HETEROSIS OF PEARL MILLET [*Pennisetum glaucum* (L.) R. Br.] HYBRIDS INVOLVING DIVERSE CGMS LINES AND RESTORERS

ABSTRACT

The present investigation was carried out to estimate the extent and magnitude of heterotic effects of hybrids over better parent and standard check for grain yield, and its 13 attributing traits at Main Pearl Millet Research Station, J.A.U., Jamnagar during *kharif* 2023. The experimental material comprised of five female lines, ten male lines of pearl millet, their 50 hybrids developed by line × tester design and one standard check hybrid (GHB 1231). They were evaluated in randomized block design with three replications. The analysis of experimental variance revealed highly significant differences among the genotypes, parents and crosses for all the traits studied. The heterobeltiosis for grain yield per plant was laid between -56.38% ($JMSA_5$ 20212 × J-2580) to 97.86% ($ICMA_1$ 95444 × J-2372). while, the standard heterosis ranged from -53.87% ($JMSA_1$ 20209 × J-2637) and 82.97% ($JMSA_5$ 20212 × J-2637). The maximum value of standard heterosis was recorded for grain yield per plant by cross $JMSA_5$ 20212 × J-2637 (82.97%) followed by $ICMA_1$ 94555 × J-2580 (81.49%) and $JMSA_5$ 20212 × J-2562 (72.35%). Further exploitation of these crosses might produce desirable hybrid of pearl millet.

Key words: Pearl millet, heterosis, gene action, combining ability.

INTRODUCTION

"Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a key member of the Poaceae (Gramineae) family and the *Pennisetum* genus. Commonly known as bajra, bajri, cattail millet, spiked millet, and bulrush millet, this crop is highly cross-pollinated and features protogynous flowering with wind-borne pollination. These traits facilitate hybrid development and the commercial benefits of heterosis. In India, pearl millet is a major staple food, ranking fourth in acreage after rice, wheat, and sorghum, and it is the sixth most important cereal globally. It occupies an area of 70.08 lakh hectares with an average production of 95.31 lakh tonnes and productivity of 1360 kg/ha in India during 2023-24" (Anon., 2023a). The total area of pearl millet in the Gujarat state is 5.19 lakh hectares and production of 13.04 lakh tones with average productivity of 2511 kg/ha in 2023-24 (Anon., 2023b). Believed to have originated in tropical Western Africa around 4000 years ago, pearl millet is diploid, with a chromosome number of 2n=2x=14. Exploitation of hybrid vigor is considered to be one of the outstanding achievements in this crop. Cross pollinated nature and availability of male sterile lines in crop had made of its feasible to exploit hybrid vigor on commercial scale. Therefore, to identify better heterotic response for grain yield and its components characters are of paramount important.

MATERIALS AND METHODS

The experimental material comprised of five CGMS (Female) lines viz., $ICMA_1$ 94555, $ICMA_1$ 95444, $ICMA_1$ 11222, $ICMA_1$ 20209, $JMSA_5$ 20212; ten restorer (male) lines of pearl millet viz., J-2372, J-2496, J-2562, J-2597, J-2569, J-2580, J-2634, J-2637, J-2639, J-2641 and their 50 F_1s hybrids developed by line × tester design and one standard check hybrid (GHB 1231). They were evaluated in randomized block design (RBD) with three replications at Main Pearl Millet Research Station, J.A.U., Jamnagar during *kharif* 2023. Row to row and plant to plant spacing was of 60 cm × 15 cm. To produce a better crop, the region's recommended agronomic practices were followed. The observations were recorded on five randomly selected plants expect the plot basis from parents and crosses for 12 characters *viz.*, days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant, grain yield per plant, threshing index and harvest index. Mean data were used for statistical analysis. The variance analysis for each character was performed using the method described by Panse and Sukhatme (1995). Heterosis was estimated in term of two parameters, *i.e*. heterobeltiosis (heterosisover better parental value) as suggested by Fonseca and Patterson (1968) and standard heterosis (heterosis over standard check) as suggested by Meredith and Bridge (1972).

