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# Evaluation of the combining ability of mutant maize lines

V. Valkova*, N. Petrovska

Maize Research Institute, 5835 Knezha, Bulgaria

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***Abstract.*** *The study shows the results of a preliminary evaluation of the combining ability for grain yield of 17 mutant maize lines. For the purpose the top cross method for early testing and the mathematical model of Savchenko for analysis of the general and the specific combining ability were used. The lines were tested on three testers with high general combining ability that belong to two genetic groups: K 46 52 and XM 552 from SSS and N 192 – Lancaster. For the purposes of evaluation of the productive abilities of the received top cross two preliminary varietal experiments were carried out at the experimental field of Maize Research Institute, Knezha As a result of the conducted experimental work and the analysis it was found that the highest general combining ability have lines XM 11 6 and XM 12 1. These lines can be included as components of high-yielding synthetics or as testers in analyzing crosses to determine general combining ability in early stages of the selection process. The above lines with high specific combining ability – XM 11 13 and XM 11 46 are suitable for inclusion in combinations to develop high-yielding hybrids. Three of the tested lines XM 11 7 11 XM 10 and XM 11 11 have both high GCA and SCA. These lines can be used in corresponding breeding in the selection programs.*

**Keywords:** maize, mutant lines, combining ability, grain yield

**Abbreviations:** CA – combining ability, GCA – general combining ability, SCA – specific combining ability

## Introduction

The problems concerning the narrowing of the genetic diversity in the source material for maize selection, as well as the genetic vulnerability that threatens the development of maize due to the unification of source material that is used on a large scale, have remained pressing in the last years (Maunder, 1991). According to Brown's data (1983) and Hallayer (1990), the present-day used hybrids are a product of a relatively small number of elite and well-known lines that have originated from the varieties Lancaster, Reid Yellow Dent and Krug. Experimental mutagenesis and mutation selection were widely used during the last few decades with the aim of searching for new opportunities for expanding and enriching the genetic diversity of maize (Genov and Genova, 1987; Hristov and Hristova, 1995; Ilchovska, 2013; Valkova and Petrovska, 2014). A large number of mutant lines with a complex of valuable biological and economical qualities were created in Maize Research Institute, Knezha through the use of physical and chemical mutagenesis with a subsequent reciprocal mutation selection. The lines' further use in selection-genetic activity of improving maize, as well as their inclusion in breeding programs require detailed phenotypic and genetic characteristics. The methods for evaluating the newly-created mutant lines do not differ from those of lines that have been created by Pedigree selection.

The aim of the present study is to analyze the Combining Ability for grain yield of newly-stabilized mutant maize lines in terms of their more direct use in different stages of the heterosis selection.

## Material and methods

The experimental work was carried out in the period of 2009 – 2011 on the field of Maize Research Institute, Knezha. The lines that have been tested are a product of mutation breeding – they are obtained by a treatment of heterozygous material with DES – 0.1% and NEU 0 0.001% and are stabilized in 2011 and 2012. In order to evaluate their CA, the lines are included in a topcross hybridization of three testers from different genetic groups – Stiff Stalk Synthetic (N 192) and Lancaster (K 46 52 and XM 552). The crosses were obtained in 2013 and tested in 2014 and 2015. The trials were carried out by the "Latin rectangle" method with two repetitions, a test plot of 5m$^2$, plant density 60000 plant/ha and without irrigation.

ANOVA was performed by Dimova and Marinkov (1999) and the CA was assessed through the method of Savchencko (1978).

* e-mail: valkova_valentina@mail.bg

## Results and discussion

The lines included in this study are newly-stabilized ones of unknown breeding value, which necessitates their inclusion in the topcross testing with a common tester, as the tested lines are mothers and the analyzer is a father. The topcross is used in the initial stages of the breeding test and its results allow a quick and satisfactory valuation of CA of the research material to be made. The success of its implementation depends primarily on the right choice of a tester and the crossing of two or more analyzers increases the accuracy of the analysis and allows preventing the masking effect of the dominant and epistatic genetic effects of the analyzer (Savchenko, 1978; Wolff, 1980; Anachenkov, 2012). The results of the crossing allow obtaining information about the combining ability and the genetic properties of the experimental material in F1. According to Pakudin (1972), the evaluations from the top-crossing analysis are in no way inferior to those obtained by diallel crossing, as they save time and work in pointing out valuable lines in terms of combining ability.

