Electronic Journal of Plant Breeding

Research Article

Nature of gene action for kernel yield and its component traits in maize (Zea mays L.)

N. Sabitha*, D. Mohan Reddy, D. Lokanath Reddy, M. Hemanth Kumar, P. Sudhakar and B. Ravindra Reddy

Acharya N. G. Ranga Agricultural University, Department of genetics and plant breeding, S.V. Agricultural college, Tirupati – 517 502, A. P.

*E-Mail: nsabitha84@gmail.com

Abstract
Towards understanding the nature of gene action for kernel yield and its components traits, a set of 45 F₁ hybrids generated by adopting diallel mating design (Method IV and Model I) involving 10 inbred lines were tested across three seasons for their performance and combining ability. Combining ability analysis revealed that the mean sum of squares due to general and specific combining ability were significant indicating the contribution of both additive and non-additive gene action in controlling days to 50% flowering, days to 50% silking, anthesis-silking interval, days to maturity, plant height, SPAD chlorophyll meter reading, specific leaf area, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index and kernel yield. Estimates of components of variances (σ²GCA and σ²SCA) and ratio of σ²GCA/σ²SCA indicated the predominance of non-additive gene action for all the characters studied. Among the inbred lines, BML 2, DFTY, Heypool and PDM 1474 were found to be the best general combiners across seasons for kernel yield and most of yield components as well as developmental characters. DFTY, Heypool, PDM 1452 and PAM 1474 were identified as good general combiners for earliness. Among the top 20 best performing hybrids, BML 15 × PDM 1452, BML 15 × PDM 1474 and BML 7 × DFTY were rated as promising hybrids based on their superior performance and sca effects for kernel yield and most of the yield components. These hybrids could be recommended for commercial cultivation after extensive testing in multilocation trials.

Key words: Maize, Combing ability analysis, Gene action, Yield components

INTRODUCTION
Maize is a versatile staple cereal crop with wider genetic variability which can be successfully cultivated in tropical, sub-tropical and temperate agro-climatic conditions. In India, maize is the third most important cereal crop after wheat and rice. It is cultivated in an area of 9.2 million hectares with a production of 21.80 million tones and productivity of 2965 kg per ha primarily during kharif and rabi season (DES, 2020). In Andhra Pradesh, it is grown in an area of 2.77 lakh hectare with a production of 17.77 lakh metric tonnes. The productivity of maize in the state is 6403 kg per ha (DES, 2018). Maize is cultivated round the year under different seasons. Cultivation of high yielding and stable hybrids suitable for all the seasons would be a better proposition rather than growing specific hybrids in different seasons. Nature and magnitude of gene action controlling the yield and its component traits are important in understanding the genetic potential of a population. Further, knowledge on the genetic architecture of characters is essential in choosing an appropriate breeding procedure in a given population.

The use of inbred lines in generating superior hybrids has become more effective with the increased use of recurrent selection. Combining ability analysis provides information on the identification of potential parents which can be used for the development of hybrids and synthetics. The
diallel cross analysis provides the estimates of genetic parameters pertaining to combining ability and dominance relationship of parents using the first filial generation (F₁’s). Assessment of the stability of a genotype over different seasons is useful for recommending hybrids suitable for commercial seed programme. The present study was carried out to identify suitable inbred lines for hybridization programme, select promising hybrid combinations and estimate the nature and magnitude of gene action for kernel yield and components traits so as to adopt an appropriate breeding methodology in maize.

**MATERIALS AND METHODS**

Ten maize inbred lines were crossed in a diallel fashion excluding reciprocals during rabi, 2015-16 and kharif, 2016 by adopting staggered sowings in order to achieve synchrony in flowering and to generate F₁ hybrids. Simultaneously the parental lines were selfed to get the parental seeds. Forty-five F₁ hybrids and their parents were tested in a randomized block design with three replications during rabi, 2016-17, summer, 2016-17 and kharif, 2017 at Agricultural Research Station, Perumalapalli, Chittoor, Andhra Pradesh. Each genotype was planted in a row of 5 m length with a spacing of 75 cm between rows and 25 cm between plants in the row. A fertilizer dose of 100 kg/ha N, 80 kg/ha P₂O₅, 60 kg/ha K₂O kg/ha during kharif, 2017 and 120 kg/ha N, 80 kg/ha P₂O₅, 60 kg/ha K₂O kg/ha during rabi, 2016-17 and summer, 2016-17 was applied. All the recommended agronomic management practices and plant protection measures were followed in raising a good crop. Observations were recorded on five randomly selected plants from row for plant height (cm), SPAD chlorophyll meter readings, specific leaf area (cm² g⁻¹), cob length (cm), cob girth (cm), number of kernel rows per cob, number of kernels per row, 100 kernel weight (g), harvest index (%) and kernel yield per plant (g). Days to 50% tasseling, days to 50% silking and days to maturity were recorded on a whole plot basis. Specific leaf area (cm² g⁻¹) was determined as the ratio of leaf area to leaf weight, while harvest index (%) as the ratio of kernel yield to total dry matter (kernel yield + biomass). The chlorophyll content of the third leaf was measured with a SPAD-502 Chlorophyll Meter (Minolta Co Ltd, Osaka, Japan). Pooled analyses of variance over three seasons was also carried out after testing for the homogeneity of error variances by using Bartlett’s test of homogeneity (Bartlett, 1937) as quoted by Panse and Sukhatme (1985). General combining ability (GCA) and specific combining ability (SCA) estimates were determined adopting diallel cross analysis Model I and Method IV of Griffing’s approach (1956) and Singh and Chaudhary (1985).

