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# Combining ability studies from line × tester mating design for grain yield and its related traits in maize (*Zea mays* L.)

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**Abstract**

The identification of superior parental lines is the pre-requisite for hybrid maize breeding. The experimental material for present study was consisting of 42 hybrids of maize which were developed by crossing 14 inbred lines and 3 genetically diverse testers in line × tester mating design. These 17 parents along with 42 hybrids and 3 standard check hybrids were evaluated in randomized block design in three replications at three different locations. The variances due to line × tester differ significantly for all the traits indicating the predominance of inherent variability among all the cross combinations. The magnitude of SCA variance was greater than GCA variance for all the traits studied, indicating pre-dominance of non-additive variance in controlling the expression of all traits under study. Inbred lines *viz.,* EI-2403-1, EI-170 and EI-07 were good general combiner for grain yield per plant and majority of yield contributing traits. Among the testers, tester EI-03-1 was found good general combiner for grain yield per plant and majority of yield contributing traits. Among forty-two hybrids, nine hybrids manifested positive significant SCA effects in all the environments as well as on pooled basis for grain yield per plant. Four promising hybrids EI-2159-2 × EI-090, EI-161 × EI-03-1, EI-2149-2 × EI-03-1 and EI-2403-1 × EI-090 identified based on GCA and SCA effects along with highest *per se* performance for grain yield per plant on pooled basis and were found suitable for heterosis breeding.

**Keywords:** Combining ability, GCA effect, SCA effect, maize, gene action

## Introduction

Maize is a highly cross pollinated $C_4$ plant species and can utilize solar energy more efficiently than any other cereals. Maize acreage and production have an increasing tendency with the introduction of hybrids due to its high yield potential. In 2020-21 maize crop occupied an area of 197.28 mha with production of 1120.65 MMT and productivity 5680 kg/ha globally (USDA 2021) [9]. In India during 2020-21, it occupied an area of 9.70 mha with production of 30.25 MMT and productivity of 3120 kg/ha (USDA 2021) [9]. Globally, it is considered one of the most important cereal crops following rice and wheat in terms of cultivated area and production. Wheat, rice and maize together make-up three-fourths of the world grain production (Gebre *et al.* 2019) [4]. Combining ability studies are of prime importance in maize hybridization programme, since it provides information on the genetic mechanisms governing inheritance of quantitative traits and assist the breeders in selection of potential inbreds for further crop improvement or use in hybridization programme for commercial uses.

## Materials and Methods

The experimental material consists of 14 inbred lines *viz.,* EI-568-2, EI-2149-2, EI-2159-2, EI-161, EI-2153-1, EI-2553-2, EI-1280-2, EI-2403-1, EI-170, EI-2818-3, EI-2507-2, EI-166, EI-2172 and EI-07 were crossed with 3 testers *viz.,* EI-2185-1, EI-03-1 and EI-090 in line × tester mating design to develop a total of 42 hybrids. These 17 parents along with 42 hybrids and 3 checks *viz.,* Pratap hybrid 3, Pratap Makka 9 and DHM-117 were evaluated at three different locations *viz.,* Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur (E1), A.R.S.S. Vallabhnagar, MPUAT, Udaipur (E2) and A.R.S.S. Pratapgarh, MPUAT, Udaipur (E3) during *kharif* 2021. Each treatment will be sown in single row plot of 3-meter row length maintaining crop geometry 60 cm × 20 cm row to row and plant to plant spacing, respectively. Recommended agronomic package and practices will be followed to raise a healthy crop under each environmental condition. Observations for the traits *viz.,* days to 50 percent tasseling, days to 50 percent silking, anthesis silking interval (ASI) and days to 75 percent brown husk were recorded on plot basis.

While traits *viz.*, tassel length after pollination (cm), number of branches per tassel, number of leaves per plant, plant height (cm), cob length (cm), cob girth (cm), number of rows per cob, number of grains per row, 100 grain weight (g), grain yield per plant (g), shelling percent, harvest index (%), grain protein content (%), grain starch content (%) and grain oil content (%) were recorded on ten randomly selected competitive plants per plot in each replication. The combining ability effects for line × tester mating design was performed as per method suggested by Kempthorne (1957) [6] for individual environments as well as over the environments.

**Results and Discussion**

In the present study, combining ability indicated that mean sum of squares due to crosses were significant for all the traits in all the environments as well as over the environments except number of leaves per plant in E3 and harvest index on pooled basis. Partitioning of the mean sum of squares into lines, testers and line × tester interaction revealed that the mean sum of squares due to line, tester and line × tester were found to be significant for most of the traits in all the environments as well as over the environments (Table 1 and 2). Analysis of variance for combining ability on pooled basis showed that mean sum of squares due to environments were significant for all the characters studied except days to 75 percent brown husk and grain starch content. Mean sum of squares due to lines as well as crosses were significant for all the characters studied except harvest index, while mean sum of squares due to testers were significant for all the characters except number of rows per cob and harvest index, which indicated differences between lines for GCA, testers for GCA and hybrids for SCA. The analysis of variance for combining ability in individual environment indicated that both GCA and SCA variances were important for all the traits in all the three environments. The present findings are in close agreement with the earlier reports of Chinthiya *et al.* (2019), Kumar *et al.* (2019), Bangarwa *et al.* (2021) and Chavan *et al.* (2022) [3, 7, 1, 2].

