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Research Article

Performance of pearl millet hybrids under arid conditions

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Abstract:
Sixteen male-sterile lines of pearl millet (*Pennisetum glaucum* (L.) R. Br.) found promising at CAZRI, Jodhpur were crossed with nine diverse restorers from different sources in this region, in a line x tester fashion to develop 144 hybrid combinations, with the objective to identify suitable A lines, R lines and hybrid combinations for arid Rajasthan. These hybrids were evaluated at three different locations in western Rajasthan (Tinwari, Pali and Jodhpur) during the rainy season of 2003. Eighteen promising hybrids based upon their performance over locations during 2003, were again evaluated in larger plots during the rainy season of 2004. Considering grain yield over all the five locations during the two seasons 2003 and 2004, ten high yielding hybrids were identified. Among these hybrids grain yield ranged from 1932 kg/ha to 2293 kg/ha, and flowering time from 43 to 48 days. The highest yielding hybrid was ICMA 96111 x RIB-3135-18 followed by ICMA 98333 x RIB-3135-18, ICMA 98222 x CZI 9621, ICMA 98004 x RIB-3135-18, ICMA 97555 x RIB-3135-18 and ICMA 95555 x H 77/833-2. It was observed that the restorer lines RIB-3135-18, CZI 9621, H77/833-2, CZI 1676-2, MIR 97171 and ICMR 356 gave high yielding hybrids. Similarly male sterile lines, ICMA 98222, ICMA 97555 and ICMA 98004 were involved in promising hybrid combinations. The hybrid ICMA 98222 x CZI 9621, which was one of the top five high yielding hybrids, ranked first in a multilocation trial conducted during the rainy season of 2005, at Jodhpur, Bawal, Durgapura and Bikaner, representing extreme arid conditions. This hybrid again recorded 12.8% and 6.6% higher grain yield over national checks GHB 538 and ICMH 356 respectively in Initial hybrid trial 2007, and was promoted to the Advance Hybrid and Population Trial for *Kharif* 2008.

Key words: Pearl millet, *Pennisetum glaucum,* Hybrids, Arid conditions

Introduction

Pearl millet (*Pennisetum glaucum*) is traditionally cultivated in low rainfall regions on sandy soils with low fertility, where other coarse grain cereals fail to produce grain. Out of 9.43 m ha of pearl millet area in India, 4.38 m ha is cultivated in Rajasthan. Development of high yielding varieties of pearl millet in the last forty years has led to its increased productivity and stability largely in the regions with relatively better environments, while regions like western Rajasthan with poor environments still suffer from low productivity (470 kg/ha). This is because area under high yielding varieties of pearl millet in Rajasthan is still < 40% (Anon., 2005). Pearl millet hybrids recommended for this region are not widely used by farmers, as they lack the desired adaptability and other characteristics required for this region (Kelley *et. al.,* 1996). There is greater risk for failure of hybrid crop during poor rainfall years due to their poor adaptation to this region and under such conditions they yield even less than the local land races. Under drought situations, available hybrids also give poor stover yield, which has equal importance to grain yield due to high livestock population in the arid regions. Hence a hybrid development programme specifically targeted for poor environments like western Rajasthan would be beneficial as hybrid combinations based on parents developed under, and selected for adaptation to the harsh climatic conditions of the arid regions are likely to be more successful. Keeping this requirement in mind hybrid combinations developed on male sterile lines and restorer lines adapted to this region were evaluated under ICAR-ICRISAT partnership programme, and were evaluated under arid conditions for identification of suitable parents and hybrids, for arid regions of Rajasthan.

Material and methods

Sixteen male-sterile lines, ICMA 91444; ICMA 92111; ICMA 92444; ICMA 93333; ICMA 94111; ICMA 94555; ICMA 95444; ICMA 95555; ICMA 96111; ICMA 97555; ICMA 98004; ICMA 98111; ICMA 98222; ICMA 98333, 841A, and CZMS 47B, were chosen on the basis of their performance under arid climate preliminary evaluation for downy mildew resistance at CAZRI, Jodhpur (Manga *et.al.*, 2004). Similarly nine diverse restorer inbreds,