**RESULTS AND DISCUSSION**

Analysis of variance for kernel yield and the its contributing characters performed on season-wise data indicated that mean sum of squares due to genotypes (F₁’s) were highly significant for all the characters viz., days to 50% flowering, days to 50% silking, anthesis-silking interval, days to maturity, plant height, SCMR, specific leaf area, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index, kernel yield per plant indicating the existence of sufficient variability among the genotypes. The presence of variability among the hybrids for characters of interest helps in the selection of best hybrid combinations. Similar results were reported by Azad et al. (2014) in maize.

Pooled analysis of variance for combining ability over three seasons is presented in Table 1. The variance components due to GCA, SCA and seasons showed the highly significant differences for all the characters. Mean sum of squares due to GCA × Seasons were significant for days to 50% tasseling, days to 50% silking, days to maturity, plant height, SCMR and ear girth, while they were non-significant for the characters viz., anthesis-silking interval, specific leaf area, specific leaf weight, ear length, number of kernel rows per ear, number of kernels per row, 100 kernel weight, harvest index and kernel yield per plant. The interaction of SCA × Seasons exhibited non-significant differences for all characters except days to 50% tasseling, days to 50% silking, days to maturity, plant height, ear girth and kernel yield per plant. Significant mean sum squares due to seasons, GCA × Seasons and SCA × Seasons for yield and yield components indicate that both additive and non-additive genetic variances are greatly influenced by environments (Seasons).

Significant mean sum of squares in pooled analysis due to GCA were recorded for days to 50% flowering, days to 50% silking, anthesis-silking interval, days to maturity, plant height, SCMR, specific leaf area, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index and kernel yield per plant. As a rule, GCA is the result of additive gene effects, while the SCA is the result of dominance and non-allelic interactions (Sprague and Tatum, 1942). In the present study, it was observed that both additive and non-additive gene actions are involved in governing these characters. Similarly, importance of both additive and non-additive gene actions for yield and yield related characters in maize was reported in maize by Joshi et al. (1998), Dubey et al. 2001, Akbar et al. (2008), Haddadi et al. (2012) and Kumari et al. (2017).

Estimates of components of genetic variances viz., $\sigma^2_{GCA}$, $\sigma^2_{SCA}$ and ratio of $\sigma^2_{GCA}/\sigma^2_{SCA}$ are presented in Table 1. The greater magnitude of $\sigma^2_{SCA}$ than $\sigma^2_{GCA}$ and the ratio of $\sigma^2_{GCA}/\sigma^2_{SCA}$ less than one were recorded for all the characters indicating the predominance of non-additive gene action. Based on results of genetic variance components, it is evident that non additive types of genetic actions is predominant for days to 50% flowering, days to 50% silking, anthesis-silking interval, days to maturity, plant height, SCMR, specific leaf area, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index, kernel

https://doi.org/10.37992/2021.1204.186 1360
Table 1. Analysis of variance for kernel yield and its contributing characters (pooled analysis)

