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Research Article

Identification of Pearl Millet [*Pennisetum glaucum* (L.) R.Br.] Heterotic Crosses involving Cytoplasmic-Genetic Male Sterility in Low Rainfall Areas

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Abstract

Fifty crosses (obtained by crossing five male sterile lines with ten inbreds in line x tester mating design at ICRISAT, Hyderabad) were evaluated in terms of economic or standard heterosis for grain yield and its component characters in randomized block design under three different environments at Research Farm, Agricultural Research Station, Bikaner, Rajasthan, India. The highest and desirable standard heterosis was recorded for the traits number of effective tillers per plant (107.46%) followed by grain yield per plant (97.04%), dry stover yield per plant (72.47%) and total number of tillers per plant (57.11%). This suggested feasibility of heterosis breeding in pearl millet. The crosses namely ICMA 843-22 x BIB-343, ICMA 843-22 x BIB-451, RMS 7A x BIB-407, ICMA 843-22 x BIB-423 and ICMA 88004 x BIB-423 showed high and significant standard heterosis for grain yield and its attributing characters over the environments. Hence, these were considered promising for use in yield improvement under difference environments including low rainfall areas.

Keywords: Standard Heterosis, Pearl Millet, Crosses, Grain Yield, Hybrid Vigour

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Introduction

The poor man's bread (pearl millet) is considered as staple food for majority of poor farmers and also an important fodder crop for livestock in arid and semi-arid regions. India is the largest producer of pearl millet [*Pennisetum glaucum* (L.) R. Br.] throughout the world. It is extensively cultivated as dual purpose crop over large areas in Asia, Africa and Australia. It also serves as staple food for the millions of people thriving under hunger. The crop is able to thrive under adverse conditions. It is highly cross pollinated crop and diploid (2n=14) in nature and believed to have originated in Africa [1]. Its plants are highly heterozygous because of its cross pollinating system due to protogynous nature. The improvement in this crop in India started extensively when the first and the most widely used cytoplasmic male sterile line, Tift 23A, was released [2]. The basic aim of any crop improvement programme is to increase the yield potential of concerned crop. Exploitation of hybrid vigour is considered to be one of outstanding achievements of plant breeding in this crop. Cross-pollinated nature and availability of cytoplasmic male sterile line in pearl millet had made it feasible to exploit hybrid vigour on commercial scale. To identify potential hybrid combinations, the study of the magnitude and direction of heterotic behaviour under varying environments is of importance. With this perspective, the present investigation was carried out to estimate the nature and magnitude of standard heterosis in pearl millet crosses under arid and/or semi-arid regions.

Materials and Methods

Present investigation was carried to find out superior hybrids based on standard heterosis. 50 pearl millet crosses were generated by crossing 5 male sterile lines (RMS 7A from Rajasthan Agricultural Research Institute, Jaipur, Rajasthan, India and ICMA 843-22, ICMA 88004, ICMA 93333 and ICMA 97111 from ICRISAT, Hyderabad) with 10 genetically diverse restorer lines (selected from All India Coordinated Research Project on Pearl Millet, Bikaner, Rajasthan, India) in line x tester mating design at The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad during *Summer*, 2018. These crosses along with three standard checks (HHB 67 Improved, RHB-177 and MPMH-17) were evaluated during *Kharif*, 2018 at Research Farm, Agricultural Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India. The material was evaluated in randomized block design with three replications under three different moisture regimes (which were considered as environments later on). The three different environments were created by differentiating number of irrigations. The environment E_1, E_2 and E_3 were provided three, two and one irrigations, respectively with recommended doses of fertilizers. The each plot was consisted of two rows of 4 meter length with 60 cm of row spacing and 15 cm of plant to plant spacing. All recommended cultural practices were followed to raise good crop except irrigation. The observations were recorded on ten morphological characters namely days to 50% flowering, days to maturity, total number of tillers per plant, number of effective tillers per plant, ear head length (cm), ear head diameter (cm), test weight (g), dry stover yield per plant (g), grain yield per plant (g) and harvest index (%). The standard heterosis was estimated as percent increase or decrease of mean performance over the best check (RHB-177) in the experiment. The mean values of data recorded on various characters were used to calculate standard or economic heterosis by using following formula:

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \overline{SC}}{\overline{SC}} x100$$

Where, $\bar{F}_1$ = Mean over replications of hybrid between ith and jth parent and $\overline{SC}$= Mean performance of superior check (RHB-177) used in the present investigation. The significance of the standard heterosis estimates was done using t-test. The S.E. for testing the significance was calculated by the following formula:

$$SE_{(\bar{F}_1 - \overline{SC})} = \sqrt{\frac{2Ems}{re}}$$

Where, Ems = Error mean square, r = number of replications and e = number of environments. The t-value was estimated by the following formula:

$$t = \frac{\bar{F}_1 - \overline{SC}}{SE_{(\bar{F}_1 - \overline{SC})}} x100$$

Calculated ‘t’ value was compared with the table value at error degrees of freedom.

