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# COMBINING ABILITY ANALYSIS AND HETEROSIS FOR YIELD AND YIELD ATTRIBUTING TRAITS INLATE MATURING WINTER MAIZE INBRED LINES (*Zea mays* L.)

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## Abstract

A study was conducted to assess the general and specific combining ability of the newly developed late maturing inbred lines.Twenty eightlate maturing inbred lines of winter season were crossed with two testers BML 6 and BML7 using line × tester mating design. The resulting 56 crosses along with 30 parents were evaluated during rabi 2015-16 andrabi 2016-17 in a randomized block design. ANOVA for combining ability revealed significant mean squares for GCA and SCA for all the traits studied which indicated the presence of both additive and non-additive gene action in the inheritance of these traits. The parent IMLSB-1299-5 followed by IMLSB-406-2 and IMLSB-334B-2 along with other four inbreds was identified as best combiner for grain yield. Out of the 28 lines, nine parents showed the positive significant GCA for days to anthesis and silking which can be utilized for development of medium to late hybrid varieties (Late varieties desirable in rabi maize).The crosses IMLSB-343-3× BML7 followed by IMLSB-428-2× BML-6and IMLSB-156-2× BML-7 along with other six crosses showed positive significant SCA effects. Six hybrids *viz.* IMLSB-406-2 × BML-6, IMLSB-1299-5 × BML-7, IMLSB-1299-5 × BML-6, IMLSB-334B-2 × BML-7, IMLSB-814-2 × BML-6 and IMLSB-334B-2 × BML-6 showed positive and significant economic heterosis for grain yield over the standard commercial check.Thesepromising cross combinations identified in this study could be utilized for future breeding work as well as for direct release after confirming the stability of their performances observed in the current study.

***Key words :*** *Combining ability, economic heterosis, late maturing, winter maize.*

**Maize (***Zea mays* L.) standsas the leading contributor to the global food and feed basketwith annual production of 1046 million ton (1). Out of which Indiacontributesaround 2.5% of this production chart with anannual production of 26.26 million tons of grain from an area of 10.20 million hectares with productivity of 2.57 mt/ha (1). In terms of area, production and productivity, maize ranks thirdmost important crop in the world next towheat and rice. The economic importance of maize is that nearly 15 million farmers are engaged in maize cultivation and it generates employment for more than 650 million person-days at farming and its related business ecosystem levels due to the broadpossibilities of use in fresh or processed form (2). Maize consumption has increased by 2 percent during FY 2016–17 (24 Mn MT) over previous year. This cumulative demand comprises of 13.5 Mn MT from poultry feed, 1.2 Mn MT from ethanol, 1.8 Mn MT from starch and rest for food, seed and other usage. It is also used to produce medicinal products such as glucose as well as an ornamental plant (3). Specifically, the feed industry growing at a rate of 6-7% globally and in India at rate of 9% presents a huge scope for maize growers. In order to meet the needs of domestic consumption only, India would require 45 Mn MT of Maize by the year 2022. (2).

Winter maize has emerged as an important crop in the non-traditional areas. Winter maize has potential to increase the maize production in the coming years as it has a higher yield at 4 MT/hectare against 2.5MT/hectare for kharif maize. In India winter maize could help meet demand requirements consistently throughout the year (4). The predominant winter maize growing states are Andhra Pradesh, Bihar, Tamil Nadu, Karnataka, Maharashtra and West Bengal. Due to low temperature and humidity in winter season, level of infection or infestation by various diseases and insect pests is quite low, resulting in higher yield. In the absence of any major environmental impediments during winter, the desired field operations can be planned and executed at the most desired time which provide ideal environment for maize crop.

To meet this increasing demand,maizeproduction can be enhancedby developing and exploiting high yielding parental lines to develop heterotic and high yielding hybrids. The continuous tired less effort of scientists are required for the developmentofbetter than the best high yielding single cross hybridsalong with superior qualitative and quantitative traits and hybrids resilientto biotic and abiotic stresses. The nature and magnitude of combining ability of various available diverse inbred linesto be used in the hybridization program and gene actions is imperative (Shengu *et al*., 2016). The practical phase of maize breeding towards development of single cross hybrid varieties is based upon huntingfor elite inbred lines possessing better combining ability based on GCA and SCA which could be used as parents to pave the way in the development ofbetter than the best single cross maize hybrids.

Out of the various suggested breeding approaches for the estimation of GCA and SCA, the line × tester analysis method introduced by Kempthorne, 1957 is one of the powerful tools available to estimate thecombining ability effects whichaids in selecting desirable parentsand make crosses accordingly toexploit theheterosis (5). A desirable tester may be defined as one that combines facilely with the lines and gives maximum information on the performance expected from the tested lines. No single tester can completely fulfil these requirements. Therefore, the choice of a suitable tester is an important decision. (6) showed that a narrow genetic base tester contributes more to line × tester interaction than does a heterogeneous one.

Performances *per se* do not necessarily reveal which parentsare good or poor combiner. To surmount this difficulty, it isnecessary to gather information on the nature of gene actions. General combining ability attributes additive type of gene action, while specific combining ability attributes non-additive type of gene actions. Non-additive type ofgene actions is not reliably fixable whereas additive types of gene actions arereliably fixable (7). Estimation of heterosis for different morphological and yieldrelated traits are attributed to both additive and non-additivegene actions. However, many studies have been made on the combining ability analysis on various maize inbred lines by several workers (8), butcombining ability analysis for the twenty-eight newly developed late maturing maize inbred lines have not been made since. As the rabi maize is gaining much importance due to having more yield because of late maturing hybrids which are recommended for the rabi maize. Late maturing maize hybrids utilises more time for grain filling and for transfer of photosynthates from the source to sink leading to higher grain yield. So, the main objectives of current study were to identify the elite late maturing inbred lines among these 28 lines with good GCA and SCA effects, to determine the nature and magnitude of gene actions and to estimate the economic heterosis for yield and yield related traits in a line×tester mating design in late maturing winter maize.

## MATERIALS AND METHODS

The present investigation was carried out at RMR and SPC (ICAR-IIMR) farm, Kushmahaut, Begusarai, India during the year 2015-2016 and 2016-2017 in rabicropping season. The experimental material comprised 30 winter maize (*Zea mays* L.) inbredgenotypes. The 28newly developed maize inbreds were used as females and designated as lines while two established inbred (BML-6and BML-7) designated as testers, were used as males. The 28 female lineswere crossed with two testers to produce 56 $F_1$ hybridsas per line×tester mating design developed by (9). $F_1$ seeds were sown in the rabi season along withtheir parents in a Randomized Block Design withthree replications. Each plot comprised one row of 4mlength with space of 60 cm between row to row and seeds were placed 20cm apart. Recommended cultural package and practices werefollowed to raise a good crop. Weedswere controlled by the hand weeding and applicationof pre-emergence herbicide Atrazine.

Five competitive plants (excluding border plants) weretagged before floweringand data were recorded for the plant height, PH (cm); ear height, EH (cm); ear length, EL (cm); ear girth, EG (cm); kernel rows, KR (cm); kernels per row, K/R (cm); shelling percent except for the days to anthesis (DTA), days to silking (DTS), Anthesis silking interval (ASI), days to maturity (DTM) and grain filling duration (GFD)which were recorded on plot basis.Grain yield, GY was obtained on plot basis and converted to q/ha. Data recordedwere subjected to analysis of variance according to Steeland Torrie (1980) to determine significant differences amonglines, crosses and line× tester. Combining ability analysis (pooled over years) was carried out according to model as suggested by (9). Data was analysed using Windostat (9.1) software. The ANOVA for Line× tester analysis was performed as suggested by Singh and Chaudhary (1992). Economic heterosis was estimated frommean values and its significance was performed using *t*-test.