| S.No. | Characters                               | GCA (D.F=9) | SCA (D.F=35) | $\sigma^2$ GCA | $\sigma^2$ SCA | $\sigma^2GCA/\sigma^2SCA$ |
|-------|-----------------------------------------|-------------|--------------|----------------|----------------|--------------------------|
| 1.    | Days to 50% tasseling                   | 10.56**     | 2.83**       | 1.23           | 2.31           | 0.53                     |
| 2.    | Days to 50% silking                     | 13.53**     | 4.10**       | 1.59           | 3.32           | 0.48                     |
| 3.    | Anthesis-silking interval               | 0.60*       | 0.32*        | 0.04           | 0.05           | 0.84                     |
| 4.    | Days to maturity                        | 14.94**     | 2.92**       | 1.77           | 2.13           | 0.83                     |
| 5.    | Plant height                            | 377.45**    | 158.94**     | 40.48          | 105.34         | 0.38                     |
| 6.    | SPAD chlorophyll meter readings (SCMR)  | 13.19**     | 3.34**       | 1.54           | 2.45           | 0.63                     |
| 7.    | Specific leaf area                      | 33.75**     | 10.39*       | 3.44           | 4.15           | 0.83                     |
| 8.    | Cob length                              | 4.64**      | 2.97**       | 0.51           | 2.41           | 0.09                     |
| 9.    | Cob girth                               | 2.39**      | 0.79**       | 0.28           | 0.68           | 0.42                     |
| 10.   | Number of kernel rows per cob           | 2.51**      | 0.62**       | 0.28           | 0.34           | 0.83                     |
| 11.   | Number of kernels per row               | 35.92**     | 9.23**       | 4.13           | 6.37           | 0.65                     |
| 12.   | 100 kernel weight                       | 12.45**     | 4.40**       | 1.46           | 3.64           | 0.40                     |
| 13.   | Harvest index                           | 1.27**      | 0.46**       | 0.13           | 0.26           | 0.52                     |
| 14.   | Kernel yield per plant                  | 1222.91**   | 263.59**     | 148.03         | 224.89         | 0.66                     |

*Significant at 5% level, **Significant at 1% level:

GCA – general combining ability; SCA – specific combining ability; DF – degrees of freedom

yield per plant. Similar results were also reported by Premalatha, (2006), Akbar et al. (2008), Kanagarasu et al. (2010), Kapoor et al. (2014), Purushottam and Shantanayumar (2017) and Varalakshmi Wali, (2017) maize.

Per se performance and estimates of gca effects in pooled analysis over seasons pertaining to parental lines and their respective standard errors for 14 characters studied are presented in Table 2. Significant differences were recorded among parental lines for their general combining ability effects. However, none of the inbred lines recorded significant gca effects for all the characters studied. Significant negative gca effects across seasons for days to 50% tasseling, silking and maturity were recorded by four inbred lines viz., DFTY, Heypool, PDM 1452 and PDM 1474. All these four inbred lines also recorded low per se performance for these characters. Negative gca effects are desirable for these characters as they are associated with earliness. Significant negative gca effects in the desirable direction indicates that these four parental lines are the best general combiners for days to 50% tasseling, silking and maturity. Significant results were reported in maize by Kumari et al., Matin et al. (2016) and Darshan and Marker, (2019).

However, BML 7, BML 15, DFTY, Heypool and PDM 1474 recorded significant negative gca effects for plant height. Negative gca effects are desirable to select the inbred lines for use as a source lines in breeding for dwarf plant types suitable for stress conditions. Positive significant gca effects were recorded by BML 6, PDM 1416 and PDM 1428 for plant height besides high mean performance and thus they are found to be good general combiners for plant height.

The value of an inbred line in the commercial production of hybrid maize depends on characteristics (yield, adaptability, disease resistance and toleration to environmental factors) and behavior of the line in hybrid combinations and therefore per se performance and its combining abilities should be considered. Parental lines viz., DFTY, Heypool and PDM 1452 exhibited significant positive gca effects for SCMR, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index and kernel yield per plant, days to 50% tasseling and maturity across the seasons in addition to high per se performance for these characters. Based on the above results, the inbred lines viz., DFTY, Heypool and PDM 1474 could be adjudged as good general combiners. BML 2 recorded significant gca effects and mean performance in desirable direction for specific leaf area, cob girth and kernel yield per plant, however significant gca effects were recorded in undesirable direction for days to 50% tasseling, days to
Table 2. General combining ability (gca) effects of inbred lines (pooled analysis)

