Combining abilities in green corn genotypes for yield and industrial quality traits

Filipe Augusto Bengosi Bertagna1*, Mauricio Carlos Kuki1, Henrique José Camargo Senhorinho1, Hingrid Ariane da Silva2, Antônio Teixeira do Amaral Júnior3, Ronald José Barth Pinto4 and Carlos Alberto Scapim4

1PhD student, Genetic and Breeding Graduate Program (PGM).
2PhD student, Graduate Program in Agronomy (PGA).
3Agronomy Department, State University of Norte Fluminense Darcy Ribeiro
4Agronomy Department, State University of Maringá, Paraná, Brazil.
*Corresponding author: Filipe Augusto Bengosi Bertagna, Address: 148 Clementina Bassetto St., apt 1005 Maringá, Paraná, Brazil, 87030110 Phone number: (44) 99901-2912, E-mail: filipeabbertagna@gmail.com

Abstract
The general and specific combining abilities and the reciprocal effects of seven hybrids and two open pollination varieties of green corn were evaluated, aiming the formation of base populations to be used as a source of superior inbred lines. For the purpose of this study, two experiments were carried out in Maringá/PR and Sabáudia/PR, during the crop season of 2014/15. The experiments were evaluated in incomplete block design alpha lattice, with three replications. The parents AM811, HTMV1, CatiVerde 02 and Al Piratininga were selected based on their \( \hat{g} \) and the following hybrid combinations AM811 x CD316, AM811 x AG1051, AM811 x HTMV1, AM606 x CatiVerde 02 and Al Piratininga x AG4051 presented the most desirable \( \hat{s} \) effects. Regarding the reciprocal effects, the genotype AM811 is recommended to be used as male parent in further hybrid combinations

KeyWords Alpha lattice; diallel analysis; reciprocal effect.

Introduction
Green corn is obtained by harvesting the ears early, and the kernels are used as canned and dehydrated industrial products or in the preparation of traditional cooking recipes (Rodrigues et al., 2009). To be suitable for both the canning industry and the in natura consumption market, a genotype must have an unhusked ear yield greater than 12 t ha\(^{-1}\), a production cycle between 90 and 110 days, a commercial ear length greater than 15 cm and a diameter larger than 3 cm (Pereira Filho, 2003; Albuquerque et al., 2008). Thus, dent corn genotypes with a light yellow to cream color, no caterpillar damage, a good husk covering and straight rows are preferred (Cancellier et al., 2011).

The lack of genotypes in the market that aggregate both agronomic and quality traits results in lower-quality products that fail to meet the expected requirements of the consumer market. To illustrate this situation, only 17 of the 477 maize cultivars available to producers in Brazil present desirable traits for use as green corn (Cruz et al., 2015); therefore, the generation of new genotypes, especially for small farmers, is imperative for the growth of this market.

The correct choice of germplasm to form base populations is an essential step in any breeding program, since the quality of the inbreds extracted to generate new hybrids will be directly related to the presence of certain alleles and their frequencies in these populations (Hallauer et al., 2010). Among the diversity of available genotypes, breeding programs have chosen commercial maize hybrids to form their base populations, primarily because they present a wide range of adaptation and a higher frequency of favorable alleles for desirable traits (Oliboni et al., 2013; Senhorinho et al., 2015).

Diallel analysis is one of the most-used tools for obtaining genetic information in any breeding program. This controlled mating system enables the estimation of the general combining ability (GCA) and the specific combining ability (SCA), which are associated with the additive and non-additive genetic effects, respectively, as well as the reciprocal effect (RE), which enables the extrachromosomal and maternal effects to be estimated (Cruz et al., 2012). According to the genetic basis of the parents involved in the crossings, the results of the diallel analysis allow the base populations to be selected and formed to extract superior inbred lines and, consequently, form new genotypes.

