Madras Agric. J., 99 (4-6): 188-191, June 2012
https://doi.org/10.29321/MAJ.10.100044

# Combining Ability and Heterosis for Yield and Quantitative Traits in Maize, *Zea mays* (L.)

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**Combining ability analysis was conducted in late maturing maize (*Zea mays* L.) inbred lines for yield attributes. Both additive and non additive gene effects were present in the material under study. Variance due to *gca* was preponderant for days to 50% pollen shedding, days to 50% silk emergence, plant height, ear height, number of kernel rows, number of kernels per row and grain yield indicating importance of additive genes in controlling the traits. Three lines KML-70, KML-223 and KML-286 and two testers, KML-36 and KML-226 were good general combiners for grain yield. The crosses KML-57 x KML-226, KML-70 x KML-3, KML-70 x KML-29 and KML-286 x KML-29 are desirable with significant positive *sca*, heterosis and high mean values for grain yield. KML-223 x KML-3 recorded significant negative heterosis for days to 75 per cent dry husk, combined with significant negative *sca* and low mean performance. Hence, this hybrid could be suitable for medium maturity situations.**

**Key words:** Maize, heterosis, combining ability, gene action, line x tester analysis

Maize (*Zea mays* L.) is the second most important cereal crop in the world and provides more human food than any other cereal. In India, maize is the third most important cereal after rice and wheat growing in an area of 8.26 MHa with the productivity of 2.02 t $ha^{-1}$ and production of 16.72 MT. Maize has many possible uses *viz*., food, feed for livestock and as raw material for industry. The knowledge of gene action and combining ability helps in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate genes through selection and in understanding the characters to choose the proper selection method to be followed in breeding programme. In the present study, an attempt has been made to estimate the heterosis in $F_1$ hybrids with respect to yield, combining ability and gene action governing the quantitative traits in maize, using line x tester mating design.

## Materials and Methods

Fifteen diverse late maturity genotypes of maize including seven lines namely, KML-57, KML-70, KML-141, KML-223, KML-234, KML-235 and KML-286 and eight testers namely, KML-3, KML-29, KML-32, KML-35, KML-36, KML-58, KML-99 and KML-226 were involved in crossing in a line x tester mating design in *Rabi,* 2009-10 and the resultant fifty six crosses along with popularly grown hybrid of Monsanto India Pvt Ltd. i.e. 900MGold as check were grown in Randomized Block Design with three replications during *Kharif,* 2010 at Agricultural Research Station, Karimnagar. The seed material was sown in a two row plot of 4 m length, having an inter and intra-row spacing of 75 cm and 20 cm, respectively. Two seeds per hill were planted and later on thinning was done at 2-leaf stage to have optimum plant population. Heterosis was assessed over the standard check (standard heterosis). Five plants from each plot were randomly selected for recording observations on plant height, ear height, ear length, ear girth, number of kernel rows and number of kernels per row. Observations on days to 50 per cent pollen shedding, days to 50 per cent silk emergence, days to75 per cent dry husk, number of ears per plant, grain yield (q/ha) and 100 kernels weight were recorded on plot basis. Number of ears per plant was recorded on plot basis to know barrenness, an undesirable trait. Combining ability analysis was carried out as per the method suggested by Kempthorne (1957). Heterosis was estimated over the check as per the standard procedure.

## Results and Discussion

In the present investigation, the analysis of variance for all the yield and yield component traits showed that, variance due to hybrids was highly significant for all the traits studied indicating the manifestation of parental genetic variability in their crosses. The mean squares for hybrids were partitioned into three components *viz.,* due to lines, due to testers and due to line x tester interactions. The differences among hybrids due to the lines, testers and line x tester interaction were significant for all the characters except plant height, ear height, number of ears per plant, number of kernel rows in line x testers thereby suggesting that the

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experimental material possessed considerable variability and that both *gca* and *sca* were involved in genetic expression of these traits. A higher proportion of *sca* variance than *gca* variance for days to 75% dry husk, ear length, ear girth and equal proportion of *sca* variance to *gca* variance for number of ears per plant, 100 kernel weight indicates that the both the additive and non-additive interactions were significantly higher among the hybrids, which would be important for their exploitation. Higher *sca* variance than the *gca* variance exhibiting preponderance of non-additive gene effects has also been earlier reported by Joshi *et al*. (2002) and Gautam (2003). However, the component of variation due to *gca* was higher than that due to *sca* for days to 50% pollen shedding, days to 50% silk emergence, plant height, ear height, number of ears per plant, number of kernel rows, number of kernels per row, 100 kernels weight and grain yield, revealing the preponderance of additive gene actions for major attributes (Table 1). It infers that the experimental materials may be more efficiently

