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Heterosis for Grain Yield and its Components in Pearl Millet [*Pennisetum glaucum (*L.) R. Br.]

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Abstract: The heterosis study for grain yield and its contributing characters was carried out in among 50 hybrids of pearl millet (*Pennisetum glaucum* (L.) R. Br.) through line x tester mating design. The analysis of variance showed highly significant mean squares differences among the hybrids for all the characters. The variance due to hybrids, lines, testers and line x tester were also significant for all the characters studied indicating presence of considerable variability among the material studied and existence of overall heterosis for all the characters. Based on the standard heterosis, five hybrids ICMA JMSA 20073 × RCB-IC 925 S3 19-3-1, ICMA 92777 × H77/833-2, ICMA 843-22 × H77/833-2, ICMA 04999 × H77/833-2 and JMSA 20073 × H77/833-2 were identified superior over best check HHB 67 improved for seed yield per plant along with other desirable characters. Hence, these crosses were considered to be most desirable for grain yield per plant.

Key words: Pearl millet, hybrid, standard heterosis, grain yield.

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] locally known as bajra is a highly cross-pollinated (allogamous) crop and belong to the family Poaceae with the diploid chromosome (2n=14). It was domesticated along the southern margins of the Saharan Central Highlands at the onset of the present dry phase (Clark, 1962 and Davies, 1968). Pennisetum is largest genera in the tribe paniceae comprised nearly 140 species that are widely distributed in tropics and subtropics region (Clayton, 1972). It is an important coarse grain cereal crop of dry land agriculture. Pearl millet is traditionally grown as rain fed crop mostly under low fertility and rainfall condition. However, it also responses well to irrigation and improved management conditions.

In India, it is grown in drier areas of central and western regions. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana, covering nearly 90% acreage. It was grown on 4.3 mha area in Rajasthan during 2021-2022 with production is 5.81 mt and an average productivity of 1338 kg ha^{-1} (APEDA, 2022). Government of India has declared Year 2018 as the “Year of Millet” to bring millets into mainstream for exploiting the nutritional rich properties and promoting their cultivation. Likewise, United Nation has also declared year 2023 as "International Year of Millet" to promote it globally.

Exploitation of hybrid vigour is one of the most efficient means of elevating the productivity potential, particularly in cross pollinated crops like pearl millet (Dutt and Baniwal, 2000; Yadav *et al*., 2021). It is well established that the pearl millet hybrids perform better than open pollinated cultivars. With this view the work was undertaken to investigate the standard heterosis for quantifying the extent of heterosis for grain yield and its component characters in pearl millet.

Materials and Methods

The experimental material for the present investigation consisted of ten female parents from diverse cytoplasmic male sterility sources viz., RMS 6A, RMS 7A, RMS 18A, RMS 21A, ICMA 843-22, ICMA 92777, ICMA 93333, ICMA 97111, JMSA 20073 and ICMA 04999 and five elite restorers viz., H77/833-2, RIB 57SO5, MIR 97092-2-4-1, RCB-IC 925 S3 19-3-1 and BIB I 6 developed in AICRP breeding program on pearl millet, ARS Bikaner. All the parental material was planted during summer season 2014 at ICRISAT, Hyderabad and hybridized under L x T fashion. The developed fifty fresh F_1 hybrids and three standard checks (HHB 67, RHB 177 and GHB 538) were evaluated in randomized block design with 3 replications at ARS, Bikaner during kharif 2014. Each plot consisted of two rows each of 4 m length. Spacing between row to row was 50 cm and between plant to plant was 15 cm. Normal and uniform cultural operations were followed during the crop season to raise a good crop. The observations were recorded on five randomly selected competitive plants from each replication for 10 traits viz., days to 50% flowering, days to maturity, plant height (cm), number of effective tillers per plant, ear head length (cm), ear head diameter (cm), test weight (g), biological yield per plant (g), harvest index (%) and seed yield per plant (g). Standard heterosis referred as the superiority of F_1 over standard hybrid HHB 67- Improved and was estimated as per the formula given by Meredith and Bridge (1972).