Several authors have reported the use of diallel analysis of commercial genotypes to improve grain yield (Pfann et al., 2009; Oliboni et al., 2013; Senhorinho et al., 2015), but there is a shortage of studies regarding the GCA, SCA and RE effects for traits related to green corn in commercial maize hybrids. Therefore, the objective of the present study was to evaluate the GCA and SCA, as well as the RE of nine commercial field corn genotypes in relation to the yield and quality of green corn, with the aim of forming base populations to extract superior inbred lines.
Materials and Methods

Nine commercial genotypes from different companies were used as parents in a complete diallel design with reciprocal effects (Table 1). The F₁ hybrids and reciprocals were obtained in the second season of 2014. The experiments were performed during the 2014/15 main crop season at Fazenda Experimental de Iguatemi (lat 23º 25' S; long 51º 33' W and alt 725 m asl) in Maringá/PR and at Unidade Experimental Sementes Balu (lat 23º 19' S; long 51º 57' W and alt 550 m asl) in Coodetec/TH Sabáudia/PR.

The experiments were performed in an alpha lattice incomplete block design with three replications, in which eight plots were assigned to each of seven blocks, and nine plots were assigned to two blocks in each replication. Thirty-six hybrids were evaluated alongside their 36 reciprocals and two controls, a three-way hybrid from EMBRAPA and a single-cross flint maize from Sementes Balu, for a total of 74 treatments. Each plot consisted of two 5-m rows spaced 0.90 m apart, resulting in a usable area of 9 m². Each plot was thinned at 30 days to a density of 5 plants m⁻², resulting in a population of approximately 55,500 plants ha⁻¹ at harvest time.

Yield and quality analyses

Green corn harvesting and the evaluation of quality characteristics began at the R3 stage (kernel milk) when the moisture content was between 70 and 80%. The following traits were evaluated in both environments (E): average plant height (PH, cm), average main ear height (EH, cm), and yield of unhusked ears (YU, kg ha⁻¹). The following traits were only evaluated in Maringá/PR: yield of commercial ears (YC, kg ha⁻¹), average length (LG, cm) and diameter (DM, mm) of ten commercial ears, fresh grain mass (GM, g) of five ears and corrected to a 75% moisture content, pericarp texture (PT, in N), and the grain color (GC) of five commercial ears, according to the scale proposed by Albuquerque et al. (2008).

To evaluate PT, 200 g of fresh grains from each plot were canned similarly to the process used by the canning industry. The texture analysis was performed using a model TA.TX Plus texturometer (Stable Micro System, Surrey, England) with a HDP/WBR probe. Five grains of uniform size were used for each test, and the test was replicated five times in each plot. For the analysis, it was considered the average of the peak force necessary to break the grains in the five tests.

Statistical analysis

Analysis of variance was performed for each environment, and the effects were considered significant when p<0.05. Adjusted treatments and environments were considered as fixed effects, and the degrees of freedom of the adjusted treatments were partitioned into hybrid combinations (F₁), reciprocals (RC), checks (C) and the interactions F₁ vs RC and (F₁+RC) vs C. For all traits evaluated in both environments, a joint analysis of variance was performed, in which the degrees of freedom of the adjusted treatment vs environment interaction were partitioned into F₁ vs E, RC vs E, Checks vs E, (F₁ vs RC) vs E and [(F₁+RC) vs C] vs E.

Considering only the diallel analysis from Maringá, the sums of squares of the adjusted treatments were partitioned into GCA, SCA and RE according to Griffing’s (1956) diallel analysis method 3, which considers only hybrid combinations and their reciprocals. For the traits evaluated in both environments, the sums of squares of the Adjusted Treatments x E were partitioned into GCA vs E, SCA vs E and RE vs E. All analysis was performed using the software’s SAS 9.4 (2013) and Genes (Cruz, 2013).