The parental material was categorized as good, average and poor combiners on the basis of their general combining ability effects (Table 3). Parents possessing significant general combining ability effects in desirable direction were classified as good combiners, whereas parents possessing non-significant general combining ability effects in desirable direction were grouped into average combiners. Parents with undesirable general combining ability effects were classified as poor combiners. The estimates of GCA effects for yield and yield contributing characters revealed that good general combiner inbred lines for grain yield per plant were EI-2403-1, EI-07, EI-170, EI-2818-3 and EI-2149-2 with range varied from 7.22 (EI-2149-2) to 12.06 (EI-2403-1). The maximum significant GCA effects in positive direction were exhibited by line EI-170 for cob length and number of rows per cob, line EI-2818-3 for cob girth, line EI-161 for number of grains per row and line EI-07 for 100 grain weight. For quality traits, good general combiner inbred lines are EI-2172, EI-170, EI 2159-2, EI-161 and EI-1280-2 for grain protein content, lines EI-2149-2, EI-2172, EI-170, EI-568-2 and EI-2553-2 for grain starch content and lines EI-2149-2, EI-2159-2, EI-161, EI-2403-1, EI-2172 and EI-07 for grain oil content. With respect to maturity related traits, inbred lines *viz.*, EI-2153-1, EI-161, EI-2507-2 and EI-07 were good general combiner for day to 50 percent tasseling, lines EI-2153-1, EI-07, EI-2149-2, EI-161 and EI-2403-1 for days to 50 percent silking, lines EI-2403-1, EI-2153-1, EI-170, EI-07 and EI-2149-2 for ASI and lines EI-161, EI-2153-1, EI-2818-3, EI-2507-2 and EI-07 for days to 75 percent brown husk. Among the testers, EI-03-1 was considered good general combiner for grain yield per plant, number of branches per tassel, 100-grain weight, grain protein content and grain oil content. The tester EI-2185-1 was considered good general combiner for anthesis silking interval, days to 75 percent brown husk, plant height and cob length, whereas tester EI-090 was good general combiner for anthesis silking interval, cob girth, 100 grain weight, grain starch content and grain oil content. The high general combining ability effects were due to additive gene effects and additive × additive gene effects (Griffing, 1956 and Sprague, 1966). The magnitude of SCA variance was greater than GCA variance for most of the traits indicating preponderance of non-additive variance in controlling the expression of these traits. Similar results were also reported by Keimeso *et al.* (2020), Riache *et al.* (2021) and Chavan *et al.* (2022) [5, 8, 2].

A perusal of SCA effects among hybrids revealed that maximum magnitude of positive SCA effects for grain yield per plant were exhibited by hybrid EI-2159-2 × EI-090 in E1, E2, E3, and over the environments. Nine hybrids *viz.*, EI-2153-1 × EI-2185-1, EI-2403-1 × EI-2185-1, EI-2172 × EI-2185-1, EI-2149-2 × EI-03-1, EI-161 × EI-03-1, EI-2507-2 × EI-03-1, EI-2159-2 × EI-090, EI-2403-1 × EI-090 and EI-07 × EI-090 manifested positive significant SCA effects in all the environments as well as on pooled basis for grain yield per plant. On pooled basis, the maximum positive SCA effects were exhibited by hybrid EI-1280-2 × EI-090 for cob length, hybrid EI-161 × EI-03-1 for cob girth, hybrid EI-2403-1 × EI-090 for number of rows per cob, hybrid EI-2149-2 × EI-2185-1 for number of grains per row and hybrid EI-166 × EI-2185-1for 100-grain weight. For quality traits, maximum significant SCA effects was expressed by hybrid EI-2153-1 × EI-090 for grain protein content, EI-2553-2 × EI-03-1 for grain starch content and EI-2172 × EI-090 for grain oil content. For maturity related traits, hybrid EI-2507-2 × EI-090 showed maximum significant SCA effects for days to 50 percent tasselling, EI-2172 × EI-2185-1 for days to 50 percent silking, EI-170 × EI-03-1 for anthesis silking interval and EI-2553-2 × EI-090 for days to 75 percent brown husk (Table 4).