## RESULTS AND DISCUSSION

**Analysis of Variance (ANOVA) :** Theanalysis of variance (Table-1) revealed significant differences among the lines, crosses, parents vs crosses and line × tester effect for all the traits under study which witness the sufficient genetic variability among lines,testers and hybrids selected for all the traits under study and suggests further assessment of combining ability analysis. Similar significance among the inbred lines of maize was also reported by (10). The significance of mean sum of squares, due to lines for days to anthesis, days to silking anthesis-silking interval, days to maturity, plant height,ear girth,kernel rows,kernels per row,shelling percent and grain yield suggested the prevalence of additive genetic effects for these traits.While, simultaneously, significance of mean sum of squares dueto lines × testers for days to anthesis, days to silking,anthesis -silking interval, days to maturity, plant height,ear girth,kernel rows,kernels per row,shelling percent and grain yieldindicated the existence of both additive and non-additive type ofgene action in the genetic control of thesecharacters.The significant difference among the L × T component provides evidence of the presence of high SCA among the hybrids. ANOVA for combining ability revealed

**Table-1 :** Analysis of variance for yield and yield contributing traits of inbred lines, testers and line × tester crosses in late maturing maize.

| Source of variation | d.f. | DTA | DTS | ASI | DTM | GFD | PH | EH | EL | EG | KR | K/R | SP | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 2 | 73.59** | 64.51** | 0.56 | 30.57 | 5.16 | 28.40 | 345.30** | 2.72 | 0.11 | 0.78 | 25.86 | 9.36 | 122.90 |
| Treatments | 85 | 123.05** | 126.1** | 5.28** | 140.56** | 59.82** | 7529.67** | 2508.07** | 67.58** | 19.07** | 13.51** | 370.75** | 4377.48** | 7443.38** |
| Parents | 29 | 95.23** | 97.96** | 6.15** | 166.6** | 80.96** | 1104.13** | 255.58** | 18.09** | 4.32** | 12.72** | 82.31** | 88.17** | 140.49** |
| Parents (Line) | 27 | 97.82** | 96.91** | 5.876** | 175.73** | 85.72** | 1069.41** | 261.13** | 17.57** | 4.44** | 12.44** | 76.94** | 92.83** | 150.33** |
| Parents (Testers) | 1 | 120.33** | 216.75** | 14.08** | 80.08** | 33.33* | 1287.54** | 20.54 | 1.84 | 1.20 | 15.87** | 33.67* | 10.45 | 0.24 |
| Parents (L vs T) | 1 | 0.10 | 7.56 | 5.91** | 8.23 | 0.01 | 1858.29** | 340.86** | 48.20** | 4.161** | 16.94** | 276.15** | 40.11** | 15.26 |
| Parent vs Crosses | 1 | 3786.02** | 4202.81** | 20.84** | 2582.59** | 162.81** | 558311.10** | 169468.40** | 4781.86** | 1249.72** | 416.73** | 26060.88** | 368522.80** | 584339.80** |
| Crosses | 55 | 71.13** | 66.95** | 4.54** | 82.40** | 46.80** | 903.47** | 660.10** | 7.96** | 4.47** | 6.60** | 55.74** | 18.30** | 804.97** |
| Line effect | 27 | 102.21** | 94.46** | 7.03** | 98.36** | 70.27** | 1497.61** | 1018.27** | 11.669** | 7.26** | 11.16** | 68.41 | 22.40 | 1125.35* |
| Tester effect | 1 | 653.25** | 604.82** | 1.24 | 1038.12** | 26.75 | 847.73 | 30.24 | 1.34 | 5.55 | 3.97 | 58.50 | 70.31* | 23.21 |
| Line * Tester effect | 27 | 18.48** | 19.52** | 2.16** | 31.05** | 24.08** | 311.39** | 325.28** | 4.49** | 1.64** | 2.15** | 42.97** | 12.29** | 513.55** |
| Error | 340 | 2.72 | 3.13 | 0.83 | 5.92 | 6.66 | 64.83 | 31.44 | 1.70 | 0.60 | 0.73 | 7.77 | 2.74 | 51.96 |
| Total | 515 | 34.44 | 32.27 | 2.48 | 38.02 | 22.36 | 1464.10 | 573.15 | 13.48 | 3.96 | 3.26 | 71.12 | 726.34 | 1331.88 |

*, ** Significant at P=0.05 and 0.01, respectively.

DTA = days to anthesis, DTS = days to silking, ASI = anthesis silking interval, DTM = days to maturity, GFD = grain filling duration PH = Plant height (cm) , EH = ear height (cm), EL = ear length (cm), EG = ear girth (cm), KR = kernel rows , K/R = kernels per row, SP= shelling percent and GY =Grain yield (q/h),

significant mean squares for GCA and SCA effects for all the traits studied which indicated the presence of both additive and non-additive gene action in the inheritance of these traits.Therefore, it shows that both additive as well as non-additive genetic variances are going to play role during the exploitation of the genetic potential of the inbred lines in hybrid development program. (11) found the importance of both additive and non-additive gene actions in controlling grain yield.

**General and Specific Combining Ability Effects :** Genetic variability and meanperformance of the parents and hybrids are important criteria forgenotypic evaluation; however, the parents with high meanvalue may not transmit their characteristic to their offspring.These parents and theirabilities to combine well are estimated in termsof general combining ability (GCA) and specific combiningability (SCA) effects respectively. Hybrids evaluated in this study manifested considerable variation in general combining ability effects in all the yield and yield related traits studied, which is in line with the study of (12).

**General combining ability effects :** The General combining ability (GCA) effects reflect the additive nature of the gene action. In the present study, the GCA of parents (28 linesand 2 testers) was estimated to reveal their genetic worth for use in production of superior progeny. The estimates of GCA effects has been presented in table-2. For grain yield, the best combiner identified among the line was IMLSB-1299-5 followed byIMLSB-406-2>IMLSB-334B-2>IMLSB-814-2>IMLSB-231-1>IMLSB-164-1>IMLSB-975-2>IMLSB1062-2-2.

These lines can be used directly as parents for developing high yielding single cross hybridsin maize grain improvement programs as these lines have great potential to transfer desirable traits to their cross progenies. Similar result of significant positive GCA for grain yield among the inbred lines has also been reported by (13). Two inbred lines IMLSB-1299-5 and IMLSB-164-1 were also accompanied with significant GCA in desired direction for days to anthesis, days to silking, days to maturity, ear girth, ear length, kernel rows and kernels per row. IMLSB-1062-2-2 also showed the significant GCA in desired direction for the traits days to anthesis, days to maturity, plant height, ear height, ear girth, kernel row, kernel per row and shelling percent and IMLSB-406-2 showed positive significant effect for kernel rows and shelling percent. IMLSB-334B-2 had positive significant effect for the traits grain filling duration, ear girth, kernel rows and kernels per row. IMLSB-231-1 also exhibited positive significant effect for the traits days to anthesis, days to silking, plant height, ear height, ear length, kernels per row and shelling percent. These traits can contribute directly in the yield enhancement.Similar significantresults were reported foryield and yield related traits by Pavan et al., 2011 and Singh et al., 2012.For the flowering traits,

**Table-2 :** Pooled estimates of GCA effects of lines and testers for yield and yield contributing traits in late maturing maize.