developed at different centers and adapted to arid conditions (MIR 97137 and MIR 97171 from ARS, Mandor; CZI 1676-2, CZI 9621 and CZI 98/11 from CAZRI, Jodhpur; RIB 3135-18 and RIB 335/74 from ARS, Durgapura, Jaipur, and H 77/833-2 from CCSHAU, Hisar and ICMR 356 from ICRISAT), were chosen. These were crossed with the above mentioned sixteen male sterile lines to develop one hundred and forty four hybrid combinations during summer 2002 at ICRISAT Patancheru. These hybrids however, could not be evaluated for their performance because planting could not be done due to severe drought during 2002. But these hybrids were evaluated for downy mildew susceptibility in green house at ICRISAT, using 81B, ICMP 451, 843B and 7042S as susceptible checks and P7-4 and 700651 as resistant checks. During the year 2003, all the 144 hybrids along with two checks HHB 67 and ICMH 356, were tested at three locations; Pali, Jodhpur and Tinwari in western Rajasthan. Pali (25°47'N and 73°19'E) is located about 70 km south of Jodhpur, while Tinwari (26°32'N and 72°50'E)is located 42 km north of Jodhpur. At Jodhpur (26°18'N and 73°01'E), the trial was conducted at the central farm of CAZRI, Jodhpur. Soil at pali is shallow sandy loam, while soil of Tinwari and Jodhpur is loamy sand. At Pali, trial was conducted at the CAZRI regional research station, while trial at Tinwari was conducted on a private farm. All the 144 hybrids along with two checks HHB 67 and ICMH 356, recommended for the area, were planted during 2003, in four replications at all the three locations. Each entry was planted in two rows of 4m length spaced 50 cm apart. Plant to plant distance was maintained at 15 cm. Trials were planted immediately after the first effective rainfall in the month of July 2003. A basal dose N @ of 20 kg/ha and P_2O_5 @ 20 kg/ha was applied at the time of sowing. Another 20 kg N/ha was applied three to four weeks after planting when effective rainfall was received. These trials were conducted completely under rainfed conditions. During 2003, Pali and Jodhpur received 258 mm and 282 mm of rainfall respectively, during the crop growth period. Crop experienced terminal stress at both of these locations leading to low mean grain yield of 1118 kg/ha at Pali and 1475 kg/ha at Jodhpur. Tinwari received 425 mm of well-distributed rainfall, hence recorded high mean grain yield of 2758 kg/ha. Eighteen hybrids that were found promising on the basis of high mean grain yield over locations were re-evaluated during the rainy season of 2004 at all the three locations in larger plots of four rows of 4 m length, with row to row spacing of 50 cm. Trials at all the three locations were managed in the same way as in 2003. During the cropping season of 2004, Jodhpur, Pali and Tinwari received a rainfall of 189, 226 and 191 mm respectively. Crop experienced severe terminal moisture stress at Jodhpur and Pali, and moderate stress at Tinwari location. At Jodhpur crop experienced a long dry spell of 28 days at reproductive stage leading to low grain yield (trial mean grain yield 668 kg/ha). Trial at Pali failed due to severe stress as no rains were received after August. Due to early sowing and well distribution of rains at Tinwari location, crop growth was good and as a result high mean grain yield of 2664 kg/ha was obtained. During both seasons of 2003 and 2004, data were recorded on various agronomic traits like plant height, days to 50% flowering, head length, head count, head yield, grain yield and dry fodder yield, and were subjected to statistical analysis. A hybrid developed on restorer developed at CAZRI, Jodhpur and identified as promising in this study was further evaluated in a multi-location trial during 2005 and was later contributed to the Initial Hybrid Trial – I of the All India Coordinate Pearl millet Improvement Project during *kharif* 2007.

Results and discussions

Owing to severe drought during the rainy season of 2002, hybrids made by crossing male sterile lines with restorer lines could not be evaluated for their performance in Rajasthan. However to get some information on the downy mildew susceptibility, hybrids and their parental lines (A and R lines) were screened against Jodhpur pathotype of downy mildew in green house at ICRISAT. Downy mildew incidence in susceptible checks ranged from 81% in 81B to 97.2% in 7042S, while in resistant checks it was 9.6% in P 7-4 and 8.4% in case of 700651. ICMA 94555 and ICMA 97555 were found to be free from downy mildew. Similarly three restorers, MIR 97137; RIB 3135-18 and ICMR 356, were highly resistant and showed ≤1% disease incidence. H 77/833-2 recorded maximum (99.1%) downy mildew incidence. Disease incidence among hybrids varied from 0.0 to 82.8%. The hybrid ICMA 98333 x H77/833-2 recorded maximum downy mildew incidence (82.8%). It was observed that majority of the hybrids were resistant to Jodhpur pathotype of downy mildew, despite one of the parents being susceptible. This could be because downy mildew resistance is dominant and controlled by one or two genes (Appadurai et. al., 1975, Singh 1974, Gill et. al., 1975, 1978).

