COMBINING ABILITY FOR EAR LENGTH AND ROW NUMBER OF SOME MAIZE HYBRID COMBINATIONS
(\textit{Zea mays} \textit{L.})

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\textbf{Abstract}

The main object was to evaluate \(F_1\) maize hybrids for ear length and the number of rows. Investigations included ten (10) diallel crossed inbred lines analyzed for General Combining Ability (GCA) and Specific Combining Ability (SCA). The components of genetic variance were calculated using Griffing’s formula, method 2, mathematic model I; 
\[ X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}. \]

Additive gene effects were more important than non additive since the ratio was 0.45 for ear length (EL) and 2.67 for the number of rows (NR/E), among GCA and SCA. The grand mean \(\mu\) for EL and NR/E was 20.4 cm/ear and 16.7 rows/ear. Heterozygote combinations \(L_6xL_{10}\) (22.33 cm/ear) showed maximum EL, while for NR was \(L_5xL_9\) (19.2 rows/ear). Hybrid combination \(L_{1}xL_{10}\) showed minimum values EL (15.9 cm/ear) and NR/E (14.3 rows/ear).

\textbf{Keywords:} \(F_1\) generation, combining ability, ear length, number of rows per ear.

\textbf{Introduction}

Maize (\textit{Zea mays} \textit{L.}) is the world’s most widely grown cereal and the primary staple food in many developing countries. The first maize hybrids for farm use were produced in the 1920s, but until the 1940s most farmers still were growing open-pollinated (OP) varieties. In very short season areas, the OPs were flints because of their...
tolerance to cool, wet spring conditions and requi-
rements for fewer heat units to reach harvest-
able maturity. But the most maize by far was
planted to OPs form a new race of maize, Corn
Belt Dent that arose somewhat serendipitously
during the early decades of the 1800s, according
to the data [2]. The use of heterosis in the world
started in 1933 when in USA were planted about
1% of the total surfaces, while latter in year 1953
the heterosis of the maize hybrids were expand-
ed up to 96% [12]. The production of hybrid seed
requires the development and maintenance of
inbred lines and subsequent controlled crosses
to produce commercial seed [14]. The improve-
ment of maize traits depends on the knowledge
of the type of the gene action involved in its
inheritance and also the genetic control of the
related traits such as capacity of production [9].
Also the choice of the most efficient breeding
program depends on that information [3], and
[7]. The concept of general combining ability
(GCA) and specific combining ability (SCA) was
introduced [12] and its mathematical modelling
was presented by Griffing [1] in his classical pa-
er in conjunction with the diallel crosses [5].
Diallel crosses have been widely used in genetic
research to investigate the inheritance of impor-
tant traits among a set of genotypes. Analyses of
diallel data is usually conducted according to the
methods of Griffing [1] which partition the total
variation of diallel data into GCA of the parents
and SCA of the crosses [13]. The objective of this
study was to evaluate the performance of ten
maize inbred lines at agro ecological conditions
in Kosovo for ear length and number of rows.
These were specifically designed to investigate
the combining ability of the parental lines for
the purpose of identification of superior parents for
use in hybrid development programmes.

**Material and methods**

**Plant material and field design**

The experimental material comprised of ten
(10) superior medium maturity inbred lines of
maize (L1, L2,… L10), originating from the Ag-
riculture University of Tirana (AUT)–Albania
(see Tables 2 and 3), were used for crosses in this
study. These ten (10) inbred lines of maize were
crossed in a diallel mating design without recip-
crocal combinations and tested in randomized
block (RBDE) with three replications (45 hybrid
combination x 3 replications = 135 experimental
plots,(EP)). Location was in agro-ecological
conditions in Kosovo, in the area near Ferizaj (580
m a.s.l). After the fourth year, ten (10) selected
maize inbred lines were crossed using diallel
model and the next year these genotypes were
placed in EP of hybrid combination (C) and to
study GCA and SCA for yield kernel per ear
(YK/E) was conducted. The experimental plot
was 3 m long and 60 cm apart, with 30 cm plant
to plant distance or 55000 plants per ha. The
experimental plots were 5.4 m² per each replication
x 3R = 16.20 m². In order to determine length and
number of rows we measured the average of 10
ears or plants randomly selected from each plot
(10 ear per plants x 3R =30 plants or in total 1350
plants).