| Inbred | Pedigree | DTA | DTS | ASI | DTM | GFD | PH | EH | EL | EG | KR | K/R | SP | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IMLSB-107-2 | ZH116001F2-2-2-1-1-1#-1-2 | 1.15* | 1.38* | 0.35 | 1.16 | -2.60** | -2.55 | -0.84 | -0.39 | 0.12 | -0.83** | -1.20 | -1.88** | -10.17** |
| IMLSB-126-2 | ZH112635F2-2-2-2-1-1#-1-1 | -1.44** | -1.87** | -0.32 | -2.92** | -0.94 | -2.94 | -4.878* | -1.54** | 0.31 | -0.01 | -1.26 | 2.31** | -1.17 |
| IMLSB-128-1 | VH112902F2-1-2-1-1-2#-1-2 | 0.72 | 0.76 | 0.10 | -0.34 | -0.98 | -13.50** | -8.63 | -1.10** | 0.11 | -0.90** | -3.31** | 1.44** | -11.63** |
| IMLSB-156-2 | ZH12421F2-2-2-1-1-1#-1-1 | -4.98** | -5.66** | -0.40 | 0.33 | 6.19** | -14.90** | -10.82** | 0.63 | 0.32 | -0.34 | -0.41 | 1.53** | -3.25 |
| IMLSB-164-1 | ZH111670F2-2-1-2-1-1-1-2# | 2.76** | 2.26** | -0.23 | 5.08** | 2.94** | -10.86** | -11.61** | 1.50** | 0.52** | 0.66** | 2.68** | -1.43** | 6.86** |
| IMLSB-231-1 | VH112650F2-2-1-2-3-1-1-1# | 1.94** | 3.09** | 1.27** | -0.76 | -3.73** | 9.15** | 10.00** | 1.02** | -0.12 | 0.27 | 4.24** | 1.41** | 8.50** |
| IMLSB-254-1 | VH112906F2-1-2-2-1-1#-1-2 | 0.52 | 0.30 | -0.11 | -0.05 | -0.98 | 4.77* | 1.11 | -0.66 | 0.50** | 1.91** | -1.55 | 1.05* | 2.59 |
| IMLSB-274-1 | VH1279F2-1-2-1-1-1#-1-2# | 0.61 | 1.59** | 1.10** | -0.21 | -1.69* | 6.14** | 5.67** | -1.82** | -0.09 | -0.40 | -0.99 | -0.53 | -2.64 |
| IMLSB-334B-2 | VH121043F2-2-2-1-2-2#-1-1 | -0.77 | -0.95 | -0.10 | 0.66 | 1.73* | -1.65 | 0.17 | 0.61 | 0.75** | 1.11** | 1.97* | 0.91 | 17.74** |
| IMLSB-342-1 | VH1224F2-1-2-1-2-1#-1-2 | 1.15* | 1.28* | 0.25 | 1.69* | 0.52 | 0.36 | 5.84** | -0.76* | -0.61** | -0.50* | -0.16 | -1.64** | 4.03 |
| IMLSB-343-3 | VH126F2-3-2-1-2-1-1-1# | 0.61 | 0.51 | 0.02 | -1.01 | -1.39 | 1.68 | 5.19** | 0.10 | -0.54** | -0.17 | -0.16 | -1.36* | -2.46 |
| IMLSB-406-2 | VH112650 (PAC745) F2-2-2-1-1-1#-1-2 | -2.72** | -2.58** | 0.27 | -4.42** | -1.73* | -21.19** | -13.74** | 0.62 | 0.27 | 0.55* | 0.63 | 1.14* | 20.55** |
| IMLSB-428-2 | VH1293F2-1-5-2-1-1-1-2# | -2.10** | -1.47** | 0.75* | 0.10 | 1.69* | -14.68** | -4.01* | -1.86** | -0.22 | -0.73** | -4.80** | -0.11 | -9.70** |
| IMLSB-457-2 | ZH111688F2-2-5-3-2-1-1-2# | -2.44** | -2.50** | 0.06 | -1.26 | 1.36 | -17.79** | -13.40** | -0.75 | -0.60** | 0.22 | -1.89* | -0.69 | -9.67** |
| IMLSB-571-2 | VH11130F2-2-1-1-1-1#-1-2 | -1.69** | -1.04 | 0.77** | -4.13** | -2.98** | 1.56 | 0.86 | 0.21 | -0.313 | -0.50* | 1.04 | 1.88** | -6.74** |
| IMLSB-800-1 | Pro4794F2-25-2-1-2-1#-1 | 1.60** | 1.10* | -0.39 | -1.08 | -2.06** | 0.73 | -6.28** | -0.31 | -0.69** | -0.50* | -2.04* | 1.12* | 2.54 |
| IMLSB-814-2 | Bio-9681F2-14-1-1-1-1-1-2# | -0.94 | -0.89 | 0.17 | -1.48* | -0.48 | -4.40* | -9.14** | 1.37** | -0.69** | -1.00** | 0.96 | -1.30* | 15.49** |
| IMLSB-883-1 | P3785F2-8-1-1-2-1#-1 | -1.48** | -1.18* | 0.25 | -0.73 | 0.56 | 2.76 | 0.91 | 0.26 | -0.77** | -0.22 | 0.49 | -2.25** | -6.62** |
| IMLSB-975-2 | NK6240F2-25-2-1-2-1#-1 | -0.85 | -0.89 | 0.08 | -3.73** | -2.72** | -3.29 | -6.70** | 0.19 | -1.08** | -1.31** | 0.02 | 0.27 | 6.21* |
| IMLSB-976-2 | P3522F2-1-2-1-1-1#-1 | -5.35** | -4.75** | 0.72* | -5.84** | -0.73 | 3.56 | -5.40** | -0.08 | -1.19** | -1.45** | -1.97* | 0.87 | -6.01* |
| IMLSB-1043-1-1 | NPool43-1-1-1-1-1-1-2# | 4.02** | 3.51 ** | -0.23 | 3.33** | -0.06 | -9.34** | -4.46** | 1.06** | -0.64** | -0.163 | 1.97* | -1.94** | -1.42 |
| IMLSB-1047-1-1 | NPool47-1-1-1-1-1-1-2# | -0.10 | -0.39 | -0.17 | -1.06 | -0.56 | 8.57** | 4.68** | -0.68 | 1.56** | 0.91** | -1.34 | 0.89 | -3.02 |
| IMLSB-1062-2-2 | PinnacleF2-1-2-1-1-1-2-1# | 1.86** | 1.34* | -0.40 | 2.49** | 1.27 | 25.96** | 20.37** | -0.48 | 0.47* | 0.95** | 4.37** | 1.64** | 5.06* |
| IMLSB-1299-2 | 900MF2-2-2-2-1-2-1# | 7.52** | 6.87** | -2.35** | 6.64** | -0.12 | 8.18** | 6.32** | 1.54** | 2.09** | 2.48** | 3.20** | -1.49** | -6.77** |
| IMLSB-1299-5 | 900MF2-5-1-1-2-2-1# | 5.86** | 5.30** | -2.11** | 4.37** | -0.56 | 5.33* | 8.36** | 1.25** | 1.16** | 1.48** | 4.46** | 0.07 | 20.91** |
| IMLSB-2028 | VL103-1-1-1-1-2-2# | 0.48 | 0.53 | 0.21 | 1.49* | 1.02 | 23.69** | 19.43** | 0.52 | 0.29 | -0.86** | -0.14 | -1.66** | 2.68 |
| IMLSB-2039 | VL108305-1-2-1-1-2-1# | -4.39** | -4.55** | -0.04 | 2.44** | 6.86** | 11.46** | 14.34** | 0.62 | 0.01 | 0.11 | -1.09 | -0.07 | -2.07 |
| IMLSB-2166 | VL109126-1-1-1-1-2-1# | -1.44** | -1.08* | 0.47 | -0.76 | 0.19 | 3.87 | -3.40* | -1.09** | -0.92** | -0.75** | -3.73** | -0.18 | -16.14** |
| BML-6 (Tester) | BML-6 | -1.39** | -1.34** | 0.06 | -1.76** | -0.28 | -1.59* | -0.30 | -0.06 | 0.13** | 0.11 | 0.42 | 0.46** | 0.26 |
| BML-7 (Tester) | BML-7 | 1.39** | 1.34** | -0.06 | 1.76** | 0.28 | 1.59* | 0.30 | 0.06 | -0.13** | -0.11 | -0.42 | -0.46** | -0.26 |
| S. E. (gi) Line | | 0.50 | 0.54 | 0.29 | 0.74 | 0.74 | 2.33 | 1.54 | 0.38 | 0.18 | 0.22 | 0.82 | 0.53 | 2.54 |
| S. E. (gi) Line | | 0.13 | 0.15 | 0.08 | 0.20 | 0.20 | 0.62 | 0.41 | 0.10 | 0.05 | 0.06 | 0.22 | 0.14 | 0.68 |
| S. E. (gi– gj) Line | | 0.71 | 0.77 | 0.41 | 1.04 | 1.05 | 3.30 | 2.18 | 0.54 | 0.26 | 0.31 | 1.16 | 0.75 | 3.59 |
| S. E. (gi– gj)Tester | | 0.19 | 0.21 | 0.11 | 0.28 | 0.28 | 0.88 | 0.58 | 0.15 | 0.07 | 0.08 | 0.31 | 0.20 | 0.96 |

