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Multiple-resistance to sorghum shoot fly, spotted stemborer and sugarcane aphid in sorghum

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Abstract. Sorghum is one of the most important cereal crops in the semi-arid tropics. Several insect pests damage it. The possibility of identifying genotypes with multiple resistance to these pests and transferring the relevant genes into high-yielding varieties and hybrids has been considered as an attractive approach to reducing yield losses. A set of 12 cytoplasmic male-sterile and maintainer lines, 12 restorer lines and their F_1 hybrids were evaluated for resistance to sorghum shoot fly *Atherigona soccata* Rondani, spotted stemborer *Chilo partellus* (Swinhoe) and sugarcane aphid *Melanaphis sacchari* (Zehntner) under field conditions. There were significant differences among the genotypes tested. A total of 50% of male-sterile lines, 41.7% maintainers, 58.3% restorers and 35.4% of the hybrids tested showed moderate to high level of resistance to the three pests. The male-sterile and restorer lines showing resistance to different insects can be exploited for developing hybrids with multiple insect resistance for cultivation by the resource-poor farmers in the semi-arid tropics.

Key words: sorghum, *Atherigona soccata*, *Chilo partellus*, *Melanaphis sacchari*, host plant resistance, mulitiple resistance

Résumé. Le sorgo est l'une des céréales les plus affectées par les insectes en zones tropicales semi-arides. Il est donc important d'identifier des variétés possédant de multiples résistances, et d'insérer les gènes qui confèrent ces résistances dans des variétés ou hybrides à fort potentiel de rendement. Nous avons évalué au champ, un lot de 12 variétés possédant la stérilité mâle cytoplasmique ainsi que leurs mainteneurs et, 12 lignées restauratrices de la fertilité, ainsi que leurs hybrides, pour la résistance à la mouche des feuilles *Atherigona soccata* Rondani, le foreur de tige *Chilo partellus* (Swinhoe), et le puceron de la canne à sucre *Melanaphis sacchari* (Zehntner). Nous avons trouvé des différences significatives entre les variétés pour la sensibilité aux insectes. Cinquante pour cent des mâles stériles, 41,7% des mainteneurs, 58,3% des restaureurs et 35,4% des hybrides testés ont montré une résistance moyenne à élever à la mouche des feuilles, au mineur de la tige et au puceron de la canne. Les mâles stériles et les restaureurs montrant une résistance aux insectes pourraient êtres utilisés pour développer des hybrides avec une résistance aux insectes multiples, adéquats pour leur culture par les paysans pauvres des tropiques semi-arides.

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Mots clés: sorgho, *Atherigona soccata*, *Chilo partellus*, *Melanaphis sacchari*, résistante de la plante, résistance multiple

Introduction

Sorghum *Sorghum bicolor* (L.) Moench is one of the most important cereal crops in Africa, Asia, USA, Australia and Latin America. In India, sorghum is planted in an area of 10.4 million ha with an annual production of 8 million tonnes (FAO, 2002). Under subsistence farming conditions, the productivity levels are quite low (500–800 kg/ha), primarily due to biotic and abiotic constraints. Over 150 species of insects infest the sorghum crop at different stages of growth in the semi-arid tropics and cause an estimated loss of 1 billion US$ annually (ICRISAT, 1992). Among these, sorghum shoot fly *Atherigona soccata* Rondani, spotted stemborer *Chilo partellus* (Swinhoe), sorghum midge *Stenodiplosis sorghicola* (Coquillett), head bugs *Calocoris angustatus* Lethiery and *Eurystylus oldi* (Poppius), sugarcane aphid *Melanaphis sacchari* (Zehntner), shoot bug (*Peregrinus maidis* (Ashmead) and the oriental armyworm *Mythimna separata* (Walker) are the most important pests.

Agronomic practices, natural enemies, synthetic insecticides and host plant resistance have been employed for minimizing the losses due to insect pests in sorghum. However, farmers cannot plant at times when pest damage can be avoided as planting times are dictated by the onset of rainfall, while insecticide application is beyond the reach of resource-poor farmers in the semi-arid tropics (Sharma, 1985). Host plant resistance can play a major role in minimizing the extent of losses in this crop (Sharma, 1993) and is compatible with other tactics of pest management, including the use of natural enemies and chemical control. Importantly, deployment of insect-resistant cultivars in integrated pest management would also lead to a drastic reduction in pesticide residues in food and food products, and reduce environmental pollution.