Results and discussion

Heterosis is a measure of deviation of progeny means from parental mean. The genotypes with early flowering and maturity have a special significance in the harsh environment of western Rajasthan. In the present experiment, out of 50 hybrids, two hybrids showed negative and significant standard heterosis for days to 50% flowering. Maximum negative significant standard heterosis was recorded in ICMA 97111 × RIB 57SO5 (-12.50) followed by RMS 6A × MIR 97092-2-4-1 (-11.81). The crosses RMS 6A × MIR 97092-2-4-1 (-8.23) and RMS 6A × RIB 57SO5 (-7.79) depicted negative heterosis for days to maturity. The negative (desirable) heterosis was observed by Karad and Harer (2005), Yadav (2006) and Warrier *et al.* (2019). The cross combination RMS 6A × RIB 57SO5 (35.68) exhibited significant and positive heterosis for plant height. Kushwah and Singh (1992) have reported positive heterosis for more than 75% of the crosses for plant height. Chavan and Nerkar (1994) and Patil *et al.* (1994), Aher and Ugale (1995), Patel *et al.* (2008a) and Salagarkar and Wali (2016) also recorded high heterosis for this trait. With respect to the performance of hybrids for number of effective tillers per plant, it was observed that five hybrids viz., JMSA 20073 × H77/833-2 (41.00) followed by JMSA 20073 × RCB-IC 925 S3 19-3-1 (39.71), ICMA 92777 × H77/833-2 (36.33), ICMA 04999 × H77/833-2 (34.00), RMS 6A × H77/833-2 (33.14) recorded significant standard heterosis (Table 1).

Out of 50 hybrids five hybrids, RMS 6A × RIB 57SO5 (21.59) followed by ICMA 92777 × RIB 57SO5 (17.94), ICMA 04999 × H77/833-2 (17.52), RMS 21A × H77/833-2 (17.46) and ICMA 92777 × H77/833-2 (13.38) showed positive standard heterosis for ear head length. The above results are in agreement with the findings of Kulkarni *et al.* (1993), Balakrishnan and Das (1996), Yadav (2006), Salagarkar and Wali (2016) and Warrier *et al.* (2019).

In case of ear head diameter, eight cross exhibited positive standard heterosis. The cross JMSA 20073 × RCB-IC 925 S3 19-3-1 (17.29) followed by ICMA 97111 × BIB I 6 (17.07), RMS 6A × MIR 97092-2-4-1 (16.39), RMS 7A × H77/833-2 (15.39) and ICMA 92777 × RIB 57SO5 (15.24) showed positive standard heterosis for ear head diameter. Moderate to low heterosis for ear head girth was reported by Patil *et al.* (1994), Patel *et al.* (2008) and Salagarkar and Wali (2016).