**Statistical analyses**

The diallel analysis, as described by Griffing’s
method 2, mathematical model I fixed model:

\[
X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}
\]

Where:

- \(X_{ijk}\) is the mean of \(i \times j\)th genotypes,
- \(\mu\) is the experimental grand mean,
- \(g_i\) and \(g_j\) = is the GCA effects of \(i^{th}\) female
  parent, effects of \(j^{th}\) male parent,
- \(S_{ij}\) = is the SCA effects specific to the hybrid

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>S.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCA</td>
<td>(p-1)</td>
<td>(\delta^2 + (P+2) \times \left(\frac{1}{p-1}\right) \sum g_i^2)</td>
</tr>
<tr>
<td>SCA</td>
<td>(\frac{p(p-1)}{2})</td>
<td>(\delta^2 + \frac{2}{p(p-1)} \sum \sum S_{ij})</td>
</tr>
<tr>
<td>Error</td>
<td>m</td>
<td>(\delta^2)</td>
</tr>
</tbody>
</table>

Table 1: ANOVA for GCA and SCA according to Griffing’s method 2
of the $i^{th}$ female line and the $j^{th}$ male line, and 
$e_{ij}$ = is the experimental error.

ANOVA for GCA and SCA was evaluated as presented in Table 1.

$$S_g = \frac{1}{p+2} \left[ \sum (t_i + ii) - \frac{4}{p} GT^2 \right]$$

Where, $S_s = \frac{1}{n+2} \sum {y_j^2} - \frac{1}{n+2} \sum (t_j + ii)^2 + \frac{2}{(p+1)\times(p+2)} GT^2$

$$p\text{- Number of parents involved}$$
$$m\text{- Error of degree freedom}$$
$$T+ ii = \text{Total rows + value of average parent}$$
$$GT = \text{Total sum of parent crosses}$$

GCA effect of the inbred line was calculated as following:

$$g_i = \frac{1}{(p+2)} \left[ (T_i + ii) - \frac{2}{p} GT \right]$$

SCA effect of the cross was calculated as following:

$$S_{ij} = S_{ij} - \frac{1}{(p+2)} \left[ (T_i + ji) + (T_j + j) + \frac{2}{(p+1)\times(p+2)} GT \right]$$

$$SE = \sqrt{\frac{2}{p+2}} \times M'e \quad \text{(calculated for GCA)}$$
$$SE = \sqrt{\frac{2p}{p+2}} \times M'e \quad \text{(calculated for SCA)}$$

Whereas midparent heterosis (MPH) was calculated as:

$$MPH = \frac{F_1 - MP}{MP} \times 100,$$

Where:

$F_1$ is the mean of the $F_1$ hybrid performance and

$$MP = \frac{P_1 + P_2}{2}$$

where $P_1$ and $P_2$ are the means of the inbred parents. Statistical analyses package were conducted using program MSTAT-C, version 2.10.

RESULTS AND DISCUSSION

ANOVA’s tests and combining ability for all hybrid combination were significantly different ($P \leq 0.01$) for ear length and number of rows (Tables 2 and 3). According to our results for ear length (EL) and number of rows per ear (NR/E), the hybrid combination L6xL10 exhibited the maximum EL (22.3 cm/plant) and L5xL9 (19.2 rows/ear), while the minimum values were obtained for hybrid combination L1xL10 (15.9 cm/plant) and L7xL10 (14.3 rows/ear). The average value ($\mu$) of EL and NR/E at all studied hybrid combination was 20.4 cm/ear, and 16.7 rows/ear, while significant differences among extreme values were 6.40 cm/ear and 4.9 rows/ear. The difference between the mean of all $F_1$ hybrids and the mean of all parents ($F_1-\text{MP}$) was + 6.06 cm/ear, on the other hand the difference for NR/E was + 2.8 rows/ear. This is due to heterosis of $F_1$ generations and the effects of additive and non additive genes responsible for the development of EL and NR/E. The coefficient of variation (CV) for all hybrid combinations for EL and NR/E was 4.70 and 5.38%, while SE was 0.91 (EL) and 0.85 (NR/E). The statistical analysis for combining ability indicates that there are significant differences among hybrid combination in both GCA and SCA for EL and NR/E. The ratio between GCA and SCA for EL and NR/E was 0.45 and 2.67. The finding of [11], that besides non-additive effects an important role belonged also to additive variance what was later confirmed [6]. As reported [10] and [12] GCA is preliminary associated with additive effects, whereas SCA is attributed to the non-additive genetic effects. The GCA effects for EL and NR/E consistently showed significant variation between hybrid combinations of parent lines. The highest GCA effect for EL and NR/E was for L7 (+1.122) and L9 (+1.062), indicating that they were good general combiners. The lowest GCA value was obtained by L10 (-0.924) and L4 (-0.744) (Tables 2 and 3). The SCA effects showed by the crosses on the traits that we studied are presented in Tables 6 and 7. The highest value of SCA for EL and NR/E was obtained for combinations L6xL10 (4.125) and L5xL9 (1.865). The lowest value of SCA for EL was obtained for L1xL10 (-2.564), while for NR/E for L7xL10 (-1.69).
Table 2. Ear Length of parents (diagonal, underlined) and their F1 hybrids (above diagonal)

