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# Heterosis analysis in pearl millet hybrids [*Pennisetum glaucum* (L.) R.Br.]

**M.R. Reshma Krishnan*, M.S. Patel[1] and R.A. Gami[2]**

Department of Genetics and Plant Breeding, Chimanbhai Patel College of Agriculture,
Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar-385 506, Gujarat, India.
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## ABSTRACT

The present investigation was carried out with the objective to ascertain the magnitude of heterosis of 35 hybrids resulted from Line x Tester mating design of seven CMS lines and five restorer tester parents along with the standard check (GHB 558). The highly significant analysis of variance for parents and hybrids among all traits revealed that, the existence of an appreciable amount of genetic variability in the experimental material. In practical plant breeding, the heterosis measured over standard check is more realistic and is of more practical importance. In the present study, heterosis has been estimated over the better parent and popular check hybrid. The aim of present study was to find out the best combination of parents giving a high degree of heterobeltosis and standard heterosis and its exploitation to get better transgressive segregants and characterization of parents for their prospects for further use in the breeding programme of pearl millet. The mean sum of due to parents vs. hybrids for most of the traits is significant for heterosis. The degree of heterosis varied from the cross to cross for all the 10 characters. Considerable high heterosis in certain crosses and low in others revealed that the nature of gene action varied with the genetic makeup of the parents. The hybrids *viz*., ICMA 07777 x 18488 R, ICMA 06777 x 18805 R and ICMA 96222 x 18488 R showed high per se performance with highly significant positive heterobeltiosis, standard heterosis for grain yield per plant.

**Key words:** Heterosis, Heterobeltiosis, Line x Tester, Pearl millet, Transgressive segregants.

## INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] (also known under synonyms: *P. americanum* (L.) Leeke or *P. typhoides* (Burm.) Stapf and C.E. Hubb.) is an important millet crop of traditional farming systems in tropical and subtropical Asia and sub-Saharan Africa. This nutri-millet abode vitamins, minerals, amino acids such as tryptophan, threonine, arginine, and lysine, phyto-chemicals and antioxidants that can help to eschew the plethora of nutritional deficiency diseases. Pearl millet cultivation can keep dry lands productive and ensure future food and nutritional security. It is the fourth most important cereal crop in India, after rice, wheat and sorghum, where it is widely grown in the states of Rajasthan, Maharashtra, Gujarat and Haryana where the food security of the poorest population depends vastly on pearl millet production. Taxonomically, pearl millet belongs to the family *of Panicoidae, genus Pennisetum*. Cultivated pearl millet belongs to the section *Penicillaria*. The cultivated crop and its wild progenitors are an annual, sexual diploid (2n = 14), and its chromosomes are designated as the A genome (Jauhar and Hanna 1998). Pearl millet possesses seven pairs of large chromosomes and a haploid DNA content of 2.5pg (Bennet and Smith 1976). Cultivated pearl millet is a cross-pollinated annual $C_4$ crop with a protogynous flowering habit and can be intercrossed with a large group of wild relatives (Jauhar 1998).

One of the close relatives is a Napier grass (*Pennisetum purpureum*) which is sexual perennial tetraploid (2n = 4x = 28) with chromosomes A‘ and B. P. *purpureum* readily hybridizes with cultivated crop species and therefore allows continuous gene flow into domesticated gene pools (Harlan 1975).

The discovery of $A_1$ cytoplasmic-nuclear male sterility (CMS) at Tifton, Georgia, USA (Burton 1958) initiated the era of hybrid cultivar develop-ment in pearl millet [*Pennisetum glaucum* (L). R. Br.], which led to the release of the first grain hy-brid in India in 1965 (Athwal 1965). Since then hundreds of commercial hybrids, all of them based on the $A_1$-CMS system, have been developed and released or commercialized. This dependence on single cytoplasm makes the pearl millet hybrid seed industry vulnerable to disease and insect-pest epidemics. This concern necessitated the search for new sources of CMS in pearl millet (Rai *et al*. 2006). Hanna (1989) identified an $A_4$ CMS system at Tifton, Georgia, USA in a wild grassy *Pennisetum glaucum* (L.) R. Br. subsp. *monodii* (Maire) Brunken. Also, an $A_5$ CMS system was identified in a pearl millet gene pool. Among the various CMS systems reported so far, $A_4$ and $A_5$

*Corresponding author’s e-mail: reshmakrishnan086@gmail.com
[1]Center for crop improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar-385 506, Gujarat, India.
[2]Maize Research Station, Sardarkrushinagar Dantiwada Agricultural University, Bhiloda-383 245, Gujarat, India.