Considerable progress has been made in screening and breeding for resistance to sorghum shoot fly, spotted stemborer, head bugs, midge and sugarcane aphid (Sharma, 1993), and a number of genotypes with different levels of resistance to these pests have been identified. However, the levels of resistance to some insect species are low to moderate (Sharma *et al.*, 2003). In general, two or more insect species attain damaging proportions on the same crop in a crop-growing season. Therefore, cultivars with multiple resistance to the major pests that damage the crop during the various stages of crop growth in a region would be the most desirable. We tested a set of parental lines and their hybrids for resistance to sorghum shoot fly, spotted stemborer and sugarcane aphid to identify the ones with multiple resistance to these pests.

Materials and methods

Plant material

The experiments were conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India between 2003 and 2004 rainy (June–September), early post-rainy (September–December) and post-rainy (October–February) seasons. The experimental materials consisted of 12 cytoplasmic male-sterile (CMS) and maintainer lines, 12 restorer lines and their 144 F_1 hybrids. The origins and development of the materials have been reported earlier (Dhillon *et al.*, 2006). A basal dose of ammonium phosphate (at 150 kg/ha) was applied to the experimental plot before sowing. Each entry was sown in four rows of 2 m length each, and the rows were spaced 75 cm apart. There were three replications in a randomized complete block design. The seeds were sown with a four-cone planter at 5 cm depth below the soil surface. The field was irrigated immediately after sowing early in the rainy season. One week after seedling emergence, the plants were thinned to a spacing of 10 cm between the plants. No insecticide was applied in the experimental plots. Interculture and earthing up operations were carried out at 15 and 30 days after seedling emergence (DAE), respectively. Top dressing was carried out with urea (at 100 kg/ha) before earthing up at 30 DAE. Hand weeding was carried out as and when required. The experimental plots were irrigated at 20-day intervals during the post-rainy season.

Insect infestation

Interlard fish-meal technique was used to test the material for resistance to sorghum shoot fly (Soto, 1974). For spotted stemborer, the material was infested artificially with insects reared in the laboratory (Sharma *et al.*, 1992). Eighty grams of poppy seed was mixed with larvae that emerged from 300 egg masses of *C. partellus* in a Bazooka applicator (each egg mass contained 30–40 eggs). The plants were infested with neonate larvae at 18

Table 1. Evaluation of 12 cytoplasmic male-sterile, maintainer and restorer lines of sorghum for multiple resistance to sorghum shoot fly, spotted stemborer and sugarcane aphid under field conditions (ICRISAT, Patancheru 2003–2004)

	Resistance/susceptibility to:					
	Sorghum shoot fly		Spotted stemborer		Sugarcane aphid	
Genotypes	Deadhearts (%)	Reaction	Deadhearts (%)	Reaction	Damage score	Reaction
Cytoplasmic male-sterile lines						
SPSFR 94011A	32.0 (4)+	MR	36.3 (4)†	MR	4.1	MR
SPSFR 94012A	65.6 (7)	S	36.4 (4)	MR	3.7	MR
SPSFR 94006A	44.4 (5)	MR	26.5 (3)	R	4.8	MR
SPSFR 94007A	47.5 (5)	MR	43.1 (5)	MR	4.3	MR
SPSFR 94010A	51.9 (6)	S	31.6 (4)	MR	4.6	MR
SPSFR 94034A	31.8 (4)	MR	48.1 (5)	MR	4.3	MR
SP 55299A	43.7 (5)	MR	33.2 (4)	MR	4.6	MR
SP 55301A	29.8 (3)	R	21.2 (3)	R	4.7	MR
296A	58.1 (6)	S	70.9 (8)	S	4.6	MR
Tx 623A	83.3 (9)	S	37.0 (4)	MR	5.1	MR
CK 60A	59.0 (6)	S	42.5 (5)	MR	6.3	S
ICSA 42A	80.6 (9)	S	48.6 (5)	MR	4.9	MR
Maintainer lines						
SPSFR 94011B	36.4 (4)	MR	33.9 (4)	MR	3.4	R
SPSFR 94012B	59.8 (6)	S	28.5 (3)	R	3.4	R
SPSFR 94006B	35.6(4)	MR	35.2 (4)	MR	4.3	MR
SPSFR 94007B	32.3 (4)	MR	56.7 (6)	S	4.0	MR
SPSFR 94010B	30.2 (3)	R	49.2 (5)	MR	4.0	MR
SPSFR 94034B	27.6 (3)	R	54.4 (6)	S	3.8	MR
SP 55299B	28.5 (3)	R	41.6 (5)	MR	3.9	MR
SP 55301B	37.3 (4)	MR	21.9 (3)	R	4.7	MR
296B	64.8 (7)	S	71.3 (8)	S	4.4	MR
Tx 623B	79.1 (8)	S	46.4 (5)	MR	4.9	MR
CK 60B	67.9 (7)	S	41.9 (5)	MR	6.0	S
ICSA 42B	65.6 (7)	S	70.7 (8)	S	4.4	MR
Restorer lines						
ICSV 705	24.6 (3)	R	45.9 (5)	MR	5	MR
ICSV 700	34.5 (4)	MR	15.6 (2)	R	3	R
ICSV 708	27.6 (3)	R	37.0 (4)	MR	3	R
PS 30 710	32.1 (4)	MR	47.3 (5)	MR	3	R
IS 18 551	23.4 (3)	R	7.4 (1)	R	4	MR
SFCR 151	27.0 (3)	R	20.5 (3)	R	4	MR
SFCR 125	43.6 (5)	MR	38.3 (4)	MR	4	MR
ICSV 91 011	42.0 (5)	MR	51.4 (6)	S	3	R
CS 3541	58.5 (6)	S	50.7 (6)	S	4	MR
MR 750	69.5 (7)	S	78.8 (8)	S	4	MR
ICSV 745	66.8 (7)	S	55.5 (6)	S	4	MR
Swarna	73.6 (8)	S	32.2 (4)	MR	6	S
SE ±	4.29		7.21		0.25	
LSD	12.09		20.33		0.71	
CV (%)	15.6		29.8		10.2	
$F-p$	<0.001		<0.001		<0.001	

