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Exploitation of Heterosis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] for Yield and its Component Traits by Using Male Sterile Line

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A B S T R A C T

An experiment was conducted to study the mean performance and magnitude of heterosis of grain yield per plant and its thirteen yield attributing components in bajara. Experimental material consisting of 60 entries comprised of five male sterile lines and nine lines as well as their 45 hybrids developed through line x tester mating design along with standard check hybrid (GHB 732) were evaluated in a randomized block design with three replications. Perusal of mean data revealed that among females, JMSA 20102 and ICMA 04999 as well as among males, J-2508, J-2503 and J-2433 exhibited higher per se performance for grain yield per plant and its contributing traits. Considering per se performance of hybrids, the superior cross combinations for grain yield per plant were JMSA 20102 x J-2496 (19.56 g), JMSA 20102 x J-2479 (18.13 g) and JMSA 20102 x J-2500 (15.53 g).These cross combinations also had high per se performance for one or more yield contributing traits. Out of twenty eight significant heterotic cross combinations over better parents, nineteen showed positive and significant standard heterosis for grain yield per plant. Thus, the magnitude of heterosis toward the positive direction.The observed range of variation for grain yield per plant in hybrids was varied from 6.63g (ICMA 04999 x J-2510) to 19.56g (JMSA 20102 x J-2496). The general mean of hybrids (10.24 g) and parents (8.27 g) indicated that the hybrids gave higher grain yield as compared to the parents.

Keywords

Heterobeltiosis, Standard heterosis, Grain yield, Hybrids, Pearl millet.

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Introduction

Pearl millet (*Pennisetum glaucum* (L.). R.Br.) is annual, tillering diploid (2n = 14) crop. It belongs to family *Poaceae* and sub family *Paniceidae* and believed to be originated in Africa. Pearl millet is one of the important staple food crops of India ranking fourth in acreage next to rice, wheat, and sorghum and world's sixth important cereal food crop. However, it is primarily grown as forage crop in USA, Australia and South Africa. It is a highly cross pollinated crop with protogynous flowering and wind borne pollination mechanism. Being a C_4 species, it is endowed with a very high photosynthetic efficiency and more ability for dry matter production. Pearl millet is not only a quick growing short duration crop, but also found drought as well as heat tolerant and well adapted to different soil types. Because of its propensity for high dry matter production at high temperature, it has made a mark in tropics and sub-tropics. It is a drought resistant cereal having the maximum potentiality of grain production in adverse conditions. The better nutritive value of pearl millet grains appear from its protein, fat and mineral matters contents. It is also rich in vitamin A, vitamin B, thiamin as well as riboflavin contents and imparts substantial energy to the body with easy digestibility (Pal *et al.*, 1996). Apart from grain, it also supplies fair quality of dry matter (forage and stover) at harvest in large bulk; which is an important secondary product in low resource agriculture for animal feed. The improvement in this crop in India started as early as in 1920. However, the real breakthrough was made when the first and the most widely used cytoplasmic male sterile line *Tift* 23A (Burton, 1965) was utilized in development of grain hybrids in India. Extensive testing of single crosses with $23A_1$, Indian breeders could able to announce the release of 'HB–1' hybrid in 1965 (Athwal, 1965). Subsequently, availability of several cytoplasmic genetic male sterility systems have facilitated production and release of number of hybrids with increased drought tolerance as well as resistance to biotic stress and increased yield with greater efficiency in growth factor use (Burton, 1983; Andrews and Anand, 1992).

Materials and Methods

Experimental material consisting of 60 entries comprised of five male sterile lines (used as testers/females JSMA 101, JSMA 20102, ICMA 841, ICMA 89111, ICMA 04999) and nine inbred lines (used as lines/males J-2433, J-2479, J-2482, J-2500, J-2503, J-2507, J-2508, J-2510) and their 45 hybrids developed through line x tester mating design along with standard check hybrid (GHB 732) were evaluated in a randomized block design with three replications. The 45 crosses made in line x tester mating design during summer 2016 at Instructional Farm, College of Agriculture, JAU, Junagadh, which were evaluated during kharif 2016 at the Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. The data were recorded on five randomly selected plants per plot for each replications for the characters, viz., grain yield per plant, number of nodes on main stem, number of effective tillers per plant, plant height, ear head length, earhead girth, ear head weight, test weight, panicle index, total biomass per plant and harvest index. However, days to 50% flowering and days to maturity were recorded on plot basis.

The analysis of variance for experimental design was performed to test the significance of difference among the genotypes for the entire characters model as suggested by Panse and Sukhatme (1985). Heterobeltiosis was estimated as per the procedure given by Fonseca and Patterson (1968) using mean values for various characters over replications. Standard heterosis referred as the superiority of F1 over standard hybrid GHB 732 and was estimated as per the formula given by Meredith and Bridge (1972) for various characters over replications.