**Table 1:** Mean square for different characters

| SN | Characters | Env | Rep | Genotype | Checks | Chk Vs P | Parents | Tester | Lines | L Vs L | P Vs C | Crosses | Tester | Lines | L X T | Error | Model I | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | [2] | [61] | [2] | [1] | [16] | [2] | [13] | [1] | [1] | [41] | [2] | [13] | [26] | [122] | Tester | Lines | L X T |
| 1 | Days to 50 percent tasseling | 1 | 0.72 | 10.46** | 21.44** | 19.94** | 9.59** | 5.78 | 10.48** | 5.65 | 2.71 | 10.29** | 2.00 | 7.89** | 12.13** | 2.07 | -0.00 | 8.40 | 87.17 |
| | | 2 | 1.17 | 9.23** | 16.33** | 22.26** | 10.08** | 2.33 | 11.93** | 1.52 | 2.07 | 8.21** | 1.20 | 12.03** | 6.84** | 2.05 | -0.04 | 14.41 | 41.49 |
| | | 3 | 1.35 | 12.30** | 27.44** | 19.14** | 10.96** | 2.33 | 11.93** | 15.63** | 0.29 | 12.19** | 1.17 | 5.98** | 16.14** | 2.06 | -0.04 | 5.66 | 122.04 |
| 2 | Days to 50 percent silking | 1 | 0.92 | 11.52** | 27.00** | 39.58** | 10.59** | 12.33** | 11.01** | 1.68 | 13.07* | 10.66** | 4.79 | 9.80** | 11.54** | 1.96 | 0.14 | 11.33 | 83.02 |
| | | 2 | 1.84 | 9.59** | 14.78** | 35.80** | 10.22** | 4.11 | 11.51** | 5.65 | 0.05 | 8.61** | 3.43 | 12.51** | 7.05** | 2.31 | 0.05 | 14.74 | 41.11 |
| | | 3 | 1.23 | 13.03** | 23.44** | 33.88** | 12.46** | 4.11 | 13.85** | 11.07* | 4.26 | 12.55** | 8.10* | 7.43** | 15.45** | 2.17 | 0.28 | 7.60 | 115.11 |
| 3 | Anthesis silking interval (ASI) | 1 | 0.02 | 1.08* | 0.44* | 3.33** | 1.00** | 1.44** | 0.92** | 1.17** | 3.88** | 1.07** | 3.84** | 1.09** | 0.84** | 0.13 | 0.18 | 1.40 | 6.20 |
| | | 2 | 0.11 | 0.97 | 0.11 | 1.60** | 1.16** | 0.44* | 1.25** | 1.31** | 2.75** | 0.90** | 2.06** | 0.52** | 1.00** | 0.13 | 0.09 | 0.56 | 7.46 |
| | | 3 | 0.06 | 1.07* | 0.44* | 2.09** | 1.31** | 0.44* | 1.52** | 0.39 | 2.32** | 0.98** | 4.20** | 0.53** | 0.96** | 0.12 | 0.19 | 0.59 | 7.28 |
| 4 | Tassel length after pollination | 1 | 6.56 | 16.38* | 16.60* | 1.17 | 19.00** | 10.39 | 21.66** | 1.72 | 5.85 | 16.00** | 9.77 | 17.58** | 15.68** | 3.63 | 0.29 | 20.14 | 104.47 |
| | | 2 | 9.23 | 24.31 | 6.66 | 1.02 | 22.33** | 17.23* | 22.99** | 24.01* | 0.73 | 27.10** | 6.53 | 19.99** | 32.24** | 3.68 | 0.14 | 23.56 | 247.51 |
| | | 3 | 7.26 | 13.55 | 0.83 | 19.25* | 13.41** | 5.60 | 15.20** | 5.68 | 22.26* | 14.12** | 15.56* | 17.05** | 12.54** | 3.66 | 0.57 | 19.34 | 76.96 |
| 5 | Number of branches per tassel | 1 | 1.83 | 18.32** | 12.97** | 45.62** | 6.57** | 8.96** | 6.71** | 0.00 | 269.18** | 17.45** | 16.86** | 21.61** | 15.41** | 1.17 | 0.75 | 29.53 | 123.41 |
| | | 2 | 3.47 | 22.67** | 11.78** | 41.50** | 9.66** | 11.97** | 9.97** | 0.96 | 268.48** | 22.80** | 13.31** | 30.61** | 19.62** | 1.46 | 0.56 | 42.10 | 157.40 |
| | | 3 | 3.80 | 18.01** | 16.16** | 64.41** | 8.16** | 16.42** | 7.37** | 1.81 | 291.52** | 15.55** | 18.74** | 18.10** | 14.03** | 1.44 | 0.82 | 24.07 | 109.17 |
| 6 | Number of leaves per plant | 1 | 2.64 | 2.03 | 0.98 | 4.61* | 2.95** | 0.70 | 3.53** | 0.00 | 7.75** | 1.59** | 4.87** | 1.12 | 1.56* | 0.88 | 0.19 | 0.35 | 5.93 |
| | | 2 | 1.14 | 2.33 | 0.70 | 14.85** | 0.97 | 0.22 | 1.08 | 1.02 | 25.15** | 2.31** | 1.18 | 3.22** | 1.94** | 0.81 | 0.02 | 3.48 | 9.81 |
| | | 3 | 0.85 | 1.02 | 0.14 | 2.40 | 1.27* | 0.12 | 1.47* | 0.94 | 0.73 | 0.95 | 0.91 | 1.14 | 0.86 | 0.67 | 0.01 | 0.67 | 1.59 |
| 7 | Days to 75 % brown husk | 1 | 1.56 | 21.68 | 3.44 | 3.88 | 17.25** | 47.44** | 13.93** | 0.05 | 9.44 | 24.88** | 6.17 | 19.85** | 28.83** | 2.86 | 0.16 | 24.54 | 225.11 |
| | | 2 | 9.38 | 22.22 | 1.44 | 1.26 | 17.45** | 64.33** | 11.47** | 1.52 | 9.64 | 25.82** | 7.45 | 22.01** | 29.14** | 3.11 | 0.21 | 27.30 | 225.65 |
| | | 3 | 6.44 | 33.29** | 27.44** | 2.71 | 42.87** | 30.11** | 46.28** | 24.06** | 25.72** | 30.53** | 2.21 | 24.03** | 35.97** | 2.67 | -0.02 | 30.85 | 288.57 |
| 8 | Plant height (cm) | 1 | 412.50 | 496.38 | 397.04 | 565.34* | 394.67** | 174.59 | 456.78** | 27.39 | 25.30 | 546.86** | 1286.65** | 449.81** | 538.48** | 147.88 | 54.23 | 436.13 | 3385.24 |
| | | 2 | 305.56 | 469.97 | 29.63 | 506.93 | 98.55 | 139.11 | 99.06 | 10.77 | 984.38* | 605.99** | 450.69 | 879.50** | 481.18** | 179.50 | 12.91 | 1011.12 | 2614.56 |
| | | 3 | 361.84 | 504.07 | 65.18 | 2016.33** | 358.46** | 73.42 | 423.09** | 88.32 | 4.95 | 549.91** | 1526.07** | 458.69** | 520.43** | 146.01 | 65.72 | 451.65 | 3245.00 |
| 9 | Cob length (cm) | 1 | 0.10 | 7.84 | 0.48 | 31.58** | 4.87** | 4.11 | 5.33** | 0.43 | 29.10** | 8.62** | 19.59** | 8.48** | 7.85** | 1.37 | 0.87 | 10.27 | 56.15 |
| | | 2 | 0.50 | 8.41 | 1.11 | 46.24** | 2.47* | 0.29 | 2.84* | 2.10 | 99.58** | 8.73** | 7.88** | 9.08** | 8.61** | 1.27 | 0.31 | 11.28 | 63.61 |
| | | 3 | 2.53 | 7.97* | 2.94* | 11.84** | 2.96** | 5.57** | 2.76** | 0.38 | 36.31** | 9.61** | 21.15** | 11.32** | 7.86** | 0.94 | 0.96 | 15.00 | 60.00 |