<table>
<thead>
<tr>
<th>Line</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>L7</th>
<th>L8</th>
<th>L9</th>
<th>L10</th>
<th>L10 Mean</th>
<th>GCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>12.7</td>
<td>21.2</td>
<td>22.1</td>
<td>22.3</td>
<td>22.2</td>
<td>21.4</td>
<td>21.1</td>
<td>21.8</td>
<td>19.9</td>
<td>15.9</td>
<td>20.8</td>
<td>+0.023</td>
</tr>
<tr>
<td>L2</td>
<td>13.1</td>
<td>21.6</td>
<td>20.9</td>
<td>20.9</td>
<td>20.8</td>
<td>21.6</td>
<td>21.5</td>
<td>21.7</td>
<td>17.0</td>
<td>15.9</td>
<td>20.7</td>
<td>+0.038</td>
</tr>
<tr>
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<td>13.2</td>
<td>20.2</td>
<td>20.9</td>
<td>20.0</td>
<td>21.4</td>
<td>21.3</td>
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<td>20.9</td>
<td>15.9</td>
<td>20.9</td>
<td>+0.336</td>
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<tr>
<td>L4</td>
<td>17.2</td>
<td>18.1</td>
<td>20.6</td>
<td>19.7</td>
<td>19.2</td>
<td>20.2</td>
<td>19.1</td>
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<td>17.0</td>
<td>19.4</td>
<td>18.1</td>
<td>+0.113</td>
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<tr>
<td>L5</td>
<td>14.7</td>
<td>19.4</td>
<td>18.7</td>
<td>18.6</td>
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<td>18.1</td>
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<td>-0.914</td>
<td></td>
</tr>
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<td>12.2</td>
<td>22.6</td>
<td>19.7</td>
<td>21.3</td>
<td>22.3</td>
<td>21.4</td>
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<tr>
<td>L7</td>
<td>18.2</td>
<td>13.1</td>
<td>22.1</td>
<td>21.6</td>
<td>20.8</td>
<td>21.3</td>
<td>20.6</td>
<td>21.4</td>
<td>14.1</td>
<td>20.0</td>
<td>20.4</td>
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<tr>
<td>L8</td>
<td>15.2</td>
<td>15.2</td>
<td>20.4</td>
<td>20.4</td>
<td>20.4</td>
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<td>14.1</td>
<td>20.4</td>
<td>14.1</td>
<td>-0.924</td>
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<tr>
<td>L9</td>
<td>14.1</td>
<td>14.1</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
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<td>16.0</td>
<td>14.1</td>
<td>20.4</td>
<td>20.4</td>
<td>20.4</td>
</tr>
</tbody>
</table>

LSD (p<0.05) = 1.46, SE(Gi)=0.02
LSD (p<0.01) = 1.70, SE(Gi-Gj)=0.04

GCA/SCA = 0.45

Table 3. Number of rows per ear of parents (diagonal, underlined) and their F1 hybrids (above diagonal)