Results and Discussion

Considering *per se* performance of hybrids, more than 30 hybrids yielded higher than GHB 732 for seed yield per plant, of which two hybridsJMSA 20102 x J-2479 (18.13 g) and JMSA 20102 x J-2500 (15.53 g) yielded significantly higher than GHB 732.Five superior cross combinations for seed yield per plant placed in Table 1 based on *per se* performance. Among them, three cross combinations JMSA 20102 x J-2496, JMSA 20102 x J-2479 and JMSA 20102 x J-2500 had high *per se* performance along with significant heterobeltiosis and standard heterosis for seed yield per plant. These crosses also manifested the significant and desirable heterotic effects for one or more yield contributing traits (Table 1).

In the present study, heterosis over better parent (heterobeltiosis) and over standard check, GHB 732 (standard heterosis) was estimated. Several crosses exhibited conspicuous level of heterobeltiosis and standard heterosis for different characters are presented in Table 2 to 6. Range of heterosis as well as number of crosses exhibited significance positive as well as negative heterobeltiosis and standard heterosis are presented in Table 2 to 6.

With respect to the performance of hybrids for grain yield per plant, it was observed that twenty eight recorded significant heterobeltiosis, out of these, 19 hybrids had significant positive heterobeltiotic effect over standard check (GHB 732). The range of heterosis over better parent was from -41.93 to 112.68 per cent, while over standard check, it ranged from -23.17 to 112.60per cent.

The cross JSMA 20102 x J-2496 and depicted the significantly the highest and positive heterobeltiosis (112.68 %), standard heterosis (126.60%) as well as the highest seed yield per plant. JMSA 20102 x J-2479 and JMSA 20102 x J-2500 were the next two best crosses exhibited significant and positive heterobeltiosis (97.10 % and 68.84 %, respectively), standard heterosis (110.04% and 79.92 %, respectively). In such cases, expression of heterotic response over better and standard parents indicated the real superiority of hybrids from the commercial point of view. The high magnitude of heterobeltiosis was also observed by for other trait in pearl millet Aruselvi *et al.*, (2006), Umaretiya (2006), Patel (2008), Vetriventhan *et al.*, (2008), Shah (2009), Vagadiya *et al.*, (2010), Patel (2012), Jethva *et al.*, (2012) and Patel (2014).The medium magnitude of heterobeltiosis and standard heterosis were noticed for number of effective tillers per plant, plant height, ear head length, ear head weight and test weight. The medium magnitude of heterobeltiosis for these traits were also reported by Ramamoorthi and Govindarasu (2006), Aruselvi *et al.*, (2008), Patel (2008), Vetriventhan *et al.*, (2008), Shah (2009), Jethva *et al.*, (2012), Patel (2012) and Patel (2014).

Table.1 Promising hybrids for seed yield per plant with standard heterosis and heterobeltiosis and component traits showing significant desirable standard heterosis

Heterotic crosses	**Grain yield per plant (g)**	**Per cent heterosis of grain yield per plant over**		**Desirable heterosis for other traits over**	
		standard heterosis	**Heterobeltiosis**	**Better parent**	**Check (GHB 732)**
JMSA 20102 x J-2496	19.56	126.60**	112.68**	3,9	1,2,3,4,5,6,8
JMSA 20102 x J-2479	18.13	110.04**	97.10**	3,9	1,2,3,4,5,6,8
JMSA 20102 x J-2500	15.53	79.92**	68.84**	1,3,8	1,2,3,4,6,8
JMSA 101 x J-2503	13.60	57.57**	18.26**	1,3,5,6,7,8	1,3,4,5,6,7,8
ICMA 89111 x J-2433	12.70	47.14**	33.68**	1,3,5,8	1,2,3,4,5,6,7,8

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively

1 = Numbers of nodes on main stem
2 = Numbers of effective tillers per plant
3 = Plant height (cm)
4 = Earhead girth (cm)
5 = Earhead weight (g)
6 = Test weight (g)
7 = Panicle index (%)
8 = Total biomass per plant (g)
9 = Harvest Index

Table.2 Per cent heterobeltiosis (BP) and standard heterosis (SC) for grain yield per plant, days to 50% flowering, days to maturity in pearl millet