RESULTS AND DISCUSSION

The analysis variance revealed highly significant differences among genotypes for all traits, demonstrating the significant degree of variability present in the materials studied. "The genotypic variance was further partitioned into different source of variances. The differences among parents and crosses were also found highly significant for all characters under investigation. Differences due to parents *vs* crosses were also found highly significant for all the characters under studied except for number of effective tillers per plant and earhead length, indicating the significant difference between the parents and crosses for these important characters The mean squares due to females were significant for all the characters under studied while, the male parents differed significantly for all the 12 characters studied except for days to maturity. These were indicated the presence of genetic diversity in both the female and male parents" (Meredith and Bridge, 1972). The males and females were completely differed from each other for plant height, number of effective tillers per plant, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant, grain yield per plant, threshing index and harvest index, that indicated significance of mean squares due to females *vs* males. Magnitude of variability was higher earhead length, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant, grain yield per plant, threshing index and harvest index in comparison to females. This indicated that the more contribution of males in total variance for these characters, while, the magnitude of variability was higher with female for the rest of the traits under studied to the total variance (Table 1).

A number of crosses depicted significant heterosis over better parent and standard check in favourable direction for grain yield per plant (24 g, 17 g), days to 50% flowering (20, 40), days to maturity (11, 32), plant height (21 cm, 34 cm), number of effective tillers per plant (3, 0), earhead length (8 cm, 12 cm), earhead diameter (15 cm, 11 cm), dry earhead weight per plant (23 g, 14 g), 1000-grain weight (19 g, 11 g), dry fodder yield per plant (21 g,13 g), threshing index (8 %, 2%) and harvest index (8%, 16%), respectively.

Grain yield per plant, plant height, earhead length, earhead diameter, 1000-grain weight, dry earhead weight per plant, dry fodder yield per plant, and harvest index all showed significant and high mangnitude of heterobeltiosis in the desired direction. The number of effective tillers per plant and the threshing index showed moderate heterosis over the better parent. A low level of heterobeltiosis was observed for days to 50% flowering and days to maturity. Pethani *et al.* (2004). made similar observations for grain yield per plant, plant height, earhead length, earhead diameter, 1000-grain weight, dry earhead weight per plant, and dry fodder yield per plant, Patil *et al.* (2008) for days to 50% flowering and days to maturity, Jethva *et al.* (2012) for threshing index and Patel *et al.* (2019) for number of effective tillers per plant.

The high amount of heterosis over standard check (GHB 1231) in desirable direction was found for grain yield per plant, plant height, earhead length, earhead diameter, dry earhead weight per plant, dry fodder yield per plant and harvest index. The moderate magnitude of standard heterosis was manifested days to 50% flowering, days to maturity and 1000-grain weight. The low magnitude of heterosis over standard check was noticed for number of effective tillers per plant and threshing index. The result conformed the earlier finding obtained by Valu (2006) for threshing index, Davda *et al.* (2012) for grain yield per plant, earhead length, earhead diameter, dry earhead weight per plant, dry fodder yield per plant and harvest index, Bachkar *et al.* (2014) for number of effective tillers per plant and Bhuri *et al.* (2015) for days to 50% flowering, days to maturity, plant height and 1000-grain weight in pearl millet.

As earliness is desirable character in case of pearl millet and days to 50% flowering is attributing character which influence on earliness. The range of heterobeltiosis for days to 50% flowering was -20.86% ($ICMA_1$ 11222 × J-2372) to 8.28% ($JMSA_5$ 20212 × J-2597). The standard heterosis ranged from -23.16% ($ICMA_1$ 95444 × J-2641) to 3.39% ($JMSA_5$ 20212 × J-2597). The range of heterobeltiosis for days to maturity was -14.72% ($ICMA_1$ 95444 × J-2641) to 4.30% ($JMSA_5$ 20212 × J-2597). The range of standard heterosis for days to maturity was between -25.10% ($ICMA_1$ 95444 × J-2641) to 1.52% ($JMSA_5$ 20212 × J-2597).