| S. No. | Inbred line | Days to 50% tasseling | Days to 50% silking | Anthesis-silking interval | Days to maturity | Plant height (cm) | SPAD chlorophyll meter readings (SCMR) | Specific leaf area (cm² g⁻¹) |
|--------|-------------|-----------------------|---------------------|---------------------------|----------------|------------------|-------------------------------------|------------------------------|
|        |             | Mean gca effects      | Mean gca effects    | Mean gca effects          | Mean gca effects | Mean gca effects | Mean gca effects                     | Mean gca effects             |
| 1      | BML 2       | 66.67                | 0.40**              | 70.11                     | 0.63**          | 3.44             | 0.19                  | 106.27                      | 0.39*                        |
| 2      | BML 6       | 66.78                | 0.39**              | 69.44                     | 0.26            | 2.67             | -0.12                 | 106.18                      | 0.33*                        |
| 3      | BML 7       | 67.44                | 0.46**              | 70.89                     | 0.42*           | 3.44             | -0.03                 | 106.78                      | 0.22                         |
| 4      | BML 15      | 65.56                | 0.19                | 69.22                     | 0.46*           | 3.67             | 0.30*                 | 105.33                      | 0.69**                       |
| 5      | DFTY        | 64.78                | -0.91**             | 67.33                     | -1.02**         | 2.56             | -0.13                 | 104.34                      | -0.94**                      |
| 6      | Heypool     | 65.00                | -0.30*              | 67.67                     | -0.48*          | 2.67             | -0.16                 | 104.44                      | -0.79**                      |
| 7      | PDM 1416    | 68.00                | -0.03               | 71.89                     | -0.03           | 3.89             | -0.02                 | 105.04                      | 0.52**                       |
| 8      | PDM 1428    | 66.56                | 1.21**              | 70.00                     | 1.31**          | 3.44             | 0.13                  | 106.02                      | 1.24**                       |
| 9      | PDM 1452    | 65.56                | -0.73**             | 68.89                     | -0.78**         | 3.33             | -0.06                 | 106.72                      | -0.66**                      |
| 10     | PDM 1474    | 64.67                | -0.67**             | 67.89                     | -0.77**         | 3.22             | -0.09                 | 104.56                      | -1.00**                      |
|        | Grand Mean  | 66.10                | 69.33               | 3.23                      | 105.57          | 179.38           | 43.19                  | 80.00                       |                              |
|        | SE(gi)      | 0.14                 | 0.17                | 0.11                      | 0.16            | 1.42             | 0.21                  | 0.48                        |                              |

Table 2. contd….

| S. No. | Inbred line | Cob length (cm) | Cob girth (cm) | Number of kernel rows cob⁻¹ | Number of kernels row⁻¹ | 100 kernel weight (g) | Harvest index (%) | Kernel yield plant⁻¹ (g) |
|--------|-------------|-----------------|----------------|------------------------------|------------------------|----------------------|-------------------|---------------------------|
|        |             | Mean gca effects| Mean gca effects| Mean gca effects             | Mean gca effects        | Mean gca effects     | Mean gca effects   | Mean gca effects         |
| 1      | BML 2       | 12.54           | -0.06          | 9.57                        | 0.13*                  | 12.14                | 0.05              | 20.22                     | 0.02                        |
| 2      | BML 6       | 12.44           | -0.14          | 10.31                      | -0.15*                 | 12.58                | -0.10             | 21.33                     | -0.22                        |
| 3      | BML 7       | 12.73           | -0.20          | 10.42                      | -0.20**                | 12.73                | -0.24             | 22.78                     | -0.20                        |
| 4      | BML 15      | 12.86           | -0.24          | 10.06                      | -0.04**                | 12.47                | -0.11             | 20.67                     | -0.23                        |
| 5      | DFTY        | 13.97           | 0.62**         | 11.44                      | 0.33**                 | 13.34                | 0.35**            | 24.67                     | 1.70**                       |
| 6      | Heypool     | 14.12           | 0.52**         | 11.43                      | 0.39**                 | 13.54                | 0.32**            | 25.00                     | 1.04**                       |
| 7      | PDM 1416    | 12.41           | -0.51**        | 10.25                      | -0.33**                | 12.55                | -0.43**           | 21.89                     | -1.45**                      |
| 8      | PDM 1428    | 12.49           | -0.58**        | 10.12                      | -0.53**                | 12.22                | -0.49**           | 20.78                     | -2.09**                      |
| 9      | PDM 1452    | 13.34           | 0.02           | 10.37                      | 0.04                   | 12.93                | -0.01             | 23.11                     | -0.22                        |
| 10     | PDM 1474    | 13.21           | 0.58**         | 10.79                      | 0.36**                 | 13.25                | 0.65**            | 23.33                     | 1.66**                       |
|        | Grand Mean  | 13.01           | 10.48          | 12.78                      | 22.38                  | 21.38                | 34.18             | 69.52                      |                              |
|        | SE(gi)      | 0.14            | 0.06           | 0.1                        | 0.33                   | 0.17                | 0.08              | 1.38                      |                              |

*Significant at 5% level,**Significant at 1% level

https://doi.org/10.37992/2021.1204.186
50% silking and days to maturity. Three inbred lines viz., BML 7, PDM 1416 and PDM 1428 are considered as poor general combiners based on negative gca effects and low mean performance for yield and its contributing characters.