**Table 1. Analysis of variance for combining ability.**

| Source | df | Grain yield | Days to 50% pollen shedding | Days to 50% silk emergence | Days to 75% dry husk | Plant height | Ear height | Ear length | Ear girth | No. of ears/ plant | No.of kernel rows | No.of kernels/ row | 100 kernels weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 183.789* | 14.024** | 16.685** | 10.661* | 994.667** | 1164.875** | 8.046** | 0.662 | 0.004 | 1.256 | 31.327* | 0.554 |
| Hybrids | 55 | 1011.06** | 13.339** | 11.395** | 9.549** | 875.628** | 255.975** | 6.442** | 3.294** | 0.015** | 3.415** | 43.16** | 53.066** |
| Lines | 6 | 4788.548** | 38.534** | 34.206** | 37.496** | 3994.927** | 1427.913** | 26.69** | 7.646** | 0.064** | 13.774** | 241.635** | 231.387** |
| Testers | 7 | 1771.208** | 53.04** | 44.595** | 7.067* | 2136.149** | 428.5** | 4.81** | 7.334** | 0.02** | 5.707** | 20.395* | 104.142** |
| Lines x testers | 42 | 344.731** | 3.123** | 2.603* | 5.97** | 219.927 | 59.80 | 3.821** | 1.999** | 0.007 | 1.554 | 18.601** | 19.079** |
| Error | 110 | 48.969 | 1.612 | 1.648 | 2.436 | 177.273 | 81.80 | 1.039 | 0.419 | 0.006 | 1.104 | 8.546 | 1.057 |
| *gca* variance | | 130.451 | 1.896 | 1.635 | 0.725 | 126.472 | 38.60 | 0.53 | 0.244 | 0.002 | 0.364 | 4.996 | 6.608 |
| *sca* variance | | 98.587 | 0.504 | 0.318 | 1.178 | 14.218 | -7.33 | 0.927 | 0.527 | 0.000 | 0.15 | 3.352 | 6.007 |
| Additive variance (VA) | | 521.804 | 7.584 | 6.540 | 2.900 | 505.888 | 154.384 | 2.120 | 0.976 | 0.008 | 1.456 | 19.984 | 26.432 |
| Dominance Variance (VD) | | 394.348 | 2.016 | 1.272 | 4.712 | 56.872 | -29.336 | 3.708 | 2.108 | 0.000 | 0.600 | 13.408 | 24.028 |
| *gca* variance/*sca* variance | | 1.323 | 3.762 | 5.142 | 0.615 | 8.895 | -5.263 | 0.572 | 0.463 | 0.000 | 2.427 | 1.490 | 1.100 |

Significant at P<0.05; **Significant at P<0.01

exploited by adopting any population improvement method for composite development to derive new inbred lines. There exists great potential for improving these traits through recurrent selection. These findings were in close agreement with those of Vasal *et al*. (1993) and Singh *et al.* (1998) for days to silking and plant and ear heights.

Estimates of *gca* effects (Table 2) indicated that the lines KML-70, KML-223 and KML-286 were good general combiners for grain yield. Line KML-223 was a good general combiner for all the yield contributing traits viz., ear girth, number of ears per plant, number of kernel rows and number of kernels per row. Lines KML-70 and KML-286 were found to be good general combiners for plant height, ear height and 100 kernels weight, where as KML-70 was good combiner for number of ears per plant and KML-286 was a good combiner for days to 50% silk emergence and ear length.