Plant height is regarded as a favorable character due to the important role of the stem in supplementing assimilates during grain development. The range of heterobeltiosis, for plant height was -17.89% ($JMSA_1$ 20209 × J-2569) to 40.62% ($JMSA_5$ 20212 × J-2641). The range of standard heterosis for plant height varied from -15.97% ($ICMA_1$ 11222 × J-2562) to 38.02% ($JMSA_1$ 20209 × J-2597).

The minimum and maximum values of heterobeltiosis for number of effective tillers per plant were -51.35% ($ICMA_1$ 11222 × J-2580) and 70.59% ($ICMA_1$ 94555 × J-2639), respectively. The values of heterosis over standard check lied between -60.54% ($ICMA_1$ 94555 × J-2562, $ICMA_1$ 11222 × J-2496 and $ICMA_1$ 11222 × J-2562) to -15.79% ($JMSA_5$ 20212 × J-2637) for number of effective tillers per plant. None of the crosses were found significant positive heterosis over standard check for number of effective tillers per plant.

Earhead directly affect on grain yield so, positive heterosis is desirable for this character. Heterobeltiosis values for earhead length were between -45.21% ($JMSA_5$ 20212 × J-2372) to 32.28% ($ICMA_1$ 95444 × J-2569). The standard heterosis ranged from -26.64% ($JMSA_5$ 20212 × J-2372) to 46.79% ($JMSA_5$ 20212 × J-2597). The heterosis over better parent for earhead diameter laid between -24.52% ($JMSA_1$ 20209 × J-2569) to 43.57% ($JMSA_5$ 20212 × J-2562). The estimates of standard heterosis ranged between -24.51% ($JMSA_1$ 20209 × J-2569) and 37.17% ($JMSA_5$ 20212 × J-2562) for this trait. The estimated heterosis over better parent varied from -51.35% (JMSA$_1$ 20209 × J-2496) to 92.23% (ICMA$_1$ 95444 × J-2372) for dry earhead weight per plant. Magnitude of standard heterosis varied from -47.42% (JMSA$_1$ 20209 × J-2637) to 80.64% (ICMA$_1$ 94555 × J-2580).

Considering heterosis over better parent, the variation for 1000-grain weight was from -17.85% (JMSA$_1$ 20209 × J-2569) to 31.43% (JMSA$_1$ 20209 × J-2634). Estimations of standard heterosis for 1000-grain weight was ranged from -16.67 (JMSA$_1$ 20209 × J-2562) to 20.33% (ICMA$_1$ 95444 × J-2569).

For dry fodder yield per plant, the estimates of heterobeltiosis ranged from -63.06% (JMSA$_5$ 20212 × J-2580) to 128.80% (ICMA$_1$ 95444 × J-2372). The range of heterosis over standard check for dry fodder yield per plant recorded from -56.47% (JMSA$_5$ 20212 × J-2639) to 71.47% (JMSA$_5$ 20212 × J-2562).

The range of heterosis over better parent for grain yield per plant was -56.38% (JMSA$_5$ 20212 × J-2580) to 97.86% (ICMA$_1$ 95444 × J-2372). The minimum and the maximum values of heterosis over standard check were -53.87% (JMSA$_1$ 20209 × J-2637) and 82.97% (JMSA$_5$ 20212 × J-2637), respectively for grain yield per plant.

The values of heterobeltiosis for threshing index ranged from -21.79% (ICMA$_1$ 11222 × J-2372) to 14.43% (ICMA$_1$ 94555 × J-2637). The range of standard heterosis for threshing index varied between -21.30% (ICMA$_1$ 11222 × J-2372) to 4.63% (JMSA$_5$ 20212 × J-2496). The range of heterobeltiosis for harvest index laid between -36.77% (ICMA$_1$ 11222 × J-2634) to 53.90% (ICMA$_1$ 94555 × J-2580). The range of heterosis over standard check for harvest index varied between -29.89% (ICMA$_1$ 11222 × J-2634) to 52.34% (ICMA$_1$ 94555 × J-2580).