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

DTA = days to anthesis, DTS = days to silking, ASI = anthesis silking interval, DTM = days to maturity, GFD = grain filling duration PH = Plant height (cm) , EH = ear height (cm), EL = ear length (cm), EG = ear girth (cm), KR = kernel rows , K/R = kernels per row, SP= shelling percent and GY = Grain yield (q/h),

**Table-3 :** Pooled estimates of SCA effects of crosses foryield and yield for yield contributing traits in late maturing maize.

| Hybrid | DTA | DTS | ASI | DTM | GFD | PH | EH | EL | EG | KR | K/R | SP | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IMLSB-107-2× BML-6 | 0.94 | 0.38 | -0.56 | -0.99 | 1.32 | -6.22 | -3.88 | -0.89 | 0.62* | 0.05 | -0.27 | -1.17 | 1.46 |
| IMLSB-107-2× BML-7 | -0.94 | -0.38 | 0.51 | 0.92 | -1.32 | 6.22 | 3.88 | 0.89 | -0.62* | -0.00 | 0.27 | 1.17 | -1.46 |
| IMLSB-126-2× BML-6 | -0.40 | -0.28 | 0.11 | 0.92 | 1.07 | 0.61 | 6.14** | 0.02 | -0.07 | 0.23 | 0.72 | -0.41 | 7.43* |
| IMLSB- 126-2× BML-7 | 0.407 | 0.28 | -0.11 | -0.92 | -1.07 | -0.61 | -6.14** | -0.02 | 0.07 | -0.23 | -0.72 | 0.41 | -7.43* |
| IMLSB-128-1× BML-6 | 3.06** | 3.09** | 0.03 | 2.34* | -0.89 | 4.55 | 0.08 | -0.01 | -0.24 | -0.38 | 0.37 | -0.1 2 | -7.82* |
| IMLSB-128-1× BML-7 | -3.06** | -3.09** | -0.23 | -2.34* | 0.89 | -4.55 | -0.08 | 0.01 | 0.24 | 0.38 | -0.37 | 0.12 | 7.82* |
| IMLSB- 156-2× BML-6 | -0.27 | 0.01 | 0.11 | 1.34 | 1.12 | -1.60 | -5.15* | 0.36 | -0.53* | -0.11 | -1.09 | 0.33 | -8.63* |
| IMLSB- 156-2× BML-7 | 0.27 | -0.01 | -0.11 | -1.34 | -1.12 | 1.60 | 5.15* | -0.36 | 0.53* | 0.11 | 1.09 | -0.33 | 8.63* |
| IMLSB-164-1× BML-6 | 0.73 | 0.76 | 0.02 | 1.09 | 0.20 | -3.47 | 0.11 | -0.40 | -0.11 | 0.06 | -1.33 | -1.63* | -4.67 |
| IMLSB-164-1× BML-7 | -0.73 | -0.76 | -0.02 | -1.09 | -0.20 | 3.47 | -0.11 | 0.40 | 0.11 | -0.06 | 1.33 | 1.63* | 4.67 |
| IMLSB-231-1× BML-6 | 0.56 | 0.66 | 0.11 | 1.51 | 0.700 | 6.24 | 3.85 | 0.50 | 0.10 | 0.17 | 1.94 | -2.26** | 7.77* |
| IMLSB-231-1× BML-7 | -0.56 | -0.66 | -0.11 | -1.51 | -0.70 | -6.24 | -3.85 | -0.50 | -0.10 | -0.17 | -1.94 | 2.26** | -7.77* |
| IMLSB-254-1× BML-6 | 0.98 | 0.63 | -0.35 | -0.04 | -0.05 | -3.22 | -2.84 | -0.35 | -0.14 | 0.24 | -1.33 | 0.85 | -5.75 |
| IMLSB-254-1× BML-7 | -0.98 | -0.63 | 0.35 | 0.04 | 0.05 | 3.22 | 2.84 | 0.35 | 0.14 | -0.24 | 1.33 | -0.85 | 5.75 |
| IMLSB-274-1× BML-6 | -0.36 | 0.01 | 0.36 | -1.20 | -1.34 | -9.14** | -6.33** | 0.01 | 0.14 | -0.12 | -2.28* | 0.98 | -3.55 |
| IMLSB-274-1× BML-7 | 0.36 | -0.01 | -0.36 | 1.20 | 1.34 | 9.14** | 6.33** | -0.01 | -0.14 | 0.12 | 2.28* | -0.98 | 3.55 |
| IMLSB-334B-2× BML-6 | 1.27 | 1.38 | 0.11 | 2.01 | 0.49 | 1.45 | 0.12 | 0.91 | 0.35 | 0.83** | 2.57 | -0.09 | -0.75 |
| IMLSB-334B-2× BML-7 | -1.27 | -1.38 | -0.11 | -2.01 | -0.49 | -1.45 | -0.12 | -0.91 | -0.35 | -0.83** | -2.57 | 0.09 | 0.75 |
| IMLSB- 342-1× BML-6 | -0.15 | -0.60 | -0.46 | 2.32* | 2.78** | 2.76 | 7.08** | 0.51 | 0.03 | -0.19 | 1.92 | 0.83 | 5.88 |
| IMLSB- 342-1× BML-7 | 0.15 | 0.60 | 0.46 | -2.32* | -2.78** | -2.76 | -7.08** | -0.51 | -0.03 | 0.19 | -1.92 | -0.83 | -5.88 |
| IMLSB- 343-3× BML-6 | 0.06 | 0.01 | -0.06 | -0.83 | -0.97 | -5.91 | -7.24** | -0.83 | -0.42 | 0.68 | -2.93* | -1.96** | -16.82** |
| IMLSB- 343-3× BML-7 | -0.06 | -0.01 | 0.06 | 0.83 | 0.97 | 5.91 | 7.24** | 0.83 | 0.42 | -0.68 | 2.93* | 1.96** | 16.82** |
| IMLSB-406-2× BML-6 | 1.40 | 1.66* | 0.27 | 0.84 | -0.97 | -0.08 | -2.08 | 0.98 | -0.03 | -0.19 | 3.77** | 0.25 | 8.37* |
| IMLSB-406-2× BML-7 | -1.40 | -1.66* | -0.27 | -0.84 | 0.97 | 0.08 | 2.08 | -0.98 | 0.03 | 0.19 | -3.77** | -0.25 | -8.37* |
| IMLSB- 428-2× BML-6 | 1.10 | 0.90 | -0.21 | 1.15 | 0.12 | 1.03 | 4.53* | -0.07 | 0.45 | 0.50 | -0.12 | 0.44 | 11.65** |
| IMLSB- 428-2× BML-7 | -1.10 | -0.90 | 0.21 | -1.15 | -0.12 | -1.03 | -4.53* | 0.07 | -0.45 | -0.50 | 0.12 | -0.44 | -11.65** |
| IMLSB-457-2× BML-6 | -1.40* | -1.66* | -0.27 | 0.09 | 1.62 | -10.61** | -9.83** | -1.45** | -0.20 | -0.22 | -5.23** | -1.79* | 0.35 |
| IMLSB-457-2× BML-7 | 1.40* | 1.66* | 0.27 | -0.09 | -1.62 | 10.61** | 9.83** | 1.45** | 0.20 | 0.22 | 5.23** | 1.79* | -0.35 |
| IMLSB-571-2× BML-6 | 0.10 | 1.13 | 1.02* | 1.38 | 0.12 | 4.52 | 3.83 | 0.11 | 0.11 | 0.44 | 0.66 | -0.27 | 0.99 |
| IMLSB-571-2× BML-7 | -0.10 | -1.13 | -1.02* | -1.38 | -0.12 | -4.52 | -3.83 | -0.11 | -0.11 | -0.44 | -0.66 | 0.27 | -0.99 |
| IMLSB-800-1× BML-6 | -1.02 | -1.03 | -0.02 | -0.70 | 0.20 | -0.58 | -1.45 | 0.75 | 0.18 | -0.16 | 1.97 | 0.47 | 0.20 |
| IMLSB-800-1× BML-7 | 1.02 | 1.03 | 0.02 | 0.70 | -0.20 | 0.58 | 1.45 | -0.75 | -0.18 | 0.16 | -1.97 | -0.47 | -0.12 |
| IMLSB-814-2× BML-6 | -1.06 | -0.93 | 0.12 | -0.18 | 0.62 | -2.95 | -1.53 | 0.85 | 0.06 | 0.01 | 0.77 | 0.60 | 1.69 |
| IMLSB-814-2× BML-7 | 1.06 | 0.93 | -0.12 | 0.18 | -0.62 | 2.95 | 1.52 | -0.85 | -0.06 | -0.01 | -0.77 | -0.60 | -1.69 |
| IMLSB- 883-2× BML-6 | -0.77 | 0.16 | 1.09** | -1.30 | -1.59 | 3.86 | -3.14 | -0.32 | 0.10 | -0.11 | 1.92 | 2.43** | -0.01 |
| IMLSB- 883-2× BML-7 | 0.77 | -0.16 | -1.09** | 1.30 | 1.59 | -3.86 | 3.14 | 0.32 | -0.10 | 0.11 | -1.92 | -2.43** | 0.01 |