Results and Discussion

The pooled analysis of variance (**Table 1**) over the environments indicated the presence of significant genetic variability among the crosses for all the characters studied. In commercial exploitation of hybrid vigour, mean increase or decrease of F_1 crosses over standard check is of significance. Hence, in present investigation, the amount of standard heterosis over best check hybrid (RHB-177) for grain yield per plant and some other yield component traits is discussed. The range of standard heterosis and number of crosses showing significant and desirable standard heterosis over the environments is presented in **Table 2**. Grain yield per plant in pearl millet is the character of economic importance for which considerable magnitude of standard heterosis was registered in number of crosses in present study. On the basis of data pooled over all the three environments, the standard heterosis ranged from -48.06 (ICMA 97111 x BIB-359) to 97.04 (RMS 7A x BOB-407) for grain yield per plant. Six crosses viz., RMS 7A x BIB-343, RMS 7A x BIB-407, ICMA 843-22 x BIB-343, ICMA 843-22 x BIB-423, ICMA 843-22 x BIB-451 and ICMA 88004 x BIB-423 were exhibited positive significant standard heterosis in pooled analysis for grain yield per plant.

The cross combinations with significant standard heterosis over the environments for four or more characters (**Table 3**) were ICMA 843-22 x BIB-343 for days to 50% flowering, days to maturity, total number of tillers per plant, number of effective tillers per plant, dry stover yield per plant and grain yield per plant, RMS 7A x BIB-407 for total number of tillers per plant, number of effective tillers per plant, ear head diameter, dry stover yield per plant and grain yield per plant, RMS 7A x BIB-343 for days to 50% flowering, days to maturity, dry stover yield per plant and grain yield per plant and ICMA 88004 x BIB-423 for total number of tillers per plant, number of effective tillers per plant, 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 effects for yield and its component characters. Similar results for standard heterosis were also reported by [3], [4], [5] and [6] in pearl millet.

Table 1 The pooled analysis of variance for grain yield per plant and its component traits over the environments

Source of Variation	d.f.	Mean sum of squares									
		Days to 50% flowering	Days to maturity	Total no. of tillers/ plant	No. of effective tillers/ plant	Ear head length	Ear head diameter	Test weight	Dry stover yield/ plant	Grain yield/ plant	Harvest index
R	2	7.20	2.59	0.03	0.10	0.29	0.05	0.98	131.03	30.91*	34.59
E	2	295.49**	634.77**	20.45**	9.88**	27.57**	2.99**	101.88**	2555.69**	999.42**	841.59**
R x E	4	4.96	4.40	0.06	0.08	3.13	0.04	0.99	99.51	16.48	29.48
C	49	56.56**	62.65**	4.13**	1.52**	56.58**	0.44**	5.01**	872.21**	173.29**	160.10**
C x E	98	4.36*	3.12**	0.17*	0.13*	4.30**	0.07*	1.00**	77.00**	12.69**	38.63**
Error	294	3.29	2.15	0.13	0.10	2.95	0.04	0.69	53.10	8.50	13.84
Total	449	10.67	11.80	0.66	0.30	9.20	0.11	1.68	159.61	31.99	39.13

Where, R = Replications, E = Environments, C = Crosses and * and ** = significant at 5% and 1% level of significance, respectively

Table 2 Range of standard heterosis (%) and number of crosses showing significant and desirable standard heterosis over the environments in pearl millet

Characters	Range of standard heterosis (%)	Number of crosses showing significant heterosis over the environments
Days to 50% flowering	-10.06 to 13.02	3
Days to maturity	-6.98 to 9.48	6
Total number of tillers per plant	-55.22 to 57.11	3
Number of effective tillers per plant	-31.36 to 107.46	4
Ear head length (cm)	-30.65 to 22.20	2
Ear head diameter (cm)	-33.08 to 20.87	1
Test weight (g)	-22.92 to 13.57	0
Dry stover yield per plant (g)	-23.91 to 72.47	11
Grain yield per plant (g)	-48.06 to 97.04	6
Harvest index (%)	-46.28 to 21.59	1