Analysis of variance of *kharif* 2003 data revealed significant differences among hybrids at all locations. Tinwari location recorded the highest mean grain yield of 2758 kg/ha as compared to 1475 kg/ha at Pali and 1118 kg/ha at CAZRI, Jodhpur. This was because Tinwari location received higher rainfall

(425 mm) during the crop growth period as compared to Pali (258 mm) and Jodhpur (282 mm). Mean over locations revealed that grain yield among hybrids ranged from 1041 kg/ha to 2704 kg/ha and days to flowering from 40 to 48 days. The highest yielding hybrid (table 1) was ICMA 96111 x RIB-3135-18 (46 days, 2704 kg/ha) followed by ICMA 92111 x RIB-3135-18 (47 days, 2622 kg/ha), ICMA 98004 x RIB-3135-18 (43 days, 2357 kg/ha), ICMA 94111 x RIB-3135-18 (45 days, 2283 kg/ha) and ICMA 95444 x RIB-3135-18 (43 days, 2282 kg/ha). It was interesting to note that all of these hybrids had common restorer i.e. RIB 3135-18 as male parent. In this trial, the earliest check HHB 67 recorded grain yield of 1562 kg/ha and flowered in 41 days, while another check ICMH 356, had grain yield of 1932 kg/ha and flowered in 45 days. The highest yielding hybrid ICMA 96111 x RIB-3135-18 recorded 42 % grain yield advantage over ICMH 356, while ICMA 98004 x RIB-3135-18 and ICMA 95444 x RIB-3135-18 had 51% and 46% grain yield advantage over HHB 67. On the basis of mean performance of hybrids during kharif 2003, eighteen high yielding hybrids (involving 10 A lines and 7 R lines) were identified. Most of these hybrids had <5% downy mildew incidence compared to 36.5% in HHB 67. Out of eighteen hybrids, eight hybrids flowered in 42–44 days and had 4 to 24% grain yield advantage over ICMH 356 and 27 to 51% grain yield advantage over HHB 67. Restorer inbred RIB-3135-18 was involved in eight of these high yielding hybrids and on as many as A-lines. The above identified promising eighteen hybrids were again evaluated in larger plots at three arid zone locations during the rainy season of 2004. Precipitation at all three locations was low. Jodhpur, Pali and Tinwari received 158mm, 226mm and 160mm rainfall respectively. At Tinwari the rainfall though low but well distributed, as a result crop growth was good and there was moderate terminal stress. At Pali the rainfall was sufficient but skewed, resulting to severe moisture stress at flowering and later stages. This led to crop failure due to poor growth and no seed setting. Considerable yield reduction occurred at Jodhpur, while grain yield at Tinwari was much better as compared to other two locations. Grain yield at Jodhpur location varied from 326 kg/ha to 1074 kg/ha, while at Tinwari location it varied from 1878 kg/ha to 3583 kg/ha. On the basis of mean over locations (Table 2), check hybrid HHB67 flowered in 41 days and recorded a grain yield of 1258 kg/ha, while ICMH 356 flowered in 46 days and recorded a grain yield of 1407 kg/ha. Out of the top ten high yielding hybrids (Table 3), five hybrid flowered in 42 to 45 days and had 47 to 81% grain yield advantage over HHB 67, and 32 to 62 % grain yield advantage over ICMH 356. The highest yielding hybrid during *kharif* 2004 was ICMA 98222 x CZI 9621 (45 days, 2277 kg/ha). It was observed that restorer inbred RIB-3135-18 was involved in six of the top ten hybrids. Other restorers were CZI 9621, H 77/833-2, CZI 1672-2 and MIR 97171.

