

Developing Pearl Millet Seed Parents Adapted to Arid Regions of North-Western India

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Abstract: Rajasthan contributes about 50% to area and 42% to the production of pearl millet in the country. Despite release of large number of hybrids in the country, area under high yielding cultivars in the arid western Rajasthan is about 25%. For hybrids to be successful in the arid region, it is important that the hybrids are developed using parents that are downy mildew resistant and adapted to the harsh climatic conditions of this region. CAZRI has a strong restorer (male parents) development program, but lacked in development of male sterile lines. Hence a targeted program was initiated in 2002 for the development of B lines (maintainer lines) adapted to arid conditions. Twenty B lines of identified promising A lines were crossed in a diallel fashion. A composite was constituted from these crosses and progenies were selected and advanced by selection. Similarly from eighteen promising crosses, segregating populations were developed. Promising plants were self selected from these populations to develop B lines. These B lines were crossed with male sterile lines ICMA 95111 and ICMA 94555 having A₁ cytoplasm and ICMA 97555 having A₄ cytoplasm. The F₁s were backcrossed with the recurrent parents up to BC₆ to develop sixteen male sterile lines in the year 2010. Evaluation of new ms lines revealed presence of sufficient variability for various agronomic traits. Crossing new ms lines with inbred restorers has given promising hybrids that have been contributed to the coordinated trials.

Key words: Pearl millet, *Pennisetum glaucum*, ms lines, arid region.

Pearl millet (*Pennisetum glaucum* (L.) R. Br.), traditionally a dryland crop, is cultivated mostly in marginal environments of the arid and semi-arid regions, characterized by low rainfall, sandy soils with low fertility, where other coarse cereals such as sorghum and maize fail to produce assured yields. This crop is primarily cultivated for grain purpose, but is also valued for its stover and fodder. The crop residue/stover forms an important source of fodder (particularly in low rainfall regions) accounting for 40-50% of the dry matter intake and is often the only source of feed in dry months. India is the largest producer of pearl millet, both in terms of area (9.3 Mha) and production (7.97 Mt), with an average productivity of 856 kg ha⁻¹. This crop contributes 7.8% to the total food grain area of the country and 3.9% to the total food grain production. Rajasthan constitutes about 50% area and 42% of production of pearl millet in the country. Other principle pearl millet growing states are Maharashtra (16% area, 13% production), Uttar Pradesh (9.5% area

and 16% production), Gujarat (8% area and 7% production) and Haryana (6.6% area and 13% production). The average productivity of A zone (north-western states) is 685 kg ha⁻¹. Within this zone, parts of Rajasthan, Haryana and Gujarat receiving less than 400 mm of rainfall are grouped into a sub-zone i.e. A1 zone. This sub-zone is highly drought prone with average annual rainfall below 400 mm, light sandy soils, and high temperatures. Average productivity of the A1 zone (Rajasthan state) is about 410 kg ha⁻¹.

The first hybrid in pearl millet was released in India in the year 1965 (Athwal 1965, 1966). Since then more than 125 hybrids have been released for cultivation. Development of hybrids of pearl millet in the last forty five 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 of about 470 kg ha⁻¹. This is because most of the hybrids recommended for this region were developed elsewhere and lacked the desired adaptability and

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Table 1. Downy mildew incidence in F_2 populations and selected F_3 progenies of pearl millet