Sr. No.	Crosses	Grain yield per plant		Days to 50 % flowering		Days to maturity	
		BP	SC	BP	SC	BP	SC
1	JMSA 101 x J-2433	10.53	21.66**	-5.44	1.23	-4.76	-0.41
2	JMSA 101 x J-2479	36.44 **	18.53*	0.68	8.04*	-0.79	3.73
3	JMSA 101 x J-2482	8.17	2.78	0.00	7.29*	0.00	4.57
4	JMSA 101 x J-2496	12.00	-13.55	-2.72	4.38	-0.40	4.15
5	JMSA 101 x J-2500	-19.20 *	-22.01**	-8.16 *	-1.47	-8.73 *	-4.57
6	JMSA 101 x J-2503	18.26 **	57.57**	3.40	10.95**	0.79	5.39
7	JMSA 101 x J-2507	22.54 *	-1.16	6.20	0.00	4.72	1.24
8	JMSA 101 x J-2508	-3.96	40.54**	3.40	10.95**	2.38	7.06*
9	JMSA 101 x J-2510	10.44	6.60	2.04	9.48**	0.79	5.39
10	JMSA 20102 x J-2433	-12.95	-4.17	4.73	13.14**	1.17	7.88*
11	JMSA 20102 x J-2479	97.10 **	110.04**	-0.65	11.67**	-1.54	6.22
12	JMSA 20102 x J-2482	14.13	21.66**	2.03	10.23**	1.56	8.30*
13	JMSA 20102 x J-2496	112.68 **	126.60**	4.70	13.86**	-2.36	2.90
14	JMSA 20102 x J-2500	68.84 **	79.92**	3.97	14.61**	1.59	6.22
15	JMSA 20102 x J-2503	7.54	43.20**	0.00	11.67**	-0.38	9.12**
16	JMSA 20102 x J-2507	34.78 **	43.67**	13.95 **	7.29*	2.15	-1.24
17	JMSA 20102 x J-2508	-41.93 **	-15.06*	0.00	15.33**	-1.91	6.63*
18	JMSA 20102 x J-2510	20.29 *	28.15**	0.65	12.42**	2.27	12.04**
19	ICMA 841 x J-2433	-25.58 **	-18.07*	5.41	13.86**	-10.89 **	-4.98
20	ICMA 841 x J-2479	11.16	-3.47	-1.30	10.95**	-0.38	7.47*
21	ICMA 841 x J-2482	9.76	4.29	4.05	12.42**	-1.17	5.39
22	ICMA 841 x J-2496	-4.10	-19.69**	3.36	12.42**	-0.39	4.98
23	ICMA 841 x J-2500	48.80 **	43.67**	-3.31	6.57*	-7.54 *	-3.46
24	ICMA 841 x J-2503	-16.49 *	11.24	1.31	13.14**	-4.18	4.57
25	ICMA 841 x J-2507	35.48 **	13.55**	13.95 **	7.29*	6.87	3.32
26	ICMA 841 x J-2508	-40.63 **	-13.09	-5.06	9.48**	-3.05	5.39
27	ICMA 841 x J-2510	24.40 **	20.04**	-0.65	10.95**	-3.04	5.81
28	ICMA 89111 x J-2433	33.68 **	47.14**	3.38	11.67**	-0.78	5.81
29	ICMA 89111 x J-2479	20.44 *	4.63	-1.30	10.95**	-1.94	4.98
30	ICMA 89111 x J-2482	14.63	8.92	4.05	12.42**	-1.56	4.98
31	ICMA 89111 x J-2496	54.05 **	10.08	0.67	9.48**	-0.39	4.98
32	ICMA 89111 x J-2500	-8.00	-11.24	-0.66	9.48**	0.79	5.39
33	ICMA 89111 x J-2503	6.96	42.51**	-0.65	10.95**	1.16	8.30*
34	ICMA 89111 x J-2507	51.67 **	22.36**	11.63 **	5.10	3.43	0.00
35	ICMA 89111 x J-2508	-16.89 **	21.66**	-0.65	12.42**	-0.39	6.63*
36	ICMA 89111 x J-2510	28.00 **	23.51**	-1.31	10.23**	-3.49	3.32
37	ICMA 04999 x J-2433	9.86	20.85**	3.38	11.67**	3.70	4.57
38	ICMA 04999 x J-2479	56.02 **	45.17**	5.84	18.99**	3.70	4.57
39	ICMA 04999 x J-2482	7.72	2.32	4.05	12.42**	3.70	4.57
40	ICMA 04999 x J-2496	33.20 **	23.98**	3.36	12.42**	-0.41	0.41
41	ICMA 04999 x J-2500	-4.76	-8.11	9.93 **	21.18**	1.65	2.49
42	ICMA 04999 x J-2503	-36.52 **	-15.41*	3.92	16.05**	5.76	6.63*
43	ICMA 04999 x J-2507	43.57 **	33.59**	23.26 **	16.05**	1.29	-2.08
44	ICMA 04999 x J-2508	-25.30 **	9.27	0.00	15.33**	4.53	5.39
45	ICMA 04999 x J-2510	-20.40 *	-23.17**	-5.44	17.52**	-4.76	5.39
	S.E.+	0.73		1.72		2.99	
Significantly positive crosses		19	23	5	40	0	10
Significantly negative crosses		9	6	1	0	3	0

*, ** were significant at 5 % and 1 % levels of probability, respectively.