| 10 | Cob girth (cm) | 1 | 0.22 | 0.79 | 0.06 | 5.13** | 0.34** | 0.84** | 0.28** | 0.12 | 20.14** | 0.53** | 1.05** | 0.44** | 0.53** | 0.08 | 0.05 | 0.53 | 3.93 |
| | | 2 | 0.20 | 0.58 | 0.11 | 4.11** | 0.24** | 0.33* | 0.20** | 0.44* | 12.87** | 0.43** | 0.12 | 0.22** | 0.56** | 0.07 | 0.00 | 0.21 | 4.25 |
| | | 3 | 0.21 | 0.78 | 0.15 | 5.10** | 0.30** | 0.52** | 0.25** | 0.42* | 15.66** | 0.63** | 0.60** | 0.39** | 0.75** | 0.08 | 0.02 | 0.46 | 5.87 |
| 11 | Number of rows per cob | 1 | 2.26 | 6.24** | 7.51** | 57.15** | 2.99** | 7.54** | 2.44* | 1.03 | 154.60** | 3.64** | 0.20 | 3.13** | 4.16** | 1.25 | -0.05 | 2.72 | 25.27 |
| | | 2 | 3.35 | 4.53 | 0.42 | 43.30** | 2.20* | 0.91 | 2.03 | 7.11* | 80.12** | 3.54** | 6.98** | 2.56* | 3.77** | 1.27 | 0.27 | 1.86 | 21.67 |
| | | 3 | 3.60 | 5.35 | 0.51 | 23.86** | 2.55* | 0.22 | 2.59* | 6.62* | 121.97** | 3.93** | 4.51* | 2.95* | 4.37** | 1.37 | 0.15 | 2.27 | 25.99 |
| 12 | Number of grains per row | 1 | 0.24 | 5.11 | 2.70 | 2.99 | 2.95 | 4.04 | 2.04 | 12.56* | 60.15** | 4.83** | 3.82 | 2.92 | 5.87** | 2.64 | 0.06 | 0.40 | 27.98 |
| | | 2 | 5.22 | 4.91 | 3.39 | 2.26 | 2.85 | 1.30 | 3.31 | 0.02 | 8.66* | 5.81** | 1.07 | 5.47** | 6.35** | 1.92 | -0.04 | 5.12 | 38.33 |
| | | 3 | 0.36 | 4.57 | 2.76 | 6.30 | 3.62* | 2.09 | 3.50 | 8.21* | 38.91** | 4.30** | 0.62 | 7.24** | 3.11 | 2.02 | -0.07 | 7.54 | 9.49 |
| 13 | 100-grain weight (g) | 1 | 13.50 | 156.06 | 10.25 | 1877.56** | 6.21 | 1.70 | 6.16 | 15.84 | 8345.68** | 20.75** | 41.06** | 26.37** | 16.38** | 5.18 | 1.71 | 30.61 | 97.05 |
| | | 2 | 12.57 | 190.34 | 3.29 | 2124.85** | 7.26 | 2.26 | 8.52* | 0.92 | 9844.60** | 34.98** | 164.15** | 36.85** | 24.11** | 4.27 | 7.61 | 47.06 | 172.01 |
| | | 3 | 6.31 | 194.74 | 0.20 | 2428.47** | 11.07** | 3.01 | 12.83** | 4.39 | 9884.62** | 36.62** | 93.02** | 55.26** | 22.96** | 4.16 | 4.23 | 73.81 | 162.93 |
| 14 | Grain yield per plant (g) | 1 | 63.26 | 2442.90 | 39.36 | 16331.42** | 833.47** | 380.25** | 966.52** | 10.31 | 76641.33** | 1400.02** | 1194.37** | 909.10** | 1661.31** | 76.66 | 53.22 | 1202.42 | 13733.60 |
| | | 2 | 99.03 | 2111.55* | 236.68* | 23182.90** | 1073.55** | 342.93** | 1245.42** | 300.51* | 64321.64** | 1010.80** | 303.66* | 957.55** | 1091.83** | 63.56 | 11.43 | 1291.32 | 8911.63 |
| | | 3 | 143.61 | 2466.69 | 7.07 | 11439.22** | 598.49** | 497.68** | 595.40** | 840.22** | 92746.76** | 1172.43** | 763.74** | 823.90** | 1378.13** | 85.73 | 32.29 | 1066.23 | 11200.77 |
| 15 | Shelling percent | 1 | 32.30 | 76.89 | 32.42 | 484.28** | 40.27* | 84.15* | 36.28 | 4.30 | 1967.55** | 47.58** | 177.04** | 34.24 | 44.29** | 22.40 | 7.36 | 17.10 | 189.70 |
| | | 2 | 8.93 | 72.13 | 0.03 | 426.88** | 43.91* | 69.95 | 40.08 | 41.74 | 1323.35** | 55.80** | 143.37** | 66.34** | 43.80* | 24.18 | 5.68 | 60.90 | 170.01 |
| | | 3 | 25.13 | 98.65 | 47.10 | 704.32** | 37.19 | 20.12 | 42.65 | 0.30 | 3080.02** | 52.91** | 64.12 | 44.50 | 56.26** | 25.59 | 1.83 | 27.30 | 265.78 |
| 16 | Harvest index (%) | 1 | 28.22 | 59.26 | 18.79 | 640.71** | 39.82** | 33.60* | 36.95** | 89.63** | 1898.96** | 22.05** | 18.44 | 17.42 | 24.65** | 10.98 | 0.36 | 9.30 | 118.46 |
| | | 2 | 32.39 | 68.13 | 24.09 | 532.43** | 32.13** | 11.74 | 37.35** | 5.16 | 2303.83** | 29.97** | 51.76* | 32.30** | 27.12** | 13.80 | 1.81 | 26.73 | 115.48 |
| | | 3 | 26.11 | 46.80 | 7.35 | 410.27** | 18.92 | 0.20 | 18.98 | 55.54* | 1737.77** | 18.30* | 12.89 | 21.75* | 16.99 | 11.64 | 0.06 | 14.60 | 46.38 |
| 17 | Grain protein content (%) | 1 | 0.15 | 1.28 | 0.10 | 5.54** | 1.50** | 0.62** | 1.75** | 0.00 | 9.13** | 1.03** | 1.50** | 0.85** | 1.09** | 0.10 | 0.07 | 1.09 | 8.59 |
| | | 2 | 0.11 | 1.37 | 0.23 | 9.47** | 1.66** | 0.25 | 1.82** | 2.36** | 14.02** | 0.94** | 0.27 | 0.76** | 1.08** | 0.10 | 0.01 | 0.96 | 8.54 |
| | | 3 | 0.28 | 1.07 | 0.10 | 4.37** | 1.16** | 0.05 | 1.17** | 3.21** | 3.69** | 0.98** | 0.34* | 1.12** | 0.96** | 0.09 | 0.01 | 1.49 | 7.52 |
| 18 | Grain starch content (%) | 1 | 1.68 | 21.84** | 4.46** | 17.97** | 21.25** | 32.18** | 20.38** | 10.65** | 7.30** | 23.50** | 19.82** | 21.47** | 24.80** | 0.63 | 0.91 | 30.10 | 209.50 |
| | | 2 | 0.11 | 22.45** | 6.86** | 71.48** | 24.14** | 40.13** | 23.20** | 4.43** | 5.19** | 21.89** | 6.05** | 27.00** | 20.56** | 0.64 | 0.26 | 38.08 | 172.63 |
| | | 3 | 0.18 | 21.84** | 6.04** | 65.06** | 23.12** | 38.83** | 22.09** | 5.08** | 5.26** | 21.58** | 6.55** | 26.11** | 20.47** | 0.40 | 0.29 | 37.14 | 174.00 |
| 19 | Grain oil content (%) | 1 | 0.01 | 0.50** | 0.54** | 0.62** | 0.56** | 0.88** | 0.51** | 0.53** | 0.25** | 0.48** | 1.91** | 0.28** | 0.46** | 0.01 | 0.09 | 0.39 | 3.94 |
| | | 2 | 0.00 | 0.57** | 0.52** | 0.11** | 0.56** | 1.65** | 0.43** | 0.12** | 0.04* | 0.59** | 1.94** | 0.57** | 0.51** | 0.01 | 0.09 | 0.81 | 4.31 |
| | | 3 | 0.01 | 0.46** | 0.06** | 0.00 | 0.65** | 1.62** | 0.52** | 0.29** | 0.00 | 0.43** | 1.16** | 0.27** | 0.46** | 0.01 | 0.05 | 0.37 | 3.93 |