**Table 2. Estimates of General combining ability effects of inbred lines of maize.**

| Line / Testers | Grain yield | Days to 50% pollen shedding | Days to 50% silk emergence | Days to 75% dry husk | Plant height | Ear height | Ear length | Ear girth | No. of ears/ plant | No.of kernel rows | No.of kernels/ row | 100 kernels weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KML-57 | 0.882 | 0.994** | 1.268** | 1.304** | -7.488** | -1.78 | -1.604** | -0.421** | -0.074** | 0.321 | -4.220** | -0.149 |
| KML-70 | 18.952** | 0.327 | -0.065 | -0.03 | 11.804** | 6.637** | 0.146 | -0.408** | 0.028* | -1.054** | -2.637** | 3.601** |
| KML-141 | -12.743** | -1.506** | -1.274** | -1.988** | 2.762 | 1.637 | 1.271** | -0.754** | 0.053** | -0.095 | 5.071** | -3.232** |
| KML-223 | 9.873** | 0.411 | 0.143 | -0.071 | -1.571 | -1.238 | -0.812** | 0.617** | 0.060** | 1.030** | 1.988** | -3.065** |
| KML-234 | -10.273** | -1.673** | -1.065** | -0.946** | -16.821** | -8.738** | -0.633** | 0.271* | -0.030* | -0.304 | -1.304* | -2.774** |
| KML-235 | -18.335** | 1.786** | 1.851** | 1.679** | -9.280** | -8.821** | 1.009** | 0.738** | -0.047** | 0.780** | 1.905** | 1.935** |
| KML-286 | 11.644** | -0.339 | -0.857** | 0.054 | 20.595** | 12.304** | 0.621** | -0.042 | 0.01 | -0.679** | -0.804 | 3.685** |
| SE (Lines) ± | 1.322 | 0.240 | 0.243 | 0.295 | 2.516 | 1.709 | 0.193 | 0.122 | 0.014 | 0.199 | 0.552 | 0.194 |
| KML-3 | -3.152* | 2.613** | 2.321** | 0.089 | 17.125** | 1.798 | 0.08 | 0.804** | -0.024 | -0.565** | 0.262 | 2.339** |
| KML-29 | -1.462 | 0.423 | 0.321 | 0.899** | -3.256 | -4.583* | -0.162 | 0.004 | 0.021 | 0.911** | 0.643 | -0.28 |
| KML-32 | 1.452 | -0.815** | -1.250** | -0.577 | -9.399** | -3.917* | 0.261 | -0.082 | -0.002 | -0.423 | 1.119 | -0.375 |
| KML-35 | -1.205 | -2.673** | -2.393** | -0.625 | -14.446** | -4.488* | -0.539* | 0.466** | 0.023 | 0.339 | -0.881 | 1.815** |
| KML-36 | 5.276** | -0.815** | -0.536* | 0.280 | -1.256 | -1.726 | 0.857** | 0.280* | 0.007 | 0.244 | 0.833 | 0.958** |
| KML-58 | -11.381** | -0.625* | -0.298 | -0.720* | -2.113 | 6.893** | -0.672** | -0.939** | 0.012 | -0.613** | 0.262 | -4.661** |
| KML-99 | -8.229** | 0.851** | 1.036** | 0.28 | 3.839 | 0.321 | 0.009 | -0.753** | -0.064 | 0.149 | -1.833** | -1.137** |
| KML-226 | 18.700** | 1.042** | 0.798** | 0.375 | 9.506** | 5.702** | 0.166 | 0.218 | 0.027 | -0.042 | -0.405 | 1.339** |
| SE (Testers) ± | 1.428 | 0.259 | 0.262 | 0.319 | 2.718 | 1.846 | 0.208 | 0.132 | 0.016 | 0.215 | 0.597 | 0.210 |

Significant at P<0.05; **Significant at P<0.01

Lines KML-141 and KML-234 were found to be good general combiners for earliness i.e. days to 50% pollen shedding, days to 50% silk emergence and days to 75% dry husk, Line KML-141 for number of ears per plant and number of kernels per row, KML-234 for ear girth and KML-235 for ear length, ear girth, number of kernel rows, number of kernels per row and 100 kernels weight.

Among testers, KML-36 and KML-226 were good general combiners for grain yield. For 100 kernels weight, KML-3, KML-35, KML-36 and KML-226 were good general combiners and KML-3, KML-35 and KML-36 for ear girth. For ear length KML-36 was good general combiner. For earliness *i.e.* for days to 50% pollen shedding and days to 50% silk emergence, KML-32, KML-35 and KML-36 were good general combiners. For days to 50% pollen shedding and days to 75% dry husk, KML-58 was good general combiner.