Results and discussion

The least square means of the treatments resulted significantly different (p<0.05) for PH, EH and YU (Table 2). Hybrids and their reciprocal combinations differed from each other, indicating a genetic variation between the genotypes obtained from parental crosses. The F₁ x RE contrast was not considered significant in this study (p>0.05); therefore, it is possible to conclude that the order of the parents in the crossings does not influence the traits. Based on the significant effects of the D x C contrast, the means of the checks were higher than those of the hybrid combinations for PH and YU but lower for EH.

Table 1. Description of the genotypes evaluated in this study

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Genetic base</th>
<th>Cycle</th>
<th>Company</th>
<th>Kernel type</th>
<th>Grain colour</th>
<th>Aptitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG 1051</td>
<td>DH</td>
<td>SME</td>
<td>Agroeste</td>
<td>Dent</td>
<td>Yellow</td>
<td>OPV</td>
</tr>
<tr>
<td>AG 4051</td>
<td>TH</td>
<td>SME</td>
<td>Agroeste</td>
<td>Dent</td>
<td>YC</td>
<td>F/S/GC</td>
</tr>
<tr>
<td>AL</td>
<td>OPV</td>
<td>SME</td>
<td>CATI</td>
<td>Semi-dent</td>
<td>YO</td>
<td>F/S/GC</td>
</tr>
<tr>
<td>Piratinonga</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cativerde-O2</td>
<td>OPV</td>
<td>SME</td>
<td>CATI</td>
<td>Dent</td>
<td>Yellow</td>
<td>S/G/C</td>
</tr>
<tr>
<td>CD 316</td>
<td>SH</td>
<td>SE</td>
<td>Coodetec</td>
<td>Semi-flint</td>
<td>Yellow</td>
<td>F</td>
</tr>
<tr>
<td>CD 392</td>
<td>SH</td>
<td>SE</td>
<td>Coodetec</td>
<td>Flint</td>
<td>Orange</td>
<td>F/S/GC</td>
</tr>
<tr>
<td>AM 606</td>
<td>SH</td>
<td>SE</td>
<td>M.A.</td>
<td>Semi-dent</td>
<td>Orange</td>
<td>F/S/GC</td>
</tr>
<tr>
<td>AM 811</td>
<td>SH</td>
<td>SE</td>
<td>M.A.</td>
<td>Semi-dent</td>
<td>Orange</td>
<td>F/S/GC</td>
</tr>
<tr>
<td>HTMV1</td>
<td>TH</td>
<td>SME</td>
<td>Embrapa</td>
<td>Semi-dent</td>
<td>Yellow</td>
<td>F/S/GC</td>
</tr>
</tbody>
</table>

1 DH: Double-cross hybrid; 2 TH: triple-way hybrid; 3 OPV: open pollinated variety; 4 SH: Single hybrid; 5 SME: Semi-early; 6 SE: Super-early; 7 YC: Yellow cream kernel; 8 YO: Yellow orange kernel; 9 F: used as field corn; 10 S: used as silage; 11 GC: used as green corn; 12 Melhoramento Agropastoril.
Combining ability in green corn

Table 2. Joint analysis of variance and joint diallel analysis for plant height (PH), ear height (EH) and yield of unhusked ears (YU)