Table.3 Per cent heterobeltiosis (BP) and standard heterosis (SC) for number of nodes on main stem, number of effective tillers per plant and plant height in pearl millet

Sr. No.	Crosses	Number of nodes on main stem		Number of effective tillers per plant		Plant height	
		BP	SC	BP	SC	BP	SC
1	JMSA 101 x J-2433	80.56 **	78.08**	-5.00	11.47	41.25 **	57.91**
2	JMSA 101 x J-2479	54.17 **	51.99**	-13.04	17.65	49.37 **	50.27**
3	JMSA 101 x J-2482	44.44 **	42.53**	8.70	46.76**	37.42 **	36.87**
4	JMSA 101 x J-2496	46.59 **	76.64**	-19.23	23.82	47.38 **	46.78**
5	JMSA 101 x J-2500	0.00	27.33*	-11.54	35.29*	30.19 **	36.73**
6	JMSA 101 x J-2503	34.18 **	45.21**	-2.50	15.00	52.49 **	51.88**
7	JMSA 101 x J-2507	51.32 **	57.53**	10.00	29.12	42.87 **	42.30**
8	JMSA 101 x J-2508	26.67 *	30.21*	50.00 **	76.76**	14.40 *	13.94**
9	JMSA 101 x J-2510	15.85	30.21*	23.81	52.94**	42.19 **	41.62**
10	JMSA 20102 x J-2433	13.25	28.77*	-4.00	41.47**	0.00	16.36**
11	JMSA 20102 x J-2479	15.66	31.44*	4.00	52.94**	21.37 **	41.22**
12	JMSA 20102 x J-2482	28.92 **	46.64**	-28.00 *	6.18	22.98 **	43.10**
13	JMSA 20102 x J-2496	-1.14	19.11*	3.85	59.12**	22.41 **	42.43**
14	JMSA 20102 x J-2500	30.11 **	65.75**	-11.54	35.29*	15.78 **	34.72**
15	JMSA 20102 x J-2503	1.20	15.00	20.00	76.76**	24.19 **	44.51**
16	JMSA 20102 x J-2507	33.73 **	51.99**	-8.00	35.29*	15.38 **	34.25**
17	JMSA 20102 x J-2508	3.61	17.88	-20.00	17.65	16.42 **	35.46**
18	JMSA 20102 x J-2510	10.84	26.10*	-4.00	41.47**	14.75 **	33.51**
19	ICMA 841 x J-2433	16.67	43.77**	-4.76	17.65	0.88	14.88**
20	ICMA 841 x J-2479	4.44	28.77*	-17.39	11.47	2.24	16.42**
21	ICMA 841 x J-2482	-12.22	8.22	34.78 **	82.06**	16.60 **	32.77**
22	ICMA 841 x J-2496	1.11	24.66*	-26.92 *	11.47	10.42 *	25.74**
23	ICMA 841 x J-2500	31.18 **	67.19**	-23.08 *	17.65	12.65 *	28.28**
24	ICMA 841 x J-2503	0.00	23.22*	9.52	35.29*	-7.59	5.23
25	ICMA 841 x J-2507	13.33	39.66**	-4.76	17.65	3.06	17.36**
26	ICMA 841 x J-2508	22.22 *	50.75**	-4.76	17.65	4.94	19.50**
27	ICMA 841 x J-2510	-15.56	4.11	-4.76	17.65	-0.24	13.60**
28	ICMA 89111 x J-2433	27.14 *	21.99*	9.09	41.47**	18.17 **	32.10**
29	ICMA 89111 x J-2479	12.86	8.22	-17.39	11.47	12.30 *	19.98**
30	ICMA 89111 x J-2482	45.07 **	41.1**	-13.04	17.65	9.85	17.36**
31	ICMA 89111 x J-2496	-21.59 *	-5.55	-23.08 *	17.65	5.58	12.80*
32	ICMA 89111 x J-2500	-21.51 *	0.00	-34.62 **	0.00	9.47	16.96**
33	ICMA 89111 x J-2503	26.58 **	36.99**	-13.64	11.47	9.28	16.76**
34	ICMA 89111 x J-2507	-10.53	-6.78	0.00	29.12	3.58	10.66*
35	ICMA 89111 x J-2508	4.00	6.78	0.00	29.12	10.35	17.9**
36	ICMA 89111 x J-2510	4.88	17.88	9.09	41.47**	10.10	17.62**
37	ICMA 04999 x J-2433	6.94	5.55	10.00	29.12	3.36	15.55**
38	ICMA 04999 x J-2479	11.11	9.66	-4.35	29.12	23.12**	29.56**
39	ICMA 04999 x J-2482	12.50	10.89	-8.70	23.82	9.81	15.55**
40	ICMA 04999 x J-2496	-9.09	9.66	42.31 **	117.35**	14.84*	20.84**
41	ICMA 04999 x J-2500	-30.11 **	-10.89	-30.77 **	6.18	9.55	15.28**
42	ICMA 04999 x J-2503	0.00	8.22	17.65	17.65	1.85	7.17
43	ICMA 04999 x J-2507	14.47	19.11*	26.32	41.47**	18.09	24.26**
44	ICMA 04999 x J-2508	8.00	10.89	16.67	23.82	8.34	14.00**
45	ICMA 04999 x J-2510	-2.44	9.66	19.05	46.76**	-3.95	1.08
	S.E.±	0.51		0.19		5.90	
Significantly positive crosses		15	27	3	18	24	42
Significantly negative crosses		3	0	6	0	0	0