*Table-3 : Contd.......*

| Hybrid | DTA | DTS | ASI | DTM | GFD | PH | EH | EL | EG | KR | K/R | SP | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IMLSB-975-2× BML-6 | -1.98** | -1.93* | 0.04 | 0.57 | 2.37* | -1.60 | 0.43 | 0.63 | -0.26 | -0.13 | 0.83 | 0.25 | 6.03 |
| IMLSB-975-2× BML-7 | 1.98** | 1.93* | -0.04 | -0.57 | -2.37* | 1.60 | -0.43 | -0.63 | 0.26 | 0.13 | -0.83 | -0.25 | -6.03 |
| IMLSB-976-2× BML-6 | 0.77 | 1.09 | 0.34 | -2.99** | -3.97** | -0.77 | -10.00** | -0.85 | -0.35 | -1.05** | -1.60 | -0.15 | -7.75* |
| IMLSB-976-2× BML-7 | -0.77 | -1.092 | -0.31 | 2.99** | 3.97** | 0.77 | 10.00 ** | 0.85 | 0.35 | 1.05** | 1.60 | 0.15 | 7.75* |
| IMLSB-1043-1-2× BML-6 | 0.14 | -0.16 | -0.14 | 0.17 | 0.20 | 3.34 | 4.26 | 0.06 | 0.10 | -0.12 | -1.51 | 0.98 | -4.81 |
| IMLSB-1043-1-2× BML-7 | -0.14 | 0.16 | 0.14 | -0.17 | -0.2 0 | -3.34 | -4.26 | -0.06 | -0.10 | 0.12 | 1.51 | -0.98 | 4.81 |
| IMLSB-1047-1× BML-6 | -1.23 | -0.68 | 0439 | -0.68 | -0.14 | -5.27 | -2.79 | -0.66 | -0.01 | 0.31 | 1.22 | -0.05 | 3.75 |
| IMLSB-1047-1× BML-7 | 1.21 | 0.68 | -0439 | 0.68 | 0.14 | 5.27 | 2.79 | 0.66 | 0.01 | -0.31 | -1.22 | 0.05 | -3.75 |
| IMLSB-1062-1-2× BML-6 | 1.64* | 1.18 | -0.48 | 1.01 | -0.30 | 12.23** | 6.06** | 0.33 | 0.07 | -0.34 | -0.84 | 0.22 | -5.57 |
| IMLSB-1062-1-2× BML-7 | -1.64* | -1.18 | 0.48 | -1.01 | 0.30 | -12.23** | -6.068** | -0.33 | -0.07 | 0.34 | 0.84 | -0.22 | 5.57 |
| IMLSB-1299-2× BML-6 | -1.61* | -1.93* | -0.31 | -0.84 | 0.92 | 2.07 | 3.15 | -0.72 | 0.57* | 0.91** | -0.05 | 0.49 | 7.70* |
| IMLSB-1299-2× BML-7 | 1.61* | 1.93* | 0.31 | 0.84 | -0.92 | -2.07 | -3.15 | 0.72 | -0.57* | -0.91** | 0.05 | -0.49 | -7.70* |
| IMLSB-1299-5× BML-6 | -0.52 | -0.45 | 0.06 | -0.04 | 0.03 | -3.06 | 0.46 | -0.16 | -0.50 | -0.69* | -1.71 | -0.07 | -1.65 |
| IMLSB-1299-5× BML-7 | 0.52 | 0.45 | -0.06 | 0.04 | -0.03 | 3.06 | -0.46 | 0.16 | 0.50 | 0.69* | 1.71 | 0.07 | 1.65 |
| IMLSB-2039× BML-6 | 1.353 | 0.87 | -0.45 | 0.17 | -0.86 | 8.93** | 2.77 | 0.03 | 0.51 | 0.32 | 0.32 | 0.78 | 4.33 |
| IMLSB-2039× BML-7 | -1.35 | -0.87 | 0.45 | -0.17 | 0.88 | -8.93** | -2.77 | -0.03 | -0.51 | -0.32 | -0.32 | -0.78 | -4.33 |
| IMLSB-2028× BML-6 | -1.11 | -1.88* | -0.79 | -4.72** | -2.88** | 2.38 | 12.45** | 0.36 | 0.51* | 0.21 | -0.23 | -0.11 | 5.62 |
| IMLSB-2028× BML-7 | 1.11 | 1.88* | 0.79 | 4.72** | 2.88** | -2.38 | -12.45** | -0.36 | -0.51* | -0.21 | 0.23 | 0.11 | -5.62 |
| IMLSB-2166× BML-6 | -2.23** | -2.41** | -0.19 | -2.41* | 0.12 | 0.50 | 0.97 | 0.31 | -1.04** | -0.69* | 1.51 | 0.17 | -5.44 |
| IMLSB-2166× BML-7 | 2.23** | 2.40** | 0.19 | 2.41 * | -0.12 | -0.50 | -0.97 | -0.31 | 1.04** | 0.69* | -1.51 | -0.17 | 5.44 |
| **S. E. (Sij) Crosses** | 0.71 | 0.77 | 0.41 | 1.04 | 1.05 | 3.30 | 2.18 | 0.54 | 0.26 | 0.31 | 1.16 | 0.75 | 3.59 |
| **S. E ($S_{ij}$– $S_{kl}$)** | 1.00 | 1.09 | 0.58 | 1.48 | 1.48 | 4.67 | 3.09 | 0.77 | 0.36 | 0.44 | 1.64 | 1.06 | 5.07 |
| **S.E ($S_{ij}$ – $S_{ik}$)** | 3.81 | 4.14 | 2.20 | 5.62 | 5.63 | 17.77 | 11.76 | 2.92 | 1.38 | 1.66 | 6.23 | 4.04 | 19.32 |

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

DTA = days to anthesis, DTS = days to silking, ASI = anthesis silking interval, DTM = days to maturity, GFD = grain filling duration PH = Plant height (cm) , EH = ear height (cm), EL = ear length (cm), EG = ear girth (cm), KR = kernel rows , K/R = kernels per row, SP= shelling percent and GY = Grain yield (q/h).