Table 1. Standard heterosis for different characters of pearl millet

S. No.	Genotypes	DF	DM	PH	ET	EHL	EHD	TW	HI	BY	SY
1	RMS 6A × H77/833-2	8.33	6.49	-10.42*	33.14*	-17.26**	14.51*	10.83*	-9.62	41.32**	26.49*
2	RMS 7A × H77/833-2	-2.78	0.87	-4.72	9.67	-7.69	15.39*	6.51	24.9	0	25.75*
3	RMS 18A × H77/833-2	4.86	3.03	-8.09	-10.33	-20.73**	12.55	10.00*	-4.05	13.05	8.88
4	RMS 21A × H77/833-2	4.17	3.03	-19.02**	0	17.46**	-6.54	-4.73	13.96	11.1	26.71*
5	ICMA 843-22 × H77/833-2	6.25	1.73	-11.06*	-2.57	-8.31	-4.35	-4.01	6.81	24.52**	32.73**
6	ICMA 92777 × H77/833-2	7.64	6.49	-8.95	36.33*	13.38*	15.15*	11.40*	-7.26	61.29**	50.15**
7	ICMA 93333 × H77/833-2	5.56	5.63	-8.44	-12	-1.64	4.49	-7.83	-7.08	12.49	4.44
8	ICMA 97111 × H77/833-2	-0.69	0.00	-13.03**	-26.67	-10.98	-7.8	5.28	-25.81	-5.46	-29.92*
9	JMSA 20073 × H77/833-2	3.47	3.9	-9.74	41.00**	-16.90**	13.59	-2.5	-20.15	61.14**	29.70*
10	ICMA 04999 × H77/833-2	0.69	0.87	-3.9	34.00*	17.52**	15.05*	-5.59	-21.24	67.89**	32.73**
11	RMS 6A × RIB 57SO5	-7.64	-7.79*	35.68**	0.67	21.59**	8.19	-9.02	-26.35	57.07**	16.26
12	RMS 7A × RIB 57SO5	9.72	7.79*	5.14	-25	7.8	-16.27*	-3.22	-22.66	6.69	-17.01
13	RMS 18A × RIB 57SO5	-4.17	-2.16	-0.89	-16.67	-18.18**	-13.27	4.13	-15.99	20.30*	1.95
14	RMS 21A × RIB 57SO5	5.56	6.49	-12.21*	-6.67	5.1	-8.05	-7.17	0.07	10.8	10.14
15	ICMA 843-22 × RIB 57SO5	11.11	10.39**	3.12	11.27	12.3	-12.69	-4.01	-3.59	27.40**	23.78*
16	ICMA 92777 × RIB 57SO5	9.03	6.06	1.7	-1.33	17.94**	15.24*	10.45*	14.1	12.2	26.29*
17	ICMA 93333 × RIB 57SO5	10.42	7.36	2.03	-14	-4.83	-12.01	-29.62**	-32.67*	11.72	-25.24*
18	ICMA 97111 × RIB 57SO5	-12.50*	-3.46	-2.37	-3.5	-2.39	-10.8	5.08	-5.71	19.33*	13.3
19	JMSA 20073 × RIB 57SO5	1.39	2.6	-2.03	-22	1.16	-6.18	-18.33**	-36.76**	21.04*	-22.5
20	ICMA 04999 × RIB 57SO5	19.44**	14.29**	-13.10**	-25.33	11.3	-14.66*	-15.24**	-9.64	-4.74	-12.92
21	RMS 6A × MIR 97092-2-4-1	-11.81*	-8.23*	0.00	2.00	12.07	16.39*	6.78	-20.07	57.26**	25.31*
22	RMS 7A × MIR 97092-2-4-1	13.89*	10.82**	-4.9	-13.33	-12.78*	-20.64**	-14.77**	-1.17	11.16	10.01
23	RMS 18A × MIR 97092-2-4-1	15.28*	11.69**	-13.58**	-28	-15.41*	-7.56	2.17	-29.37*	-11.82	-37.31**
24	RMS 21A × MIR 97092-2-4-1	15.28*	12.12**	-0.87	-16.67	-1.05	-15.61*	-31.05**	-22.47	12.96	-12.37
25	ICMA 843-22 × MIR 97092-2-4-1	16.67**	15.58**	-16.84**	-21.33	-6.3	-13.17	-16.55**	-30.45*	-11.82	-38.76**
26	ICMA 92777 × MIR 97092-2-4-1	25.00**	16.02**	-3.74	-16	-7.69	-11.11	-24.24**	-17.84	11.97	-7.42
27	ICMA 93333 × MIR 97092-2-4-1	31.94**	23.38**	-7.08	-31.00*	2.81	-2.46	-33.11**	-11.78	-17.92*	-27.42*
28	ICMA 97111 × MIR 97092-2-4-1	25.00**	15.58**	2.87	-20	-6.14	-2.84	-23.98**	-36.79**	6.1	-31.18**
29	JMSA 20073 × MIR 97092-2-4-1	19.44**	13.42**	-25.39**	-32.00*	-20.24**	-12.69	-8.95	44.80**	-28.54**	4.4
30	ICMA 04999 × MIR 97092-2-4-1	15.28*	9.96*	-5.58	-40.00**	-0.74	-9.8	-20.23**	-13.96	-35.30**	-44.26**
31	RMS 6A × B-IC 925 S3 19-3-1	18.06**	9.96*	-4.65	-13.67	12.07	-13.96	-9.02	-14.21	14.27	-2.25
32	RMS 7A × RCB-IC 925 S3 19-3-1	11.81*	6.93	-13.54**	-16	-1.44	1.65	15.58**	-20.76	2.75	-19.31
33	RMS 18A × RCB-IC 925 S3 19-3-1	15.28*	11.26**	-20.65**	-16	-19.11**	2.99	-1.42	-27.62*	13.56	-17.31
34	RMS 21A × RCB-IC 925 S3 19-3-1	20.83**	14.72**	-29.28**	-20	-10.23	0.76	-24.12**	-21.34	-12.28	-30.61**
35	ICMA 843-22 × RCB-IC 925 S3 19-3-1	16.67**	9.96*	-8.11	-32.00*	-15.87*	-11.99	-5.3	-50.87**	-25.17**	-63.06**
36	ICMA 92777 × RCB-IC 925 S3 19-3-1	13.19*	9.96*	-9.18	-24	-3.44	0	-8.86	-15.41	0.21	-14.65
37	ICMA 93333 × RCB-IC 925 S3 19-3-1	26.39**	16.88**	-17.91**	-15.33	-10.5	-6.39	-15.81**	-3.37	10.74	6.89
38	ICMA 97111 × RCB-IC 925 S3 19-3-1	20.14**	14.72**	-20.41**	-16	-8.15	13.2	4.48	-9.5	-7.79	-16.29

Table 1. Contd...