CMS systems were found to have the most stable male sterility (Rai *et al*. 2006). Further, the frequency of maintainers is much higher for the $A_4$CMS system than for the $A_1$ CMS system, and almost all lines are maintainers of the $A_5$ CMS system (Rai *et al*. 2006). Hence, these two CMS sources provide a much greater opportunity for the genetic diversi-fication of A-lines and thus a greater opportunity for diversifying the genetic base of hybrids provided more diversity is generated in the restorer lines. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, developed and dis-seminated 31 diverse and productive A-lines based on the $A_4$ CMS system during the period 1996–2004 (Rai *et al*. 2006). In this research topic, as female parent, CMS lines were used.

In the pearl millet, spectacular achievements in increasing grain yield have been obtained through exploitation of hybrid vigour in India. Identification of desirable genotypes in a mixed or base population is one of the main objectives of plant breeders. For a successful heterosis breeding programme in any crop, the evidence of the presence of significant heterotic effects in the hybrid is an important pre-requisite.

## MATERIALS AND METHODS

The experiment was carried out using seven lines and five testers during *kharif* 2015 at Centre for Crop Improvement, S. D. Agricultural University Sardarkrushinagar. Parent material was sown during *kharif* of 2015 to carryout crossing based on line × tester analysis. The crosses were carried out between seven female maintainer lines (ICMA -06777, ICMA -07777, ICMA-96222, ICMA-97111, ICMA-98444, ICMA-04999 and ICMA-05444) and five male restorer lines (J18488-R, 18587-R, 18805–R, 17369-R and 17548-R). Being protogynous, immediately after emergence of panicle, the style start protrudes and they remain receptive for two to three days. The inflorescence to be used as female or male is covered with butter paper bag. From male plant, the fresh pollen will be visible as yellow powder in the transparent butter paper bags, which can be collected by tapping the inflorescences. The pollination is carried out by removing the butter paper bag inflorescences with completely emerged stigma, dusting the pollen followed by re-bagging.

A set of 48 genotypes comprising of 12 parents (7 female and 5 male parents) and their 35 $F_1$‘s with a standard check GHB 558 were sown in randomized block design with three replications in 2016 summer. Each and every hybrids and parents represented one row having 4 meters length spaced at 45 cm between rows and 15 cm apart from plant to plant within row.

The observations were recorded on five randomly selected competitive plants of each genotype in each replication for various characters *i.e.* days to flowering, days to maturity, plant height (cm), number of effective tillers per plant, ear head length (cm), ear head girth(mm), test weight (g), grain yield per plant (g), harvest index (%) and protein content (%). Days to flowering (DF) on the basis of 50% plants of each genotype flowered, days to maturity (DM) on the basis of 80% plants of each genotype matured were recorded. The protein content (PC) was estimated in percentage by using NIR spectroscopy technique. The replication wise mean values were used in statistical analysis. The data were subjected to analysis of variance as per the procedure suggested by Panse and Sukhatme (1978). The hybrid performance (%) tested in comparison with mean value of two parents (Relative heterosis/RH), better parent (heterobeltiosis/BPH) and standard check (Standard heterosis/SH) suggested by Fonseca and Patterson (1968) and Meredith and Bridge (1972) respectively.

