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Estimation of standard heterosis for grain yield and yield components in pearl millet (*Pennisetum glaucum* (L.) R. Br.)

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Abstract
Ten CMS lines were crossed with six testers in a line x tester design to study the extent of heterosis in pearl millet for yield and its component traits. Heterosis was observed in both directions for most of the characters. The standard heterosis for grain yield per plant ranged from -18.42 to 355.96 per cent. Highest and significant positive standard heterosis for grain yield per plant was recorded in ICMA 04999 x BIB-76 (355.96) followed by JMSA 20042 x BIB-40 (315.26), ICMA 04999 x BIB-40 (300.7) and ICMA 04999 x BIB -65 (294.91). Among 60 hybrids studied, eighteen hybrids namely RMS 6A x BIB-65, RMS 7A x BIB-40, RMS 7A x BIB-75, RMS 21A x BIB-186, ICMA 832-22 x BIB- 65, ICMA 832-22 x BIB- 186, ICMA 92777 x BIB- 66, ICMA 971111 x BIB- 186, ICMA 93333 x BIB- 66, ICMA 93333 x BIB- 75, ICMA 93333 x BIB- 186, ICMA 04999 x BIB- 65, ICMA 04999 x BIB- 76, ICMA 04999 x BIB- 186, JMSA 20042 x BIB- 40, JMSA 20042 x BIB- 65, JMSA 20042 x BIB- 66 and JMSA 20042 x BIB- 76 were selected as best crosses since they expressed high standard heterosis for many of the traits studied for high grain yield.

Keywords: Standard heterosis, Line x tester, Pearl Millet, Male sterile line

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is predominantly grown as the dual purpose crop, grain as well as fodder in marginal lands under erratic and poor rainfed conditions, and is amazingly tolerant to adverse environmental conditions. It is the fourth most important cereal crop grown mainly in Rajasthan, U. P., Maharashtra, Gujarat and Haryana in India which account for 95 % of the area under this crop. Pearl millet has an embodiment of unique features like allogamy, protogyny, male sterility, huge genetic variability and remarkable geographic diversity. The availability of cytoplasmic genetic male sterile lines in this crop is made feasible to exploit heterosis commercially and hybrid seed production on large scale. The exploitation of heterosis on commercial scale in pearl millet is regarded as one of the major breakthroughs in the improvement of its productivity. Heterosis breeding is an important one, among conventional breeding programme to identify the best hybrids which are promising. 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
Ten male sterile lines viz., RMS 6A, RMS 7A, RMS 21A, ICMA 843-22, ICMA 92777, ICMA 93333, ICMA 97111, ICMA 04999, ICMA 06999 and JMSA 20042 were crossed with six testers viz., BIB- 40, BIB-65, BIB-66, BIB-75, BIB-76 and BIB-186 in line x tester fashion at ICRISAT, Hyderabad, during off season crop (January-April 2016). The 60 F_1 hybrids, thus, produced along with two standard checks HHB-67 Improved and RHB-177 were grown in Randomized Block Design with three replications in each of the environments at Agricultural Research Station, Beechhwal, Bikaner during *Kharif* 2016. Each plot consisted of two rows each of 4 meter length with row spacing of 60 cm. Plant to plant distance was maintained at 15 cm. Recommended agronomic practices and plant protection measures were adopted to raise healthy crop. Observations were recorded on five randomly selected plants for each entry, in each replication for various characters. The expression of heterosis was measured in terms of Standard heterosis in comparison with RHB-177, the hybrid as the best standard check.

Results and Discussion
The analysis of variance for yield and its components traits revealed that the mean square values due to genotypes were highly significant for all the characters, which indicated existence

