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Agronomic Characteristics of Different Cytoplasmic Male-Sterility Systems and their Reaction to Sorghum Shoot Fly, *Atherigona soccata*

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Introduction

The discovery of cytoplasmic male-sterility (*milo* cytoplasm) led to commercial exploitation of hybrid vigor in sorghum (Stephens and Holland 1954). Several CMS systems have been identified in sorghum for diversifying hybrid production. However, only the A_1 CMS system has been deployed for producing sorghum hybrids worldwide, with the exception of A_2 CMS-based hybrids in China (Shan et al. 2000). The use of a single source of male-sterility (A_1 cytoplasm) has narrowed the genetic base of sorghum hybrids. As a result, there is considerable risk of insect pest and disease outbreaks in cultivars based on a single source of male-sterility (Sharma et al. 2004).

Sorghum is damaged by over 150 species of insect pests, of which shoot fly *Atherigona soccata* (Rondani) is important in Asia, Africa, and Mediterranean Europe. Plant resistance is an important component for the management of this pest, and efforts are being made at ICRISAT to transfer resistance genes into male-sterile lines. Since there is considerable risk of single MS system-based hybrids becoming vulnerable to this major pest, it is important to determine the agronomic desirability and the reaction of different CMS systems to sorghum shoot fly, *A. soccata.*

Materials and Methods

Plant material. The experimental material consisted of six isonuclear lines in six cytoplasmic backgrounds (A_1, A_2, A_3, A_4G_1, A_4M, and A_4V_zM), and six maintainer (B) lines. The test material was evaluated during the 2002 and 2003 rainy, and 2003 postrainy seasons. Each entry was planted in 4 row plots of 2 m row length, and the rows were 75 cm apart. There were three replications in a randomized complete block design. One week after seedling emergence, thinning was done to maintain a spacing of 10 cm between plants. Normal agronomic practices were followed for raising the crop. At the milk stage, the panicles were covered with nylon bags to avoid damage from birds.

Observations. Data were recorded on numbers of plants with shoot fly deadhearts in the central two rows at 14 days after seedling emergence, and expressed as percentage of plants with deadhearts. Data were also recorded on days to 50% flowering, plant height, and agronomic desirability. Plant height was recorded at maturity. Agronomic desirability was evaluated at crop maturity on a scale of 1 to 5 (1 = good productive potential and ability to withstand insect damage, 5 = poor productive potential and prone to insect damage). The data was analyzed using factorial analysis. The significance of differences between the treatment means was tested using least significant differences (LSD) at P 0.05.

Results and Discussion

There were significant differences among the CMS lines for all the traits under study (Tables 1 to 4). The mean squares due to genotype x CMS systems for plant height, agronomic desirability and shoot fly infestation were nonsignificant (Tables 2, 3, and 4). The isonuclear lines in A_1, A_2, and A_3 cytoplasmic backgrounds flowered 1–2 days earlier than in other CMS backgrounds. Similar results have earlier been reported by Quinby (1970). The A_4G_1 and A_4VzM cytoplasms flowered one-day later than the B-lines. These results are in conformity with those of Nagur and Menon (1974). The isonuclear lines in A_2 cytoplasmic background (except in case of ICSA 26 and ICSA 38) were shorter than in other cytoplasmic backgrounds, but the differences among the CMS systems were nonsignificant (Table 2). Similar observations have been reported by Williams-Alanis and Rodriguez-Herrera (1994). Pederson and Toy (1997) observed similar pattern for plant height in A_1, A_2, and A_3 cytoplasms. The

differences in agronomic score of different CMS systems were nonsignificant (Table 3). Ross and Kofoid (1979) reported comparable agronomic performance and grain yield in different CMS systems. However, Gangakishan and Borikar (1989) and Wang et al. (1990) observed that the hybrids based on *Maldandi* (A_4M) cytoplasm are bold and yield better than those on *milo* cytoplasm. Shoot fly deadhearts in different CMS systems varied from 69.9 to 88.7% (Table 4). The male sterile lines showed more deadhearts [77.1 (A_4M) to 81.0% (A_4G_1)] compared to the maintainer lines (74.4%) (Table 4). Among the cytoplasms tested, A_4M suffered lower deadheart incidence than the other CMS systems. Therefore, it can be exploited for producing shoot fly-resistant hybrids in future (Dhillon et al. 2005).