R, resistant (1–3); MR, moderately resistant (4–5); S, susceptible (6–9).
+ Figures in parentheses are damage scores.

DAE. Two central rows of each entry were artificially infested with five to seven neonate larvae per plant in the morning (0800 and 1100 h). Natural infestation of the sugarcane aphid *M. sacchari* occurred during the 2003 rainy and post-rainy seasons, and during the 2004 rainy season. Resistance to shoot fly and stemborer was recorded in separate experimental plots, while aphid infestation was recorded in plots prepared for estimating stemborer damage.

Table 2. Evaluation of sorghum hybrids based on 12 male-sterile and restorer lines for multiple resistance to sorghum shoot fly, spotted stemborer and sugarcane aphid under field conditions (ICRISAT, Patancheru 2003–2004)

R-lines	Reaction of hybrids to shoot fly[1], stemborer[2] and sugarcane aphid[3]											
CMS lines	ICSV 705	ICSV 700	ICSV 708	PS 30710	IS 18551	SFCR 151	SFCR 125	ICSV 91011	CS 3541	MR 750	ICSV 745	Swarna
SPSFR 94011A	MR[1], R[2], MR[3]	MR, R, MR	MR, R, R	MR, MR, R	MR, R, MR	MR, R, MR	MR, R, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, R, S
SPSFR 94012A	S, R, MR	S, R, R	S, R, MR	S, R, R	S, R, MR	S, MR, MR	S, R, MR	S, MR, R	S, MR, MR	S, MR, MR	S, R, MR	S, R, MR
SPSFR 94006A	MR, MR, MR	MR, R, MR	MR, R, MR	MR, R, R	MR, R, MR	MR, MR, MR	MR, MR, MR	MR, R, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, MR, S
SPSFR 94007A	MR, MR, MR	MR, R, MR	MR, R, R	MR, R, MR	MR, R, MR	MR, MR, MR	MR, R, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, R, MR	S, R, S
SPSFR 94010A	MR, MR, MR	S, R, R	S, R, MR	S, R, R	MR, R, MR	S, MR, MR	S, R, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, R, S
SPSFR 94034A	S, R, MR	MR, R, R	MR, R, R	MR, MR, MR	MR, R, MR	MR, R, MR	MR, R, MR	MR, MR, MR	MR, MR, MR	S, S, MR	S, R, R	S, MR, MR
SP 55299A	MR, R, MR	MR, R, R	MR, R, R	MR, MR, R	MR, R, MR	MR, R, MR	MR, R, MR	S, MR, MR	S, S, MR	S, S, MR	S, R, MR	S, R, S
SP 55301A	MR, R, MR	MR, R, MR	MR, R, MR	R, R, R	R, R, MR	R, R, MR	R, R, MR	MR, MR, MR	MR, R, MR	MR, MR, MR	MR, R, MR	MR, R, S
296A	S, MR, S	S, R, MR	S, R, R	S, R, MR	S, R, MR	S, R, MR	S, MR, MR	S, S, MR	S, MR, MR	S, MR, MR	S, R, MR	S, MR, S
Tx 623A	S, R, MR	S, R, R	S, R, MR	S, R, MR	S, R, MR	S, R, MR	S, R, MR	S, R, MR	S, MR, MR	S, R, MR	S, MR, MR	S, R, S
CK 60A	S, R, S	S, R, MR	S, R, MR	S, R, MR	S, R, MR	S, R, S	S, R, MR	S, R, MR	S, R, MR	S, MR, MR	S, R, MR	S, R, S
ICSA 42A	S, S, MR	S, R, R	S, MR, MR	R, MR, MR	S, R, MR	S, R, MR	S, MR, MR	S, MR, MR	S, MR, MR	S, S, MR	S, R, MR	S, R, S