of sufficient genetic variability in the experimental material for all the characters (Table 1). In the commercial exploitation of hybrid vigour, excess of F_1 over standard check (standard heterosis), is of significance. Hence, in the present investigation, the extent of heterosis over standard check hybrid (RHB-177) for grain yield and nine yield component traits is discussed. The range of standard heterosis as well as number of hybrids showing significant heterosis in desirable direction is presented in (Table 2). Pearl millet being grown in erratic conditions of rainfall, the earliness in flowering and maturity is desirable in pearl millet for escaping the drought. Hence, negative heterosis is useful for days to 50 per cent flowering and days to maturity. Out of 60 crosses, 20 and 31 crosses had significant and desirable negative heterosis over standard check for days to 50 per cent flowering and days to maturity, respectively. Heterosis over standard check for days to 50 per cent flowering ranged from -8.98 to 6.38 per cent; whereas, it ranged from -7.15 to 6.08 per cent for days to maturity. The tall plant height is a desirable character in pearl millet. The extent of standard heterosis for this trait ranged from -18.75 to 15.80 per cent. Out of 60 crosses, 10 crosses had significant and desirable positive heterosis over standard check for this trait. Number of effective tillers per plant, ear head length and ear head diameter are considered as important yield contributing characters. Heterosis over standard check for number of effective tillers per plant ranged from -21.92 to 123.97 per cent, from -34.88 to 32.72 for ear head length whereas, it ranged from -39.84 to 27.64 per cent for ear head diameter. Amongst 60 crosses 43, 20 and 15 crosses had significant and desirable positive heterosis over standard check for number of effective tillers per plant, ear head length and ear head diameter. Test weight being an important yield attributing character, use of parents with high test weight in breeding programme may be most desirable. The range of standard heterosis varied from -23.12 to 72.08 per cent. Out of 60 crosses, 37 crosses showed positive and significant standard heterosis for test weight. Paramount of heterosis has been observed in dry stover yield per plant, which is an important component of pearl millet being a dual-purpose crop. Amongst 60 crosses, 33 crosses had significant and positive heterosis over standard check for this trait. The extent of standard heterosis for this trait ranged from -55.38 to 110.56 per cent. Grain yield is of economic importance for which considerable degree of standard heterosis was registered in a number of crosses. Amongst 60 crosses 47 crosses had significant and desirable positive heterosis over standard check for this trait. The extent of standard heterosis for this trait ranged from -18.42 to 355.96 per cent. For harvest index the values of standard heterosis varied from -10.29 to 196.72 per cent. Amongst 60 crosses, 55 crosses had significant and positive heterosis over standard check for this trait.

A comparative study of crosses for grain yield per plant (Table 3) indicated that none of the cross combinations depicted desired standard heterosis for all the characters studied. However, cross combination with significant heterosis over all the environments for five or more than five characters were RMS 6A X BIB- 65 for days to maturity, number of effective tillers per plant, test weight, dry stover yield per plant, grain yield per plant and harvest index, RMS 7A X BIB- 40 for number of effective tillers per plant, ear head diameter, test weight, dry stover yield per plant and grain yield per plant, RMS 7A X BIB- 75 for days to maturity, number of effective tillers per plant, ear head diameter, test weight, dry fodder yield per plant, grain yield per plant and harvest index, RMS 21A X BIB- 186 for plant height, number of effective tillers per plant, ear head length, test weight, dry stover yield per plant, grain yield per plant and harvest index, ICMA 843-22 X BIB-65 for plant height, number of effective tillers per plant, test weight, dry fodder yield per plant, grain yield per plant and harvest index, ICMA 843-22 X BIB-186 for plant height, number of effective tillers per plant, ear head length, grain yield per plant, harvest index, ICMA 92777 X BIB-66 for number of effective tillers per plant, ear head length, ear head diameter, dry stover yield per plant, grain yield per plant, harvest index, ICMA 97111 X BIB-186 for number of effective tillers per plant, ear head length, test weight, dry stover yield per plant, grain yield per plant, harvest index, ICMA 93333 X BIB-66 for number of effective tillers per plant, ear head length, ear head diameter, test weight, dry fodder yield per plant, grain yield per plant and harvest index, ICMA 93333 X BIB-75 for number of effective tillers per plant, ear head length, test weight, dry stover yield per plant, grain yield per plant, harvest index, ICMA 93333 X BIB-186 for plant height, number of effective tillers per plant, ear head length, dry stover yield per plant, grain yield per plant and harvest index, ICMA 04999 X BIB-65 for number of effective tillers per plant, ear head length, dry stover yield per plant, grain yield per plant and harvest index, ICMA 04999 X BIB-76 for number of effective tillers per plant, ear head length, dry fodder yield per plant, grain yield per plant and harvest index, ICMA 04999 X BIB-186 for number of effective tillers per plant, test weight, dry stover yield per plant, grain yield per plant and harvest index, JMSA 20042 X BIB- 40, JMSA 20042 X BIB- 66, and JMSA 20042 X BIB- 76 for number of effective tillers per plant, test weight, dry stover yield per plant, grain yield per plant, harvest index and JMSA 20042 X BIB- 65 for days to 50 per cent flowering, test weight, dry stover yield per plant and grain yield per plant. These crosses were considered promising for their use in yield improvement because of having high heterotic effect for yield as well as component characters. Similar results in varying environments for different characters were also reported by Shinde and Mahetre (2014) [17], Bhardwaj *et al.* (2015) [2] and Nandaniya *et al.* (2016) [14].