<table>
<thead>
<tr>
<th>SV</th>
<th>DF</th>
<th>MS</th>
<th>PH</th>
<th>EH</th>
<th>YU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep/Environment</td>
<td>4</td>
<td>431.13</td>
<td>626.75</td>
<td>8619120.0</td>
<td></td>
</tr>
<tr>
<td>Bl/Rep/E</td>
<td>48</td>
<td>315.06</td>
<td>293.83</td>
<td>7909715.0</td>
<td></td>
</tr>
<tr>
<td>Environment (E)</td>
<td>1</td>
<td>22305227.54*</td>
<td>7590016.83*</td>
<td>119051494094*</td>
<td></td>
</tr>
<tr>
<td>Treatm. (Adj.)</td>
<td>73</td>
<td>306178.31*</td>
<td>306178.31*</td>
<td>164459715113*</td>
<td></td>
</tr>
<tr>
<td>Diallel (D)</td>
<td>71</td>
<td>761.47*</td>
<td>761.47*</td>
<td>1389454323*</td>
<td></td>
</tr>
<tr>
<td>F₁</td>
<td>35</td>
<td>736.02*</td>
<td>736.02*</td>
<td>143374752*</td>
<td></td>
</tr>
<tr>
<td>Reciprocal Effect (RE)</td>
<td>35</td>
<td>794.35*</td>
<td>794.35*</td>
<td>1312922986*</td>
<td></td>
</tr>
<tr>
<td>F₁ vs RE</td>
<td>1</td>
<td>501.55*</td>
<td>501.55*</td>
<td>2530836075*</td>
<td></td>
</tr>
<tr>
<td>Checks (C)</td>
<td>1</td>
<td>525.10*</td>
<td>525.10*</td>
<td>245436075*</td>
<td></td>
</tr>
<tr>
<td>D vs C</td>
<td>1</td>
<td>1229642673*</td>
<td>1229642673*</td>
<td>119066625102*</td>
<td></td>
</tr>
<tr>
<td>Treatm. (Adj.) x E</td>
<td>73</td>
<td>252.59*</td>
<td>252.59*</td>
<td>3929993</td>
<td></td>
</tr>
<tr>
<td>Diallel x E</td>
<td>71</td>
<td>134.85*</td>
<td>134.85*</td>
<td>3953415</td>
<td></td>
</tr>
<tr>
<td>F₁ x E</td>
<td>35</td>
<td>80.30</td>
<td>80.30</td>
<td>3410057</td>
<td></td>
</tr>
<tr>
<td>RE x E</td>
<td>35</td>
<td>192.69*</td>
<td>192.89*</td>
<td>4591394</td>
<td></td>
</tr>
<tr>
<td>(F₁ vs RE) x E</td>
<td>1</td>
<td>12.69</td>
<td>12.69</td>
<td>641718</td>
<td></td>
</tr>
<tr>
<td>Checks x E</td>
<td>1</td>
<td>326.25</td>
<td>326.25</td>
<td>1590251</td>
<td></td>
</tr>
<tr>
<td>(D vs C) x E</td>
<td>1</td>
<td>8538.91*</td>
<td>8538.91*</td>
<td>4606765</td>
<td></td>
</tr>
<tr>
<td>Effective mean error</td>
<td>244</td>
<td>86.60</td>
<td>94.51</td>
<td>34948468</td>
<td></td>
</tr>
<tr>
<td>VC (%)</td>
<td>-</td>
<td>4.15</td>
<td>7.44</td>
<td>11.42</td>
<td></td>
</tr>
<tr>
<td>Diallel mean</td>
<td>-</td>
<td>218.04</td>
<td>130.84</td>
<td>15.899</td>
<td></td>
</tr>
<tr>
<td>Check mean</td>
<td>-</td>
<td>223.88</td>
<td>127.57</td>
<td>17.599</td>
<td></td>
</tr>
<tr>
<td>Lattice Efficiency (%)</td>
<td>-</td>
<td>143.37</td>
<td>134.67</td>
<td>120.74</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Individual analysis of variance and diallel analysis considering only the Maringá/PR environment, for the following traits: yield of commercial ears (YC); length of commercial ears (LG); diameter of commercial ears (DM); fresh grain mass (GM); grain colour (GC) and pericarp texture (PT)