Among hybrids, KML-286 x KML-29 was the best specific combiner for grain yield followed by KML-57 x KML-35, KML-235 x KML-32, KML-235 x KML-58, KML-57 x KML-226 and KML-223 x KML-3 (Table 3). The cross KML-223 x KML-3 is desirable for early maturity with significant negative *sca*, heterosis and low mean values for number of days to 75 per cent dry husk. The cross KML-57 x KML-226 was desirable with significant positive *sca*, heterosis and high mean values for grain yield and ear girth, significant *sca* and heterotic effects for ear length, ear girth and 100 kernels weight. The crosses KML-57 x KML-226, KML-70 x KML-3, KML-70 x KML-29, KML-57 x KML-35, KML-223 x KML-3 and KML-286 x KML-29 are desirable with significant positive *sca*,

**Table 3. Estimates of *sca* effects, standard heterosis and *per se* performance of best performing crosses.**

| Character | | Cross combinations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | KML-286 x KML-29 | KML-57 x KML-35 | KML-235 x KML-32 | KML-235 x KML-58 | KML-57 x KML-226 | KML-223 x KML-3 | KML-70 x KML-3 | KML-70 x KML-29 | SE (m) ± |
| Grain yield | *Sca* | 16.870** | 16.676** | 16.035** | 14.302** | 13.871** | 13.865** | 12.852** | 9.729** | 3.499 |
| (*q/ha*) | het. | 32.757** | 17.709** | -6.480 | -26.966** | 41.757** | 23.662** | 35.007** | 32.992** | 5.714 |
| | *per se* | 94.400 | 83.700 | 66.50 | 51.933 | 100.80 | 87.933 | 96.00 | 94.567 | - |
| Days to 50 per | *Sca* | -0.423 | -0.327 | 0.024 | -0.500 | -1.042 | -2.030** | 0.720 | -0.089 | 0.635 |
| cent pollen | het. | -5.78** | -8.67** | -3.47** | -4.05** | -3.47** | -3.47** | 1.16 | -4.05** | 1.037 |
| shedding | *per se* | 54.333 | 52.667 | 55.667 | 55.333** | 55.667 | 55.667 | 58.333 | 55.333 | - |
| Days to 50 per | *Sca* | -0.571 | 0.018 | 0.292 | -0.661 | -1.173 | -1.571* | 0.637 | 0.304 | 0.642 |
| cent silk | het. | -7.73** | -7.73** | -4.42** | -4.42** | -4.42** | -4.42** | -1.10 | -4.97** | 1.048 |
| emergence | *per se* | 55.667 | 55.667 | 57.667* | 57.667* | 57.667 | 57.667 | 59.667 | 57.333 | - |
| Days to 75 per | *Sca* | -0.482 | 1.125 | -0.631 | -0.488 | -0.542 | -5.548** | 0.411 | -0.399 | 0.780 |
| cent dry husk | het. | -0.71 | 2.13 | 0.71 | 0.71 | 1.42 | -5.67** | 0.71 | 0.71 | 1.274 |
| | *per se* | 94.667 | 96.000 | 94.667 | 94.667 | 95.333 | 88.667 | 94.667 | 94.667 | - |
| Plant height | *Sca* | -6.786 | 0.821 | -0.768 | -7.054 | 6.869 | 13.000 | -6.042 | -2.661 | 6.657 |
| | het. | 8.78 | -14.39 | -13.17 | -12.44 | 7.56 | 21.95 | 17.80 | 5.37 | 10.871 |
| | *per se* | 148.667 | 117.000 | 118.667 | 119.667 | 147.000 | 166.667 | 161.000 | 144.000 | - |
| Ear height | *Sca* | -4.875 | 3.113 | -1.083 | 1.107 | 7.589 | 3.619 | 0.411 | -1.875 | 4.522 |
| | het. | 8.52 | -1.70 | -19.886* | 2.27 | 23.295** | 10.795 | 18.751* | 3.98 | 7.385 |
| | *per se* | 63.667 | 57.667 | 47.000 | 60.000 | 72.333 | 65.000 | 69.667 | 61.000 | - |
| Ear length | *sca* | -0.917 | -0.382 | -0.228 | 0.205 | 1.646** | 0.14 | -0.151 | -1.575** | 0.510 |
| | het. | 4.615* | -8.105** | 13.846** | 10.769** | 8.720** | 3.797** | 7.895** | -2.357** | 0.832 |
| | *per se* | 17.000 | 14.933 | 18.500** | 18.100* | 17.667 | 16.867 | 17.533 | 15.867 | - |
| Ear girth | *sca* | -0.258 | -0.641 | 0.115 | 0.972** | 1.64** | -1.317** | -0.492 | -0.525 | 0.324 |
| | het. | -2.733** | -4.624** | 3.992** | 3.992** | 8.195** | -0.212 | -1.472** | -6.723** | 0.529 |
| | *per se* | 15.433 | 15.133 | 16.500 | 16.500 | 17.167 | 15.833 | 15.633 | 14.800 | - |
| No. of | *sca* | -0.003 | 0.002 | 0.04 | -0.047 | 0.036 | 0.019 | 0.031 | 0.002 | 0.038 |
| ears/plant | het. | 3.236** | -4.793** | -0.622 | -8.234** | -0.935 | 6.052** | 3.966** | 5.635** | 0.063 |
| | *per se* | 0.990 | 0.913 | 0.953 | 0.880 | 0.950 | 1.017 | 0.997 | 1.013 | - |
| No. of kernel | *sca* | -0.369 | 0.202 | -0.827 | 0.030 | 0.583 | -0.268 | 0.149 | -0.994 | 0.525 |
| rows | het. | 2.379** | 9.521** | 0.000 | 4.764** | 9.521** | 4.764** | -7.143** | -4.764** | 0.858 |
| | *per se* | 14.333 | 15.333 | 14.000 | 14.667 | 15.333 | 14.667 | 13.000 | 13.333 | - |
| No. of kernels/row | *sca* | 0.232 | -2.494 | 0.381 | -2.429 | 2.363 | 0.155 | 0.780 | -1.935 | 1.462 |
| | het. | -3.001 | -25.999** | 7.001** | -4.000 | -10.000** | 4.001 | -7.999** | -15.001** | 2.387 |
| | *per se* | 32.333 | 24.667 | 35.667 | 32.000 | 30.000 | 34.667 | 30.667 | 28.333 | - |
| 100 kernel weight | sca | -1.304* | 1.101* | -0.125 | 0.161 | 1.577** | -3.173** | -2.506** | 4.113** | 0.514 |
| | het. | 1.922* | 3.846** | 0.001 | -11.538** | 3.846** | -15.386** | 5.770** | 17.309** | 0.839 |
| | per se | 35.333 | 36.000 | 34.667 | 30.667 | 36.000 | 29.333 | 36.667 | 40.667 | - |

