Shoot fly (*Atherigona soccata*) resistance in improved grain sorghum hybrids

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Introduction

Sorghum (*Sorghum bicolor*) is one of the most important cereal crops widely grown for food, feed, fodder, forage and fuel in the semi-arid tropics (SAT) of Asia, Africa, the Americas and Australia. Insect pests are the major biotic constraints for production and productivity of sorghum causing economic losses over US$1 billion annually in the SAT. Among insects, shoot fly (*Atherigona soccata*) is a major grain yield limiting factor that causes damage when sowings are delayed in rainy season. The early-sown crop escapes from shoot fly damage but the late-sown crop in most cases is affected. Shoot fly infestation is high when sorghum sowings are staggered due to erratic rainfall distribution which is common in the SAT. Agronomic practices, natural enemies, synthetic insecticides and host plant resistance have been employed for shoot fly management to minimize the losses. Early planting is not always feasible as the sowing window is short in rainfed situations and there exists a competition with other crops for sowing. Insecticide application is beyond the reach of resource-poor farmers in the SAT. Host plant resistance can play a major role in minimizing the extent of losses and is compatible with other tactics of pest management, including the use of natural enemies and chemical control. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is the global repository of sorghum germplasm and contributed for development and refinement of interlard fish meal technique and no-choice-cage screening technique for selecting the sources of resistance against shoot fly and over the years made progress in developing shoot fly resistant lines.

Heterosis for grain yield is well established in sorghum and it is possible to produce hybrid seeds easily because of availability of the cytoplasmic male-sterility (CMS) system (Stephens and Holland 1954). The seed industry is well established in Asia and hence the target materials for sorghum in Asia are hybrid parents. It helps to capitalize on the strengths of both public and private sectors for better delivery of products. The objective of this study is to identify sorghum hybrids and their parental lines with high levels of shoot fly resistance and high grain yields in recently developed material in the sorghum improvement program at ICRISAT, Patancheru, India.

Materials and methods

Fifteen grain sorghum hybrids developed at ICRISAT, Patancheru were evaluated along with their parents comprising seven shoot fly resistant B-lines and seven R-lines (three shoot fly resistant and four high grain yielding) and three controls at ICRISAT, Patancheru in 2006 and 2007 rainy seasons. The three controls were 296 B, a high-yielding B-line susceptible to shoot fly; CSH 16, a popular hybrid developed by National Research Centre for Sorghum (NRCS), Hyderabad, India; and IS 18551, a shoot fly resistant landrace. The performance of the hybrids was compared with the commercial hybrid CSH 16 and parents' performance was compared with 296 B. The material was planted in a randomized complete block design (RCBD) with three replications in Vertisols at ICRISAT, Patancheru located at an altitude of 545 m above mean sea level, latitude of 17.53° N and longitude of 78.27° E, for evaluation of agronomic traits following the recommended cultural practices. The same set was planted for shoot fly resistance screening in the insect nursery in RCBD with three replications using infector row technique with three weeks delay in planting to assess shoot fly damage as influenced by the time of sowing of sorghum in relation to the normal date of sowing for a region (Sharma 2001). The data were recorded for seedling vigor (scored on a 1 to 5 scale, where 1 = most vigorous and 5 = least vigorous), leaf glossiness (scored on a 1 to 5 scale, where 1 = most glossy and 5 = non-glossy), time to 50% flowering (days), plant height (m), plant aspect score for agronomic desirability (on a 1 to 5 scale, where 1 = most desirable and 5 = least desirable) and grain yield (t ha^{-1}) in agronomic block. In the screening block, the shoot fly incidence was monitored in the infector rows; the total number of plants and the number of plants with shoot fly dead hearts were recorded at 18 days after seedling emergence and shoot fly dead hearts percentage was calculated. The data from agronomic block and shoot fly screening block were analyzed using GENSTAT (Edition 10) to test the significant differences among the genotypes for mean performance to select the high-yielding genotypes with shoot fly resistance and estimate correlations among the characteristics.