<table>
<thead>
<tr>
<th>S.V.</th>
<th>D.F.</th>
<th>M.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>2</td>
<td>4095938</td>
</tr>
<tr>
<td>Bl/Rep (adj.)</td>
<td>24</td>
<td>4714070</td>
</tr>
<tr>
<td>Treatm. (Adj.)</td>
<td>73</td>
<td>3148754</td>
</tr>
<tr>
<td>Diallel (D)</td>
<td>71</td>
<td>3283709</td>
</tr>
<tr>
<td>F₁</td>
<td>35</td>
<td>2758396</td>
</tr>
<tr>
<td>RE</td>
<td>35</td>
<td>3918127</td>
</tr>
<tr>
<td>F₁ vs RE</td>
<td>1</td>
<td>7279306</td>
</tr>
<tr>
<td>Checks (C)</td>
<td>1</td>
<td>38592</td>
</tr>
<tr>
<td>D vs C</td>
<td>1</td>
<td>8572874</td>
</tr>
<tr>
<td>Effective error</td>
<td>122</td>
<td>1119901</td>
</tr>
<tr>
<td>VC (%)</td>
<td>-</td>
<td>16.04</td>
</tr>
<tr>
<td>Diallel mean</td>
<td>-</td>
<td>6.50</td>
</tr>
<tr>
<td>Check mean</td>
<td>-</td>
<td>7.772</td>
</tr>
<tr>
<td>Lattice err. (%)</td>
<td>-</td>
<td>153.15</td>
</tr>
</tbody>
</table>

Table 5. Joint diallel analysis

<table>
<thead>
<tr>
<th>S.V.</th>
<th>D.F.</th>
<th>M.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diallel</td>
<td>71</td>
<td>3933769</td>
</tr>
<tr>
<td>GCA</td>
<td>8</td>
<td>6106037</td>
</tr>
<tr>
<td>SCA</td>
<td>27</td>
<td>4866122</td>
</tr>
<tr>
<td>RE</td>
<td>36</td>
<td>1671778</td>
</tr>
<tr>
<td>Error</td>
<td>122</td>
<td>1119901</td>
</tr>
</tbody>
</table>

The interaction between treatments and environments (Table 2) was significant only for PH, reflecting the differential performance of the genotypes in both environments and indicating that selection for this trait must be separate for each environment. Considering plant and ear height, Pfann et al. (2009) found non-significant interactions between 49 genotypes and two environments. In contrast, Senhorinho et al. (2015) showed significant effects between genotypes and environments for grain yield, plant and ear height using a partial diallel analysis of 22 commercial maize hybrids evaluated in two distinct seasons.

The analysis of variance for traits related to yield and quality of commercial ears (Table 3) indicated significant differences (p<0.05) for F₁ and RE, although when considering the reciprocal effect, the difference was only significant in YC (p<0.05), indicating that the order of the parents used in the crosses significantly affects this trait. The checks evaluated in this study differed from each other in PT, demonstrating the influence of grain type over pericarp texture. Considering the comparison of the checks to the hybrid combinations in this study, YC, LG, DM and PT exhibited significant differences (p<0.05), with the overall means indicating superiority of the checks over the hybrid combinations.

The joint diallel analysis (Table 2) indicated significant differences (p<0.05) in GCA and SCA, but RE did not display such an effect for any trait. The non-significant effect for RE was also reported by Mendes et al. (2015) using a diallel analysis of traits related to grain yield and forage quality of commercial hybrids.

PH trait was significantly influenced by the GCA x Environment and RE x Environment interactions, while the SCA x Environment interaction was not significant for all evaluated traits. These results indicate that apart from the order in which they are present in the crosses, the best parents should be selected for each environment only when considering PH.

Considering EH and YU traits, the mean squares
of the GCA, SCA and RE interactions with the environments in which the experiments were performed, showed no significant effects, indicating that the parents can be selected based on these effects because the average environment only affects the GCA and SCA.

The experimental coefficients of variation in both the individual and joint analysis were considered low to medium magnitude, when compared to other reported studies for green corn (Albuquerque et al., 2008; Rodrigues et al., 2009; Cancellier et al., 2011), as well when considering the ones proposed by Fritsche-Neto et al. (2012) for maize, indicating an excellent experimental precision. The adoption of the alpha lattice as the experimental design for this study was satisfactory since the lattice efficiency coefficient was higher than 110% for all traits except LG and PT (Pimentel Gomes, 1990).