Conclusion

Isogenic lines in A_1, A_2, and A_3 cytoplasmic backgrounds flowered two days earlier than the other CMS and maintainer lines. The male-sterile lines in A_4G_1 and A_4VzM CMS backgrounds flowered one day later than the maintainer lines. The A_1, A_2, A_3, and A_4VzM CMS lines were comparable in height, but shorter than A_4M and A_4G_1 CMS and B-lines. The differences in agronomic

Table 1. Days to 50% flowering of different cytoplasmic male-sterile (A) and maintainer (B) lines of sorghum (ICRISAT, Patancheru, India).

	Days to 50% flowering							
Genotypes	A_1	A_2	A_3	A_4G_1	A_4M	A_4VzM	B	Mean
ICSA 11	71.3	67.0	69.1	72.3	75.1	75.7	74.6	73.2
ICSA 17	71.3	73.0	73.3	71.7	69.7	73.6	70.7	71.4
ICSA 26	75.2	79.5	77.6	79.2	77.7	78.5	75.3	76.6
ICSA 38	72.7	77.2	68.6	76.6	75.6	76.6	80.6	77.6
ICSA 88001	74.7	76.0	73.6	77.7	79.6	76.7	76.9	76.6
ICSA 88004	78.7	75.7	77.6	80.6	78.1	79.0	76.0	77.1
Mean	74.0	74.7	73.3	76.3	75.9	76.7	75.7	
For comparing	SE±		LSD				F-test	
Cytoplasm (C)	0.63		0.83				0.002	
Genotypes (G)	0.58		0.89				<0.001	
C x G	1.54		2.18				0.004	

Genotypes (P = 0.05; df = 5); Cytoplasms (P = 0.05; df = 6); Cytoplasms x genotypes (P = 0.05; df = 30); Error (P = 0.05; df = 82).

Table 2. Plant height at maturity in different cytoplasmic male-sterile (A) and maintainer (B) lines of sorghum (ICRISAT, Patancheru, India).

	Plant height (cm)							
Genotypes	A_1	A_2	A_3	A_4G_1	A_4M	A_4VzM	B	Mean
ICSA 11	101.1	98.6	99.2	105.8	102.8	98.9	100.5	100.8
ICSA 17	88.3	80.0	88.6	94.4	91.1	93.1	86.9	88.1
ICSA 26	102.2	111.7	108.1	99.4	103.1	103.9	110.0	107.4
ICSA 38	104.7	103.1	103.3	101.7	103.1	101.7	109.2	106.1
ICSA 88001	125.0	122.5	122.5	123.3	129.2	126.9	123.3	124.1
ICSA 88004	110.0	108.3	109.2	119.7	112.8	109.2	113.9	112.7
Mean	105.2	104.0	105.2	107.4	107.0	105.6	107.3	
For comparing	SE±			LSD			F-test	
Cytoplasm (C)	1.68			NS			0.737	
Genotypes (G)	1.56			4.34			<0.001	
C x G	4.12			NS			0.748	

Genotypes (P = 0.05; df = 5); Cytoplasms (P = 0.05; df = 6); Cytoplasms x genotypes (P = 0.05; df = 30); Error (P = 0.05; df = 205). NS = Nonsignificant.

Table 3. Agronomic desirability of different cytoplasmic male-sterile (A) and maintainer (B) lines of sorghum (ICRISAT, Patancheru, India).

	Agronomic score[a]							
Genotypes	A_1	A_2	A_3	A_4G_1	A_4M	A_4VzM	B	Mean
ICSA 11	3.2	3.2	3.3	3.5	3.2	2.8	3.4	3.3
ICSA 17	3.3	3.5	3.3	3.2	3.5	3.2	3.5	3.4
ICSA 26	2.8	2.7	2.8	3.0	2.8	2.8	2.8	2.8
ICSA 38	3.2	3.5	3.5	2.8	3.0	2.8	3.2	3.2
ICSA 88001	3.0	3.3	3.2	2.8	3.2	3.0	3.2	3.1
ICSA 88004	2.8	3.2	3.0	2.8	2.8	2.7	2.8	2.9
Mean	3.1	3.2	3.2	3.0	3.1	2.9	3.2	
For comparing	SE±		LSD			F-test		
Cytoplasm (C)	0.10		NS			0.253		
Genotypes (G)	0.10		0.26			<0.001		
C x G	0.24		NS			0.995		

Genotypes (P = 0.05; df = 5); Cytoplasms (P = 0.05; df = 6); Cytoplasms x genotypes (P = 0.05; df = 30); Error (P = 0.05; df = 205). [a] = Agronomic score (1 = good, and 5 = poor). NS = Nonsignificant.

Table 4. Evaluation of different CMS systems of sorghum for susceptibility to shoot fly, *Atherigona soccata* (ICRISAT, Patancheru, India).