## RESULTS AND DISCUSSION

In practical plant breeding, the heterosis measured over the better parent is more realistic and is of more practical importance. However, the commercial usefulness of a hybrid would primarily depend on its performance in comparison with the best commercial variety/hybrid of the concerned crop species. Hence, in the present study, heterosis has been estimated over the better parent and standard heterosis. Thus, the aim of heterosis analysis in the present study was to find out the best combination of a parent giving a high degree of heterobeltosis and standard heterosis and its exploitation to get better transgressive segregants and characterization of parents for their prospects for further use in the breeding programme of pearl millet. In the present study, the degree of heterosis varied from the cross to cross for all the 10 characters. Considerable high heterosis in certain crosses and low in others revealed that the nature of gene action varied with the genetic makeup of the parents.

Among the parents, the lines ICMA 96222, ICMA 98444 and 17548 R were promising for grain yield. Among seven females parents, ICMA 96222 was found to be promising for early flowering and maturity and harvest index. The female ICMA 07777 was promising for plant height, the number of effective tillers per plant, ear head length, ear head girth and test weight. Whereas, among five males, the male *viz*., 17548 R was promising for grain yield per plant, days to maturity, harvest index and protein content. The male parent 18488 R is promising for the number of effective tillers per plant, ear head length, ear head girth, test weight and protein content. Out of 35 hybrids, the hybrids ICMA 96222 x 18488 R, ICMA 07777 x 18488 R and ICMA 06777 x 18805 R were identified for high *per se* performance for grain yield per plant. Among them the hybrid ICMA 96222 x 18488 was also identified with a high *per se* performance for ear head length, test weight, and harvest index.

The analysis of variance explaining mean squares due to genotypes were found to be highly significant for all the characters are presented in Table 1. Partitioning of the genotypes variance into parents, hybrids and parents vs. hybrids revealed the parents as well as hybrids exhibited significant differences for all the traits, indicating the existence of the appreciable amount of genetic variability in the experimental material. The comparison of parents vs. hybrids were highly significant for all the traits except protein content indicating that the presence of heterosis.

The aim of heterosis analysis in the present study was to find out the best combination of a parent giving a high degree of heterobeltosis and standard heterosis and its exploitation to get better transgressive segregants and characterization of parents for their prospects for further use in the breeding programme of pearl millet. The mean sums of squares due to parents vs. hybrids for most of the traits were found to be significant for heterosis.

Heterosis over mid-parent, better parent and standard heterosis were recorded positive in the desired direction for all the characters. The estimates of heterosis over the mid-parent value (relative heterosis), over better parent (heterobeltiosis) and over standard check *i.e.,* GHB 558 (standard heterosis/economic heterosis) in different $F_1$ hybrids expressed as a percentage for different characters are given in Table 2. It may be mentioned here that for calculation of heterobeltiosis for days to flowering, days to maturity and plant height, the low scoring parent was considered as the better parent.

For days to flowering, out of 35 hybrids, 19 hybrids showed significant negative heterosis in the desired direction and 11 hybrids showed significant negative relative heterosis. The cross ICMA 04999 × 17369 R exhibited desirable heterobeltiosis. Similar results were reported by Chavan and Nerkar (1994), Yadav *et al* (2000), Manga and Dubey *et al* (2004), Yadav *et al* (2006) and Piyanka (2015).

Out of 35 crosses, seven hybrids, including, ICMA 04999 × 17369 R followed by ICMA 04999 × 18805 R and ICMA 98444 × 17548 R exhibited negative standard heterosis over check hybrid GHB 558. The results were supported by the studies of Kushwah and Singh (1992), Kulkarni *et al.* (1993), Karale *et al.* (1997), Katti *et al.* (1997), Yadav (2006) and Pawar *et al* (2015).

For days to maturity, the perusal of estimates of better parent heterosis indicated that 27 hybrids out of 35 showed significant negative heterosis in the desired direction. Out of 35 crosses, 19 hybrids including ICMA 04999 × 18805 R showed significant heterosis in a negative direction over check hybrid GHB 558 (Table 2). These results were in agreement with the studies conducted by Kushwah and Singh (1992), Yadav *et al* (2000a) and Manga and Dubey (2004).

