | 492.09 | -8.28 | 0.27 | 0.80 | 0.56 | 0.55 | -0.26 | -0.94 | 62.77 | -6.42 | 0.07 |

**Table 4.** Genealogy of maize lines used to obtain the top crosses. UFG – Jataí, 2018.

| Hybrid Code | Origin | Hybrid Code | Origin |
|---|---|---|---|
| 1 | TG02R2 X AG 1051 | 41 | TG02R2 X AG 1051 |
| 2 | TG02R2 X AG 1051 | 42 | TG02R2 X AG 1051 |
| 3 | TG02R2 X AG 1051 | 43 | TG02R2 X AG 1051 |
| 4 | TG02R2 X AG 1051 | 44 | TG02R2 X AG 1051 |
| 5 | TG02R2 X AG 1051 | 45 | TG02R2 X AG 1051 |
| 6 | TG02R2 X AG 1051 | 46 | TG02R2 X AG 1051 |
| 7 | TG02R2 X AG 1051 | 47 | TG02R2 X AG 1051 |
| 8 | TG02R2 X AG 1051 | 48 | TG02R2 X AG 1051 |
| 9 | TG02R2 X AG 1051 | 49 | TG02R2 X AG 1051 |
| 10 | TG02R2 X AG 1051 | 50 | TG02R2 X AG 1051 |
| 11 | TG02R2 X AG 1051 | 51 | TG02R2 X AG 1051 |
| 12 | TG02R2 X AG 1051 | 52 | TG02R2 X AG 1051 |
| 13 | TG02R2 X AG 1051 | 53 | TG02R2 X AG 1051 |
| 14 | TG02R2 X AG 1051 | 54 | TG02R2 X AG 1051 |
| 15 | TG02R2 X AG 1051 | 55 | TG02R2 X AG 1051 |
| 16 | TG02R2 X AG 1051 | 56 | TG02R2 X AG 1051 |
| 17 | TG02R2 X AG 1051 | 57 | TG02R2 X AG 1051 |
| 18 | TG02R2 X AG 1051 | 58 | TG02R2 X AG 1051 |
| 19 | TG02R2 X AG 1051 | 59 | TG02R2 X AG 1051 |
| 20 | TG02R2 X AG 1051 | 60 | TG02R2 X AG 1051 |
| 21 | TG02R2 X AG 1051 | 61 | TG02R2 X AG 1051 |
| 22 | TG02R2 X AG 1051 | 62 | TG02R2 X AG 1051 |
| 23 | TG02R2 X AG 1051 | 63 | TG02R2 X AG 1051 |
| 24 | TG02R2 X AG 1051 | 64 | TG02R2 X AG 1051 |
| 25 | TG02R2 X AG 1051 | 65 | TG02R2 X AG 1051 |
| 26 | TG02R2 X AG 1051 | 66 | TG02R2 X AG 1051 |
| 27 | TG02R2 X AG 1051 | 67 | TG02R2 X AG 1051 |
| 28 | TG02R2 X AG 1051 | 68 | TG02R2 X AG 1051 |
| 29 | TG02R2 X AG 1051 | 69 | TG02R2 X AG 1051 |
| 30 | TG02R2 X AG 1051 | 70 | TG02R2 X AG 1051 |
| 31 | TG02R2 X AG 1051 | 71 | TG02R2 X AG 1051 |
| 32 | TG02R2 X AG 1051 | 72 | TG02R2 X AG 1051 |
| 33 | TG02R2 X AG 1051 | 73 | TG02R2 X AG 1051 |
| 34 | TG02R2 X AG 1051 | 74 | TG02R2 X AG 1051 |
| 35 | TG02R2 X AG 1051 | 75 | TG02R2 X AG 1051 |
| 36 | TG02R2 X AG 1051 | | |
| 37 | TG02R2 X AG 1051 | | |
| 38 | TG02R2 X AG 1051 | | |
| 39 | TG02R2 X AG 1051 | | |
| 40 | TG02R2 X AG 1051 | | |

by Clovis et al. (2015), who selected promising lines with negative GCA for male and female flowering, suggesting the selected lines provided an enhancement in the earliness of the hybrids. Taking into consideration the different crop seasons, the reduction of the cycle takes an important part. For this reduction, closely related to the style-stigma yield and shorter time for female flowering should be prioritized. In this way, the five best lines were 12, 17, 8, 11, and 3. As for tassel branch number (TBN), GCA values ranged from -2.43 (Line 18) to 4.12 (Line 8). For plant height (PH), GCA ranged from -32.38 cm (Line 4) to 118.72 cm (Line 48), and for ear height (EH) from -25.13 cm (Line 13) to 71.07 cm (Line 16). Considering the reduction of plant height as a priority, lines 4, 41, 13, 46, 33 and 52 would be the most suitable.