B x B F_2 population	Days to 50% flowering	Agronomic score*	Downy mildew (%)	No. of plants selected in F_2	No. of F_3 progenies	No. of F_3 progenies showing DM incidence	
						< 10%	>10%
ICMB 93111 x ICMB 91444	49	3	78	27	27	8	19
ICMB 94555 x ICMB 96333	55	2	54	19	19	18	1
ICMB 94555 x ICMB 91444	51	3	36	23	23	10	13
ICMB 94555 x ICMB 96222	52	3	14	29	29	27	2
ICMB 95333 x ICMB 96333	51	3	48	23	23	13	10
ICMB 94111 x ICMB 93333	53	2	74	27	27	11	16
ICMB 94555 x ICMB 92111	50	2	50	29	29	10	19
ICMB 94555 x ICMB 94111	50	2	28	29	29	19	10
ICMB 95444 x ICMB 92111	43	2	28	51	51	12	39
ICMB 95444 x ICMB 93333	42	4	0	50	50	8	42
ICMB 95444 x ICMB 94555	44	2	24	51	51	35	16
ICMB 97555 x ICMB 94555	45	2	30	23	23	23	0
ICMB 97555 x ICMB 95555	43	2	20	31	31	10	21
ICMB 93111 x ICMB 91444	45	3	42	38	38	10	28
ICMB 93111 x ICMB 97555	44	3	82	25	25	8	17
ICMB 95111 x ICMB 93333	44	4	6	58	58	27	31
ICMB 93111 x ICMB 98004	45	2	74	25	25	12	13
ICMB 841 x ICMB 93333	44	2	50	35	35	12	23
Control 843A	44	2	100	-	-	-	-

*Agronomic score is based upon overall performance of a genotype recorded at maturity visually, and rated from 1-5, where 1= poor and 5= best.

characteristics required for this region (Kelley *et al.*, 1996). For successful cultivation of pearl millet hybrids in the arid western Rajasthan, it is important that the hybrids are developed using parents that are downy mildew (DM) resistant and adapted to the harsh climatic conditions of this region. Such hybrids would lead to better adaptation, beside providing cultivar diversity, giving more choice to farmers.

CAZRI has a strong restorer parent development program, and used them in crossing with ms lines from ICRISAT to develop hybrids. Majority of the ICRISAT male-sterile (ms) lines are primarily based on African material and lacked adaptability to the harsh climatic conditions of arid region, and are also susceptible to the downy mildew race prevalent in this region. Hence need was felt to initiate a separate targeted program to develop pearl millet ms lines in this region that are well adapted to the harsh climatic conditions of the western Rajasthan and are also downy mildew resistant. Hybrids developed on such ms lines would have better adaptation to the conditions of this region, besides providing

cultivar diversity, thereby giving more choice to farmers.

Materials and Methods

On the basis of a three years (2002–2004) study conducted at the Central Arid Zone Research Institute Jodhpur, maintainers (B lines) of seventeen male sterile lines (ICMA 91444, ICMA 92111, ICMA 92444, ICMA 93111, ICMA 93333, ICMA 94111, ICMA 94555, ICMA 95111, ICMA 95444, ICMA 95555, ICMA 96111, ICMA 97555, ICMA 98004, ICMA 98111, ICMA 98222, 841A, ICMA 98333) found promising for their performance and ability to generate hybrids for this region (Manga *et al.*, 2004); CZMS 44A and CZMS 47A developed at CAZRI, Jodhpur (Manga and Yadav, 1997) and HMS 9A developed at HAU, Hisar were crossed in a diallel fashion during the summer 2002 at ICRISAT to develop crosses among them to identify good general combiners both for grain yield and downy mildew resistance and to constitute a B composite and to identify crosses for pedigree breeding of B lines. After screening of these crosses against DM in the seedling

Table 2. Range for some agronomic traits in the developing male sterile lines kharif 2008

Character	MS lines under development	MS lines used as check (9 lines)*
Days to 50% flowering	47-70	61-70
Plant height (cm)	70-170	60-175
Panicle length (cm)	11-26	14-26
1000 grain wt (g)	6-16	8-14

* 841A; ICMA 97444; 92777; 91444; 94222; 95111; 95555; 96666; 97555.