The sca effects estimated in pooled analysis for the top 20 hybrids along with per se performance are presented in Table 3. Among the top 20 hybrids DFTY × PDM 1474 recorded higher kernel yield per plant (151.10 g) followed by BML 2 × Heypool (146.11 g), Heypool × PDM 1474 (141.94 g), BML 2 × BML 6 (141.73 g), BML 15 × PDM 1474 (140.40 g), BM 7 × DFTY (140.33 g) and BML 15 × PDM 1452 (140.14 g). Though the hybrid DFTY × PDM 1474 registered higher yield, it recorded a low 100 kernel weight and low mean values for yield components. The next best hybrids BML 2 × Heypool, BML 2 × BML 6 and Heypool × PDM 1474 recorded average mean values for yield attributes coupled with long duration for flowering. The hybrids viz., BML 7 × DFTY, BML 15 × PDM 1452 and BML 15 × PDM 1474 and recorded higher mean values for most of the yield components.

Significant and negative sca effects by BML 7 × DFTY and BML 15 × PDM 1454 for days to 50% tasseling, days to 50% silking and days to maturity across seasons indicated that they are the best specific combiners for earliness. These two hybrids also registered low mean values for the characters. Three hybrids viz., BML 15 × PDM 1452, BML 15 × PDM 1474 and Heypool × PDM 1474 exhibited significant negative sca effects for days to 50% tasseling and days to 50% silking, whereas BML 6 × PDM 1474 and BML 2 × PDM 1428 for days to 50% tasseling and days to maturity and BML 6 × PDM 1452 for days to silking and days to maturity recorded significant negative sca effects. Significant positive sca effects were recorded by BML 2 × PDM 1474, BML 15 × Heypool, DFTY × PDM 1428 and PDM 1452 × PDM 1474 for plant height. None of the hybrids recorded significant sca effects in a desirable direction (negative effects) for specific leaf area.

Table 3. Mean performance and specific combining ability (sca) effects of top 20 F₁ hybrids (pooled analysis)

| S. No. | Hybrids | Days to 50% tasseling | Days to 50% silking | Anthesis-silking interval | Days to maturity | Plant height (cm) | SPAD chlorophyll meter readings (SCMR) | Specific leaf area (cm² g⁻¹) |
|--------|---------|-----------------------|---------------------|--------------------------|-----------------|-----------------|--------------------------------------|-----------------------------|
|        |         | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects | Mean | Mean | Sca effects |
| 1      | BML 2 × BML 6 | 63.11 | 0.04 | 0.26 | 3.11 | 0.21 | 2.75 | 0.42 | -0.54 | 83.48 | -0.02 |
| 2      | BML 2 × BML 7 | 63.11 | 0.11 | 0.44 | 0.37 | 0.04 | 2.80 | 51.46 | 1.08 | 83.96 | 0.39 |
| 3      | BML 2 × Heypool | 64.00 | 1.54 | 2.62 | 4.00 | 0.72 | 7.04 | 52.28 | 0.24 | 87.07 | 1.88 |
| 4      | BML 2 × PDM 1428 | 63.22 | -0.75 | 0.75 | 3.63 | 0.05 | 181.77 | 9.88 | 50.69 | 0.11 | 82.34 | -0.09 |
| 5      | BML 2 × PDM 1474 | 61.78 | -0.30 | 0.66 | 3.04 | -0.31 | 194.53 | 8.90 | 52.57 | 0.53 | 86.98 | 1.29 |
| 6      | BML 6 × PDM 1452 | 61.56 | -0.45 | 0.10 | 2.4 | -0.62 | 201.31 | 6.65 | 49.52 | 1.26 | 84.40 | 0.03 |
| 7      | BML 6 × PDM 1474 | 61.22 | -0.84 | 0.64 | 3.26 | 0.23 | 194.44 | 6.10 | 53.62 | 1.54 | 87.4 | 1.29 |
| 8      | BML 7 × DFTY | 60.67 | -1.23 | 1.43 | 2.89 | -0.19 | 186.59 | 12.97 | 53.57 | 1.70 | 89.39 | 3.23 |
| 9      | BML 15 × Heypool | 62.89 | 0.63 | 0.76 | 3.56 | 0.17 | 198.78 | 10.26 | 51.16 | -0.89 | 85.57 | -1.21 |
| 10     | BML 15 × PDM 1452 | 59.56 | -2.26 | 2.26 | 3.22 | -0.27 | 169.76 | 12.28 | 53.41 | 2.67 | 89.41 | 3.86 |
| 11     | BML 15 × PDM 1474 | 60.89 | -0.88 | 1.16 | 3.3 | -0.15 | 166.73 | 12.00 | 53.41 | 1.37 | 90.7 | 3.40 |
| 12     | DFTY × Heypool | 60.89 | -0.25 | 0.52 | 2.63 | -0.32 | 99.89 | 17.67 | 53.7 | 0.17 | 86.76 | -1.00 |
| 13     | DFTY × PDM 1428 | 62.89 | 0.23 | 0.62 | 3.37 | 0.12 | 197.11 | 10.38 | 51.96 | -0.10 | 84.81 | -0.20 |
| 14     | DFTY × PDM 1452 | 60.44 | -0.26 | 0.11 | 3.15 | 0.09 | 185.58 | 0.56 | 52.69 | 0.46 | 85.91 | -0.62 |
| 15     | DFTY × PDM 1474 | 62.33 | 1.56 | 1.65 | 3.15 | 0.12 | 182.78 | 2.07 | 52.93 | -0.58 | 87.93 | -0.34 |
| 16     | Heypool × PDM 1452 | 64.14 | 0.12 | 0.23 | 3.15 | 0.12 | 192.93 | 6.11 | 52.27 | 0.41 | 85.75 | -0.30 |
| 17     | Heypool × PDM 1474 | 60.00 | -1.37 | 1.22 | 3.07 | 0.09 | 182.42 | 0.58 | 52.46 | -0.69 | 85.94 | -1.85 |
| 18     | PDM 1416 × PDM 1474 | 61.11 | -0.52 | 0.55 | 3.15 | 0.02 | 185.73 | -4.29 | 50.26 | -1.25 | 83.66 | -1.74 |
| 19     | PDM 1428 × PDM 1474 | 63.56 | 0.66 | 0.20 | 2.74 | -0.53 | 183.11 | 5.63 | 50.47 | -1.22 | 84.28 | -0.76 |
| 20     | PDM 1452 × PDM 1474 | 62.22 | 1.27 | 1.52 | 3.3 | 0.20 | 195.96 | 8.92 | 52.8 | 0.95 | 85.88 | -0.68 |
| Grand Mean | 61.84 | 0.45 | 3.18 | 101.02 | 185.69 | 52.08 | 86.08 | 
| SE (S₀) | 0.36 | 0.45 | 3.73 | 0.56 | 1.27 | 