In green maize yields grown in irrigated areas, it is usual to establish cooperation contracts with industries that grow maize. These industries keep a strict schedule for receiving the raw material, which demands intensive use of the cultivated area, where several subsequent plantations are held. In this case, it is common to prioritize early cultivars with smaller size, in a way that the addition of the crop residues does not damage the following planting. This enables a greater number of harvests per year and per location (Bordallo et al., 2005).

For ear diameter, GCA ranged from -0.61 cm (Line 16) to 0.39 cm (Line 8) and, for ear length, GCA ranged from -2.10 cm (Line 4) to 1.70 cm (Line 5), which enables recommending larger ear diameter or longer ear length. These values corroborate with the lines that have a higher probability of forming green maize hybrids with desirable traits.

For ears with straw yield (ESYIELD), we observed values of general combining ability (GCA) ranging from -4704.94 kg $ha^{-1}$ (Line 52) to 3055.57 $kg.ha^{-1}$ (Line 10) and, for commercial ear yield (CEYIELD), we observed GCA ranging from -2872.02 (Line 45) to 3315.99 (Line 19), suggesting possibilities to succeed in the selection of lines for synthetic yield. We also noted the presence of favorable alleles for the increase in yield. Therefore, for the commercial ear yield, the following lines could be recommended: 19, 48, 6, 28, and 42 indicating a GCA higher than 1600 $kg.ha^{-1}$. The same genotypes could be used in their hybrid form with the broad genetic base tester ($F_2$ of AG 1051 hybrid) for the production of base population and recurrent intra-population selection, with the goal of reducing the genetic trait and producing lines for hybrids or producing open-pollinated varieties. Scapim et al. (2008) and Clovis et al. (2015), estimated the effects of the general combining ability for grain yield in maize. They also identified high and positive values, indicating the possibility of selecting inbred lines with yield potential by means of top crosses. Barreto et al. (2012), analyzed the ability of combining maize $S_2$ families using testers and verified significant effects of GCA. Both studies confirmed the results found in this study.

For ear row number (ERN) trait, general combining ability (GCA) values ranging from -1.74 (Line 33) to 4.56 (Line 45) were observed. For mean weight of grain mass (MWG) trait, we noted GCA ranging from -34.57 g (Line 35) to 33.93 g (Line 8), while for ears with straw trait, GCA values ranged from -0.38 (Line 24) to 0.57 (Line 46). As such, the lines that should be recommended to obtain the ears with the largest number of rows are as following: 45, 57, 8, 64, and 16; while, for greater mean weight of grain mass, the recommended lines would be 8, 42, 61, 48, and 25. However for strawing trait, the recommended lines to obtain smaller grades for the trait were 24, 32, 13, and 51. These traits are particularly important for green maize, mainly when are used for the production of *pamonhas*, given that large volumes of grain mass are required for the production of green maize by-products.

**Materials and Methods**

***Plant material and treatments***

In this study, partially inbred $S_1$ progenies from a population with potential for green maize yield were utilized. The $S_1$ lines analyzed were obtained by crossing the synthetic TG-02R2 with AG1051, TG-02R2 being the pollen donor. The interpopulation hybrid was recombined, generating the $S_0$ population. After that, self-fertilization was performed to obtain the $S_1$ used in the trial. The synthetic TG-02 was obtained from the intercrossing of four segregating populations ($F_2$) of commercial hybrids. The population was found to have potential for prolific expression (more than one ear per plant).

