Diversification of Sorghum Male-Sterile Lines at ICRISAT

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Introduction

World sorghum production was approximately 54 million t from 44 million ha in 1995. Developing countries account for roughly 90% of the area and 70% of production. In Asia about 15 million t are produced annually from about 14.1 million ha (FAO 1996). Sorghum is grown in a wide range of environments, and encounters various biotic and abiotic stresses such as drought, low temperatures, Al^{+3} toxicity, *Striga,* stem borer, shoot fly, head bug, midge, grain mold, downy mildew, anthracnose, leaf blight, and rust. Breeding for resistance to these stresses stabilizes yield levels and is a relatively inexpensive way to protect the crop from the major yield constraints. With the discovery of cytoplasmic-nuclear male-sterility (Stephens and Holland 1954), hybrids became popular with farmers in USA, China, India, Australia, and Thailand. In recent years, there has been increasing international collaboration on sorghum research. ICRISAT aims to develop high-yielding and diversified, broad-based genetic materials (gene pools, varieties, and seed parents) with resistance to various stresses, and thus better serve the needs of collaborators and partners. This paper summarizes ICRISAT's efforts in diversifying and improving male-sterile lines through a trait-based breeding approach.

Materials and Methods

The high-yielding male-sterile lines available with ICRISAT and others are primarily caudatum, based in milo-cytoplasm sources. Selected high-yielding maintainer lines were crossed to the sources for resistance to diseases, insect pests, and *Striga,* and sources of stay-green and durra and bold-grain lines in single and three-way crosses. Selection for agronomic desirability and for high-heritability traits such as plant height and days to flowering was done in the F_2 generation. Selection coupled with test crossing and conversion of the improved maintainer lines was followed in order to develop bold grain, stay-green, and early male-sterile lines. To breed resistant male-sterile lines, appropriate screening techniques (Rao 1985, Butler and Bandyopadhyay 1990, Sharma et. al. 1992, Singh, 1993, Singh et. al. 1997) were employed from the F_3 generation onwards, coupled with pedigree selection and simultaneous conversion methods. The high-yielding milo cytoplasm B and R-lines were converted into male steriles through regular backcrossing on an A_2 cytoplasm base. In backcrossing and

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conversion, plant to plant or paired crossing with selection of desirable plants in the pollinating maintainer lines was followed. Appropriate populations and plot sizes were maintained in various generations depending on the complexity of the trait. Families were selected on the basis of resistance, following which individual plants from these families were selected for agronomic desirability and high yield.

Results and Discussion

A program for the diversification of male-sterile lines was initiated at ICRISAT-Patancheru in 1990/91. The program yielded 613 lines that are nearing the stage of complete conversion into male-sterile lines. The materials from USA (e.g., Tx 623A) and India (e.g., 296A) are milo-cytoplasm based, widely available, and adapted to tropical environments. Although these lines have high performance and high general combining ability they lack resistance to various stresses.

Based on available data on male-sterile lines developed at ICRISAT (Table 1), the following generalizations can be made.

- Significant progress has been made in improving resistance in various male-sterile lines.
- Since selection was practised for resistance and grain yield, the number of final selections generally reflects the efficiency of each selection program. Resistance to midge, anthracnose, leaf blight, downy mildew, *Striga,* and shoot fly (postrainy season) was successfully improved. Success was limited for grain mold and stem borer resistance.
- Considerable variability has been retained in the selections for plant height, days to flowering, and agronomic desirability. This variability will help further selection and development of male-sterile lines adapted to various agroclimatic conditions.
- In general, the midge-resistant and downy mildew resistant lines were highly productive, with grain yields on par with 296B. Further cycles of breeding in some resistant male-sterile lines are needed to improve grain yield to the desired levels.
- An examination of the pedigrees of the selected lines showed that several sources contributed to the final selections within each trait. This indicated that the needed diversity has been achieved.