The superior cross JMSA$_5$ 20212 × J-2637 was also exhibited significant standard heterosis in desired direction for the characters, *viz.*, days to 50% flowering, days to maturity, plant height, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant and harvest index, suggesting the greater role of these traits towards the grain yield. This cross had also registered significant heterobeltiosis in desirable for days to 50% flowering, days to maturity, earhead diameter, dry earhead weight per plant, 1000-grain weight and dry fodder yield per plant (Table 3).

The second highest heterotic cross ICMA$_1$ 94555 × J-2580 was recorded significant and positive heterosis over standard check for days to 50% flowering, days to maturity, plant height, dry earhead weight per plant and harvest index. This cross had also exhibited significant heterobeltiosis in desired direction for dry earhead weight per plant and harvest index (Table 3).

Similarly, the third highest heterotic cross JMSA$_5$ 20212 × J-2562 was recorded significant and positive heterosis over standard check for days to 50% flowering, days to maturity, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight and dry fodder yield per plant. This cross had also exhibited significant and positive heterosis over better parent for days to 50% flowering, earhead diameter, dry earhead weight per plant, 1000-grain weight and dry fodder yield per plant (Table 3).

On the other hand, the fourth highest heterotic cross ICMA$_1$ 95444 × J-2372 had significant standard heterosis in desirable for days to 50% flowering, days to maturity, plant height, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant and harvest index. The fourth highest heterotic cross, ICMA$_1$ 95444 × J-2372 was also recorded significant heterosis over better parent in desirable direction for plant height, earhead diameter, dry earhead weight per plant, 1000-grain weight and dry fodder yield per plant (Table 3).

Similarly, the fifth highest heterotic cross ICMA$_1$ 95444 × J-2569 was manifested significant standard heterosis in desirable direction days to 50% flowering, days to maturity, plant height, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight and dry fodder yield per plant. The same cross ICMA$_1$ 95444 × J-2569 had also noticed significant and positive heterobeltiosis for plant height, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight and dry fodder yield per plant (Table 3).

It is interesting to note that the high heterotic crosses for grain yield did not show high heterosis for all the yield component traits (Table 3). However, the current study found that significant and positive heterosis for grain yield was associated with significantly desirable heterosis for two or more yield-contribute traits. A similar cumulative heterotic effect of two or more yield components on grain yield of pearl millet was previously reported by Athoni *et al.* (2022) and Choudhary *et al.* (2023).

CONCLUSION

Based on the ongoing evaluation, three promising crosses, namely JMSA5 20212 × J-2637, ICMA1 94555 × J-2580, and JMSA5 20212 × J-2562, demonstrated superior per se performance, significant positive heterobeltiosis, and desirable standard heterosis for grain yield per plant and associated yield-related traits. Therefore, these elite crosses warrant further multi-environment evaluation to harness their potential for commercial exploitation via heterosis breeding. Additionally, they can be utilized in future breeding programs to identify high-yielding, superior inbred lines and to generate desirable transgressive segregants.

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Table 1: Analysis of variance for experimental design of different characters in pearl millet

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Earhead length (cm)	Earhead diameter (cm)
Replications	2	4.07	14.36	22.53	0.05	0.05	0.02
Genotypes	64	71.57**	62.70**	1514.50**	0.44**	56.75**	0.29**
Parents (P)	14	75.02**	56.57**	2013.40**	0.69**	65.81**	0.13**
Females	4	226.17**	168.60**	829.00**	0.72**	37.46**	0.13**
Males	9	15.35**	13.02	473.91**	0.71**	78.35**	0.12**
Females *vs* Males	1	7.51	0.40	20606.46**	0.33**	66.33**	0.27**
Crosses (C)	49	42.28**	42.62**	955.13**	0.38**	55.32**	0.33**
P. *vs* C.	1	1458.50**	1132.56**	21938.90**	0.06	0.14	0.16**
Error	128	2.97	14.36	49.91	0.02	2.50	0.01