<table>
<thead>
<tr>
<th>Line</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>L7</th>
<th>L8</th>
<th>L9</th>
<th>L10</th>
<th>L10 Mean</th>
<th>GCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>13.0</td>
<td>14.4</td>
<td>14.3</td>
<td>16.5</td>
<td>17.0</td>
<td>16.5</td>
<td>14.9</td>
<td>16.1</td>
<td>18.3</td>
<td>16.0</td>
<td>16.0</td>
<td>-0.388</td>
</tr>
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<td>L2</td>
<td>12.0</td>
<td>15.3</td>
<td>15.4</td>
<td>16.4</td>
<td>16.9</td>
<td>15.5</td>
<td>16.2</td>
<td>17.9</td>
<td>15.8</td>
<td>16.5</td>
<td>15.8</td>
<td>-0.536</td>
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<td>16.4</td>
<td>15.9</td>
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<td>15.3</td>
<td>17.5</td>
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<td>15.8</td>
<td>-0.743</td>
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<td>15.6</td>
<td>-0.744</td>
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<td>17.6</td>
<td>17.6</td>
<td>17.6</td>
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<td>16.0</td>
<td>16.0</td>
<td>+0.664</td>
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LSD (p<0.05) = 1.41, SE(Gi)=0.01
LSD (p<0.01) = 1.69, SE(Gi-Gj)=0.040

GCA/SCA = 2.67

Table 6. Estimated of SCA effects for Ear Length in a diallel among 10 maize inbred

<table>
<thead>
<tr>
<th>Parent</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>-6.76</td>
<td>1.74</td>
<td>2.37</td>
<td>2.56</td>
<td>3.60</td>
<td>2.12</td>
<td>0.55</td>
<td>2.34</td>
<td>0.25</td>
<td>-2.56</td>
</tr>
<tr>
<td>P2</td>
<td>1.74</td>
<td>-6.37</td>
<td>2.12</td>
<td>1.39</td>
<td>2.34</td>
<td>1.44</td>
<td>1.07</td>
<td>1.96</td>
<td>1.87</td>
<td>-1.21</td>
</tr>
<tr>
<td>P3</td>
<td>2.37</td>
<td>2.12</td>
<td>-6.90</td>
<td>0.48</td>
<td>2.08</td>
<td>0.37</td>
<td>0.57</td>
<td>1.53</td>
<td>1.52</td>
<td>2.72</td>
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<td>0.48</td>
<td>-2.39</td>
<td>-0.49</td>
<td>1.16</td>
<td>-0.93</td>
<td>-0.37</td>
<td>0.39</td>
<td>0.57</td>
</tr>
<tr>
<td>P5</td>
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<td>2.08</td>
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<td>-2.90</td>
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<td>-0.94</td>
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<td>-1.32</td>
<td>-1.06</td>
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<td>2.12</td>
<td>1.44</td>
<td>0.37</td>
<td>1.16</td>
<td>1.02</td>
<td>-7.00</td>
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<td>0.31</td>
<td>1.72</td>
<td>4.12</td>
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<td>P7</td>
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<td>1.07</td>
<td>0.57</td>
<td>-0.93</td>
<td>-0.94</td>
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<td>2.38</td>
<td>0.77</td>
<td>1.23</td>
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<tr>
<td>P8</td>
<td>2.34</td>
<td>1.96</td>
<td>1.53</td>
<td>-0.37</td>
<td>0.05</td>
<td>0.31</td>
<td>2.38</td>
<td>-6.39</td>
<td>2.55</td>
<td>1.99</td>
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<tr>
<td>P9</td>
<td>0.25</td>
<td>1.87</td>
<td>1.52</td>
<td>0.39</td>
<td>-1.32</td>
<td>1.72</td>
<td>0.77</td>
<td>2.55</td>
<td>-4.71</td>
<td>1.66</td>
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<td>2.72</td>
<td>0.57</td>
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<td>3.60</td>
<td>1.23</td>
<td>1.99</td>
<td>1.66</td>
<td>-3.28</td>
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</table>

LSD (p<0.05) = 0.43
LSD (p<0.01) = 0.60
SE(sij) = 0.2360
SE(Sij-Sik) = 0.51
SE(Sij-Skl) = 0.46

GCA/SCA = 2.67

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**COMBINING ABILITY OF SOME MAIZE HYBRID COMBINATIONS**

Table 7. Estimated of SCA effects for Number of rows per ear in a diallel among 10 maize inbred

<table>
<thead>
<tr>
<th>Parent</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.53</td>
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LSD$_{0.05}$ = 0.38
LSD$_{0.01}$ = 0.52

CONCLUSIONS

Maize inbred lines exhibited high genetic variability for agronomic traits. L7 and L3 showed higher values for GCA for EL and L9 and L10 for NR/E, while L6xL10 and L5xL9 combinations showed highest values for SCA. The investigation suggests that the some of maize inbred line have good potential to be successively used for plant breeding.

REFERENCES