Summary

The male-sterile line diversification program initiated in 1990/91 resulted in the development of male-sterile lines resistant to various stresses. They were also diversified for various agronomic traits such as stay-green, earliness, and bold grain (durra race). High-yielding lines with non-milo cytoplasm male sterility have also been bred. Some of these lines give yields lower than the high-yielding control (296 A). Future emphasis will be placed on classification and characterization of newly developed male-sterile lines, and on enhancing yield in resistant derivatives.

Table 1. Sorghum seed parents evaluated and selected for resistance at ICRISAT-Patancheru, 1995.

Stress	Trial statistics				B-lines tested		Controls		B-lines selected	
	No. of entries	Resistance levels								
		Mean	Range	SE±[1]	No.	Resistance level range	Entry[2]	Resistance level	No.	Truncation value
Grain mold										
Head mold[3] (HMR)	90	6.0	3.0-9.0	0.35 (178)	75	3.3-8.3 296^{S}	IS 15119^{R} 8.4	3.3	31	≤5.5
Grain mold[4] (TGMR)	90	6.2	2.8-9.0	0.31 (178)	75	3.3-8.1 296B^{S}	IS 15119^{R} 8.6	4.0	31	<6.0
Anthracnose[5]	50	5.5	3.0-9.0	0.30 (98)	47	3.0-7.0	A 2267-2^{R} FSRP Local^{S}	4.0 9.0	29	≤5.0
Leaf blight and rust[6]										
Leaf blight	80	4.8	2.7-9.0	0.50 (158)	38	3.3-6.3	A 2267-2^{R} FSRP Local^{S}	2.8 9.0	15	≤4.0
Rust	80	2.5	1.9-6.7	0.33 (158)	30	1.9-6.7	A 2267-2^{R} FSRP Local^{S}	2.0 3.0	16	≤2.0
Shoot fly[7]										
B-lines	90	69.9	35.4-97.3	5.70 (178)	40	35.4-86.4	IS 18551^{R} CSH 1^{S}	60.0 91.2	23	≤66
F_2s	141	90.5	43.8-100	4.25 (140)	127	79.0-100	IS 18551^{R} CSH 1^{S}	56.9	20	≤86
Stem borer[7]										
Rainy season	100	65.5	4.4-100	9.59 (297)	20	4.4-84.5	IS 2205^{R} ICSV 1^{S}	25.2 68.5	13	≤45
Midge[8]										
B-lines	90	3.1	2.0-6.0	0.41 (89)	65	2.0-4.5	ICSV 197/ ICSV 745^{R}, CSH 1^{S}	2.7 5.9	54	≤3.0
Striga[9]										
At Patancheru	61	1.1	0.0-7.0	1.13 (120)	41	0.0-2.0	SAR 1^{R} CSH 1^{S}	0.0 3.0	27	0.0
At Akola	61	2.0	0.0-10.7	1.04 (120)	41	0.0-3.3	SAR 1^{R} CSH 1^{S}	0.0	20	≤1.0

1. Applies also to B-line and controls; values in parentheses are error degrees of freedom.
2. R = Resistant control , S = Susceptible control.
3. HMR = Head Mold Rating on a 1-9 scale, where 1 = free from mold, 9 = >50% of the grains with mold.
4. TGMR = Threshed Grain Mold Rating on a 1-9 scale, where 1 = free from mold, 9 = >50% of grain surface area molded.
5. Anthracnose score on a 1-9 scale, where 1 = no lesions, 9 = >75% leaf area covered with anthracnose lesions.
6. Leaf blight and rust scored on a 1-9 scale, where 1 = leaf lamina free from disease, 9 = >80% leaf area affected by disease.
7. Shoot fly and stem borer resistance assessed based on deadheart percentage.
8. Midge visual scoring on a 1-9 scale, where 1 = <10% chaffy florets, 9 =>80% chaffy florets.
9. Maximum mean *Striga* plant count per plot.

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