For plant height, out of 35 hybrids, 7 hybrids showed significant negative heterobeltiosis in the desired

**Table 1:** Analysis of variance (Mean square) for parents and hybrids for seed yield and its component characters in pearl millet.

| Source of variation | d.f | Days to flowering | Days to maturity | Plant height (cm) | No. of effective tillers per plant | Earhead length (cm) | Earhead girth (mm) | Test weight (g) | Grain yield per plant (g) | Harvest inde× (%) | Protein content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Replication** | 2 | 3.13 | 1.68 | 866.36 | 0.03 | 1.65 | 3.51 | 0.35 | 9.53 | 2.89 | 0.70 |
| **Genotype** | 46 | 71.08** | 86.15** | 5163.65** | 1.00** | 38.68** | 72.66** | 5.10** | 46.63** | 169.69** | 3.36** |
| **Parents** | 11 | 73.48** | 80.13** | 6504.91** | 0.91** | 26.50** | 61.00** | 6.32** | 15.07** | 170.07** | 3.91** |
| **Female** | 6 | 50.54** | 96.08** | 891.96* | 0.40** | 26.79** | 83.30** | 7.44** | 21.47** | 125.04** | 3.22** |
| **Male** | 4 | 57.43** | 53.43** | 217.37 | 1.89** | 32.08** | 42.56** | 5.38** | 8.95 | 226.64** | 4.93** |
| **Female vs. male** | 1 | 275.33** | 91.21** | 65332.80** | 0.03 | 2.47 | 0.96 | 3.39** | 1.11 | 213.99** | 3.96** |
| **Parents vs. hybrids** | 1 | 41.46** | 124.47** | 41908.36** | 0.45** | 133.51** | 283.43** | 1.75** | 123.42** | 39.97* | 0.31 |
| **hybrids** | 34 | 71.17** | 86.97** | 3648.98** | 1.05** | 39.83** | 70.23** | 4.81** | 54.59** | 173.38** | 3.27** |
| **Error** | 92 | 1.54 | 0.96** | 333.65 | 0.02 | 2.87 | 2.30 | 0.16 | 6.15 | 7.74 | 0.25 |

* and** indicates significant at P = 0.05 and P = 0.01 levels respectively.

**Table 2:** Estimates of heterosis in percentage in $F_1$ hybrid over standard check GHB 558 for the following characters in pearl millet.