*, ** were significant at 5 % and 1 % levels of probability, respectively.

Table.4 Per cent heterobeltiosis (BP) and standard heterosis (SC) for earhead length, earhead girth and earhead weight in pearl millet

Sr. No.	Crosses	Earhead length		Earhead girth		Earhead weight	
		BP	SC	BP	SC	BP	SC
1	JMSA 101 x J-2433	27.12**	22.47**	-6.44	11.33	9.93	55.99**
2	JMSA 101 x J-2479	1.79	-7.35	-7.03	10.67	66.92**	119.26**
3	JMSA 101 x J-2482	12.61	5.69	0.87	20.03**	-6.86	22.29
4	JMSA 101 x J-2496	-6.25	-8.14	-5.31	15.81*	-16.62	9.51
5	JMSA 101 x J-2500	8.23	2.02	2.03	21.42**	-12.10	57.15**
6	JMSA 101 x J-2503	7.14	4.10	5.42	25.70**	49.54**	96.44**
7	JMSA 101 x J-2507	8.66	2.45	5.66	25.83**	35.40**	110.39**
8	JMSA 101 x J-2508	22.87**	11.82	-17.94*	-2.31	25.73**	94.44**
9	JMSA 101 x J-2510	13.90	3.67	11.81	33.08**	-12.44	24.40*
10	JMSA 20102 x J-2433	-5.65	-4.47	7.14	27.81**	-38.41**	24.08
11	JMSA 20102 x J-2479	-4.03	-2.88	6.17	26.62**	-14.09*	73.10**
12	JMSA 20102 x J-2482	8.47	9.80	4.86	25.11**	-24.89**	51.34**
13	JMSA 20102 x J-2496	-2.02	-0.80	8.96	33.34**	-16.71*	67.82**
14	JMSA 20102 x J-2500	2.82	4.10	4.93	25.17**	-56.90**	-13.20
15	JMSA 20102 x J-2503	12.10	13.47*	12.69	34.46**	-59.56**	-18.49
16	JMSA 20102 x J-2507	2.82	4.10	7.16	27.87**	-32.12**	36.76**
17	JMSA 20102 x J-2508	-14.92*	-13.90*	12.50	34.20**	-24.05**	53.03**
18	JMSA 20102 x J-2510	-11.69	-10.59	16.63*	39.14**	-11.92	77.43**
19	ICMA 841 x J-2433	-7.94	-5.33	5.72	32.68*	-5.50	51.23**
20	ICMA 841 x J-2479	4.76	7.78	4.50	31.17**	-2.11	56.62**
21	ICMA 841 x J-2482	-0.79	2.02	2.94	29.26**	8.89	74.26**
22	ICMA 841 x J-2496	-3.97	-1.22	12.74	41.51*	-33.10**	7.08
23	ICMA 841 x J-2500	-11.11	-8.57	11.83	40.39**	-37.59**	11.51
24	ICMA 841 x J-2503	-5.56	-2.88	1.84	27.81**	24.74**	99.61**
25	ICMA 841 x J-2507	-7.94	-5.33	6.46	33.61**	-15.54	35.18**
26	ICMA 841 x J-2508	5.16	8.14	0.87	26.62**	-33.49**	6.44
27	ICMA 841 x J-2510	-5.16	-2.45	8.08	35.65**	-5.90	50.60**
28	ICMA 89111 x J-2433	4.47	4.90	-2.85	27.87**	20.96*	98.35**
29	ICMA 89111 x J-2479	0.41	0.80	-1.62	29.45**	5.11	72.36**
30	ICMA 89111 x J-2482	6.91	7.35	9.16	43.69**	14.09	87.04**
31	ICMA 89111 x J-2496	0.41	0.80	-4.62	25.50**	-1.63	61.27**
32	ICMA 89111 x J-2500	-2.44	-2.02	-10.30	18.05*	1.26	81.02**
33	ICMA 89111 x J-2503	3.66	4.10	-4.87	25.17**	12.50	84.40**
34	ICMA 89111 x J-2507	2.03	2.45	5.49	38.81**	39.35**	128.45**
35	ICMA 89111 x J-2508	-1.22	-0.80	-13.99*	13.24	3.31	69.4**
36	ICMA 89111 x J-2510	1.63	2.02	-7.34	21.94**	23.71**	102.78**
37	ICMA 04999 x J-2433	13.56	9.37	-10.89	13.57	-46.55**	26.94*
38	ICMA 04999 x J-2479	5.08	1.22	-3.74	22.73**	-13.61*	105.21**
39	ICMA 04999 x J-2482	9.32	5.33	-12.94*	11.00	-37.21**	49.12**
40	ICMA 04999 x J-2496	16.67*	14.27*	-0.53	26.82**	-10.61	112.29**
41	ICMA 04999 x J-2500	1.69	-2.02	-7.53	17.86*	-35.75**	52.61**
42	ICMA 04999 x J-2503	0.42	-2.45	-13.08*	10.81	-43.43**	34.33**
43	ICMA 04999 x J-2507	5.51	1.65	-10.48	14.10*	-27.33**	72.57**
44	ICMA 04999 x J-2508	2.54	-1.22	0.36	27.94**	-13.82*	104.68**
45	ICMA 04999 x J-2510	3.81	0.00	-9.05	15.95*	-32.08**	61.37**
	S.E.±	1.20		1.23		1.34	
Significantly positive crosses		3	3	1	38	8	37
Significantly negative crosses		1	1	4	0	19	0