Table 1 shows the data for grain yield of the experimental crosses. The yield of the received top crosses ranges from 6774 kg/ha to 13300 kg/ha. ANOVA of the output data shows significant differences between the tested variants in which the experimental values of F outperform the theoretical meanings of F in terms of LSD 5%. The highest yields are obtained by the crosses of lines XM 11 7, XM 11 11 and XM 11 5, and from the analyzers – those in which the line XM 552 participates. The nineteen crosses (37.3%) can be viewed as practical contribution and their testing will be continued in competitive experiments. The experimental crosses also pose an interest: XM 11 x XM 552 with an average yield of 12854 kg/ha and surpassing the average for the trial by 26.7%; XM 11 10 x XM 552 with the respective indicators of 12769 kg/ha and 25.9% and XM 11 4 x K 46 52 with 1241.5 kg/ha and 22.4% above the average yield.

It is evident from the ANOVA of GCA and SCA that the mutant lines that are included in the top crossing hybridization significantly differ in terms of GCA and SCA for the "grain yield" index. This allowed the continuation of the CA analysis of the researched indicator and the resulting suggestions for applying the test material.

The effects of the tested lines (ġi) have been compared for the purpose of evaluating GCA, while for evaluating SCA a comparison is made between the variances of the effects ($\sigma^2$si). The analysis of the effect of GCA and the variance of the effects of SCA of each of the included lines allow to point out the value and perspective source materials. The obligatory condition for each "I" (Σ ġi=0 and Σ gj=0) is fulfilled.

According to a number of authors, GCA is determined by

**Table 1.** Grain yield (kg/ha) of middle early maize hybrids

| Lines | K 46 52 | | N 192 | | XM 552 | |
|---|---|---|---|---|---|---|
| | I | II | I | II | I | II |
| XM 11 3 | 11941 | 9899 | 9192 | 11100 | 9961 | 9578 |
| XM 11 4 | 10006 | 10981 | 9185 | 9260 | 10822 | 10368 |
| XM 11 5 | 10067 | 9974 | 9949 | 10062 | 11132 | 9878 |
| XM 11 6 | 10043 | 10043 | 11972 | 11050 | 11431 | 11516 |
| XM 11 7 | 12848 | 11982 | 10653 | 10012 | 11808 | 11808 |
| XM 11 8 | 10031 | 9205 | 9153 | 11151 | 11855 | 10642 |
| XM 11 10 | 9275 | 11026 | 10781 | 9007 | 13078 | 12459 |
| XM 11 11 | 11000 | 9876 | 10756 | 9452 | 1330 | 12407 |
| XM 12 1 | 10527 | 10613 | 10401 | 10401 | 10764 | 10764 |
| XM 12 2 | 10031 | 9972 | 10086 | 10086 | 10097 | 10097 |
| XM 11 12 | 10088 | 9157 | 11734 | 6948 | 8054 | 9912 |
| XM 11 13 | 10019 | 8381 | 11236 | 10774 | 7450 | 9312 |
| XM 11 40 | 10808 | 10808 | 10126 | 9894 | 9418 | 9264 |
| XM 11 41 | 10355 | 10819 | 10456 | 10036 | 9878 | 10349 |
| XM 11 42 | 9767 | 9767 | 9463 | 9986 | 9274 | 9351 |
| XM 11 45 | 9145 | 9246 | 9515 | 8386 | 8874 | 9354 |
| XM 11 46 | 8064 | 6774 | 9248 | 9391 | 9354 | 7580 |

**Table 2.** ANOVA results for grain yield of middle early maize hybrids

| Source of Variation | SS | df | MS | F | F crit |
|---|---|---|---|---|---|
| Testers | 17974.38 | 2 | 2 | 1.307 | 3.179 |
| Lines | 602897.01 | 16 | 16 | 5.479 | 1.846 |
| Interaction | 456197.76 | 32 | 32 | 2.073 | 1.670 |
| Within | 350755.12 | 51 | 51 | | |
| Total | 1427824.27 | 101 | 101 | | |

**Table 3.** ANOVA of GCA and SCA

| Source of Variation | SQ | FG | S2 | F | F crit |
|---|---|---|---|---|---|
| GCA sgi | 301448.51 | 16 | 18840.532 | 2.643 | 1.972 |
| GCA sgj | 8987.19 | 2 | 4493.595 | 0.630 | 3.295 |
| SCA | 228098.88 | 32 | 7128.090 | | |
| Total | 538534.58 | 50 | | | |