*, ** Significant at 5% and 1% respectively against pool error.

**Table 2:** Mean square over the environments for Days to 50 percent tasseling, days to 50 percent silking, anthesis silking interval (ASI), tassel length after pollination (cm), number of branches per tassel, number of leaves per plant and days to 75% brown husk

| S.N | Source | Df | Days to 50 percent tasseling | Days to 50 percent silking | Anthesis silking interval (ASI) | Tassel length after pollination (cm) | Number of branches per tassel | Number of leaves per plant | Days to 75% brown husk |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Environment | 2 | 13.62** | 11.27** | 0.98** | 36.11** | 7.52** | 10.89** | 1.21 |
| 2. | Rep./Env | 6 | 1.08 | 1.33 | 0.06 | 7.68 | 3.03* | 1.54 | 5.79 |
| 3. | Genotype | 61 | 24.87**++ | 26.71**++ | 2.62**++ | 41.48**++ | 54.31**++ | 2.65**++ | 67.26**++ |
| | Check | 2 | 61.78** | 61.15** | 0.26 | 15.65** | 38.62** | 0.76** | 21.81** |
| | P vs Chk | 1 | 61.27** | 109.15** | 6.86** | 14.00** | 150.12** | 19.00** | 7.48** |
| | Parent | 16 | 21.55**++ | 23.36**++ | 3.15** | 42.88**++ | 18.05**++ | 2.60**+ | 60.61**++ |
| | Tester | 2 | 6.37** | 15.59** | 2.11** | 29.09** | 20.59** | 0.18** | 134.37** |
| | Line | 13 | 24.88**++ | 26.22**++ | 3.35** | 46.40**++ | 18.91**++ | 3.07** | 53.62**++ |
| | T v/s L | 1 | 8.67* | 1.68 | 2.71** | 24.63** | 1.79** | 1.30** | 3.98 |
| | P v/s C | 1 | 0.19** | 11.60** | 8.84** | 21.28** | 828.87** | 24.95** | 42.18** |
| | Cross | 41 | 23.96**++ | 24.99**++ | 2.37**++ | 43.55**++ | 51.44**++ | 2.08** | 73.68**++ |
| | Tester | 2 | 0.21** | 12.10** | 9.85** | 14.68** | 44.37** | 4.83** | 14.34** |
| | Line | 13 | 22.26** | 25.75** | 1.20**+ | 45.96** | 65.72**++ | 2.32** | 58.39** |
| | L x T | 26 | 26.64**++ | 25.59**++ | 2.38**++ | 44.57**++ | 44.84**++ | 1.75** | 85.89**++ |
| 4. | G x E | 122 | 3.56** | 3.71** | 0.25** | 6.38** | 2.35** | 1.36** | 4.96** |
| | Check x E | 4 | 1.72 | 2.04 | 0.37* | 4.22 | 1.15 | 0.53 | 5.26 |
| | Chk x P x E | 2 | 0.03 | 0.06 | 0.08 | 3.72 | 0.70 | 1.43 | 0.18 |
| | P x E | 32 | 4.54** | 4.95** | 0.16 | 5.93* | 3.17** | 1.30* | 8.48** |
| | T x E | 4 | 2.04 | 2.48 | 0.11 | 2.07 | 8.38** | 0.43 | 3.76 |
| | L x E | 26 | 4.73** | 5.07** | 0.17 | 6.72** | 2.57** | 1.50** | 9.03** |
| | T v/s L x E | 2 | 7.07* | 8.36* | 0.08 | 3.39 | 0.49 | 0.33 | 10.82* |
| | P v/s C x E | 2 | 2.44 | 2.89 | 0.05 | 3.78 | 0.15 | 4.34** | 1.31 |
| | Cross x E | 82 | 3.36** | 3.42** | 0.29** | 6.83** | 2.18** | 1.38** | 3.78* |
| | T x E | 4 | 2.08 | 2.11 | 0.12 | 8.59 | 2.27 | 1.07 | 0.75 |
| | L x E | 26 | 1.82 | 2.00 | 0.47** | 4.33 | 2.30* | 1.58** | 3.74 |
| | L x T x E | 52 | 4.23** | 4.23** | 0.21** | 7.95** | 2.11* | 1.31** | 4.03* |
| 5. | Pooled Error | 366 | 2.06 | 2.15 | 0.13 | 3.66 | 1.36 | 0.79 | 2.88 |
| 6. | Bartlet | 2 | 0.00 | 0.84 | 0.47 | 0.01 | 1.82 | 2.23 | 0.71 |

*, ** Significant at 5% and 1% respectively against pool error; +, ++ Significant at 5% and 1% respectively against respective environmental interaction.

**Table 2.1:** Mean square over the environments for plant height (cm), cob length (cm), cob girth (cm), number of rows per cob, number of grains per row, 100-grain weight (g) and grain yield per plant (g)