	Deadhearts (%) 14 DAE							
Genotypes	A_1	A_2	A_3	A_4G_1	A_4M	A_4VzM	B-line	Mean
ICSA 11	81.1	88.7	83.0	85.0	78.7	77.8	82.3	82.4
ICSA 17	84.0	73.9	74.0	81.0	77.1	78.3	80.7	79.4
ICSA 26	78.7	74.1	81.7	82.0	72.9	80.2	69.9	74.1
ICSA 38	78.8	84.7	81.2	81.1	81.7	81.2	71.9	76.7
ICSA 88001	78.2	78.1	79.1	76.4	75.4	81.2	70.6	74.4
ICSA 88004	77.1	74.0	77.4	80.7	76.9	78.1	71.1	74.2
Mean	79.6	78.9	79.4	81.0	77.1	79.5	74.4	
For comparing	SE±			LSD			F-test	
Cytoplasm (C)	1.33			3.71			0.016	
Genotypes (G)	1.23			3.43			0.005	
C x G	3.26			NS			0.314	

DAE = Days after seedling emergence. Genotypes (P = 0.05; df = 5); Cytoplasms (P = 0.05; df = 6); Cytoplasms x genotypes (P = 0.05; df = 30); Error (P = 0.05; df = 328). NS = Nonsignificant.

desirability of different CMS systems were nonsignificant. The A_4M (*Maldandi*) cytoplasm was less susceptible to sorghum shoot fly, *A. soccata*, and can be exploited for producing sorghum hybrids with less susceptibility to sorghum shoot fly.

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Morphology of Sorghum Grain in Relation to Resistance to Maize Weevil

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Introduction

The maize weevil (*Sitophilus zeamais*) is one of the most destructive insect pests of stored grain, including sorghum [*Sorghum bicolor* (L.) Moench] (Teetes et al. 1981, Teetes and Pendleton 2000). This weevil is abundant in warm, humid regions of the world. Maize weevils infest developing kernels in the field and storage. A female chews a cavity to deposit an egg in a kernel. The larva develops inside and damages the kernel.

Use of sorghum cultivars that resist damage in the field and in storage is an alternative to the use of insecticide. Chitio (2004) evaluated resistance to maize weevils in grain of 20 genotypes of sorghum. The goal of this research was to relate morphology of the sorghums to resistance to maize weevil.

Materials and Methods

Chitio (2004) measured grain weight, size, hardness, and protein content and evaluated resistance to maize weevils of 20 genotypes of sorghum (ATx623, ATx631, ATx635, B1, CE151, Kuyuma, Macia, Malisor84-7-167, Malisor84-7-476, RTx430-5362, RTx430-5451, Segaolane, SC630-11E11, Sima, SRN39, Sureno, Tegemeo, Tx2737, Tx2882, and Tx2911). One gram of grain of each genotype was weighed and the number of grains per gram counted to detemine the weight of an individual grain. This was repeated five times for each genotype. A Vernier caliper was used to measure the length, width, and height in millimeters of each of five grains of each genotype.

The density method was used to determine hardness of four 25-g samples of grain of each genotype. The grain was weighed and dried for 24 hours at 89°C in an oven. Each sample of grain was weighed again and put with 70 ml of water into a 100-ml glass graduated cylinder. The amount of water displaced by the weight of the grain was used as the volume of the grain. The dry weight of the grain was divided by the volume of the grain to determine the density of the grain in g ml^{-1}. The nitrogen content of grain of each genotype was determined by using a LECO model CN-2000 Carbon/Protein/Nitrogen Elemental Analyzer and converted to the amount of protein.

Five grams of sorghum grain were infested with three female and two male newly emerged maize weevils per each of 10 vials of the 20 genotypes of sorghum. Vials of each sorghum genotype were evaluated every 3 weeks for 105 days. Each day, each grain in the 10 vials of one kind of sorghum was evaluated for damage, numbers of live and dead weevil adults were counted, and the grain in each vial was weighed. A scale of 1–5 was used to score damage, where 1 = no evidence of damage; 2 = some feeding on the surface, involving 1–25% or one shallow hole in a kernel; 3 = two tunnels, causing 26–50% damage to a kernel; 4 = 51–75% damage or more than two holes in a kernel; 5 = 76–100% damage and many tunnels in a kernel.

For microscopic observation, grains of the sorghums were split, exposed to osmium vapor, and coated with gold-palladium. The cross-section of seed coat was observed by using a JEOL JSM 6400 at 15 KeV, 12-mm working distance, and 500-2000x magnifications. Pieces of seed coat were dried, fixed, and embedded in epoxy resin and sectioned for observation by using a Zeiss Axiophot compound light microscope at 100-600x magnifications.