**Table 4.** Effects of GCA (gi, gj) for grain yield of middle early maize hybrids

| Lines | | Testers | |
|---|---|---|---|
| XM 11 3 | 13.508 | K 46 52 | -6.877 |
| XM 11 4 | -3.975 | N 192 | -11.689 |
| XM 11 5 | 3.358 | XM 552 | 18.567 |
| XM 11 6 | 86.575 | | |
| XM 11 7 | 137.508 | | |
| XM 11 8 | 19.608 | | |
| XM 11 10 | 79.425 | | |
| XM 11 11 | 98.841 | | |
| XM 12 1 | 43.491 | | |
| XM 12 2 | -8.192 | | |
| XM 11 12 | -82.792 | | |
| XM 11 13 | -61.475 | | |
| XM 11 40 | -9.042 | | |
| XM 11 41 | 17.208 | | |
| XM 11 42 | -54.209 | | |
| XM 11 45 | -105.675 | | |
| XM 11 46 | -174.159 | | |
| Sum | 0.000 | | |

additively acting genes and SCA – by genes with dominant and epistatic effect (Griffing, 1956; Turbin et al., 1974). The establishment of the proportion of one or another type of gene action in the inheritance of signs is an important factor for creating effective breeding programs.

The lines XM 11 7, XM 11 11, XM 11 6, XM 11 10 and XM 12 1 display the highest GCA (Table 4). The dominant gene effects are of additive type which makes them good components for including in synthetic populations with high grain yield direction. They can also be used as testers for evaluating GCA of newly created inbred maize lines.

High variances of the effects of the SCA of these three lines (XM 11 11, XM 11 10 and XM 11 7) allow their successful use also in combinations for obtaining hybrids with higher yield (Table 5). Lines XM 11 13 and XM 11 46 have comparatively high SCA and low GCA. They are also appropriate to be included in the heterosis selection for obtaining hybrids with high yields.

Unpublished lines included in the study have low degree GCA and SCA, which makes them unsuitable for inclusion in breeding programs for high yield. Their application will be according to the other qualities they have, which shall be analyzed in upcoming studies.

## Conclusion

Results of a preliminary evaluation of the combining ability for grain yield of 17 mutant maize lines shows that: Suitable lines for creating middle early synthetics are XM 11 6 and XM 12 1; They can be used as tester GCA in the early stages of the selection process; High SCA lines XM 11 13 and XM 11 46 allow their inclusion in heterosis programs to obtain high yielding maize hybrids (400-499 FAO); Lines XM 11 7, XM 11 10 and XM 11 11 have both high GCA and SCA and can be included in the mentioned selection directions.

**Table 5.** Variances of SCA (σ2si,σ2sj) for grain yield of middle early maize hybrids

| Lines | Testers | | | Variances |
|---|---|---|---|---|
| | K 46 52 | N 192 | XM 552 | |
| XM 11 3 | 71.027 | -1.561 | -69.467 | 4936.476 |
| XM 11 4 | 45.861 | -76.427 | 30.567 | 4439.344 |
| XM 11 5 | -8.773 | -5.461 | 14.233 | 154.683 |
| XM 11 6 | -89.739 | 61.873 | 27.867 | 6328.945 |
| XM 11 7 | 96.527 | -106.911 | 10.383 | 10427.639 |
| XM 11 8 | -65.273 | -7.061 | 72.333 | 4771.236 |
| XM 11 10 | -71.839 | -92.677 | 164.517 | 20407.858 |
| XM 11 11 | -62.506 | -91.094 | 15.6 | 17899.042 |
| XM 12 1 | 6.044 | -6.044 | 0 | 36.531 |
| XM 12 2 | 0.877 | 14.139 | -15.017 | 213.094 |
| XM 11 12 | 37.577 | 14.239 | -51.817 | 2149.894 |
| XM 11 13 | -25.989 | 159.323 | -133.333 | 21918.446 |
| XM 11 40 | 82.377 | 7.389 | -89.767 | 7449.35 |
| XM 11 41 | 34.027 | 4.739 | -38.767 | 1341.591 |
| XM 11 42 | 23.444 | 24.006 | -47.45 | 1688.706 |
| XM 11 45 | 17.761 | -1.927 | -15.833 | 284.927 |
| XM 11 46 | -91.406 | 103.456 | -12.05 | 9601.679 |
| Sum | 0 | 0 | 0 | |
| Variances | 3575.81 | 4703.23 | 5977.14 | |

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