Superscripts 1, 2 and 3, reactions of sorghum hybrids to shoot fly, spotted stemborer and sugarcane aphid, respectively, in rows and columns.
R, resistant, MR, moderately resistant and S, susceptible. R-lines, restorer lines and CMS lines, cytoplasmic male-sterile lines.

Observations

Data were recorded on the numbers of plants with sorghum shoot fly deadhearts at 14 DAE in the central two rows and expressed as a percentage of the total number of plants. Spotted stemborer damage was recorded in terms of percentage deadhearts 3 weeks after artificial infestation. Sugarcane aphid damage was evaluated on a 1–9 rating scale (1, <10% leaf area with aphid infestation on the lower one to two leaves, with no apparent damage to the leaves; 2, 11–20% leaf area with aphid infestation and aphid damage apparent on one to two leaves; 3, 21–30% leaf area with aphid infestation and aphid damage apparent on two to three leaves; 4, 31–40% leaf area with infestation and aphid damage apparent on three to four leaves; 5, 41–50% leaf area with infestation and aphid damage apparent on four to five leaves; 6, 51–60% leaf area with aphid infestation and aphid damage apparent on five to six leaves; 7, 61–70% leaf area with aphid infestation and aphid damage apparent on six to seven leaves; 8, 71–80% leaf area with aphid infestation and aphid damage apparent on seven to eight leaves and 9, >80% leaf area with aphid infestation and extensive damage to the leaves) (Kadam and Mote, 1983; Sharma *et al.*, 1997).

Data analysis

Data were subjected to analysis of variance and the significance of differences between the genotypes was tested by *F*-test, while the treatment means were compared by least-significant difference (LSD) at $P = 0.05$. Data on percentage deadhearts due to shoot fly and stemborer were converted into a 1–9 scale, and the test material was classified into resistant (DR 1–3), moderately resistant (DR 4–5) and susceptible classes (DR 6–9).

Results

There were significant differences for susceptibility to sorghum shoot fly, spotted stemborer and sugarcane aphid among the CMS, maintainer and restorer lines tested (Table 1). The CMS and maintainer lines of the genotypes SPSFR 94011, SPSFR 94006, SP 55299 and SP 55301 showed moderate to high levels of resistance to shoot fly, stemborer and sugarcane aphid. The restorer lines ICSV 705, ICSV 700, ICSV 708, PS 30710, IS 18551, SFCR 151 and SFCR 125 showed low to moderate levels of multiple resistance to these pests (Table 1). The hybrids based on the CMS lines SPSFR 94011A, SPSFR 94006A, SPSFR 94007A, SPSFR 94034A (except with ICSV 705), SP 55299A and SP 55301A with the restorer lines ICSV 705, ICSV 700,

Table 3. Distribution of shoot fly-resistant/susceptible cytoplasmic male-sterile, maintainer and restorer lines and their hybrids for multiple insect resistance in sorghum (ICRISAT, Patancheru 2003–2004)

		Reaction of genotypes with different levels of resistance to shoot fly to other insect pests (%)		
Genotype	Insect species	Resistant to shoot fly (1–3)[1]	Moderately resistant to shoot fly (4–5)[1]	Susceptible to shoot fly (6–9)[1]
CMS lines (12)[2]				
	Sorghum shoot fly	8.3	41.7	50.0
	Spotted stemborer	16.7	75.0	8.3
	Sugarcane aphid	0.0	91.7	8.3
Maintainer lines (12)[2]				
	Sorghum shoot fly	25.0	33.3	41.7
	Spotted stemborer	16.7	50.0	33.3
	Sugarcane aphid	16.7	75.0	8.3
Restorer lines (12)[2]				
	Sorghum shoot fly	33.3	33.3	33.3
	Spotted stemborer	25.0	41.7	33.3
	Sugarcane aphid	33.3	58.3	8.3
Hybrids (144)[2]				
	Sorghum shoot fly	3.5	32.6	63.9
	Spotted stemborer	62.5	33.3	4.2
	Sugarcane aphid	14.6	76.4	9.0

[1] Scores for resistance/susceptibility to insect pests.
[2] Number of genotypes tested.