Significant at P<0.05; **Significant at P<0.01

heterosis and high mean values for grain yield. These results are in similarity with the earlier findings of Lata *et al.* (2008).

In the estimation of heterosis, Sharma (1994) opined that heterosis over the best check or the local variety could be considered as the better criteria for evaluation of hybrids. The present study revealed that the distribution of heterosis in negative direction for days to 50% pollen shedding, days to 50% silk emergence and in both positive and negative directions for the remaining traits.

The hybrid combination KML-223 x KML-3 recorded significant negative heterosis for days to 75 per cent dry husk, combined with significant negative *sca* and low mean performance. Hence, this hybrid could be suitable for medium maturity situations.

For ear length, hybrids KML-70 x KML-36, KML-141 x KML-3, KML-235 x KML-29, KML-235 x KML-99 and KML-286 x KML-32 recorded significant standard heterosis combined with good *sca* and mean performance. For ear girth, KML-57 x KML-3 and KML-223 x KML-35 recorded significant standard heterosis with positive *sca* effects and good *per se* performance. KML-70 x KML-58 recorded significant *sca*, heterosis for number of ears per plant, but failed to express *per se* performance.

The crosses KML-223 x KML-35 and KML-223 x KML-36 recorded significant *sca*, heterosis and high mean values for number of kernel rows.

For number of kernels per row, crosses KML-223 x KML-36, KML-235 x KML-35 and KML-235 x KML-99 recorded significant *sca* effects coupled with heterosis but failed in *per se* performance.

For 100 kernels weight the crosses KML-57 x KML-3, KML-70 x KML-32, KML-70 x KML-35 and KML-70 x KML-36 recorded significant *sca* with heterosis and good *per se* performance.

Based on *per se* performance, KML-29 and KML-226 lines involving as one of the parents in cross combinations *i.e.,* KML-57 x KML-226, KML-223 x KML-226, KML-70 x KML-29 and KML-286 x KML-29 recorded high grain yields. These results are in similarity with the earlier findings of Srivastava and Singh (2003) and Jyoti *et al.* (2006). The lines KML-70, KML-223 and KML-286 and the testers KML-36 and KML-226 had significant *gca* effect for grain yield and its contributing characters and thus could be used as parents for the development of high yielding single cross hybrids. The high yielding hybrids KML-57 x KML-226, KML-223 x KML-226 and KML-70 x KML-3 with medium maturity could be tested for its performance over the locations for exploitation on commercial scale. The hybrids KML-57 x KML-35, KML-223 x KML-3 and KML-286 x KML-29 showed high *sca* effect, *per se* performance for grain yield and were identified for further multilocation evaluation.

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Received: November 1, 2011; Accepted: February 28, 2012