screening nursery, eighteen crosses were selected and later selfed to obtain segregating (F_2) populations. These F_2 populations of inter-maintainer inbred crosses (BxB) were planted in July 2003 in larger plots of twenty rows each of 4 m length, at the CAZRI, Jodhpur during the rainy season (kharif) of 2003. The row-to-row distance was 60 cm while plant to plant distance was maintained at 20 cm to allow full expression of traits. The crop was fertilized with 40 kg N ha⁻¹ and 20 kg P ha⁻¹. After planting, crop received a well distributed rainfall of 283 mm. This provided sufficient moisture and humidity for development of DM disease (infector rows on the average had DM incidence of 95%). Data on days to 50% flowering and DM incidence at dough stage were also recorded. Most of the plants in each of the segregating population were selfed. At maturity plants with desirable traits like DM resistance, good tillering, dwarf to medium dwarf plant height, medium to long panicles, compact panicles and having complete panicle exertion were selected for further pedigree breeding of B lines. The selected progenies (F_3) were further evaluated during 2004 in the seedling screening, nursery for identification of DM resistant lines. Resistant lines were carried forward by selfing and advance generations (F_6) of these were utilized for the development of new male sterile lines. Also a maintainer composite (IC-CZ BC) was developed in the year 2003 by intercrossing of diallel F_1 s. Progenies selected from this B composite were carried forward by selfing. S_6 of the promising progenies were crossed with male sterile lines having A_1 and A_4 cytoplasm. The ms lines used as source of A_1 cytoplasm were ICMA 95111 and ICMA 94555, while ICMA 97555 was used as source of A_4 cytoplasm. These F_1 s were backcrossed with the recurrent parents (B lines) to develop new male sterile lines. Backcrossing continued up to BC7, till morphological uniformity in A and its corresponding B line reached. By 2010, sixteen male sterile lines were developed and were named CZMS 0001A to CZMS 0016A. All

of these ms lines were planted in the year 2011 and variability for various traits was studied.

Results and Discussion

It was observed from Table 1, that lot of variability existed among the F_2 populations for DM incidence. DM incidence ranged from 0 to 82% with mean disease incidence of 41% and coefficient of variability of 61%. This variability among the F_2 populations provided ample opportunity to select desirable plants. F_2 population resulting from a cross ICMB 95444 x ICMB 93333 was free from DM symptoms and it was followed by ICMB 95111 x ICMB 93333, which showed only 6% DM incidence. Two populations ICMB 94555 x ICMB 96222 and ICMB 97555 x ICMB 95555 showed $\leq 20\%$ DM incidence. Maximum DM incidence (82%) was found in population ICMB 93111 x ICMB 97555 and it was followed by ICMB 93111 x ICMB 91444 (78%), ICMB 94111 x ICMB 93333 and ICMB 93111 x ICMB 98004 (74% each). Interestingly all the three populations resulted from crosses involving ICMB 93111 as one of the parents. This line was also found to have second highest DM incidence (26%) at Jodhpur (Manga *et al.*, 2004). Thus ICMB 93111 could be the one imparting DM susceptibility to these populations. Using this opportunity of high downy mildew incidence, selections were made in each of the eighteen populations and selfed seed was obtained. Number of progenies

Table 3. Mean and range for different traits in newly developed male sterile lines of pearl millet kharif 2011

Trait	Range		Mean
	Min	Max	
Plant height (cm)	76.0	193.0	123.0
Days to flower	45.0	57.0	52.0
Panicle length (cm)	10.8	20.8	17.3
Panicle girth (cm)	1.6	2.9	2.3
Effective tillers/plant	1.2	2.9	1.8
Grain yield (kg ha ⁻¹)	408.0	3606.0	1280.0
1000 grain weight (g)	6.0	12.0	9.0

Table 4. Characteristics of pearl millet male sterile lines developed at CAZRI, Jodhpur