**Table-4 :** Economic heterosis over best parent (DKC-9081) for yield and yield contributing traits in late maturing maize

| Hybrid | DTA | DTS | ASI | DTM | GFD | PH | EH | EL | EG | KR | K/R | SP | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IMLSB-107-2× BML-6 | 0.54 | -0.08 | -18.66 | -4.19 ** | -13.47 ** | -7.30 ** | -1.88 | -8.32 | -2.03 | -11.76 ** | -5.87 | -4.58 ** | -14.41 ** |
| IMLSB-107-2× BML-7 | 1.41 | 1.68 | 10.05 | -0.61 | -18.12 ** | 1.43 | 9.21 * | 3.53 | -11.17 ** | -13.83 ** | -6.78 | -2.87 * | -17.71 ** |
| IMLSB-126-2× BML-6 | -3.18 ** | -3.68 ** | -18.66 | -5.60 ** | -10.31 ** | -3.7 | 6.07 | -9.77 * | -5.08 * | -5.23 | -3.03 | 1.39 | -0.11 |
| IMLSB-126-2× BML-7 | 0.22 | -0.69 | -28.23 | -4.51 ** | -13.84 ** | -2.6 | -9.46 * | -9.25 | -5.79 ** | -9.59 ** | -9.96 * | 1.27 | -14.81 ** |
| IMLSB-128-1× BML-6 | 2.20 * | 1.84 | -9.09 | -2.99 ** | -14.77 ** | -7.57 ** | -6.98 | -7.28 | -7.31 ** | -15.03 ** | -10.32 * | 0.68 | -24.67 ** |
| IMLSB-128-1× BML-7 | -0.97 | -1.38 | -13.88 | -3.75 ** | -9.56 ** | -10.87 ** | -6.38 | -6.34 | -5.99 ** | -11.44 ** | -15.12 ** | -0.14 | -10.24 * |
| IMLSB-156-2× BML-6 | -6.42 ** | -6.89 ** | -21.05 | -3.21 ** | 5.69 | -11.62 ** | -16.83 ** | 5.82 | -7.82 ** | -9.59 ** | -5.97 | 1.33 | -17.44 ** |
| IMLSB-156-2× BML-7 | -3.26 ** | -4.44 ** | -30.62 | -2.67 ** | 1.97 | -8.06 ** | -2.35 | 2.18 | -2.94 | -9.59 ** | -1.87 | -0.56 | -1.45 |
| IMLSB-164-1× BML-6 | 1.72 | 1.07 | -18.66 | -0.28 | -3.61 | -10.41 ** | -10.89 ** | 6.55 | -4.06 | -1.96 | 2.68 | -4.60 ** | -17.10 ** |
| IMLSB-164-1× BML-7 | 2.99 ** | 2.14 * | -23.44 | 0.59 | -3.24 | -4.75 | -10.39 * | 12.27 * | -4.26 | -4.14 | 8.24 | -1.77 | -8.68 |
| IMLSB-231-1× BML-6 | 0.93 | 1.76 | 26.79 | -3.81 ** | -17.38 ** | 6.21 * | 22.79 ** | 9.15 | -6.70 ** | -3.81 | 17.35 ** | -1.93 | 9.46 |
| IMLSB-231-1× BML-7 | 2.52 ** | 2.99 ** | 17.22 | -3.48 ** | -19.24 ** | 1.01 | 13.35 ** | 3.74 | -9.44 ** | -7.41 ** | 3.03 | 2.41 | -5.89 |
| IMLSB-254-1× BML-6 | -0.02 | -0.84 | -25.84 | -4.35 ** | -12.91 ** | -1.53 | 2.08 | -6.65 | -4.37 * | 7.41 ** | -10.12 * | 1.39 | -9.11 |
| IMLSB-254-1× BML-7 | 0.78 | 0.46 | -9.09 | -2.02 * | -11.43 ** | 3.85 | 10.43 * | -1.46 | -4.26 | 2.83 | -4.55 | -1.77 | 1.39 |
| IMLSB-274-1× BML-6 | -1.2 | -0.23 | 29.19 | -5.22 ** | -17.38 ** | -4.07 | 3.5 | -11.64 * | -6.40 ** | -10.02 ** | -11.33 * | -0.36 | -12.01 * |
| IMLSB-274-1× BML-7 | 2.12 * | 2.22 * | 5.26 | -1.37 | -10.12 ** | 7.92 ** | 21.12 ** | -10.91 * | -9.34 ** | -9.91 ** | 0 | -3.84 ** | -5.72 |
| IMLSB-334B-2× BML-6 | -0.97 | -1.3 | -11.48 | -2.56 ** | -5.66 | -2.51 | 4.76 | 9.15 | 0.1 | 5.99 * | 12.39 * | 0.08 | 10.14 * |
| IMLSB-334B-2× BML-7 | -0.73 | -1.38 | -21.05 | -2.89 ** | -6.59 * | -2.35 | 5.25 | -1.46 | -5.69 * | -6.32 * | -5.77 | -0.8 | 11.07 * |
| IMLSB-342-1× BML-6 | -0.49 | -1.07 | -18.66 | -1.69 | -3.24 | -0.65 | 21.55 ** | -1.87 | -10.05 ** | -10.68 ** | 3.95 | -1.89 | 3.38 |
| IMLSB-342-1× BML-7 | 2.44 * | 2.50 * | 4.31 | -2.42 * | -14.40 ** | -1.97 | 3.54 | -7.48 | -11.98 ** | -10.68 ** | -10.27 * | -4.98 ** | -8.36 |
| IMLSB-343-3× BML-6 | -0.81 | -1.23 | -13.88 | -5.49 ** | -15.89 ** | -4.76 | 1.66 | -4.89 | -12.39 ** | -7.41 ** | -10.77 * | -4.90 ** | -24.51 ** |
| IMLSB-343-3× BML-7 | 1.72 | 1.23 | -13.88 | -2.13 * | -10.31 ** | 3.62 | 21.70 ** | 6.24 | -8.83 ** | -9.59 ** | 4.45 | -1.29 | 7.13 |
| IMLSB-406-2× BML-6 | -2.71 ** | -2.53 * | 2.87 | -6.63 ** | -16.64 ** | -14.28 ** | -16.63 ** | 9.67 * | -5.08 * | -3.81 | 11.94 * | 0.76 | 21.55 ** |
| IMLSB-406-2× BML-7 | -2.71 ** | -3.14 ** | -16.27 | -5.44 ** | -11.05 ** | -12.42 ** | -10.30 * | -1.77 | -6.29 ** | -3.81 | -13.45 ** | -0.94 | 5.05 |
| IMLSB-428-2× BML-6 | -2.39 * | -2.22 * | 2.87 | -3.48 ** | -6.59 * | -10.03 ** | 5.09 | -12.37 * | -5.18 * | -8.17 ** | -16.34 ** | -0.5 | -4.22 |
| IMLSB-428-2× BML-7 | -1.84 | -1.41 | 11.48 | -2.69 ** | -5.84 | -9.40 ** | -6.16 | -10.71 * | -12.18 ** | -16.12 ** | -18.16 ** | -2.67 * | -26.99 ** |
| IMLSB-457-2× BML-6 | -5.08 ** | -5.51 ** | -18.66 | -5.06 ** | -3.98 | -18.26 ** | -26.48 ** | -14.03 ** | -11.37 ** | -6.64 * | -23.01 ** | -3.90 ** | -14.99 ** |
| IMLSB-457-2× BML-7 | 0.22 | 0 | -6.7 | -2.89 ** | -9.94 ** | -4.63 | 0.44 | 4.78 | -10.56 ** | -5.23 | 6.22 | -0.68 | -16.16 ** |
| IMLSB-571-2× BML-6 | -2.94 ** | -1.61 | 38.76 * | -6.09 ** | -17.01 ** | 1.01 | 10.61 * | 1.66 | -7.82 ** | -7.08 * | 3.74 | 1.03 | -11.58 * |
| IMLSB-571-2× BML-7 | -0.49 | -1.23 | -23.44 | -5.60 ** | -16.26 ** | -2.27 | 1.24 | 1.04 | -10.66 ** | -14.27 ** | -2.78 | 0.58 | -13.98 ** |
| IMLSB-800-1× BML-6 | -0.89 | -1.64 | -24.4 | -5.46 ** | -14.77 ** | -2.31 | -5.89 | 2.39 | -9.64 ** | -11.00 ** | -1.62 | 1.01 | -3.47 |
| IMLSB-800-1× BML-7 | 3.70 ** | 2.73 ** | -26.79 | -2.26 * | -14.40 ** | 0.11 | -1.24 | -6.13 | -13.40 ** | -10.35 ** | -16.14 ** | -1.23 | -4.35 |
| IMLSB-814-2× BML-6 | -3.34 ** | -3.37 ** | -4.31 | -5.38 ** | -10.31 ** | -6.73 * | -9.79 * | 13.51 ** | -10.36 ** | -13.18 ** | 3.84 | -1.75 | 10.32 * |
| IMLSB-814-2× BML-7 | 1.33 | 0.81 | -14.83 | -2.85 ** | -11.80 ** | -1.65 | -4.94 | 3.74 | -12.69 ** | -14.71 ** | -3.39 | -4.30 ** | 6.59 |
| IMLSB- 883-2× BML-6 | -3.58 ** | -2.63 ** | 25.84 | -5.62 ** | -12.91 ** | 1.3 | 1.42 | -0.73 | -10.66 ** | -8.82 ** | 5.92 | -0.68 | -12.42 * |
| IMLSB- 883-2× BML-7 | 0.54 | -0.46 | -40.19 * | -1.64 | -4.54 | -1.24 | 10.56 * | 4.05 | -13.40 ** | -8.82 ** | -8.3 | -7.66 ** | -12.90 ** |

