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Genetic Enhancement and Breeding

Performance of a Male-sterile F_1 and its Inbred Parental Lines in Pearl Millet

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Introduction

Seed yield potential, stability of resistance to downy mildew (DM) (*Sclerospora graminicola*) and combining ability are the three key attributes defining the utility of a male-sterile line for hybrid development in pearl millet (*Pennisetum glaucum*). The male-sterile line 843A is the inbred seed parent of several early-maturing commercial hybrids in India (Stegmeier et al. 1998). Considering the vulnerability of inbred seed parents and their single-cross hybrids to DM in India (Hash 1997) and the high value of 843A in hybrid breeding, the pearl millet research program at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India developed several DM resistant inbred seed parents as possible replacement for 843A. ICMA 95111 and ICMA 97444 are two such inbred seed parents. These lines as well as 843A are similar morphologically for basic features such as flowering time, plant height, panicle length, tillering ability and seed size. Seed yield of the seed parents is now gaining increasing importance in the seed production economy of hybrids. Earlier research showed that male-sterile F_1s may outyield their high-yielding inbred parental lines by 64–107% in hybrid seed production plots (Rai et al. 2000). These F_1s, however, were based on inbred lines having large morphological differences. The objective of this research was to examine the seed yield and DM resistance advantage of a male-sterile F_1 produced by crossing two morphologically similar inbred lines derived from substantially similar genetic backgrounds.

Materials and Methods

A yield trial, consisting of ICMB 97444, ICMB 95111, a male-sterile F_1 hybrid produced from a cross between ICMA 95111 × ICMB 97444 and 843B (check), was conducted in the Alfisols at ICRISAT-Patancheru during the 2001 rainy season and 2002 postrainy season in 4-row plots, each row of 4 m length, in a randomized complete block design with four replications. Plant spacing was 75 cm × 10 cm. The plots were fertilized with 46 kg N ha^{-1} and 18 kg P_2O_5 ha^{-1} as a basal dose, with an additional 35 kg N ha^{-1} topdressed twice at 20 and 30 days after planting. Time to 50% flowering was recorded on the plot basis. Panicles from all four rows were harvested, sun-dried and threshed to determine grain yields. Plant height was determined from a random sample of five plants. Main panicles of these plants were used to determine panicle length (cm) and panicle diameter (mm). Number of panicles per plant was determined from plant count and panicle count data. A random sample of 200 seeds was weighed to determine 1000-seed mass (g).

A greenhouse seedling inoculation technique (Singh and Gopinath 1985) was used to evaluate DM resistance for four diverse pathotypes (Jalna, Durgapura, Patancheru and Jamnagar) under high disease pressure. Seedlings grown in two pots (total of 50–60 seedlings) per entry constituted a plot. The experiment was conducted in a randomized complete block design with five replications.

Results and Discussion

The average seed yield of the trial in the 2001 rainy season was 2243 kg ha^{-1}, 16% more than that in the 2002 summer season (Table 1). The two inbred parental lines ICMB 95111 and ICMB 97444 had similar mean yields, which was 18% higher than that of 843B (Table 1). The male-sterile F_1 had 22% higher mean yield than the highest yielding inbred parental line ICMB 97444. The hybrid flowered two days later than 843B, while the parental inbred lines flowered 3–5 days later than 843B. These results of male-sterile F_1s are consistent with research reported earlier where male-sterile F_1s had been developed from inbred lines of diverse morphological traits and genetic backgrounds (Rai et al. 2000).

The likely phenotypic variability in three-way hybrids resulting from the use of male-sterile F_1s is generally expressed as a major concern. Flowering time, plant height, panicle length and panicle girth are the four most striking traits for which this variability concern may arise. Genetic difference of 2–3 days for earliness in seed parents, as observed in this study, is small in magnitude, but it is important from the viewpoint of synchronizing with the flowering of the restorer parent in seed production plots. Such a small magnitude of difference, however, is of no practical significance in commercial

Table 1. Grain yield and agronomic traits[1] of a pearl millet male-sterile F_1 (ICMA 95111 × ICMB 97444) and its parental inbred lines, rainy season 2001 (2001R) and summer season 2002 (2002S) at ICRISAT, Patancheru, India.

Seed parent	Grain yield (kg ha^{-1})			Days to 50% flowering	Plant height (cm)	1000-seed mass (g)	Panicle length (cm)	Panicle diameter (mm)	Number of panicles plant^{-1}
	2001R	2002S	Mean						
ICMA 95111 × ICMB 97444	2804	2241	2523	42	86	11.1	16	26	2.9
ICMB 95111	2266	1804	2035	43	82	10.6	15	26	2.7
ICMB 97444	2161	1968	2065	45	90	12.2	16	27	2.6
843B (check)	1742	1719	1731	40	78	11.6	16	24	2.7
Mean	2243	1933	2088	42	83	11.4	16	25.6	2.7
LSD (0.05)	297.4	87.1	153.6	0.5	3.2	0.6	0.6	0.6	0.3
CV (%)	8.8	3.0	7.0	1.2	3.7	5.2	3.9	2.4	8.7

1. Data are means of two seasons.

Table 2. Downy mildew incidence in a pearl millet male-sterile F_1 (ICMA 95111 × ICMB 97444) and its parental inbred lines against four pathotypes of *Sclerospora graminicola* under greenhouse condition at ICRISAT, Patancheru, India.