https://doi.org/10.37992/2021.1204.186
Table 3. contd...

| S. No. | Hybrids | Cob length (cm) | Cob girth (cm) | Number of kernel rows | Number of kernels row⁻¹ | 100 kernel weight (g) | Harvest index (%) | Kernel yield plant⁻¹ (g) | GCA status of inbred lines |
|--------|---------|-----------------|---------------|-----------------------|------------------------|----------------------|----------------------|--------------------------|---------------------------|
|        | Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects| Mean *sca effects|
| 1      | BML 2 × BML 6  | 14.23  | 0.37  | 14.27  | 15.28  | 16.89  | 0.27  | 0.39  | 0.43  | 0.15  | 0.10  | 0.08  |
| 2      | BML 2 × BML 7  | 14.12  | 0.36  | 14.15  | 15.18  | 15.37  | 0.25  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 3      | BML 2 × Heypool| 14.21  | 0.35  | 14.26  | 15.27  | 15.34  | 0.24  | 0.30  | 0.34  | 0.13  | 0.10  | 0.09  |
| 4      | BML 2 × PDM 1428| 14.10  | 0.34  | 14.14  | 15.15  | 15.32  | 0.23  | 0.29  | 0.33  | 0.12  | 0.10  | 0.09  |
| 5      | BML 2 × PDM 1474| 14.20  | 0.36  | 14.25  | 15.26  | 15.35  | 0.24  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 6      | BML 6 × PDM 1452| 14.19  | 0.35  | 14.24  | 15.25  | 15.33  | 0.23  | 0.29  | 0.33  | 0.12  | 0.10  | 0.09  |
| 7      | BML 6 × PDM 1474| 14.20  | 0.36  | 14.25  | 15.26  | 15.35  | 0.24  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 8      | BML 7 × DFTY  | 14.21  | 0.35  | 14.26  | 15.27  | 15.34  | 0.24  | 0.30  | 0.34  | 0.13  | 0.10  | 0.09  |
| 9      | BML 15 × Heypool| 14.20  | 0.36  | 14.25  | 15.26  | 15.35  | 0.24  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 10     | BML 15 × PDM 1452| 14.21  | 0.35  | 14.26  | 15.27  | 15.34  | 0.24  | 0.30  | 0.34  | 0.13  | 0.10  | 0.09  |
| 11     | BML 15 × PDM 1474| 14.22  | 0.36  | 14.27  | 15.28  | 15.36  | 0.24  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 12     | DFTY × Heypool | 14.22  | 0.36  | 14.27  | 15.28  | 15.36  | 0.24  | 0.30  | 0.34  | 0.13  | 0.10  | 0.09  |
| 13     | DFTY × PDM 1428| 14.23  | 0.37  | 14.28  | 15.29  | 15.37  | 0.25  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 14     | DFTY × PDM 1452| 14.24  | 0.37  | 14.29  | 15.30  | 15.38  | 0.25  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 15     | DFTY × PDM 1474| 14.25  | 0.37  | 14.30  | 15.31  | 15.39  | 0.25  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 16     | Heypool × PDM 1452| 14.26  | 0.38  | 14.31  | 15.32  | 15.40  | 0.25  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 17     | Heypool × PDM 1474| 14.27  | 0.38  | 14.32  | 15.33  | 15.41  | 0.25  | 0.30  | 0.34  | 0.13  | 0.11  | 0.09  |
| 18     | PDM 1416 × PDM 1474| 14.28  | 0.39  | 14.33  | 15.34  | 15.42  | 0.26  | 0.31  | 0.35  | 0.14  | 0.12  | 0.10  |
| 19     | PDM 1428 × PDM 1474| 14.29  | 0.40  | 14.34  | 15.35  | 15.43  | 0.26  | 0.31  | 0.35  | 0.14  | 0.12  | 0.10  |
| 20     | PDM 1452 × PDM 1474| 14.30  | 0.41  | 14.35  | 15.36  | 15.44  | 0.27  | 0.32  | 0.36  | 0.15  | 0.13  | 0.11  |