Considering the traits related to yield and quality of commercial ears (Table 3), there was significant differences (p<0.05) in the effects related to GCA. These results allow the inference that the genetic contributions in these traits differed according with each parent. Conversely, the SCA effects were only significant for YC, DG, DM and PT, a direct result of the differential performance of the hybrid combinations evaluated for these traits compared to what expected from the GCA of their parents, an indication of the contribution of non-additive effects of genes over these traits. The reciprocal effect differed significantly for YC and PT, evidence that these traits exert extranuclear gene effects; it is possible to take advantage of these effects by choosing the appropriate female genotype for future crossings.

Breeding programs for green corn seek genotypes that combine high yield of unhusked ears and good quality traits, such as a grain color ranging from light yellow to cream, no damage from insects and disease, dent-type kernel with a tender pericarp (Albuquerque et al., 2008; Rodrigues et al., 2009; Cancellier et al., 2011). Therefore, the GCA estimation enables the best parents to be selected based on the additive genetic effects to form a composite with a higher frequency of favorable alleles with additive effects, which has great importance for obtaining superior inbred lines useful for green corn breeding.

Table 4. Estimations for all nine parents, regarding traits related to yield in Sabáudia, Maringá and average environment, and also for green corn quality in Maringá.

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>PH</th>
<th>YC</th>
<th>LG</th>
<th>DM</th>
<th>GM</th>
<th>GC</th>
<th>PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM606</td>
<td>-13.75</td>
<td>-8.868</td>
<td>-5.234</td>
<td>94.167</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM811</td>
<td>-4.845</td>
<td>-10.413</td>
<td>-7.976</td>
<td>1.729952</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTMV1</td>
<td>-3.092</td>
<td>-5.248</td>
<td>-3.174</td>
<td>-235.798</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL PR.</td>
<td>8.871</td>
<td>5.572</td>
<td>3.635</td>
<td>29.933</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT 02</td>
<td>10.664</td>
<td>12.995</td>
<td>8.824</td>
<td>117.381</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD316</td>
<td>-5.975</td>
<td>-5.071</td>
<td>-4.579</td>
<td>-457.905</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CD393</td>
<td>-1.161</td>
<td>-0.428</td>
<td>-3.322</td>
<td>4.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AG1051</td>
<td>3.622</td>
<td>5.317</td>
<td>7.144</td>
<td>-765.44</td>
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</tr>
<tr>
<td>AG4055</td>
<td>4.99</td>
<td>6.146</td>
<td>1.964</td>
<td>-456.563</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1: AE - Average environment; 2: PH - Plant height (cm); 3: EH - Ear height (cm); 4: YU - Yield of unhusked ears (kg ha\(^{-1}\)); 5: GC - Grain color; 6: PT - Pericarp texture.
Combining ability in green corn

Table 5A Specific combining ability (SCA) and reciprocal effect (RE) estimations for traits related to yield in Maringá, Sabáudia, average environment and quality traits in Maringá

<table>
<thead>
<tr>
<th>Genotype</th>
<th>SCA</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PH</td>
<td>EH</td>
</tr>
<tr>
<td></td>
<td>Sab</td>
<td>Mar</td>
</tr>
<tr>
<td>AM606 x AM811</td>
<td>4.10</td>
<td>1.81</td>
</tr>
<tr>
<td>AM606 x HTMV1</td>
<td>-6.71</td>
<td>1.09</td>
</tr>
<tr>
<td>AM606 x AL PR.</td>
<td>2.74</td>
<td>2.99</td>
</tr>
<tr>
<td>AM606 x CAT02</td>
<td>-8.30</td>
<td>-6.73</td>
</tr>
<tr>
<td>AM606 x CD316</td>
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1AE: Average environment; ²PH = Plant height (cm); ²EH = Ear height (cm); ³YU = Yield of unhusked ears (kg ha⁻¹); ⁴Y = Yield of commercial ears (kg ha⁻¹); ⁵L = Length (cm); ⁶D = Diameter (mm); ⁷G = Grain mass (g); ⁸GC = Grain color; ⁹PT = Pericarp texture

display with favorable \( \delta \) estimations that involve at least one parent with a favorable \( \delta \) effect for the trait. In this sense, the best hybrids should be those for which at least one of the parents was selected based on its \( \delta \) estimation, thereby presenting a higher level of favorable alleles than the average frequency of the parents involved in the crosses (Cruz et al., 2012).