Seed parent	Downy mildew incidence (%)			
	Patancheru	Durgapura	Jalna	Jamnagar
ICMA 95111 × ICMB 97444	0.0	0.9	1.2	1.5
ICMB 95111	0.0	0.8	1.3	0.0
ICMB 97444	2.6	8.4	3.8	8.5
843B (check)	93.8	94.8	8.2	91.3
Mean	24.1	26.3	3.6	25.3
LSD (0.05)	1.4	1.5	1.9	1.4
CV (%)	4.6	4.6	37.9	4.3

crops of hybrids. Similarly, differences of 4–8 cm for plant height, 1 cm for panicle length and 1 mm for panicle diameter, though statistically significant, are of no practical significance in a commercial hybrid crop. Further, these differences are likely to be blurred to a considerable extent with the use of non-d_2 pollen parents having longer and thicker panicles (which behave as complete to partial dominant traits) as compared to these seed parents; this would mostly be the case, as these seed parents have characteristic features of dwarf height and short panicles of below average thickness. These aspects and the extent of heterosis in three-way hybrids as compared to those in single-cross hybrids need to be investigated.

Although the male-sterile F_1 and its parental lines were highly resistant to all four pathotypes of DM, the DM incidence levels among these lines varied, and the differences were statistically significant (Table 2). ICMB 95111 was the most DM resistant line with 0–1.3% DM incidence, followed by ICMB 97444 that had 2.6–8.5% DM incidence under high disease pressure (>90% DM incidence in 843B against three of the four pathotypes). The DM resistance of the male-sterile F_1 was similar to that of the more resistant parental line ICMB 95111. This supports previous findings (Rai et al. 2000) and indicates complete dominance of resistance over susceptibility, implying the usefulness of this approach in DM management. The F_1 seed parent approach is also useful in resistance gene deployment (Witcombe and Hash 2000) including enhancement of intra-locus genetic diversity and inter-locus combination of alleles for DM resistance at the hybrid seed production stage. Though such intra-locus diversity for DM resistance in F_1 seed parents will be lost in the three-way hybrids, its practical consequences are negligible if the restorer line involved in three-way hybrids is DM resistant.

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Effectiveness of Within-progeny Selection for Downy Mildew Resistance in Pearl Millet

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Introduction

Development of trait-specific breeding lines with high grain yield and resistance to downy mildew (DM) (*Sclerospora graminicola*) is a major research and development objective of the pearl millet improvement program at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. While selecting for grain yield and agronomic traits during the course of inbreeding and generation advance, it is not uncommon to find progenies that have good combinations of these traits, but have unacceptable levels of DM susceptibility. The question, therefore, arises as to whether or not such progenies should be discarded from further selection, or can within-progeny selection be used to improve resistance to acceptable levels. A high-tillering and early-maturing Mandor Restorer Composite (MRC) has recently been jointly developed by ICRISAT and the All India Coordinated Pearl Millet Improvement Project (AICPMIP) Unit at Mandor, Rajasthan from diallel crosses among 10 diverse restorer lines selected for high tillering, early maturity and adaptation to dry environments of northwestern India. During the course of S_2 progeny selection in this composite, it was observed that several progenies with outstanding performance for grain yield potential, high tillering ability, and other agronomic traits were highly susceptible to DM assessed in unreplicated single pots (30–40 seedlings) under high disease pressure in the greenhouse. The objective of this study was to determine whether single-pot DM screening of a limited number of seedlings would be effective enough for mass evaluation of a large number of progenies in a breeding program, and whether within-progeny selection would be effective to improve the DM resistance to acceptable levels.

Materials and Methods

Based on the visual assessment of agronomic performance of 1200 S_2 progenies in an unreplicated observation nursery during summer 2002 at Patancheru and DM incidence against Durgapura pathotype (Sg 212) in a greenhouse seedling screening (Singh and Gopinath 1985) done in unreplicated single pots consisting of 30–40 seedlings (hereafter referred to as screen 1), a large proportion of the progenies in the test were selected for further selection and R-line development. Using remnant seed, 51 progenies with high agronomic scores were re-screened in unreplicated two pots with a total of 50–60 seedlings (hereafter referred to as screen 2). Eighteen of these progenies tracing to as many different S_1 progenies and with varying DM incidence levels were selected for conducting the DM resistance selection efficiency trial. The DM incidence in the inoculated seedlings was recorded and the DM-free seedlings of each progeny were transplanted. Selfed seeds from 8 to 10 plants from each progeny were bulked to generate selected S_3 progeny bulks. Using the remnant seed, these 18 S_2 progenies were also grown in the field under disease-free condition, and seeds of 8–10 selfed plants were bulked to produce unselected S_3 progeny bulks. These 36 progenies along with two susceptible checks (7042S and 843B) were evaluated in the greenhouse under high disease pressure (>90% DM incidence in 843B and 7042S) in a split-plot design with four replications. Progenies were treated as main plots, and selected and unselected bulks as sub-plots. A plot consisted of two pots, each with 30 seedlings. The experiment was repeated twice and the two experiments were analyzed as two environments. Since the genotype × environment interaction was not significant, pooled residual from combined analysis of the data from both experiments was used for statistical test of significance.

Results and Discussion

The disease pressure in all three tests was very high with >90% DM incidence in both the susceptible checks 7042S and 843B (Table 1). The DM incidence among the