Considering grain yield over all the five locations during the two seasons 2003 and 2004, ten high yielding hybrids were identified (table 3). Grain yield among these hybrids ranged from 1932 kg/ha to 2293 kg/ha, and flowering time from 43 to 48 days. HHB 67 remained the earliest flowering hybrid. It recorded a grain yield of 1410 kg/ha. Out of ten hybrids, six hybrids fall in the early maturity group as these flowered in 43 to 45 days. These hybrids had 41 to 60% grain yield advantage over HHB 67 and 21 to 35% grain yield advantage over ICMH 356. The highest yielding hybrid was ICMA 96111 x RIB-3135-18 (47 days, 2293 kg/ha). Other high yielding hybrids were ICMA 98333 x RIB-3135-18 (44, 2227 kg/ha), ICMA 98222 x CZI 9621 (45 days, 2143 kg/ha), ICMA 98004 x RIB-3135-18 (44 days, 2105 kg/ha), ICMA 97555 x RIB-3135-18 (44 days, 2080 kg/ha) and ICMA 95555 x H 77/833-2 (43 days, 1992 kg/ha). It was again observed that RIB-3135-18 was involved in six out of the ten hybrids, hence it was the most promising restorer. Other promising restorers that gave high yielding hybrids were CZI 9621, H 77/833-2, CZI 1676-2, MIR 97171 and ICMR 356. Besides restorers eight different A-lines were also involved in these top ten hybrids. Three out of these namely, ICMA 98222, ICMA 97555 and ICMA 98004 were resistant to downy mildew and hence can be used in crossing with other promising restorers to develop suitable hybrids for this region.

Hybrid ICMA 98222 x CZI 9621, which was one of the top five high yielding hybrids, as mentioned above, resulted from a cross between a male sterile line from ICRISAT and inbred restorer CZI 9621, from CAZRI, Jodhpur. This hybrid was evaluated along with eighteen hybrids including three checks in a multilocation trial, at Jodhpur, Bawal, Durgapura and Bikaner, representing extreme arid conditions, during the rainy season of 2005. In this trial, ICMA 98222 x CZI 9621 ranked first among all the hybrids (Table 4). Looking to the performance of this hybrid in multilocation trial, this hybrid was entered to the All India Coordinated Initial Hybrid Trial (IHT-I) during the rainy season of 2007. In the Initial Hybrid trial (IHT-I), this hybrid again recorded 12.8% and 6.6% higher grain yield over GHB 538 and ICMH 356 respectively (Table 5) and was promoted to the Advance Hybrid and Population Trial for *kharif* 2008 (AICPMIP 2007).

In this study It is concluded that the hybrids, ICMA 96111 x RIB-3135-18, ICMA 98333 x RIB-3135-18, ICMA 98222 x CZI 9621, ICMA 98004 x RIB-3135-18, ICMA 97555 x RIB-3135-18 and ICMA 95555 x H 77/833-2 were found to be promising. RIB-3135-18, CZI 9621, H 77/833-2, CZI 1676-2, MIR 97171 and ICMR 356 were found to be promising restorers. Similarly ICMA 98222, ICMA 97555 and ICMA 98004 were promising male sterile lines. The study was thus able to identify suitable parents and hybrids for the arid conditions.

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Table 1 Mean performance (grain yield kg/ha) of pearl millet promising hybrids during the rainy season of 2003

Hybrid combination	LOCATION			Mean	Days to bloom	Downy mildew incidence (%)
	Tinwari	Pali	Jodhpur			
ICMA 96111 x RIB 3135-18	4537	1436	2138	2704	46	1.1
ICMA 92111 x RIB 3135-18	4851	1181	1835	2406	47	1.3
ICMA 98004 x RIB 3135-18	3766	1457	1849	2357	43	0.0
ICMA 94111 x RIB 3135-18	3946	1307	1595	2283	45	0.3
ICMA 95444 x RIB 3135-18	3973	1396	1477	2282	43	2.2
ICMA 92111 x CZI 9621	3540	1683	1608	2277	47	3.6
ICMA 98333 x RIB 3135-18	3542	1471	1742	2252	43	1.6
ICMA 94555 x RIB 335/74	3278	1566	1888	2244	46	0.0
ICMA 98222 x RIB 3135-18	3552	1110	1967	2210	45	0.0
ICMA 97555 x RIB 3135-18	3511	1164	1643	2106	45	0.0
ICMA 93333 x CZI 1676-2	2999	1015	2230	2093	46	2.3
ICMA 96111 x ICMR 356	3350	1304	1622	2092	47	3.1
ICMA 95555 x RIB 3135-18	3496	1455	1129	2027	44	0.0
ICMA 93333 X ICMR 356	3295	1156	1766	2073	47	0.0
ICMA 96111 x CZI 1676-2	3324	1034	1754	2038	46	2.7
ICMA 95555 x H 77/833/2	3088	1325	1696	2036	42	0.0
ICMA 92111 x CZI 1676-2	2896	1146	1988	2010	47	2.4
ICMA 98222 x CZI 9621	2869	1872	1282	2008	42	1.8
HHB 67	2493	997	1197	1562	41	9.5
ICMH 356	2856	1319	1620	1898	44	0.0
CD (P=0.05)	665	445	508			