*, ** were significant at 5 % and 1 % levels of probability, respectively.

Table.5 Per cent heterobeltiosis (BP) and standard heterosis (SC) for test weight and panicle index in pearl millet

	Crosses	Test weight		Panicle index	
		BP	SC	BP	SC
1	JMSA 101 x J-2433	8.85 **	19.99**	-24.49 *	28.34*
2	JMSA 101 x J-2479	24.25 **	39.59**	9.20	85.60**
3	JMSA 101 x J-2482	-9.42 **	9.54**	-29.80 **	19.31
4	JMSA 101 x J-2496	-10.58 **	21.02**	-31.31 **	26.7
5	JMSA 101 x J-2500	12.78 **	23.34**	9.74	103.63**
6	JMSA 101 x J-2503	25.29 **	35.72**	-26.52 **	24.89
7	JMSA 101 x J-2507	7.15 *	16.51**	10.39	112.62**
8	JMSA 101 x J-2508	10.92 **	20.12**	-18.41	38.69**
9	JMSA 101 x J-2510	-16.41 **	24.50**	-31.26 **	16.84
10	JMSA 20102 x J-2433	-8.31 **	24.24**	-31.63 **	29.36*
11	JMSA 20102 x J-2479	-13.39 **	17.28**	-56.61 **	-17.91
12	JMSA 20102 x J-2482	-18.18 **	10.83**	-34.09 **	24.69
13	JMSA 20102 x J-2496	-11.20 **	20.25**	-60.75 **	-25.75
14	JMSA 20102 x J-2500	-13.45 **	17.28**	-74.55 **	-51.85**
15	JMSA 20102 x J-2503	-8.47 **	23.98**	-70.00 **	-43.24**
16	JMSA 20102 x J-2507	-19.32 **	9.28**	-50.46 **	-4.57
17	JMSA 20102 x J-2508	-15.51 **	14.44**	-4.62	80.45**
18	JMSA 20102 x J-2510	-13.12 **	29.53**	-26.75 **	38.57**
19	ICMA 841 x J-2433	-10.31 **	34.3**	-3.58	84.74**
20	ICMA 841 x J-2479	-19.12 **	21.15**	-14.18	64.43**
21	ICMA 841 x J-2482	-16.88 **	24.50**	-10.35	71.77**
22	ICMA 841 x J-2496	-27.91 **	7.87**	-28.04 **	37.88**
23	ICMA 841 x J-2500	-26.41 **	10.19**	-58.25 **	-20.01
24	ICMA 841 x J-2503	-21.10 **	18.05**	-6.27	79.57**
25	ICMA 841 x J-2507	-24.52 **	13.02**	-37.69 **	20.01
26	ICMA 841 x J-2508	-34.37 **	-1.81	-33.23 **	27.93*
27	ICMA 841 x J-2510	-4.31 *	43.33**	-33.97 **	26.52
28	ICMA 89111 x J-2433	-27.03 **	6.58**	-41.64 **	35.95*
29	ICMA 89111 x J-2479	-17.34 **	20.63**	-27.20 **	69.59**
30	ICMA 89111 x J-2482	-17.26 **	20.76**	-25.74 **	73.00**
31	ICMA 89111 x J-2496	-16.11 **	22.44**	-36.98 **	46.81**
32	ICMA 89111 x J-2500	-25.41 **	8.90*	-11.10	107.11**
33	ICMA 89111 x J-2503	-15.96 **	22.70**	-44.33 **	29.68*
34	ICMA 89111 x J-2507	-21.88 **	14.06**	-19.38 **	87.81**
35	ICMA 89111 x J-2508	-27.18 **	6.32**	-40.39 **	38.88**
36	ICMA 89111 x J-2510	-27.69 **	7.74**	-28.81 **	65.84**
37	ICMA 04999 x J-2433	-23.52 **	2.19	-58.77 **	5.53
38	ICMA 04999 x J-2479	-0.84	32.50**	-44.62 **	41.74**
39	ICMA 04999 x J-2482	-12.68 **	16.63**	-42.17 **	48.04**
40	ICMA 04999 x J-2496	-20.17 **	7.99**	-32.82 **	71.96**
41	ICMA 04999 x J-2500	-10.88 **	19.08**	-35.13 **	66.05**
42	ICMA 04999 x J-2503	-9.20 **	21.28**	-37.67 **	59.55**
43	ICMA 04999 x J-2507	-15.83 **	12.38**	-49.44 **	29.42*
44	ICMA 04999 x J-2508	-16.18**	11.99**	-26.64**	87.78**
45	ICMA 04999 x J-2510	-28.79**	6.06*	-17.62**	110.86**
S.E.±		0.24		17.33	
Significantly positive crosses		6	43	0	31
Significantly negative crosses		38	0	35	2