| Genotypes | Days to flowering | Days to maturity | Plant height | No. of effective tillers/ plant | Earhead length | Earhead girth | Test weight | Grain yield per plant | Harvest index | Protein content |
|---|---|---|---|---|---|---|---|---|---|---|
| **ICMA 06777 × 18488 R** | 27.89 ** | 11.48 ** | 4.01 | 15.07 ** | 22.63 ** | 8.49 * | 19.09 ** | -11.42 | -20.67 ** | -18.99 ** |
| **ICMA 06777 × 18587 R** | 24.49 ** | 8.20 ** | -53.60 ** | 10.96 * | -4.43 | 11.80 ** | 1.46 | -10.33 | -17.12 ** | -2.79 |
| **ICMA 06777 × 18805 R** | 25.17 ** | 5.33 ** | -7.14 | 13.70 * | 16.02 * | 22.75 ** | 17.76 ** | 25.78 ** | -2.64 | -9.58 |
| **ICMA 06777 × 17369 R** | 25.85 ** | 6.97 ** | -52.97 ** | 20.55 ** | -16.85 * | 21.25 ** | -2.59 | -5.1 | -1.09 | 4.32 |
| **ICMA 06777 × 17548 R** | 20.41 ** | 3.28 ** | -9.42 | 42.47 ** | -25.51 ** | -16.79 ** | -14.52 ** | -12.03 * | -21.12 ** | 11.88 * |
| **ICMA 07777 × 18488 R** | 10.20 ** | 2.87 ** | 1.93 | 31.51 ** | 30.87 ** | 13.62 ** | 33.67 ** | 32.56 ** | -33.64 ** | -2.02 |
| **ICMA 07777 × 18587 R** | 19.73 ** | 9.02 ** | -5.66 | -6.85 | 1.72 | -0.58 | -3.89 | -12.27 * | -20.90 ** | -5.78 |
| **ICMA 07777 × 18805 R** | -1.36 | -6.56 ** | -9.35 | 45.21 ** | 18.43 ** | 20.03 ** | 14.03 ** | -9.2 | -17.47 ** | -3.88 |
| **ICMA 07777 × 17369 R** | 23.81 ** | 6.97 ** | -50.97 ** | 17.81 ** | -6.38 | -2.47 | -4.67 | -11.82 * | -16.43 ** | -17.05 ** |
| **ICMA 07777 × 17548 R** | 19.73 ** | 1.64 | -29.03 ** | -5.48 | 0.16 | 7.39 | 5.28 | -9.01 | -12.17 ** | -8.61 |
| **ICMA 96222 × 18488 R** | 6.12 ** | 0 | -2.64 | 0 | 44.41 ** | 5.31 | 23.04 ** | 22.37 ** | 6.76 | 13.45 ** |
| **ICMA 96222 × 18587 R** | 12.24 ** | -1.64 | 0.39 | -12.33 * | 35.75 ** | 9.03 * | 28.48 ** | 20.34 ** | 3.45 | 16.48 ** |
| **ICMA 96222 × 18805 R** | 3.4 | -3.69 ** | -2.39 | 6.85 | 9.92 | -2.18 | 12.22 ** | -13.30 * | 4.95 | 1.25 |
| **ICMA 9622 × 17369 R** | 4.76 * | -5.33 ** | -0.67 | -26.03 ** | 34.17 ** | -16.28 ** | 10.05 ** | -4.54 | 10.78 * | -15.23 ** |
| **ICMA 96222 × 17548 R** | 7.48 ** | -9.84 ** | -8.08 | -30.14 ** | 2.99 | -3.88 | 18.24 ** | -6.37 | 7.56 | 4.24 |
| **ICMA 97111 × 18488 R** | 8.84 ** | -4.10 ** | 2.88 | 19.18 ** | 31.18 ** | -10.66 ** | 18.31 ** | -11.41 | 4.47 | -15.56 ** |
| **ICMA 97111 × 18587 R** | -0.68 | -9.43 ** | -1.27 | 71.23 ** | 0.28 | -5.81 | 9.53 ** | -8.03 | 0.87 | 1.21 |
| **ICMA 97111 × 18805 R** | -2.04 | -9.43 ** | -14.66 | 23.29 ** | 2.83 | 0.86 | 4.15 | -11.2 | 1.8 | 22.99 ** |
| **ICMA 97111 × 17369 R** | -0.68 | -10.25 ** | -11.74 | -17.81 ** | -9.54 | -10.56 ** | 11.92 ** | -22.29 ** | -10.38 * | -13.05 * |