| S.N | Source | df | Plant height (cm) | Cob length (cm) | Cob girth (cm) | Number of rows per cob | Number of grains per row | 100-grain weight (g) | Grain yield per plant (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Environment | 2 | 5935.03** | 13.09** | 1.03** | 67.33** | 67.72** | 21.90** | 11359.33** |
| 2. | Rep./Env | 6 | 359.96* | 1.04 | 0.21** | 3.07* | 1.94 | 10.80* | 101.97 |
| 3. | Genotype | 61 | 919.58**++ | 20.10**++ | 1.89**++ | 11.64**++ | 6.94**++ | 525.51**++ | 6678.80**++ |
| | Check | 2 | 240.08** | 0.96** | 0.29** | 5.10** | 1.56** | 8.82** | 22.08** |
| | P vs Chk | 1 | 2772.20** | 83.84** | 14.31** | 120.65** | 10.99** | 6413.16** | 49925.09**+ |
| | Parent | 16 | 544.05** | 7.65** | 0.58**++ | 2.29* | 3.33** | 19.72** | 2262.92**++ |
| | Tester | 2 | 353.68** | 7.64** | 1.60** | 3.32** | 1.14** | 6.53** | 1156.60** |
| | Line | 13 | 615.17** | 8.05** | 0.46**++ | 1.31 | 2.83** | 22.00** | 2605.37** |
| | T v/s L | 1 | 0.26** | 2.46** | 0.04 | 13.03** | 14.26** | 16.50** | 23.74 |
| | P v/s C | 1 | 497.41** | 152.63**+ | 48.26** | 350.55** | 95.61** | 28032.58**++ | 232409.64**+ |
| | Cross | 41 | 1033.89**++ | 22.44**++ | 1.33**++ | 6.98**++ | 6.62**+ | 72.42**++ | 3265.44**++ |
| | Tester | 2 | 3027.03** | 41.76**+ | 1.53** | 2.72 | 0.35** | 274.10**++ | 1391.75** |
| | Line | 13 | 870.97** | 24.16**++ | 0.85** | 6.56** | 7.52** | 95.47**++ | 2358.21**++ |
| | L x T | 26 | 962.03**++ | 20.08**++ | 1.56**++ | 7.52**++ | 6.65** | 45.39**++ | 3863.19**++ |
| 4. | G x E | 122 | 275.42** | 2.06** | 0.13** | 2.24** | 3.82** | 7.82** | 171.17** |
| | Check x E | 4 | 125.88 | 1.79 | 0.02 | 1.67 | 3.64 | 2.46 | 130.52 |
| | Chk x P x E | 2 | 158.20 | 2.90 | 0.02 | 1.83 | 0.28 | 8.86 | 514.23** |
| | P x E | 32 | 153.81 | 1.33 | 0.15** | 2.73** | 3.04 | 2.41 | 121.30* |
| | T x E | 4 | 16.72 | 1.16 | 0.05 | 2.68 | 3.15 | 0.22 | 32.13 |
| | L x E | 26 | 181.88 | 1.44 | 0.14** | 2.88** | 3.01 | 2.75 | 100.99 |
| | T v/s L x E | 2 | 63.11 | 0.22 | 0.47** | 0.86 | 3.26 | 2.33 | 563.65** |
| | P v/s C x E | 2 | 258.61 | 6.17** | 0.20 | 3.07 | 6.05 | 21.16* | 650.05** |
| | Cross x E | 82 | 334.43** | 2.26** | 0.13** | 2.06** | 4.16** | 9.96** | 158.91** |
| | T x E | 4 | 118.19 | 3.43* | 0.12 | 4.49** | 2.58 | 12.07* | 435.01** |
| | L x E | 26 | 458.52** | 2.36** | 0.10 | 1.04 | 4.06** | 11.50** | 166.17** |
| | L x T x E | 52 | 289.03** | 2.12** | 0.14** | 2.39** | 4.34** | 9.03** | 134.04** |
| 5. | Pooled Error | 366 | 157.79 | 1.19 | 0.07 | 1.30 | 2.19 | 4.53 | 75.32 |
| 5. | Bartlet | 2 | 1.67 | 4.74 | 0.22 | 0.33 | 3.65 | 1.79 | 2.75 |

*, ** Significant at 5% and 1% respectively against pool error; +, ++ Significant at 5% and 1% respectively against respective environmental interaction.

**Table 2.2:** Mean square over the environments for shelling percent, harvest index (%), grain protein content (%), grain starch content (%) and grain oil content (%)

| SN | Source | Df | Shelling percent | Harvest index (%) | Grain protein content (%) | Grain starch content (%) | Grain oil content (%) |
|---|---|---|---|---|---|---|---|
| 1. | Environment | 2 | 137.99** | 288.03** | 1.66** | 0.05 | 1.14** |
| 2. | Rep./Env | 6 | 22.12 | 28.91* | 0.18 | 0.66 | 0.01 |
| 3. | Genotype | 61 | 163.56**++ | 125.86**++ | 3.35**++ | 64.22**++ | 1.22**++ |
| | Check | 2 | 13.72** | 1.58** | 0.10** | 16.12** | 0.56** |
| | P vs Chk | 1 | 1596.52** | 1570.57** | 18.85** | 143.66**+ | 0.38** |
| | Parent | 16 | 33.21 | 53.31**++ | 3.80**++ | 67.56** | 1.49**++ |
| | Tester | 2 | 57.89 | 20.25** | 0.37* | 110.88** | 4.05**++ |
| | Line | 13 | 29.85 | 57.00** | 4.35**++ | 64.61** | 1.15**++ |
| | T v/s L | 1 | 27.52** | 71.52* | 3.60** | 19.36** | 0.87**+ |
| | P v/s C | 1 | 6186.46**+ | 5919.58** | 25.14**+ | 17.62** | 0.18** |
| | Cross | 41 | 73.28**+ | 16.27 | 2.68**++ | 64.89**++ | 1.20**++ |
| | Tester | 2 | 102.16* | 14.83 | 1.71** | 29.88** | 4.55**+ |
| | Line | 13 | 79.48** | 11.32 | 2.38**++ | 73.11** | 0.92**++ |
| | L x T | 26 | 67.96**+ | 18.85* | 2.90** | 63.47**++ | 1.08**++ |
| 4. | G x E | 122 | 42.06** | 24.16** | 0.18** | 0.96** | 0.15** |
| | Check x E | 4 | 32.91 | 24.32 | 0.17 | 0.62 | 0.28** |
| | Chk x P x E | 2 | 9.48 | 6.42 | 0.26 | 5.43** | 0.18** |
| | P x E | 32 | 44.08** | 18.78* | 0.26** | 0.48 | 0.14** |
| | T x E | 4 | 58.17* | 12.64 | 0.28* | 0.13 | 0.05** |
| | L x E | 26 | 44.58** | 18.14 | 0.20** | 0.54 | 0.16** |
| | T v/s L x E | 2 | 9.41 | 39.41* | 0.99** | 0.40 | 0.04* |
| | P v/s C x E | 2 | 92.23* | 10.49 | 0.84** | 0.06 | 0.05** |
| | Cross x E | 82 | 41.51** | 27.03** | 0.14** | 1.04** | 0.15** |
| | T x E | 4 | 141.19** | 34.13* | 0.20 | 1.27 | 0.23** |
| | L x E | 26 | 32.80 | 30.08** | 0.18** | 0.73 | 0.10** |
| | L x T x E | 52 | 38.19** | 24.96** | 0.12 | 1.18** | 0.17** |
| 5. | Pooled Error | 366 | 24.06 | 12.14 | 0.10 | 0.56 | 0.01 |
| 5. | Bartlet | 2 | 0.54 | 1.74 | 0.03 | 8.61* | 1.13 |

*, ** Significant at 5% and 1% respectively against pool error; +, ++ Significant at 5% and 1% respectively against respective environmental interaction.