*, ** were significant at 5 % and 1 % levels of probability, respectively.

Table.6 Per cent heterobeltiosis (BP) and standard heterosis (SC) for total biomass per plant and harvest index in pearl millet

Sr. no.	Crosses	Total biomass per plant		Harvest index	
		BP	SC	BP	SC
1	JMSA 101 x J-2433	-20.17 *	37.66**	29.80 **	-11.68*
2	JMSA 101 x J-2479	-4.20	114.84**	23.16	-44.83**
3	JMSA 101 x J-2482	31.92 **	155.92**	-16.10	-58.94**
4	JMSA 101 x J-2496	25.43 **	121.58**	-10.43	-59.88**
5	JMSA 101 x J-2500	69.96 **	193.10**	-70.61 **	-73.34**
6	JMSA 101 x J-2503	28.78 **	122.12**	-26.43 **	-29.06**
7	JMSA 101 x J-2507	70.80 **	194.57**	-41.78 **	-66.35**
8	JMSA 101 x J-2508	36.01 **	134.57**	-53.26 **	-39.89**
9	JMSA 101 x J-2510	95.38 **	236.96**	-59.20 **	-68.38**
10	JMSA 20102 x J-2433	-33.23 **	115.05**	-34.53 **	-55.44**
11	JMSA 20102 x J-2479	-22.11 **	150.87**	116.06 **	-16.22**
12	JMSA 20102 x J-2482	-50.94 **	57.99**	57.22 **	-23.03**
13	JMSA 20102 x J-2496	-10.12 *	189.51**	114.16 **	-21.71**
14	JMSA 20102 x J-2500	9.45 *	252.55**	-43.77 **	-48.99**
15	JMSA 20102 x J-2503	4.27	235.87**	-55.71 **	-57.30**
16	JMSA 20102 x J-2507	-36.06 **	105.92**	34.37 **	-22.37**
17	JMSA 20102 x J-2508	-36.30 **	105.16**	-66.60 **	-57.06**
18	JMSA 20102 x J-2510	-13.98 **	177.07**	-40.32 **	-53.74**
19	ICMA 841 x J-2433	-6.52	105.60**	-41.43 **	-60.13**
20	ICMA 841 x J-2479	-38.53 **	37.88**	81.01 **	-29.81**
21	ICMA 841 x J-2482	52.14 **	234.62**	-36.14 **	-68.74**
22	ICMA 841 x J-2496	-39.79 **	32.45*	58.32 **	-39.72**
23	ICMA 841 x J-2500	38.22 **	203.97**	-47.85 **	-52.67**
24	ICMA 841 x J-2503	17.99 **	159.51**	-55.57 **	-57.15**
25	ICMA 841 x J-2507	8.07	137.66**	-17.43	-52.29**
26	ICMA 841 x J-2508	-6.05	106.63**	-66.83 **	-57.34**
27	ICMA 841 x J-2510	-19.77 **	76.47**	-11.45	-31.34**
28	ICMA 89111 x J-2433	15.36 *	171.36**	-20.26 *	-45.73**
29	ICMA 89111 x J-2479	-5.69	121.85**	21.98	-52.70**
30	ICMA 89111 x J-2482	-5.58	122.12**	0.14	-50.97**
31	ICMA 89111 x J-2496	-10.36	110.87**	42.92 *	-47.75**
32	ICMA 89111 x J-2500	-24.37 **	77.88**	-45.11 **	-50.20**
33	ICMA 89111 x J-2503	-10.67	110.16**	-29.68 **	-32.20**
34	ICMA 89111 x J-2507	-1.12	132.61**	-8.95	-47.39**
35	ICMA 89111 x J-2508	-19.57 **	89.18**	-50.06 **	-35.78**
36	ICMA 89111 x J-2510	-2.96	128.26**	-30.18 **	-45.88**
37	ICMA 04999 x J-2433	-3.24	110.00**	-15.44	-42.47**
38	ICMA 04999 x J-2479	-8.34	105.54**	64.98 **	-29.30**
39	ICMA 04999 x J-2482	-40.28 **	29.62*	61.83 **	-20.78**
40	ICMA 04999 x J-2496	66.11 **	260.49**	-19.77	-65.63**
41	ICMA 04999 x J-2500	-19.15 **	75.49**	-42.19 **	-47.54**
42	ICMA 04999 x J-2503	16.69 *	153.26**	-65.29 **	-66.53**
43	ICMA 04999 x J-2507	48.18 **	221.58**	-28.11 **	-58.47**
44	ICMA 04999 x J-2508	5.51	128.97**	-62.88**	-52.27**
45	ICMA 04999 x J-2510	-9.85	95.65**	-49.28**	-60.69**
S.E.±		2.64		2.87	
Significantly positive crosses		15	45	10	0
Significantly negative crosses		15	0	25	45