| **ICMA 97111 × 17548 R** | 9.52 ** | -4.51 ** | -12.02 | 15.07 ** | 2.13 | -20.86 ** | 8.98 ** | -19.81 ** | -17.13 ** | -5.17 |
| **ICMA 98444 × 18488 R** | 10.20 ** | -1.64 | 1.37 | -28.77 ** | 26.93 ** | 0.22 | 19.57 ** | -9.74 | -9.41 * | 3.35 |
| **ICMA 98444 × 18587 R** | 23.81 ** | 1.23 | -0.91 | 6.85 | 8 | 10.55 ** | 10.17 ** | -5.53 | -11.88 ** | -10.79 * |
| **ICMA 98444 × 18805 R** | 0.68 | -6.97 ** | -10.3 | -24.66 ** | 8.66 | 17.37 ** | 1.85 | 1.2 | -2.88 | 10.75 * |
| **ICMA 98444 × 17369 R** | 11.56 ** | -0.82 | -47.21 ** | -1.37 | -25.20 ** | -21.72 ** | -16.88 ** | -13.00 * | -19.98 ** | 6.42 |
| **ICMA 98444 × 17548 R** | -2.04 | -9.43 ** | -28.26 ** | 36.99 ** | 10.02 | 4.1 | -4.67 | -12.57 * | -34.43 ** | 27.92 ** |
| **ICMA 04999 × 18488 R** | 10.20 ** | -3.69 ** | -12.27 | 35.62 ** | 39.69 ** | -22.07 ** | -0.65 | -8.69 | -22.26 ** | -8.81 |
| **ICMA 04999 × 18587 R** | 4.76 * | -4.92 ** | -12.23 | 34.25 ** | 19.06 ** | -6.4 | -10.27 ** | -8.61 | -33.64 ** | 4.85 |
| **ICMA 04999 × 18805 R** | -3.4 | -13.93 ** | -17.05 * | 1.37 | -3.46 | -26.93 ** | -12.22 ** | -14.55 * | -49.38 ** | -10.99 * |
| **ICMA 04999 × 17369 R** | -4.08 | -10.66 ** | -12.21 | -20.55 ** | 8.72 | -22.38 ** | -6.51 * | -14.48 * | -29.54 ** | -0.89 |
| **ICMA 04999 × 17548 R** | 15.65 ** | -10.25 ** | -63.51 ** | -15.07 ** | 16.54 * | -32.45 ** | -7.10 * | -10.98 | -22.63 ** | -3.88 |
| **ICMA 05444 × 18488 R** | 10.20 ** | -2.05 * | -3.87 | -12.33 * | 18.11 ** | 22.78 ** | -5.51 | -10.96 | -9.35 * | 15.60 ** |
| **ICMA 05444 × 18587 R** | 18.37 ** | -0.82 | 4.32 | -9.59 | 23.20 ** | 11.37 ** | -2.66 | -14.20 * | -19.69 ** | -0.28 |
| **ICMA 05444 × 18805 R** | 22.45 ** | 6.15 ** | -7.7 | 34.25 ** | -3.62 | 18.78 ** | 2.69 | -11.31 | -23.55 ** | 34.46 ** |
| **ICMA 05444 × 17369 R** | 2.04 | -7.38 ** | -4.32 | 24.66 ** | 10.24 | -3.66 | 0.52 | -10.33 | -23.28 ** | 3.76 |
| **ICMA 05444 × 17548 R** | -0.68 | -7.79 ** | -0.81 | 21.92 ** | 0.83 | -0.18 | 1.69 | -2.15 | -32.01 ** | -2.95 |
| **S.Em. ±** | 1.0135 | 0.8014 | 14.9143 | 0.1321 | 1.38 | 1.24 | 0.33 | 2.02 | 2.27 | 0.40 |
| **Range** | -0.68 to 27.89 | -13.93 to 11.48 | -63.51 to 4.32 | -30-.14 to 71.23 | -25.51 to 44.41 | -32.45 to 22.78 | -16.88 to 33.67 | -22.29 to 32.56 | -49.38 to 10.78 | -18.99 to 34.46 |
| **Significant heterosis** | **24** | **28** | **8** | **27** | **17** | **22** | **21** | **15** | **25** | **15** |
| **No. of +ve significant** | **24** | **9** | **0** | **18** | **14** | **12** | **15** | **4** | **1** | **8** |
| **No. of -ve significant** | **0** | **19** | **8** | **9** | **3** | **10** | **6** | **11** | **24** | **7** |