The best three crosses for different characters in all the three environments as well as over the environments for standard heterosis have been mentioned in Table 4. The maximum values of standard heterosis recorded were 355.96 (ICMA 04999 X BIB- 76) for grain yield per plant while for yield components (Table 5) it was196.72 (RMS 6A X BIB-186) for harvest index,123.97 for (ICMA 04999 X BIB- 76), for number of effective tillers per plant, 110.56 (ICMA 843-22 X BIB- 76) for dry stover yield per plant, 72.08 (JMSA 20042 X BIB- 65) for test weight, 32.72 (RMS 21A X BIB- 186) for ear head length, 27.64 (RMS 7A X BIB-40) for ear head diameter, 15.82 (RMS 21A X BIB-186) for plant height, -8.98 (ICMA 97111 X BIB- 76) for days to 50% flowering and -7.15 (RMS 7A X BIB-75) for days to maturity. High heterosis for grain yield and its several components was also reported by Yadav (2006) [19], Eldie *et al.*(2007) [8], Izge *et al.* (2007) [10], Kumhar (2007) [12], Devda *et al.*(2008) [7], Ghodasara *et al.*(2008) [9], Lakshmana and Biradar (2008) [13], Patel *et al.* (2008) [5], Patil *et al.*(2008) [16], Vetriventhan *et al.* (2008) [18], Bidinger and Yadav (2009) [3], Chotaliya *et al.*(2009) [5], Chauhan *et al.*(2010) [4], Vagadiya *et at.* (2010), Devda *et al.* (2012) [6], Jethva *et al.* (2012) [11] and Bhadalia *et al.* (2013) [1] and Nandaniya *et al.* (2016) [14].

Table 1: ANOVA for grain yield per plant and its components based on data pooled over environments.

	Mean squares										
Source of variation	**d.f.**	**Days to 50% flowering**	**Days to maturity**	**Plant height**	**Number of effective tillers / plant**	**Ear head length**	**Ear head diameter**	**Test weight**	**Dry Stover yield / plant**	**Grain yield / plant**	**Harvest index**
Replication (r)	2	2.206	1.302	0.334	0.049*	0.389	0.001	0.401	3.133	0.375	104.595**
Environments (e)	2	263.356**	714.791**	2106.327**	2.424**	280.563**	5.075**	38.084**	291.588**	151.529**	275.109**
Rep. x Env.	4	0.244	0.394	6.956	0.001	0.637	0.010	0.365	4.548	0.838	1.434
Crosses	59	32.393**	41.767**	1497.909**	3.651**	84.056**	1.366**	22.875**	1452.682**	277.358**	358.957**
Crosses x Env.	118	1.595**	7.066**	151.973**	0.029**	1.275**	0.048**	0.164	0.786	0.971**	1.112**
Error	354	0.881	1.753	13.048	0.012	0.613	0.014	0.647	3.107	1.291	3.966
Total	539	5.461	9.930	213.673	0.423	10.930	0.188	3.111	162.354	31.990	43.560

*,** Significant at 5% and 1% level of significance, respectively

Table 2: Range of standard heterosis and number of crosses showing significant heterosis in desirable direction in pearl millet

Characters	**Standard heterosis (%) over best check**	
	Range	**Number of significant crosses**
Days to 50 % flowering	-8.98-6.38	20
Days to maturity	-7.15-6.08	31
Plant height	-18.75-15.80	10
Number of effective tillers per plant	-21.92-123.97	43
Ear head length	-34.88-32.72	20
Ear head diameter	-39.84-27.64	15
Test weight	-23.12-72.08	37
Dry stover yield per plant	-55.38-110.56	33
Grain yield per plant	-18.42-355.96	47
Harvest index	-10.29-196.72	55

Table 3: Best heterotic crosses with *per se* performance for grain yield per plant and significant desirable standard heterosis for other traits in pearl millet.