S. No.	Genotypes	DF	DM	PH	ET	EHL	EHD	TW	HI	BY	SY
39	JMSA 20073 × RCB-IC 925 S3 19-3-1	0	-0.43	-16.37**	39.71**	12.23	17.29*	-4.14	10.77	37.82**	53.47**
40	ICMA 04999 × RCB-IC 925 S3 19-3-1	29.86**	21.21**	-27.23**	-20	-1.28	-12.18	-25.45**	-9.01	-17.91*	-25.53*
41	RMS 6A × BIB I 6	14.58*	11.69**	-3.71	-16	-2.75	-10.71	-10.61*	-29.41*	17.77*	-16.39
42	RMS 7A × BIB I 6	19.44**	16.02**	-22.20**	-29.33*	1.81	0.71	-19.83**	-0.14	-20.69*	-20.07
43	RMS 18A × BIB I 6	19.44**	12.55**	-11.39*	-19.5	-8.54	0.15	9.43	-8.77	11.36	0.48
44	RMS 21A × BIB I 6	26.39**	18.18**	-10.24*	-25	-0.9	-14.81*	-42.27**	-21.34	7.99	-14.4
45	ICMA 843-22 × BIB I 6	25.69**	16.45**	-5.64	-28.67*	-8.23	-11.31	-7.6	-41.48**	1.29	-41.41**
46	ICMA 92777 × BIB I 6	22.22**	15.58**	4.3	-20	-11.96	-12.25	-6.94	-22.06	5.36	-17.29
47	ICMA 93333 × BIB I 6	3.47	7.36	-8.98	-19	0.65	5.28	-9.71*	-30.00*	23.68**	-12.37
48	ICMA 97111 × BIB I 6	13.19*	7.36	-20.48**	-13.67	1.16	17.07*	-6.94	-32.82*	-1.3	-33.05**
49	JMSA 20073 × BIB I 6	25.00**	17.75**	-17.10**	-24	-15.79*	-10.66	-17.36**	-22.92	-4.4	-26.21*
50	ICMA 04999 × BIB I 6	25.00**	17.32**	-15.57**	-36.00*	-10.26	-5.44	-17.87**	-42.26**	-31.33**	-60.13**
51	HHB 67-imp.	0	0	0	0	0	0	0	0	0	0
52	RHB 177	1.39	2.16	-6.61	-13	-0.54	2.92	-10.61*	15.11	-36.99**	-26.81*
53	GHB 538	8.33	6.06	-13.54**	4	-11.99	-5.44	-1.42	4.4	-28.54**	-24.94*
	SE	2.86	2.99	6.68	0.24	1.37	0.16	0.42	5.85	3.37	1.96

*Level of significance at 5 % and 1%, DF: Days to 50 per cent flowering, DM: Days to maturity, PH: Plant height (cm), ET: Number of effective tillers plant^{-1}, EHL: Ear head length (cm), EHD: Ear head diameter (cm), TW: Test weight (g), BY: Biological yield plant^{-1} (g), HI: Harvest index (%) and SY: Seed yield plant^{-1} (g)

Five hybrids showed positive standard heterosis for test weight. Maximum positive and significant standard heterosis for test weight was recorded in hybrid RMS 7A × RCB-IC 925 S3 19-3-1 (15.58) followed by ICMA 92777 × H77/833-2 (11.40), RMS 6A × H77/833-2 (10.83), ICMA 92777 × RIB 57SO5 (10.45) and RMS 18A × H77/833-2 (10.00). High heterosis is reported by Dutt and Baniwal, (2000) and medium to low magnitude of heterosis for this trait was reported by Patil *et al.* (1994), Aher and Ugale (1995), Warrier *et al.* (2019). One hybrids JMSA 20073 × MIR 97092-2-4-1 (44.80) showed positive and significant standard heterosis for harvest index.

Fourteen hybrids showed positive and significant standard heterosis for biological yield per plant. Maximum positive and significant standard heterosis for this trait was recorded in ICMA 04999 × H77/833-2 (67.89) followed by ICMA 92777 × H77/833-2 (61.29), JMSA 20073 × H77/833-2 (61.14), RMS 6A × MIR 97092-2-4-1 (57.26) and RMS 6A × RIB 57SO5 (57.07). These results are in agreement with the results of earlier work of Patel *et al.* (2008) and Pawar *et al.* (2015)

Eleven hybrids showed positive and significant standard heterosis for seed yield per plant. Maximum positive and significant standard heterosis for this trait was recorded in JMSA 20073 × RCB-IC 925 S3 19-3-1 (53.47) followed by ICMA 92777 × H77/833-2 (50.15), ICMA 843-22 × H77/833-2 (32.73), ICMA 04999 × H77/833-2 (32.73) and JMSA 20073 × H77/833-2 (29.70). High heterosis for this trait was also observed by Patel *et al.* (2008) and Salagarkar and Wali (2016).

Conclusion

On the whole, considerable 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 best five promising hybrids namely ICMA JMSA 20073 × RCB-IC 925 S3 19-3-1, ICMA 92777 × H77/833-2, ICMA 843-22 × H77/833-2, ICMA 04999 × H77/833-2 and JMSA 20073 × H77/833-2 exhibited the highest per se performance, positively significant and high magnitude of standard heterosis over best check HHB 67

(I) for seed yield per plant. Therefore, these hybrids could be further evaluated over years and locations to exploit for commercial cultivation.

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