Table 1 Cont…

Source	d.f.	Dry earhead weight (g)/plant	1000-grain weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/ plant	Threshing index (%)	Harvest index (%)
Replications	2	2.74	0.08	1.95	1.35	1.78	0.48
Genotypes	64	377.76**	2.09**	950.72**	275.01**	105.66**	48.15**
Parents (P)	14	141.63**	1.14**	561.57**	131.37**	180.85**	41.49**
Females	4	56.62**	0.55**	94.54*	58.69**	81.09**	29.93**
Males	9	189.61**	1.40**	780.76**	176.63**	234.41**	45.07**
Females *vs* Males	1	49.89**	1.07**	457.00**	14.72*	97.86**	55.47**
Crosses (C)	49	432.14**	2.29**	1013.53**	305.16**	78.94**	50.82**
P. *vs* C.	1	1018.97**	5.98**	3321.33**	808.95**	361.85**	11.04*
Error	128	5.53	0.10	29.05	3.14	3.60	2.08

*, ** Significant at 5% and 1% levels, respectively

Table 2: Range of heterobeltiosis (H1) and standard heterosis (H2) as well as number of crosses with specific heterotic effects for various traits in pearl millet

Sr. No.	Characters	Range of heterosis (%)		Number of crosses with significant heterosis			
		Heterobeltiosis (H1) (%)	Standard heterosis (H2) (%)	H1 (%)		H2 (%)	
				+Ve	-Ve	+Ve	-Ve
1	Days to 50 % Flowering	-20.86 to 8.28	-23.16 to 3.39	3	20	0	40
2	Days to maturity	-14.72 to 4.30	-25.10 to 1.52	0	11	0	32
3	Plant height (cm)	-17.89 to 40.62	-15.97 to 38.02	21	7	34	1
4	No. of effective tillers/plant	-51.35 to 70.59	-60.54 to -15.79	3	21	0	50
5	Earhead length (cm)	-45.21 to 32.28	-26.64 to 46.79	8	26	12	16
6	Earhead diameter (cm)	-24.52 to 43.57	-24.51 to 37.17	15	18	11	24
7	Dry earhead weight (g)/plant	-51.35 to 92.23	-47.42 to 80.64	23	14	14	26
8	1000-grain weight (g)	-17.85 to 31.43	-16.67 to 20.33	19	17	11	24
9	Dry fodder yield (g)/plant	-63.06 to 128.80	-56.47 to 71.47	21	12	13	24
10	Grain yield (g)/ plant	-56.38 to 97.86	-53.87 to 82.97	24	16	17	26
11	Threshing index (%)	-21.79 to 14.43	-21.30 to 4.63	8	15	2	16
12	Harvest index (%)	-36.77 to 53.90	-29.89 to 52.34	8	24	16	14

Table 3: Comparative study of five most heterotic crosses for grain yield per plant and their heterotic effect for component characters in pearl millet

Heterotic crosses	Grain yield/ plant (g)	Per cent heterosis for grain yield/plant over		sca effect for grain yield/ plant	Significant and desirable heterosis for component traits over	
		Better parent	Standard check (GHB 1231)		Better parent	Standard check (GHB 1231)
$JMSA_5$ 20212 × J-2637	44.83	82.46**	82.97**	13.01**	1,2,6,7,8,9	1,2,3,5,6,7,8,9,11
$ICMA_1$ 94555 × J-2580	44.47	48.33**	81.49**	20.53**	7,11	1,2,3,7,11
$JMSA_5$ 20212 × J-2562	42.22	71.87**	72.35**	14.58**	1,6,7,8,9	1,2,5,6,7,8,9
$ICMA_1$ 95444 × J-2372	41.95	97.87**	71.21**	13.15**	3,6,7,8,9	1,2,3,5,6,7,8,9,11
$ICMA_1$ 95444 × J-2569	40.84	49.39**	66.68**	6.35**	3,5,6,7,8,9	1,2,3,5,6,7,8,9

Where, *, ** Significant at 5% and 1% levels, respectively

1= Days to 50% flowering; 2= Days to maturity; 3= Plant height (cm); 4= No. of effective tillers/plant; 5= Earhead length (cm); 6= Earhead diameter (cm); 7= Dry earhead weight (g)/plant; 8= 1000-grain weight (g); 9= Dry fodder yield (g)/plant; 10= Threshing index (%) and 11= Harvest index (%)