Table 3 Heterotic crosses for four or more characters with per se performance for grain yield per plant

Crosses	Grain yield per plant (g)	Traits with significant desirable standard heterosis
ICMA 843-22 x BIB-343	24.89	Days to 50% flowering, days to maturity, total number of tillers per plant, number of effective tillers per plant, dry stover yield per plant and grain yield per plant
RMS 7A x BIB-407	22.10	Total number of tillers per plant, number of effective tillers per plant, ear head diameter, dry stover yield per plant and grain yield per plant
RMS 7A x BIB-343	17.56	Days to 50% flowering, days to maturity, dry stover yield per plant and grain yield per plant
ICMA 88004 x BIB-423	19.30	Total number of tillers per plant, number of effective tillers per plant, dry stover yield per plant and grain yield per plant.

Highest and desirable standard heterosis (%) was recorded for number of effective tillers per plant followed by grain yield per plant dry stover yield per plant and total number of tillers per plant. This proved feasibility of heterosis breeding in pearl millet and suggested that these characters are highly heterotic. So, major emphasis should be given on these characters in heterosis breeding for pearl millet.

Three best crosses for different characters over the environments (pooled analysis) for standard heterosis are presented in **Table 4**. The highest magnitude of standard heterosis (%) were 97.04 (ICMA 843-22 x BIB-343) for grain yield per plant while for its components it was -10.06 (ICMA 843-22 x BIB-343) for days to 50% flowering, -6.98 (ICMA 843-22 x BIB-343) for days to maturity, 57.11 (ICMA 88004 x BIB-423) for total number of tillers per plant, 107.46 (ICMA 88004 x BIB-423) number of effective tillers per plant, 22.20 (ICMA 93333 x BIB-383) for ear head length, 20.87 (RMS 7A x BIB-407) for ear head diameter, 13.57 (ICMA 843-22 x BIB-451) for test weight, 72.47 (RMS 7A x BIB-407) for dry stover yield per plant and 21.59 (ICMA 843-22 x BIB-451) for harvest index. Similarly, different magnitude of standard heterosis was also reported by [3], [7], [8] and [9] in pearl millet.

Table 4 The best performing crosses on the basis of standard heterosis

Characters	Rank wise crosses		
Days to 50% flowering	ICMA 843-22 x BIB-343	RMS 7A x BIB-343	RMS 7A x BIB-359
Days to maturity	ICMA 843-22 x BIB-343	ICMA 88004 x BIB-343	ICMA 843-22 x BIB-383
Total number of tillers per plant	ICMA 88004 x BIB-423	RMS 7A x BIB-407	ICMA 843-22 x BIB-343
Number of effective tillers per plant	ICMA 88004 x BIB-423	RMS 7A x BIB-407	ICMA 843-22 x BIB-343
Ear head length (cm)	ICMA 93333 x BIB-383	ICMA 843-22 x BIB-415	ICMA 97111 x BIB-383
Ear head diameter (cm)	RMS 7A x BIB-407	ICMA 843-22 x BIB-415	ICMA 88004 x BIB-423
Test weight (g)	ICMA 843-22 x BIB-451	ICMA 843-22 x BIB-423	ICMA 88004 x BIB-423
Dry stover yield per plant (g)	RMS 7A x BIB-407	RMS 7A x BIB-451	ICMA 843-22 x BIB-359
Grain yield per plant (g)	ICMA 843-22 x BIB-343	ICMA 843-22 x BIB-451	RMS 7A x BIB-407
Harvest index (%)	ICMA 843-22 x BIB-451	ICMA 843-22 x BIB-423	ICMA 843-22 x BIB-343

Conclusions

The five crosses namely ICMA 843-22 x BIB-343, ICMA 843-22 x BIB-451, RMS 7A x BIB-407, ICMA 843-22 x BIB-423 and ICMA 88004 x BIB-423 showed high and significant standard heterosis for grain yield and its attributing characters over the environments. These hybrids also exhibited significant high and positive standard heterosis in limited moisture conditions (E_2 and E_3). Hence, these were considered promising for their use in yield improvement because of having high heterotic effect for yield as well as some other component characters. These hybrids can be tested in pearl millet improvement programmes to identify as commercial hybrids for dry areas where low rainfall is occurred.

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