ICSV 708, PS 30 710, IS 18 551, SFCR 151 and SFCR 125 showed moderate to high levels of resistance to three pests (Table 2). In addition, the hybrids SPSFR 94006A × ICSV 91 011, SPSFR 94010A × ICSV 705 and IS 18 551, SPSFR 94034A × ICSV 91 011 and CS 3541, SP 55301A × ICSV 91 011, CS 3541, MR 750 and ICSV 745, and ICSA 42A × PS 30 710 also showed multiple resistance to the pests.

Nearly 50% of the CMS lines and 41.7% of the maintainer lines showed multiple resistance to shoot fly, stemborer and sugarcane aphid, while 58.3% of the restorers showed less susceptibility to all these pests (Table 3). Out of the 144 hybrids tested, 35.4% showed multiple resistance to the three pests.

Discussion

The discovery of usable sources of CMS (Stephens and Holland, 1954) has made it easier to incorporate desired traits into hybrids (House, 1985). Most of the sorghum hybrids being grown by the farmers worldwide are based on a single source of CMS (*milo*-cytoplasm). However, large-scale cultivation of hybrids based on a single source of CMS system might increase the vulnerability of the crop to insect pests and diseases (Yang *et al.*, 1989; Sharma *et al.*, 2004; Dhillon *et al.*, 2005). Therefore, it is important to transfer genes conferring resistance to insect pests into CMS, maintainer and restorer lines to develop hybrids with agronomic desirability and resistance to the target insect pests in a region.

Considerable progress has been made in screening and breeding for resistance to insects in sorghum, but levels of resistance to multiple insect species are low to moderate (Sharma *et al.*, 2003). The sorghum crop experiences severe damage by two or more insect pests during the crop-growing season. Nwanze *et al.* (1991) reported germplasm lines with multiple resistance to insect pests, e.g. IS 18 551, with resistance to sorghum shoot fly and spotted stemborer, and IS 22 464 with resistance to spotted stemborer and midge. In North India, sorghum shoot fly and spotted stemborer cause severe damage to fodder sorghum (Nwanze *et al.*, 1991). However, damage by sorghum midge may occasionally lead to complete loss of sorghum grain. In South Central India, the sorghum shoot fly, spotted stemborer, sugarcane aphid, armyworm, midge and head bug cause severe losses across seasons and locations (Sharma, 1993). In northern Nigeria, the stemborer *Busseola fusca* Fuller, midge and head bugs have been recognized as serious pests (Harris, 1962, 1985; Ajayi, 1989). In Mali, sorghum midge and head bugs are the major insect pests, while in Burkina Faso, the stemborers, midge and head bugs cause severe losses (Nwanze, 1988). In such situations, crop improvement programmes should focus on developing genotypes with resistance to two or more key pests prevalent in a region. Present findings have shown that it is possible to combine resistance to two or more insects in the same hybrid using parental lines with multiple resistance to the target pests. However, it may be difficult to combine resistance to some groups of insect pests. For example, genotypes resistant to sorghum shoot fly and spotted stemborer are susceptible to sorghum midge and vice versa (Sharma, 1993). On the other hand, the sorghum genotypes IS 2205 (Patel *et al.*, 1989), IS 18 551, IS 2195, PS 28 060-3 (Nwanze *et al.*, 1991), ICSV 705, IS 4881, IS 13 674 (Jalaluddin *et al.*, 1995) and hybrids HC 171 (Singh and Lodhi, 1995), and HH 1 (Verma and Singh, 2000) have been reported to be resistant to both sorghum shoot fly and spotted stemborer, indicating that some of the sources of resistance are common to both these insects (Taneja and Leuschner, 1985a,b). In the present study, the CMS lines SPSFR 94011A, SPSFR 94006A, SP 55299A and SP 55301A, restorers ICSV 705, ICSV 700, ICSV 708, PS 30 710, IS 18 551, SFCR 151 and SFCR 125, and the hybrids derived from these, showed moderate to high levels of resistance to sorghum shoot fly, spotted stemborer and sugarcane aphid indicating potential for developing hybrids with multiple resistance to these insect pests.

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