**Table 3:** Classification of parents based on general combining ability (GCA) effects for various traits over the environments

| S. No. | Parents Traits | T1 | T2 | T3 | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | L11 | L12 | L13 | L14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Days to 50 percent tasseling | P | P | A | P | A | A | G | G | A | P | A | P | P | G | P | P | G |
| 2 | Days to 50 percent silking | A | P | A | P | G | P | G | G | A | P | G | P | P | A | P | P | G |
| 3 | Anthesis silking interval (ASI) | G | P | G | P | G | P | P | G | A | A | G | G | P | P | P | P | G |
| 4 | Tassel length after pollination (cm) | P | A | P | P | A | P | G | A | P | P | A | P | G | P | G | G | A |
| 5 | Number of branches per tassel | A | G | P | P | P | P | G | A | G | P | P | G | P | P | G | G | G |
| 6 | Number of leaves per plant | P | A | A | P | A | P | P | A | P | P | G | P | A | P | A | A | G |
| 7 | Days to 75 % brown husk | A | P | P | A | P | A | G | G | P | P | P | P | G | G | P | A | G |
| 8 | Plant Height (cm) | G | P | P | P | G | P | P | P | A | G | P | G | A | A | A | P | P |
| 9 | Cob length (cm) | G | A | P | P | P | G | P | P | A | A | G | G | A | P | A | G | P |
| 10 | Cob girth (cm) | P | P | G | P | P | P | A | P | P | P | P | G | G | P | P | G | G |
| 11 | Number of rows per cob | P | A | A | P | P | A | P | P | P | P | A | G | A | A | P | G | A |
| 12 | Number of grains per row | P | A | P | A | P | P | G | P | A | P | P | A | P | P | A | A | A |
| 13 | 100 grain weight (g) | P | G | G | P | P | A | G | P | P | P | P | G | A | P | A | G | G |
| 14 | Grain yield per plant (g) | P | G | P | P | G | P | P | A | P | P | G | G | G | P | P | A | G |
| 15 | Shelling percent | P | P | A | A | P | P | P | P | A | G | P | P | G | P | P | A | A |
| 16 | Harvest index (%) | P | P | A | P | A | P | A | A | P | A | P | A | P | A | P | P | A |
| 17 | Grain Protein content (%) | P | G | P | P | P | G | G | P | P | G | P | G | P | P | P | G | A |
| 18 | Grain Starch content (%) | A | P | G | G | G | P | A | P | G | P | P | G | P | P | P | G | P |
| 19 | Grain Oil content (%) | P | G | G | P | G | G | G | P | P | A | G | P | A | P | P | G | G |

Good (G) = Desirable significant (+ or -) GCA effect, Average (A) = Desirable non-significant (+ or -) GCA effect, Poor (P) = Undesirable significant (+ or -) GCA effect

**Table 4:** Significant specific combining ability (SCA) effect estimates of crosses in desirable directions for various traits over the environments

| S. No. | Traits / Crosses | Days to 50 % tasseling | Days to 50 percent silking | Anthesis silking interval (ASI) | Tassel length after pollination (cm) | Number of branches per tassel | Number of leaves per plant | Days to 75% brown husk | Plant Height (cm) | Cob length (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| 1 | $L_1$ x $T_1$ | | | | | | | | | |
| 2 | $L_2$ x $T_1$ | | | | ** | | | | | |
| 3 | $L_3$ x $T_1$ | ** | ** | | | | | ** | | |
| 4 | $L_4$ x $T_1$ | | | ** | | | | | | |
| 5 | $L_5$ x $T_1$ | | | | | * | | ** | | * |
| 6 | $L_6$ x $T_1$ | | | | ** | | | | | |
| 7 | $L_7$ x $T_1$ | ** | ** | | | | | | | |
| 8 | $L_8$ x $T_1$ | | | * | | | | | | |
| 9 | $L_9$ x $T_1$ | | | | | | * | * | | |
| 10 | $L_{10}$ x $T_1$ | | | | * | ** | | ** | * | |
| 11 | $L_{11}$ x $T_1$ | | | ** | ** | ** | | | | ** |
| 12 | $L_{12}$ x $T_1$ | | | | | | | | * | |
| 13 | $L_{13}$ x $T_1$ | ** | ** | | | | | | | ** |
| 14 | $L_{14}$ x $T_1$ | | | | | | | | | |
| 15 | $L_1$ x $T_2$ | | | | ** | | | | | ** |
| 16 | $L_2$ x $T_2$ | * | | | | | | | | |
| 17 | $L_3$ x $T_2$ | | | * | | | | | | |
| 18 | $L_4$ x $T_2$ | | | | | ** | | | | |
| 19 | $L_5$ x $T_2$ | ** | ** | ** | ** | | | ** | | |
| 20 | $L_6$ x $T_2$ | | | | | ** | | | | |
| 21 | $L_7$ x $T_2$ | | | ** | | | | ** | | |
| 22 | $L_8$ x $T_2$ | * | * | | * | | | | | |
| 23 | $L_9$ x $T_2$ | | | ** | | | | | * | ** |
| 24 | $L_{10}$ x $T_2$ | | | | | | | | | |
| 25 | $L_{11}$ x $T_2$ | | | | | | | | | |
| 26 | $L_{12}$ x $T_2$ | | | | | * | | | | |
| 27 | $L_{13}$ x $T_2$ | | | | | ** | | ** | | |
| 28 | $L_{14}$ x $T_2$ | | | * | * | ** | | | | ** |
| 29 | $L_1$ x $T_3$ | | ** | ** | | ** | | ** | | |
| 30 | $L_2$ x $T_3$ | | | * | | | | | ** | |
| 31 | $L_3$ x $T_3$ | | | | | ** | | | | * |
| 32 | $L_4$ x $T_3$ | | | * | | ** | | | | |
| 33 | $L_5$ x $T_3$ | | | | | | * | | | ** |
| 34 | $L_6$ x $T_3$ | | | | | | | ** | ** | |
| 35 | $L_7$ x $T_3$ | | | | | | | | | ** |
| 36 | $L_8$ x $T_3$ | | | | | ** | | | | * |
| 37 | $L_9$ x $T_3$ | ** | ** | | | | | | | |
| 38 | $L_{10}$ x $T_3$ | ** | ** | ** | | | | | | |
| 39 | $L_{11}$ x $T_3$ | ** | ** | | | | | ** | | |
| 40 | $L_{12}$ x $T_3$ | | | | | | | ** | | |
| 41 | $L_{13}$ x $T_3$ | | | | * | | | | | |
| 42 | $L_{14}$ x $T_3$ | | | | | | | | | |