Grand Mean 18.15 14.77 14.79 38.92 34.05 37.82 138.09

SE (S) 0.38 0.17 0.27 0.86 0.44 0.22 3.20

*Significant at 5% level, **Significant at 1% level
G-good; P-Poor

Of the top 20 performing hybrids, 14 hybrids showed significant positive *sca* effects for kernel yield, while two hybrids viz., BML 2 × PDM 1474 and BML 6 × PDM 1474 showed negative significant *sca* effects and the remaining four hybrids viz., DFTY × Heypool, Heypool × PDM 1452, Heypool × PDM 1474 and PDM 1452 × PDM 1474 recorded non-significant *sca* effects for kernel yield per plant. Among the 14 hybrids exhibiting significant positive *sca* effects and high *per se* performance for kernel yield, the hybrids BML 2 × Heypool and DFTY × PDM 1474 involved good × good general combiners, BML 2 × BML 6, BML 2 × BML 7, BML 2 × PDM 1428, DFTY × PDM 1428 and DFTY × PDM 1452 involved good × poor general combiners, BML 7 × DFTY, BML 15 × Heypool, BML 15 × PDM 1474, PDM 1416 × PDM 1474 and PDM 1428 × PDM 1474 involved poor × good general combiners and BML 6 × PDM 1452 and BML 15 × PDM 1452 involved poor × poor general combiners. Two hybrids with significant negative *sca* effects and high *per se* performance viz., BML 2 × PDM 1474 and BML 6 × PDM 1474 involved good × good and poor × good combiners, respectively. Four hybrids viz., DFTY × Heypool, Heypool × PDM 1452, Heypool × PDM 1474 and PDM 1452 × PDM 1474 with non-significant *sca* effects and high *per se* performance involved good × good, good × poor, good × good and poor × poor combinations. The superior hybrids viz., DFTY × PDM 1474, BML 2 × Heypool and Heypool × PDM 1474 which showed either significant positive *sca* or non-significant *sca* effects and involving good × good combinations may be handled through population improvement programme to accumulate favorable alleles leading to the isolation of improved inbred lines. On the other hand, high yielding hybrids viz., BML 2 × BML 6 and DFTY × PDM 1452 with positive and significant *sca* effects involving good × poor general combiners may be handled though heterosis breeding towards the development of superior hybrids or
inbred lines. Among the top 20 best performing hybrids BML 15 × PDM 1452 recorded significant sca effects for days to 50% tasseling, days to 50% silking, SCMR, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index and kernel yield per plant, while BML 15 × PDM 1474 and BML 7 × DFTY recorded for days to 50% tasseling, days to 50% silking, days to maturity, SCMR, cob length, cob girth, number of kernel rows per cob, number of kernels per row, 100 kernel weight, harvest index and kernel yield per plant in addition to high per se performance for kernel yield and its contributing characters. These three hybrids may be recommended for immediate commercial exploitation of heterosis after multi-location testing.

Combining ability analysis for yield and its contributing characters indicated that both additive and non-additive gene actions are controlling all the characters studied with the predominance of non-additive gene actions. Of the ten inbred lines BML2, DFTY, Heypool and PMD 1474 are found as the good general combiners for kernel yield of which, the latter three inbred lines viz., DFTY, Heypool and PMD 1474 are the best general combiners due to their significant gca effects and high per se performance for yield and most of the yield contributing characters. However, the inbred lines viz., BML 7, PDM 1416 and PDM 1428 are the poor general combiners. Four inbred lines DFTY, Heypool, PDM 1452 and PMD 1474 are considered as good general combiners for days to 50% flowering, days to 50% silking and days to maturity. Among the top 20 single cross hybrids, BML 15 × PDM 1452, BML 15 × PDM 1474 and BML 7 × DFTY were considered as outstanding hybrids since they registered high per se performance and desirable significant sca effects for yield and most of the yield contributing characters revealing the potential of these hybrids for immediate commercial exploitation after extensive testing under different environments and locations.