*, ** were significant at 5 % and 1 % levels of probability, respectively.

The results revealed that the best three hybrids identified on the basis of *per se* performance and standard heterosis for seed yield per plant *viz*., JMSA 20102 x J-2496, JMSA 20102 x J-2479 and ICMA 841 x J-2500 also depicted the significant positive standard heterosis over GHB 732 for important yield contributing traits like

On the basis of *per se* performance of hybrids (Table 1) for grain yield per plant, the crosses JMSA 20102 x J-2496, JMSA 20102 x J-2479 and JMSA 20102 x J-2500 were found the superior among forty five hybrids. The second highest cross combination JMSA 20102 x J-2479 also recorded higher *per se* performance for harvest index.

The third ranked cross JMSA 20102 x J-2500 notice good performer for total biomass per plant. This suggested that the parents involved in these hybrids had a strong tendency to transmit the higher gain to the off springs. Valu (2006), Davada *et al.,* (2008), Chotaliya *et al.,* (2009), Dangaria *et al.,*(2009), Vagadiya *et al.,* (2010a), Jethava *et al.,* (2012) and Bhadalia *et al.,* (2013) were also akin to this observation.

The estimates of heterobeltiosis for this important trait like harvest index varied from -70.61 to 116.06 per cent. Among the 45 crosses, ten crosses demonstrated positively significant heterobeltiosis.

The cross showed the highest heterobeltiosis was JMSA 20102 x J-2479 (116.06%) followed by JMSA 20102 x J-2496 (114.16%) and ICMA 841 x J-2479 (81.01%). The minimum heterobeltiosis for this trait was noticed by cross JMSA 101 x J-2500 (-70.61%).

On the whole, considerable heterobeltiosis and standard heterosis observed for seed yield and other associated characters suggested the presence of large genetic diversity among the parents and also unidirectional distribution of allelic constitution contributing towards desirable heterosis in the present material. The moderate to low magnitude of desirable heterosis observed for days to 50% flowering, Days to maturity indicated the narrow genetic base among the parents.

The best two promising hybrids namely JSMA 20102 x J-2496 and JSMA 20102 x J-2479exhibited the highest *per se* performance, positively significant and high magnitude of heterobeltiosis as well as standard heterosis and highly significant sca effects for grain yield per plant.

These hybrids also registered significantly higher heterosis and sca effects in desired direction for other yield attributing components. Therefore, these hybrids could be further evaluated over years and locations to exploit for commercial cultivation.

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