Current maize breeding programs aim the formation of hybrids with reduced seedling-flowering period, associated with lower average plant and ear heights (PH and EH, respectively). Therefore, it is recommended to select hybrid combinations with lower \( \delta \) for these traits to form base populations. Verifying the \( \delta \) effects for PH and EH, the parents AM606, AM811 and CD316 were selected, and the hybrid combinations of AM606 x CAT02, AM811 x CD316 and CD316 x AG1051 displayed lower-magnitude \( \delta \) effects. As the reciprocal effect was positive, the order of the parents in the crosses should be maintained.

Table 5 (A and B) displays the specific combining ability and the reciprocal effect for the evaluated traits. Considering YU, the parent AM811 was selected for its GCA effects (Table 2). Thus, the hybrid combination with the highest \( \delta \) effect was AM811 x AG1051. Lastly, there were no significant differences for the reciprocal effects and the interaction with the environments for this trait, which means that the order of the parents in the crosses does not affect the production of unhusked ears.

The genotype AM811 was also superior for the traits YC, LG and DM due to its additive effect (Table 3). The AM606 x HTMV1 hybrid combination was considered superior in terms of the effect of non-additive genes (Table 5). As the reciprocal effect was negative for YC and considered not significant for LG and DM, the genotype HTMV1 should be used as a female parent while the parent AM811 should be used as a pollen donor, thereby taking advantage of maternal or extranuclear inheritance for production of commercial ears without affecting the other traits.

Regarding the PT traits, five out of nine parents were selected based on their GCA, which included both dent and flint kernel types. However, there is a market preference for dent types; therefore, interpopulation crosses should predominantly be performed with dent types. The hybrid combinations AM606 x Cativerde 02, AL Piratinha x AG4051, Cativerde 02 x AG4051 and CD393 x AG1051 present the best \( \delta \) estimations (Table 5). The reciprocal effect indicates that it is only necessary to switch the last cited combination such that parent AG1051 should be used as the female and parent CD393 as the pollen donor.

The traits GM and GC did not exhibit any signifi-
<table>
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<tr>
<th>Genotype</th>
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\[^{1}\text{AE: Average environment; } {^{2}}\text{PH – Plant height (cm); } {^{3}}\text{EH – Ear height (cm); } {^{4}}\text{YU – Yield of unhusked ears (kg ha}\text{⁻¹); } {^{5}}\text{YC – Yield of commercial ears (kg ha}\text{⁻¹); } {^{6}}\text{LG – Length (cm); } {^{7}}\text{DM – Diameter (mm); } {^{8}}\text{GM – Grain mass (g); } {^{9}}\text{GC – Grain color; } {^{10}}\text{PT – Pericarp texture.}\]
cant differences regarding their non-additive effects. Therefore, the SCA effects obtained in the hybrid combinations reflect what would be expected from the GCA of the parents.

**Conclusions**

The parents AM811, HTMV1, Cativerde 02 and AL Piratininga were selected based on their $\hat{g}$ for grain yield and green corn quality related traits, and should be used in the formation of base populations aiming the extraction of superior inbred lines.

The hybrid combinations AM811 x CD316, AM811 x AG1051, AM811 x HTMV1, AM606 x Cativerde 02 and AL Piratininga x AG4051 showed desirable SCA, and should be inserted in interpopulational breeding programs for green corn. Based in the reciprocal effect results, the parent AM811 could be employed as male parent in future hybrid combinations.

**References**