| S. No. | Traits / Crosses | Cob girth (cm) | Number of rows per cob | Number of grains per row | 100 grain weight (g) | Grain yield per plant (g) | Shelling percent | Harvest index (%) | Grain Protein content (%) | Grain Starch content (%) | Grain Oil content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $L_1$ x $T_1$ | | | | | | | | | | |
| 2 | $L_2$ x $T_1$ | | | * | | | | | | ** | |
| 3 | $L_3$ x $T_1$ | | | | | | | | | | ** |
| 4 | $L_4$ x $T_1$ | | | | | | | | | | |
| 5 | $L_5$ x $T_1$ | | | | | ** | | | | ** | |
| 6 | $L_6$ x $T_1$ | ** | * | | | | | | ** | | ** |
| 7 | $L_7$ x $T_1$ | | | | | | | | ** | | ** |
| 8 | $L_8$ x $T_1$ | | | | | ** | | | | ** | |
| 9 | $L_9$ x $T_1$ | | | | | | | | | * | ** |
| 10 | $L_{10}$ x $T_1$ | ** | | | | | | | ** | | ** |
| 11 | $L_{11}$ x $T_1$ | | | | | | | | ** | | |
| 12 | $L_{12}$ x $T_1$ | | | | ** | ** | | | | ** | |
| 13 | $L_{13}$ x $T_1$ | ** | | | ** | ** | | | | ** | |
| 14 | $L_{14}$ x $T_1$ | | | | | | | | | | |
| 15 | $L_1$ x $T_2$ | | | | | * | | | ** | ** | |
| 16 | $L_2$ x $T_2$ | | | | | ** | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | $L_3$ x $T_2$ | | | | * | | | | | ** | |
| 18 | $L_4$ x $T_2$ | ** | | | ** | ** | | | ** | | |
| 19 | $L_5$ x $T_2$ | | | | | | | | | | |
| 20 | $L_6$ x $T_2$ | | | | | | | | | ** | |
| 21 | $L_7$ x $T_2$ | | | | * | | | | | | ** |
| 22 | $L_8$ x $T_2$ | | | | | | | | | | |
| 23 | $L_9$ x $T_2$ | ** | ** | | | ** | | | * | | |
| 24 | $L_{10}$ x $T_2$ | | * | | * | | | | | | |
| 25 | $L_{11}$ x $T_2$ | | | | | ** | | | | ** | ** |
| 26 | $L_{12}$ x $T_2$ | | | | | | | | | | |
| 27 | $L_{13}$ x $T_2$ | | | | | | | | | | |
| 28 | $L_{14}$ x $T_2$ | * | * | | | | | | | | ** |
| 29 | $L_1$ x $T_3$ | | | | ** | | | | | | ** |
| 30 | $L_2$ x $T_3$ | * | | | * | | | | | | ** |
| 31 | $L_3$ x $T_3$ | * | | | | ** | | | ** | ** | |
| 32 | $L_4$ x $T_3$ | | | | | | | | | ** | ** |
| 33 | $L_5$ x $T_3$ | ** | | | ** | | | | ** | ** | |
| 34 | $L_6$ x $T_3$ | | | | | | | | | | |
| 35 | $L_7$ x $T_3$ | | | | | | | | | | |
| 36 | $L_8$ x $T_3$ | ** | ** | | | ** | | | | | ** |
| 37 | $L_9$ x $T_3$ | | | | | | | | | ** | |
| 38 | $L_{10}$ x $T_3$ | | | | | | | | | | |
| 39 | $L_{11}$ x $T_3$ | | | | | | | | | | |
| 40 | $L_{12}$ x $T_3$ | * | | | | * | | | * | | ** |
| 41 | $L_{13}$ x $T_3$ | ** | * | | | | | | * | ** | ** |
| 42 | $L_{14}$ x $T_3$ | | | | | ** | | | | | |

(*, ** significant at 0.05 and 0.01 probability level, respectively)

**Table 5:** Four promising crosses identified on the basis of GCA and SCA effects along with highest *per se* performance for grain yield per plant on pooled basis

| S. No. | Hybrids | Grain yield per plant (g) | | |
|---|---|---|---|---|
| | | SCA effects | GCA effects | Mean value (g) |
| 1 | EI-2159-2 × EI-090 | 36.38** | -2.82 × -3.05**<br>L L | 148.36 |
| 2 | EI-161 × EI-03-1 | 26.29** | -0.33 × 3.54**<br>L H | 147.35 |
| 3 | EI-2149-2 × EI-03-1 | 24.25** | 7.22** × 3.54**<br>H H | 152.87 |
| 4 | EI-2403-1 × EI-090 | 22.65** | 12.06** × -3.05**<br>H L | 149.51 |

(*, ** significant at 0.05 and 0.01 probability level, respectively), (# best check *i.e*., Pratap hybrid 3 for grain yield per plant), (GCA effect of parents *i.e*., H: high, L: low)

## Conclusion
Four promising hybrids EI-2159-2 × EI-090, EI-161 × EI-03-1, EI-2149-2 × EI-03-1 and EI-2403-1 × EI-090 identified based on GCA and SCA effects along with highest *per se* performance for grain yield per plant on pooled basis and were found suitable for heterosis breeding (Table 5).

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## Conflict of interest
The authors declare that there is no conflict of interest.

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