The lines were crossed with a broad genetic base tester ($F_2$ of hybrid AG 1051) following the Irish system. To carry out the crosses, seeds from the $S_1$ families were sown in a five-meter line and, at every three lines, a tester line was sown. Planting was made in July 2017 in an isolated area under drip irrigation. When the male flowering occurred, the emasculation of the $S_1$ lines was performed in a way that only the tester would supply pollen, then 75 top cross hybrids were generated (Table 4).

At the harvest, a visual evaluation was made for the ears, and those with undesirable agronomic performance were discarded. The best quality-ears were used to compose the material for experimental evaluation.

***Conduction of study and experimental design***

The evaluation trial of the 75 top cross hybrids and the controls (AG 1051 commercial hybrid and tester) was conducted between February and June 2018 in the second harvest (little crop), in the municipality of Jataí, Goiás State, Brazil, in a randomized block design with four replicates. Plots were made up of four-meter rows spaced 0.90 m between rows and 0.20 m between plants. A sample of five plants/ears was used in each plot for the evaluation of the following traits: plant height, ear insertion height, strawing, mean weight of the grain mass, tassel branch number, ear length, ear diameter, and ear row number. For the ear with straw yield, commercial ear yield, and male and female flowering traits, the evaluations were executed in the whole plot.

***Traits measured***

Measurements were conducted as follows:

i. Ear with straw yield was achieved by adding the total weight of the ears with straw of each plot. Data were converted into kilograms per hectare.

ii. Commercial ear yield was derived from the sum of the weighing of husked ears larger than 15 cm, with a diameter greater than 3 cm, and free of pests and diseases.

Data collected were converted into kilograms per hectare.

iii. Male flowering was defined by the number of days from sowing until the day 50% of the plants of the useful area of each plot presented emerging tassels with anther exposures.

iv. Female flowering was established by the number of days after sowing until the day 50% of the plants of the useful area of each plot presented emerging style-stigma.

v. Plant height was determined after female flowering in five representative plants of the useful area of each plot by distance in meters from the ground level up to the flag leaf insertion.

vi. Ear insertion height was obtained after female flowering in five representative plants of the area of each plot by the distance in meters from the ground level up to the upper ear insertion.

vii. Strawing was evaluated in accordance with the scale set by the International Center for Maize and Wheat Breeding, as described by Cimmyt (1985) as follows: Completely ear with straw (grade 1), Small opening of the straw at the tip of the ear, without exposing the cob (grade 2); Cob exposed at the tip of the ear (grade 3); Presence of exposed grains at the tip of the ear (grade 4); wide exposure of grains with wide opening of the straw (grade 5). To meet the assumptions of analysis of variance, the scale values of straw grades were converted to $\sqrt{(x+1)}$.

viii. Mean weight of grain mass was obtained after removing all the grain mass of five representative ears of the plot by cutting the grains at the base of the cob and then weighing them.

ix. Tassel branch number was evaluated by counting primary tassel branches in five representative plants of the area of each plot.

x. Ear length was measured, in centimeters in five representative ears of the plot.

xi. Ear diameter was measured, in centimeters in five representative ears of the plot.

xii. Ear row number was calculated by counting the rows of grains in five representative ears of the plot.

### *Statistical analysis*

The analysis of variance was performed following the randomized block model employing the Genes computer program (Cruz, 2013). The means were compared with each other using the Scott & Knott test at 5% probability. The stand was corrected to 20 plants per plot.

The combining ability (ca) was also estimated by using the statistical-genetic model as mentioned by Miranda Filho (2018):

$Y_{ij} = m + c_i + r_j + e_{ij}$

being,

m = overall mean;

$c_i$ = combining ability effect;

$r_j$: replicate effect;

$e_{ij}$ = experimental error.

The $c_i$ effect is estimated by the contrast: $c_i = Y_{i.} - Y_{..}$ being,

$Y_{i.}$ = mean of the top cross of the i-th genotype;

$Y_{..}$ = mean of all top crosses.

## Conclusions

It is concluded that top cross hybrids of partially inbred maize $S_1$ lines have a high yield potential for green maize traits, equaling or being superior for some traits in comparison with the commercial hybrid used in the trial, and may be an option for production of synthetic or base populations for selection purposes.

Hybrids from lines 19, 48, 6, 28, and 42 should be highlighted since they are the ones that presented the best commercial ear yields.

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