*Table-4 : Contd...*

| Hybrid | DTA | DTS | ASI | DTM | GFD | PH | EH | EL | EG | KR | K/R | SP | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IMLSB-975-2× BML-6 | -4.13 ** | -4.29 ** | -9.09 | -6.36 ** | -11.43 ** | -5.12 | -3.94 | 4.78 | -14.72 ** | -16.12 ** | 1.16 | -0.28 | 5.61 |
| IMLSB-975-2× BML-7 | 2.28 * | 1.73 | -14.83 | -4.81 ** | -20.73 ** | -1.57 | -4.3 | -2.29 | -13.10 ** | -15.80 ** | -6.42 | -1.99 | -6.42 |
| IMLSB-976-2× BML-6 | -5.79 ** | -5.05 ** | 17.22 | -10.05 ** | -21.10 ** | -0.84 | -16.08 ** | -6.13 | -15.94 ** | -22.98 ** | -12.24 * | -0.04 | -19.24 ** |
| IMLSB-976-2× BML-7 | -4.60 ** | -4.59 ** | -4.31 | -3.86 ** | -2.12 | 1.8 | 11.29 ** | 5.3 | -13.20 ** | -10.68 ** | -5.06 | -0.78 | -4.92 |
| IMLSB-1043-1-2× BML-6 | 2.52 ** | 1.38 | -23.44 | -2.02 * | -10.31 ** | -5.75 * | 4.12 | 6.65 | -9.85 ** | -8.50 ** | 0 | -2.07 | -12.04 * |
| IMLSB-1043-1-2× BML-7 | 4.89 ** | 4.13 ** | -18.66 | 0.04 | -9.94 ** | -7.71 ** | -6.4 | 6.76 | -12.59 ** | -8.39 ** | 6.63 | -5.53 ** | -3.34 |
| IMLSB-1047-1× BML-6 | -2.71 ** | -2.68 ** | -1.91 | -5.44 ** | -12.17 ** | -0.55 | 6.89 | -8.63 | 2.84 | 1.31 | -1.77 | 0.1 | -5.38 |
| IMLSB-1047-1× BML-7 | 2.28 * | 1.04 | -36.36 * | -2.26 * | -10.31 ** | 7.12 ** | 15.10 ** | 0.31 | 1.42 | -4.14 | -11.73 * | -0.88 | -13.06 ** |
| IMLSB-1062-1-2× BML-6 | 1.88 * | 0.61 | -37.80 * | -2.02 * | -8.45 * | 18.95 ** | 39.50 ** | -1.25 | -3.25 | -2.61 | 9.31 | 1.33 | -6.58 |
| IMLSB-1062-1-2× BML-7 | 1.41 | 0.92 | -13.88 | -1.04 | -5.84 | 7.05 ** | 24.20 ** | -4.57 | -5.69 * | 0.22 | 11.89 * | -0.3 | 3.57 |
| IMLSB-1299-2× BML-6 | 4.18 ** | 2.85 ** | -89.00 ** | -0.52 | -8.82 ** | 3.34 | 16.96 ** | 4.78 | 9.64 ** | 15.47 ** | 8.14 | -2.11 | -5.19 |
| IMLSB-1299-2× BML-7 | 9.87 ** | 8.85 ** | -74.64 ** | 2.86 ** | -11.69 ** | 2.8 | 9.39 * | 14.55 ** | 1.12 | 2.18 | 5.92 | -4.40 ** | -20.42 ** |
| IMLSB-1299-5× BML-6 | 3.62 ** | 2.76 ** | -71.29 ** | -1.48 | -11.80 ** | -1.13 | 16.10 ** | 6.44 | -2.54 | -1.53 | 6.93 | -0.9 | 12.31 * |
| IMLSB-1299-5× BML-7 | 7.26 ** | 6.05 ** | -78.47 ** | 0.86 | -10.68 ** | 4.07 | 15.68 ** | 9.25 | 1.93 | 6.10 * | 14.77 ** | -1.85 | 14.97 ** |
| IMLSB-2039× BML-6 | 0.3 | -0.41 | -19.62 | -3.21 ** | -10.31 ** | 15.84 ** | 33.88 ** | 3.12 | -1.73 | -10.24 ** | -0.86 | -1.97 | 0.61 |
| IMLSB-2039× BML-7 | 0.38 | 0.46 | 2.87 | -1.15 | -5.1 | 7.63 ** | 27.33 ** | 3.53 | -9.44 ** | -15.80 ** | -5.36 | -4.94 ** | -8.17 |
| IMLSB-2028× BML-6 | -6.66 ** | -7.61 ** | -36.36 * | -5.78 ** | -1.75 | 5.34 * | 40.06 ** | 5.72 | -3.35 | -4.58 | -5.41 | -1.13 | -2.69 |
| IMLSB-2028× BML-7 | -1.91 * | -1.68 | 5.26 | 2.65 ** | 12.39 ** | 4.45 | 7.77 | 2.08 | -11.17 ** | -8.71 ** | -6.58 | -1.97 | -13.94 ** |
| IMLSB-2166× BML-6 | -4.92 ** | -4.90 ** | -4.31 | -6.36 ** | -9.94 ** | 0.05 | 1.15 | -5.2 | -18.27 ** | -16.12 ** | -8.14 | -0.92 | -26.71 ** |
| IMLSB-2166× BML-7 | 1.96 * | 1.99 * | 2.87 | -0.93 | -9.19 ** | 1.27 | -0.62 | -8.32 | -7.61 ** | -8.50 ** | -19.83 ** | -2.43 | -16.82 ** |

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

DTA = days to anthesis, DTS = days to silking, ASI = anthesis silking interval, DTM = days to maturity, GFD = grain filling duration PH = Plant height (cm) , EH = ear height (cm), EL = ear length (cm), EG = ear girth (cm), KR = kernel rows , K/R = kernels per row, SP= shelling percent and GY = Grain yield (q/h),

IMLSB-126-2, IMLSB-156-2, IMLSB-406-2, IMLSB-428-2, IMLSB-457-2, IMLSB-883-1, IMLSB-976-2, IMLSB-2039 and IMLSB-2166 showed significant negative GCA effect representing that it can be utilized as early flowering line while inbreds IMLSB-107-2, IMLSB-164-1, IMLSB-231-1, IMLSB-342-1, IMLSB-800-1, IMLSB-1043-1-1, IMLSB-1062-2-2, IMLSB-1299-2and IMLSB- 1299-5 showed significant positive GCA effect for these two flowering traits suggesting that these lines can be used as late flowering lines to be used in according to the occurrence of cold in particular area to avoid the risk of poor seed setting. Here, optimum positive GCA effect for flowering traits is also advisable due to acceptability of medium to late varieties in winter rabi maize.The highly significant negative GCA effect for ASI was observed in the line IMLSB-1299-2 andIMLSB- 1299-5 which can be used for better seed setting due to lesser anthesis silking interval leading to synchronization in flowering. The inbred lines IMLSB-164-1, IMLSB-342-1, IMLSB-1043-1-1, IMLSB-1062-2-2, IMLSB-1299-2, IMLSB-1299-5, IMLSB-2028 and IMLSB-2039 showed positive significant effect for the days to maturity and lines IMLSB-156-2, IMLSB-164-1, IMLSB-334B-2, IMLSB-428-2 and