MS line	Plant height (cm)	Days to flower	Grain yield (kg ha ⁻¹)	1000 grain weight (g)
CZMS 0001A ₁	116	54	617	6.0
CZMS 0002A ₁	80	56	741	8.0
CZMS 0003A ₁	76	56	508	9.2
CZMS 0004A ₁	121	55	714	8.4
CZMS 0005A ₁	154	54	1260	10.0
CZMS 0006A ₁	109	57	507	8.8
CZMS 0007A ₁	122	55	592	10.4
CZMS 0008A ₄	193	50	3606	9.6
CZMS 0009A ₄	116	46	665	8.4
CZMS 0010A ₄	83	46	408	6.6
CZMS 0011A ₄	133	55	1440	10.8
CZMS 0012A ₄	116	54	470	7.6
CZMS 0013A ₁	165	51	3096	10.2
CZMS 0014A ₁	157	56	2085	11.0
CZMS 0015A ₄	147	50	3191	7.6
CZMS 0016A ₄	78	45	586	12.0
Minimum	76	45	408	6.0
Maximum	193	57	3606	12.0
Mean	123	52	1280	9.0

selected from an F₂ population depended upon the DM incidence in the population, time taken to flower and agronomic score. More plants were selected from populations that had less disease, early in flowering and high agronomic score. Populations showing less DM, earliness and good agronomic score were ICMB 95444 × ICMB 93333 (0% DM, 4 Ag score and 42 days to flowering), ICMB 95111 × ICMB 93333 (6% DM, 4 Ag score and 44 days to flowering). Consequently maximum progenies were selected from these populations. Both of these crosses had ICMB 93333 as common parent. This line was found to be the most resistant to DM at Jodhpur (Manga *et al.*, 2004). Total of 593 plants were selected on the basis of disease resistance, plant height, compactness of earhead, earliness, tillering and agronomic score. These progenies were further carried forward by selfing and downy mildew screening and finally promising F₆ progenies were crossed with ms lines ICMA 95111, ICMA 94555 and ICMA 97555 as source of male sterility and F₁s were backcrossed up to BC₆ to get perfectly uniform male sterile lines. These were named CZMS 0001A to CZMS 0016A. CZMS 0001A₁ to CZMS 0007A₁ and CZMS 0013A₁ and CZMS 0014A₁ had A₁ cytoplasm, while CZMS 0008A₄ to CZMS 0012A₄ and CZMS 0015A₄ and CZMS 0016A₄ had A₄ cytoplasm.

Variability studied for various traits in these lines during kharif 2008 (Table 2) and kharif 2011 (Table 3) revealed sufficient variability for days to flowering, plant height, panicle length and thousand grain weight. It was observed that range for days to flowering, panicle length and 1000 grain wt was more in the newly developed ms lines compared to nine ms lines from other sources. Detailed characteristics of each male sterile line are given in Table 4. This showed that CZMS 0016A₄ was earliest to flower (45 days) followed by CZMS 0009A and CZMS 0010A (46 days). CZMS 0008A was the tallest (193 cm) followed by CZMS 0014A (157 cm). Conversely CZMS 0003A was the shortest in height (76 cm) followed by CZMS 0016A (78 cm). As for as grain yield is concerned CZMS 0008A recorded the highest grain yield (3606 kg ha⁻¹) followed by CZMS 0013A (3096 kg ha⁻¹). For thousand grain weight CZMS 0016A had the highest test weight of 12 g, followed by CZMS 0014A (11 g) and CZMS 0011A (10.8 g). These ms lines were crossed with CAZRI inbred restorer lines to develop hybrid combinations and based on the performance of these hybrids in station trials, one hybrid CZMS 0004A × CZI 2000/13 was contributed to the All India Coordinated Initial Hybrid Trial during kharif 2011. This hybrid performed well in this trial and recorded a grain yield

of 2318 kg ha⁻¹ as compared to 2250 kg by a national check ICMH 356, consequently it was promoted to the Advance Hybrid Trial 2012 for further evaluation, thus revealing success of the pearl millet seed parent development program at CAZRI Jodhpur.

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