Table 2 Mean performance for grain yield (kg/ha) of top ten hybrids during rainy season of 2004

HYBRID	LOCATION			Days to 50% flowering	Downy mildew incidence (%)
	JODHPUR	TINWARI	MEAN		
ICMA 98222 x CZI 9621	972	3583	2277	45	1.9
ICMA 98333 x RIB 3135-18	1074	3330	2202	44	1.8
ICMA 98222 x RIB 3135-18	725	3513	2119	48	0.0
ICMA 97555 x RIB 3135-18	933	3174	2053	42	0.0
ICMA 95555 x H 77/833-2	1047	2847	1947	43	0.0
ICMA 96111 x RIB 3135-18	934	2830	1882	47	0.9
ICMA 98004 x RIB 3135-18	587	3119	1853	44	0.0
ICMA 92111 x CZI 1676-2	601	3090	1846	48	1.2
ICMA 93333 x ICMR 356	817	2856	1837	46	1.4
ICMA 92111 x RIB 3135-18	714	2901	1808	47	2.2
HHB 67	370	2146	1258	41	7.1
ICMH 356	414	2400	1407	46	0.0
CD (P=0.05)	429	836			

Table 3 Top ten hybrids, on the basis of mean performance over five environments

Hybrid	Grain yield (kg/ha)	Days to 50% flowering	Downy mildew incidence (%)
ICMA 96111 x RIB 3135-18	2293	47	1.0
ICMA 98333 x RIB 3135-18	2227	44	1.7
ICMA 98222 x RIB 3135-18	2165	47	0.0
ICMA 98222 x CZI 9621	2143	45	1.9
ICMA 92111 x RIB 3135-18	2107	47	1.7
ICMA 98004 x RIB 3135-18	2105	44	0.0
ICMA 97555 x RIB 3135-18	2080	44	0.0
ICMA 95444 x RIB 3135-18	1996	45	1.0
ICMA 95555 x H 77/833-2	1992	43	0.0
ICMA 96111 x ICMR 356	1932	48	3.5
HHB 67	1410	41	8.3
ICMH 356	1653	46	0.0

Table 4 Mean grain yield (kg/ha) of hybrids at three locations during 2005

Hybrids	Locations			Mean
	Jodhpur	Bawal	Bikaner	
ICMA 98222 x CZI 9621	**431**	**3239**	**1560**	**1743**
ICMA 92777 xTCP-13-2	385	2153	1200	1246
ICMA 00444 x CZI 9621	347	1928	1040	1105
ICMA 00444 x CZI 98/9	350	1117	840	769
ICMA 00444 x TCP-22	331	1368	960	886
ICMA 00444 x CZI 9625	231	1071	900	734
ICMA 00444 x CZI 2000/3	327	1368	1260	985
ICMA 00444 x CZI 2000/6	292	1250	960	834
ICMA 00444 x 2000/13	292	1153	700	715
ICMA 00444 x TCP-20	402	1786	1300	1163
841A X CZI 2000/14	187	821	940	649
ICMA 96666 x CZI 2000/7	212	1418	500	710
ICMA 97111A x TCP-22	296	964	1200	820
ICMA 94555 x CZI 9625	125	1832	1246	1068
ICMA 94555 x CZI 2000/7	252	1118	700	690
ICMA 91444 x CZI 9621	508	1368	960	945
CHECKS				
HHB 67	383	2439	900	1241
ICMH 356	210	1475	860	848
RHB 121	348	1167	1060	858
CD (P=0.05)	103	227	210	

Table 5 Mean grain yield of hybrid in Initial Hybrid Trial-I (AICPMIP) 2007

ENTRY	GY kg/ha	Days to flower	% increase over	
			GHB 538	HHB 67
ICMA 98222 x CZI 9621	2369	48	+12.86	+31.1
CHECKS				
GHB 538	2099	48		
HHB 67	1807	48		
CD 5%	311	43		