IMLSB-2039 had longer grain filling duration which indicates that longer maturity period leads to more yield due to enhancement in longer source to sink transfer period. The lines IMLSB-164-1, IMLSB- 231-1, IMLSB-814-2, IMLSB-1043-1-1, IMLSB-1299-2 and IMLSB- 1299-5 showed positive significant GCA effect for ear length while IMLSB-164-1, IMLSB-254-1, IMLSB-334B-2, IMLSB-1047-1-1, IMLSB-1062-2-2, IMLSB-1299-2 and IMLSB-1299-5 showed significant positive GCA effect for ear girth.Netravatiet al., 2013; Khan et al., 2014 also reported positive significant GCA for the ear length and ear girth contributing towards higher yield. For kernel rows, IMLSB-164-1, IMLSB-254-1, IMLSB-334B-2, IMLSB-406-2, IMLSB-1047-1-1, IMLSB-1062-2-2, IMLSB-1299-2 and IMLSB- 1299-5, was found to be best combiner represented by highly significant positive GCA effect. Hence, inbred lines with high GCA effects for more number of kernel rows might be suitable parents for hybrid development as well as for utilization in future breeding programs to get yield enhancement. This was in conformity to (15) who suggested to utilize the linewith positive significant GCA for kernel row as good combiner parent in hybrid development program. Such parents can contribute favourable alleles during synthesis of new varieties. Five lines out of eight best combiners for grain yield *i.e.* IMLSB-1299-5 followed by IMLSB-1641-1, IMLSB-1062-2-2, IMLSB-231-1 and IMLSB-334B-2 were also found to be best combiner for kernel per row. The result of this study is in conformity with the findings of (16). The three linesout of seven best combiners for grain yield *viz.* IMLSB-1062-2-2 followed by IMLSB- 231-1 and IMLSB-406-2 were found to have positive significant GCA effect for shelling percentage.High general combining ability effects (GCA) observed were due to additive and additive × additive gene effects (17). The inbred lines found for good general combining ability could be utilized in maize hybrid development programs for improvement of the traits of interest due to the high potential among these lines to transfer desirable traits in their cross progenies.

**Specific combining ability effects :** The result of the specific combining ability effects of the 56 crosses for the various traits represented in table-3 showed that nine crosses which exhibited significant and desirable SCA for the grain yield in positive direction are IMLSB-343-3× BML-7>IMLSB-428-2× BML-6>IMLSB-156-2× BML-7> IMLSB-406-2× BML-6>IMLSB-128-1× BML-7> IMLSB-231×BML-6 > IMLSB-976× BML-7> IMLSB-1299-2× BML-6> IMLSB-126-2× BML-6. Highly significant SCA effects of the crosses suggest the significant deviation from the prediction made based on their parental performances. These crosses selected for their SCA could be used in maize improvement program as these (nine crosses) are the best combiners with each other out of 56 crosses. The results are in agreement with the findings of (7) who reported significant to highly significant level of SCA effects in most of the crosses. Out of these nine crosses, two crosses namely IMLSB-128-1× BML-7 and IMLSB-1299-2× BML-6 showed negative significant SCA for days to anthesis and days to silking revealing its earliness nature. All the nine crosses showed non-significant SCA for the trait anthesis silking interval. Hybrids with longer ASI are undesirable for grain setting as the male and female lines do not synchronize well. while materials with shorter anthesis-silking interval setts grain well as the male and female flowers nick perfectly. Cross IMLSB-976-2× BML-7 showed significant positive SCA for trait grain filling duration. (18) suggested that an early maturing variety is predisposed to lower yield than a late maturing variety which utilize the opportunity to draw on nutrients and photosynthesize over a longer period. The cross IMLSB-156-2× BML-7 and IMLSB-1299-2×BML-6 showed the positive significant SCA for the ear girth while the crosses IMLSB-976-2× BML-7and IMLSB-1299-2× BML-6, showed positive significant GCA for the trait kernel row. These result are in conformity with findings of (19) for ear girth and Shashidhara, 2008 for kernel row. Crosses IMLSB-343-3× BML-7 and IMLSB-406-2×BML-6for kernel per row and cross IMLSB-343-3× BML-7 for shelling percentage proved itself to be the best combiner. When the performance of the parents was assessed on the basis of the general combining ability, it revealed that most of the specific cross combinations were the result of crosses between high× high or high× medium or medium × high general combiners with few combinations between low× medium and low× high general combiners. Among these crosses, IMLSB-343-3× BML7 which showed highest positive SCA effect for grain yield had medium × medium combiners; IMLSB-428-2× BML-6 had low × high combiners; IMLSB-156-2 × BML-7 had medium × medium combiners; IMLSB-406-2 × BML-6 had high × high combiners which suggests that one good or medium general combiner must be involved to get the better cross combinations. The results are in general agreement with the findings of the (16) have reported that manifestation of high SCA effects in the cross combinations results due to interactionand accumulation of favourable alleles from the parents which are high or medium general combiners. Thus, the superiority of crosses which involves high × high and high × medium combiners as parents might have resulted from the accumulation and interaction of favourable alleles contributed by parents. The case of high SCA between high × low combiners could produce better segregants only if the additive genetic effects remain present in the good general combiners and complementary epistatic effects in the poor combiners and they act in the same direction to maximize desirable plant attributes (20). The high yield of such crosses (non-fixable) could be exploited through heterosis breeding.

**Estimation of economic heterosis:** Economic heterosis refers to the superiority of the $F_1$over the standard commercial check variety. Perusal of estimates of economic heterosis for grain yield (Table-4) revealed that six crosses *viz.* IMLSB-406-2 × BML-6 followed by IMLSB-1299-5× BML-7> IMLSB-1299-5 × BML-6> IMLSB-334B-2×BML-7> IMLSB-814-2× BML-6> IMLSB-334B-2 × BML-6depicted positive significant economic heterosis for grain yield over the standard commercial check DKC 9081. (19) also reported economic heterosis in maize for yield and its contributing traits.The tester used in the present study were parents of single crosses hybrid DHM-117, that hybrids was also used as one of the check. Therefore, the six cross combinations exhibited positive and significant heterosis are of importance. These promising cross combinations identified in this study could be utilized for future breeding work as well as for direct release after confirming the stability of their performances observed in this study. These crosses could be identified as the best performing hybrid as it not only exhibited maximum positive economic heterosis but also exhibited positive economic heterosis for many yield attributing traits. Hence these hybrids appear to be very promising combination for actual exploitation and could be recommended for testing in multi-location trials.

## CONCLUSION

It can be concluded that the highly significant differences observed among line and line× testers for all the traits suggest the possibility of selection for making improvement inthe yield and yield related traits. Among the 28 parents studied, seven lines showed the positive significant GCA for the grain yield which can be directly utilized in the hybrid development program. In this study, nine lines have been reported to have late anthesis and silking which can be utilized for the development of the late maturing hybrids which is desirable for the winter rabi maize to avoid the cold weather during flowering season. Out of the 28 lines, six and seven lines showed positive significant GCA for the ear length and ear girth respectively which can be utilized in the future breeding program to contribute towards development of hybrids with longer and thicker ear leading to higher yield. Moreover, nine crosses out of total 56 crosses showed significant desirable SCA for the grain yield in positive direction and six crosses showed economic heterosis over the standard check DKC 9081 which could be directly utilized for future breeding work as well as for direct release after confirming the stability of their performances to achieve quantum jump in the maize improvement program. Desirable inbred lines with good GCA and crosses with good SCA identified in the current study could be exploited in future breeding activity after confirming the repeatability of current results over years and locations.

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