Crosses	**Grain yield per plant**	**Traits with significant desirable standard heterosis**
RMS 6A X BIB- 65	79.65**	DM, ET, TW, DSY, GY, HI
RMS 7A X BIB- 40	91.23**	ET, ED, TW, DSY, GY
RMS 7A X BIB- 75	280**	DM, ET, ED, TW, DSY, GY, HI
RMS 21A X BIB- 186	236.84**	PH, ET, EL, TW, DSY, GY, HI
ICMA 843-22 X BIB-65	190**	PH, ET, TW, DSY, GY, HI
ICMA 843-22 X BIB-186	192.28**	PH, ET, EL, GY, HI
ICMA 92777 X BIB-66	215.79**	ET, EL, ED, DSY, GY, HI
ICMA 97111 X BIB-186	234.74**	ET, EL, TW, DSY, GY, HI
ICMA 93333 X BIB-66	146.67**	ET, EL, ED, TW, DSY, GY, HI
ICMA 93333 X BIB-75	232.98**	ET, EL, TW, DSY, GY, HI
ICMA 93333 X BIB-186	274.39**	PH, ET, EL, DSY, GY, HI
ICMA 04999 X BIB-65, ICMA 04999 X BIB-76	294.91**,355.96**	ET, EL, DSY, GY, HI
ICMA 04999 X BIB-186	262.28**	ET, TW, DSY, GY, HI
JMSA 20042 X BIB- 40, JMSA 20042 X BIB- 66 and JMSA 20042 X BIB- 76	315.26**,146.32**,161.40**	ET, TW, DSY, GY, HI
JMSA 20042 X BIB- 65	70.70**	DF, TW, DSY, GY

*, ** Significant at 5% and 1%, respectively, DF= Days to 50 % flowering, DM= Days to maturity, PH= Plant height, ET= Number of effective tillers per plant, EL = Ear head length, ED= Ear head diameter, TW= Test weight, DSY =Dry stover yield per plant, GY=Grain yield/plant, HI= Harvest index.

Table 4: The best performing crosses for standard heterosis

S. No.	**Characters**	**Cross**		
1.	Days to 50% flowering	1.ICMA 97111X BIB-76	2. RMS 6A X BIB- 75	3.JMSA 20042 X BIB-65
2.	Days to maturity	1. RMS 6A X BIB- 75	2.RMS 6A X BIB- 65 RMS 7A X BIB-76	3.ICMA 04999X BIB-75
3.	Plant height	1. RMS 21A X BIB-186	2. ICMA 843-22 X BIB- 75	3. ICMA 93333X BIB-186
4.	Number of effective tillers per plant	1. ICMA 04999X BIB-76	2. ICMA 04999X BIB-65	3.JMSA 20042 X BIB-40
5.	Ear head length	1. RMS 21A X BIB-186	2. ICMA 92777X BIB-40	3. ICMA 93333X BIB-186
6.	Ear head diameter	1. RMS 7AX BIB-40	2. ICMA 93333X BIB-66	3. ICMA 04999X BIB-75
7.	Test weight	1.JMSA 20042 X BIB-6	2. ICMA 93333X BIB-75	3. RMS 6AX BIB-65
8.	Dry stover yield per plant	1. ICMA 843-22X BIB-76	2. ICMA 04999X BIB-65	3. ICMA 92777X BIB-66
9.	Grain yield per plant	1. ICMA 04999X BIB-76	2. JMSA 20042 X BIB-40	3. ICMA 04999X BIB-40
10.	Harvest Index	1. RMS 6AX BIB-186	2. ICMA 04999X BIB-76	3. ICMA 04999X BIB-75

Table 5: Crosses having maximum values (%) of standard heterosis for grain yield and its components traits in pearl millet.

Characters	Crosses and their maximum values (%) for standard heterosis	
	Crosses	Values (%)
Days to 50 % flowering	ICMA 97111 x BIB-76	-8.98
Days to maturity	RMS 7A x BIB-75	-7.15
Plant height	RMS 21A x BIB-186	15.82
Number of effective tillers per plant	ICMA 04999 x BIB-76	123.97
Ear head length	RMS 21A x BIB-186	32.72
Ear head diameter	RMS 7A x BIB-40	27.64
Test weight	JMSA 20042 x BIB-65	72.08
Dry stover yield per plant	ICMA 843-22 x BIB-76	110.56
Grain yield per plant	ICMA 04999 x BIB-76	355.96
Harvest index	RMS 6A x BIB-186	196.72

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