REFERENCES

Akbar, M., Saleem, M., Azahar, F. M., Ashraf, M. Y. and Ahmed, R. 2008. Combining ability analysis in maize under normal and high temperature conditions. J. Agric. Res., 64: 27-38.

Azad, M.A.K., Biswas, B.K., Alam, N and Alam, S.K. 2014. Combining ability and heterosis for some quantitative traits in experimental hybrids. Plant Breeding and Seed Science. 70: 41-54. [Cross Ref]

Bartlett, M. S. 1937. Some examples of statistical methods of research in agriculture and applied biology. Supplement to Journal of Royal Statistical Society., 4: 137-170. [Cross Ref]

Darshan, S. S. and Marker, S. 2019. Heterosis and combining ability for grain yield and its component characters in quality protein maize (Zea mays L.) hybrids. Electronic Journal of Plant Breeding., 10 (1): 111-118. [Cross Ref]

DES, 2018. Directorate of Economics and Statistics, Govt. of Andhra Pradesh. 2018-19. Agricultural statistics at a glance.

DES, 2020. Directorate of Economics and Statistics, Govt. of India. 2020. Agricultural statistics at a glance.

Dubey, R. B., Joshi, V. N. and Pandiya, N. K. 2001. Heterosis and combining ability for quality, yield and maturity traits in conventional and nonconventional hybrids of maize (Zea mays L.). Indian Journal Genetics., 61 (4): 353-355.

Griffings, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. Aust.J. Biol. Sci., 9: 463-493. [Cross Ref]

Haddadi, M. H., Eesmeliof, M., Choukan, R. and Rameech, V. 2012. Combining ability analysis of days to silking, plant height, yield components and kernel yield in maize breeding lines. African J. Agril. Res., 7 (3): 4685-4691. [Cross Ref]

Joshi, V. N., Pandiya, N. K. and Dubey, R. B. 1998. Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (Zea mays L.). Indian Journal of Genetics and Plant Breeding., 58 (4): 519-524.

Kanagarasu, S., Nallathambi, G. and Ganesan, K. 2010. Combining ability analysis for yield and its components traits in maize. Electronic Journal of Plant Breeding., 1 (2): 915-917.

Kapoor, C., Lata, S. and Sharma, J.K. 2014. Combining ability and heterosis studies for grain yield and its component traits in maize (Zea mays L.). Electronic Journal of Plant Breeding., 5(4): 716-721.

Kumari, J., Gadag, N. and Singh, B. B. 2017. Combining ability studies among inbred lines of sweet corn (Zea mays L.). Indian J. Genet. and Pl. Breed., 67 (1): 77-78.
Kumari, J., Gadag, R. N. and Jha, G. K. 2008. Combining ability and heterosis in field vs sweet corn (Zea mays L.) hybrids using line × tester mating design. *Indian J. Agric. Sci.*, **78** (3): 261-264.

Matin, M. Q. I., Rasul, M. G., Aminul Islam, A.K.M., Khaleque Mian, M.A., Ivy, N. A. and Ahmed, J. U. 2016. Combining ability and heterosis in maize (Zea mays L.). *American J. Bioscience*, **4** (6): 84-90.

Panse, V. G. and Sukhatme, P. V. 1985. *Statistical methods for Agricultural workers*. Published by ICAR, New Delhi.

Premalatha, 2006. Combining ability and heterosis analysis for grain yield components and quality traits in maize. (Zea mays L.). *M.Sc Thesis* submitted to the Tamil Nadu Agricultural University, Coimbatore.

Purushottam, Y. and Shanthakumar, G. 2017. General and specific combining ability studies for ear traits in maize (Zea mays L.). *J. Pharmacognosy and Phytochemistry*, **6** (5): 2242-2245.

Varalakshmi, S., and Wali, M.C. 2017. Combining ability and heterosis studies in single cross hybrids synthesized from CIMMYT based inbred lines of maize (Zea mays L.). *J Farm Sci*. **30**(3): 320-325.

Singh, R. K. and Chaudhary, B. D. 1985. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi.

Sprague, G. F. and Tatum, 1942. General vs specific combining ability in single crosses of corn. *J. Amer. Soc. Agron.*, **34**: 923-932. [Cross Ref]