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

direction and 8 crosses exhibited significant negative standard heterosis. The cross ICMA 04999 × 17548 R (-63.51 %) exhibited desirable standard heterosis followed by ICMA 06777 × 18587 R (-53.60%) and ICMA 06777 × 17369 R (-52.97%).These results were in agreement with the reports of Chavan and Nerkar (1994), Kushwah and Singh (1992), Yadav (1999) and Yadav *et al.* (2006).

The data for the number of effective tillers per plant (Table 2) revealed, that out of 35 crosses 6 crosses showed significant positive heterobeltiosis over their respective better parent. For standard heterosis, 18 hybrids showed significant positive heterosis over check hybrid GHB 558. Highest desirable standard heterosis was the crosses ICMA 97111 × 18587 R followed by ICMA 07777 × 18805 R, ICMA 06777 × 17548 R and ICMA 98444 × 17548 R. Azahaguvel *et al.*, (1998), Manga and Dubey (2004), Arulselvi *et al* (2006), Vetriventhan *et al.* (2008) and Priyanka (2015) also reported the same results.

For ear head length (Table 2), out of 35 crosses, 11 crosses manifested significant positive heterobeltiosis, 14 crosses manifested significant positive standard heterosis over check hybrid GHB 558. The cross ICMA 96222 × 18488 R showed desirable standard heterosis followed by ICMA 04999 × 18488 R and ICMA 96222 × 18587 R. Azhaguvel *et al.* (1998) and Vetriventhan *et al.* (2008) also supported these results.

For ear head girth (Table 2), out of 35 crosses, 14 crosses showed significant positive heterobeltiosis in the desired direction and 12 hybrids showed positive standard heterosis over check hybrid GHB 558. The crossICMA 05444 × 18488 R showed high significant positive standard heterosis over standard check GHB-558, followed by ICMA 06777 × 18805 R, ICMA 06777 × 17369 R. The results were supported by the results obtained by Dutt and Bainiwal (2005) and Bachkar *et al.* (2014).

For test weight (Table 2), out of 35 hybrids, 9 hybrids showed significant positive heterobeltiosis. For standard heterosis out of 35 hybrids, 15 hybrids exhibited significant positive standard heterosis for this trait. The hybrid ICMA 07777 × 18488 R exhibited desirable heterosis followed by ICMA 96222 × 18587 R and ICMA 96222 × 18488 R manifested significant positive standard heterosis over check hybrid GHB 558. A similar type of results was also reported by Azhaguvel *et al.* (1998) and Vetriventhan *et al.* (2008).

The hybrids *viz.*, ICMA 07777 x 18488 R, ICMA 06777 x 18805 R and ICMA 96222 x 18488 R showed high *per se* performance with high significant positive heterobeltiosis standard heterosis for grain yield per plant (Table 2). The result of heterosis was in accordance with the studies conducted by Yadav (2006) and Pawar *et al.* (2015) for days to flowering. For days to maturity, as reported by Yadav *et al.* (2000) and Manga *et al.* (2004). For ear head length and ear, head girth was in accordance with the studies of, Manga *et al.* (2004) and Vetriventhan*et al.* (2008). For grain yield, reported by Bachkar *et al.* (2014), Bhuri Singh *et al.* (2015) and Priyanka (2015).

For harvest index (%) out of 35 crosses, 11 crosses manifested significant positive relative heterosis (Table 2). Out of 35 hybrids, 2 hybrids showed significant positive heterobeltiosis in the desired direction and 1 hybrid recorded positive significant standard heterosis. The hybrid ICMA 96222 × 17369 R exhibited desirable standard positive significant heterosis over check hybrid GHB 558. The findings of Nijhawan and Yadav (1993), Deore *et al.* (1997) and Manga and Dubey (2004), Jethva *et al.* (2012) and Bhurisingh *et al.* (2015) were supported the results.

The perusal of estimate of relative heterosis for protein content (Table 2) indicated that 10 hybrids showed significant positive heterosis. Out of 35 crosses, 3 crosses showed significant positive heterobeltiosis. The cross ICMA 05444 × 18805 R exhibited positive standard heterosis followed by ICMA 98444 × 17548 R and ICMA 97111 × 18805 R exhibited significant positive standard heterosis over check hybrid GHB 558 for this trait.

## CONCLUSION

The cross ICMA 07777 × 18488 R showed high *per se* performance, significant heterobeltiosis, standard heterosis which can produce desirable transgressive segregants in subsequent generations, also used for exploiting commercial cultivation. The cross ICMA 06777 × 18805 having high *per se* performance, significant positive heterobeltiosis and standard heterosis. These above mentioned crosses indicate their potential as parents in heterosis programme and to obtain desirable transgressive segregants in $F_2$ or subsequent generation, may be used for development of pollinated CMS line as female parent and pollen fertility restorer line as male parent for future breeding programme of grain yield per plant, production of high yielding hybrids and for commercial purpose.

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