Results and discussion

The ANOVA showed significant differences among the hybrids and years for all the agronomic traits (Table 1). There were significant differences for shoot fly resistance and other agronomic traits for hybrids and years. Mean performance of the test entries (hybrids and their parents along with the controls) over two years is given in Table 2. The seedling vigor was significantly high in 12 of the 15 hybrids tested and among the parents ICSB 425, ICSB 438, ICSB 452, ICSV 700, M 35-1-16, M 35-1-19, M 35-1-36, and SFCR 125 were highly vigorous compared to the checks CSH 16 (seedling vigor score 2.3) and 296 B (score 2.5). For leaf glossiness, CSH 16 and 296 B were non-glossy. Leaf glossiness score was significantly superior in the hybrids ICSA 438 × ICSV 702, ICSA 444 × ICSV 702, ICSA 445 × ICSV 700 and ICSA 445 × ICSV 702. Also, the parents ICSB 425, ICSV 700 and ICSV 702 were significantly glossy. Time to 50% flowering in the hybrids ICSA 444 × M 35-1-36 and ICSA 445 × M 35-1-16 was similar to that in CSH 16, while in the parents ICSB 438, M 35-1-16, M 35-1-19 and M 35-1-36, it was similar to 296 B. For plant height, 11 of the 15 hybrids recorded significantly higher plant height (range 2.4 m to 3.3 m) than CSH 16 (2.2 m) and among the parents, except ICSB 438 and ICSB 445 that were similar to 296 B, all other parents were significantly taller (range 1.6 to 3.2 m) than 296 B (1.5 m) indicating their suitability as dual purpose cultivars. The agronomic desirability was high in the hybrid ICSA 445 × ICSV 702 as in CSH 16. The grain yield was significantly high in the hybrid ICSA 434 × M 35-1-19 (6.1 t ha^{-1}) than CSH 16 (5.3 t ha^{-1}) while in the hybrid ICSA 445 × ICSV 702 (5.2 t ha^{-1}) it was similar to than in CSH 16; among the parents ICSR 90011 (3.8 t ha^{-1}), M 35-1-36 (3.3 t ha^{-1}) and ICSB 452 (3.3 t ha^{-1}) recorded significantly higher grain yield by 14 to 31% than 296 B (2.9 t ha^{-1}). High levels of shoot fly infestation were observed in screening block. The shoot fly dead hearts percentage was high in CSH 16 (81%) and 296 B (78%), whereas in the hybrids it ranged from 35 to 62% and in parents from 28 to 63%. All the hybrids and parents were significantly resistant to shoot fly compared to respective controls CSH 16 (81% dead hearts) and 296 B (78% dead hearts). In comparison with shoot fly resistant control (IS 18551) that expressed 41% dead hearts, the parents ICSB 425, ICSB 438, ICSV 700 and ICSV 702 were significantly superior.

The hybrids ICSA 434 × M 35-1-19 (6.1 t ha^{-1}) and ICSA 445 × ICSV 702 (5.2 t ha^{-1}) recorded higher grain yields with better shoot fly resistance as they were developed using shoot fly resistant seed parents and restorers. These two hybrids can be selected for high grain yield along with shoot fly resistance since they expressed 53% and 47% dead hearts respectively in delayed sowing, ie, in screening block validating the results through multilocational testing. The hybrid ICSA 434 × ICSV 700 showed less dead hearts (37.3%) with good grain yield potential (5.1 t ha^{-1}). The male parent of this hybrid (ICSV 700) recorded 33.5% dead hearts compared to 78% in 296 B indicating its high shoot fly resistance. Development of shoot fly resistant parents is critical in breeding for shoot fly resistant hybrids (Jayanthi et al. 1996, Reddy et al. 1997).

There was significant and positive correlation between shoot fly dead hearts and grain yield (r = 0.42*) and negative correlation between shoot fly dead hearts and time to 50% flowering (r = –0.49**). Grain yield also showed significant negative correlation with time to 50%

Table 1. Mean sum of squares (ANOVA) of sorghum hybrids in shoot fly resistant hybrids and parents trial in 2006 and 2007 rainy seasons at ICRISAT, Patancheru, India[1].

Source of variation	df	Time to 50% flowering (days)	Plant height (m)	Grain yield (t ha^{-1})	Shoot fly dead hearts (%)
Replication	2	2.73	0.04	1.30	108.20
Hybrids (H)	24	27.16**	2.40**	9.69**	899.30**
Year (Y)	1	4651.17**	2.56**	216.13**	4515.40**
H × Y	24	8.63**	0.22**	4.54**	209.70
Error	98	1.89	0.02	0.34	141.50
Total	149				

1. ** = Significant at 1% level.

flowering (r = –0.50**). These results, therefore, suggested that resistant genotypes though infected with shoot fly recovered from the damage and produced tillers. Tillers, which delayed crop maturity but higher grain yield was produced like normal crop.

Host plant resistance is one of the most effective means of pest management in sorghum. It is compatible with other methods of pest control; there is no cost involvement for the farmers, and it is environment-friendly. There are over 36,700 sorghum germplasm accessions in ICRISAT genebank which serves as a global repository of the sorghum germplasm. ICRISAT and partners over the years have undertaken extensive screening of the sorghum germplasm collections for resistance to key sorghum pests such as sorghum shoot fly, spotted stem borer, sorghum midge and head bugs and resistant lines for shoot fly and other pests have been identified. Using these donors, several maintainer and restorer lines were developed at ICRISAT and partner locations (Sharma et al. 2008). Some high-yielding, shoot fly resistant sorghum restorers identified at ICRISAT are ICSRs 30, 103, 112, 160, 91026 and 93005; and maintainers with high yield and shoot fly resistance are ICSs 8, 9, 11, 30, 44 and 2968 (Reddy et al. 1997). Some of the resistant source lines with desirable agronomic characters used as parents in ICRISAT sorghum

Table 2. Mean performance of sorghum hybrids evaluated in shoot fly resistant hybrids and parents trial in 2006 and 2007 rainy seasons at ICRISAT, Patancheru, India.

Hybrid/Parent	Vigor score[1]	Leaf glossiness score[2]	Time to 50% flowering (days)	Plant height (m)	Plant aspect score[3]	Grain yield (t ha^{-1})	Shoot fly dead hearts (%)
ICSA 425 × ICSR 90011	2.0	2.2	74	1.8	2.3	2.0	35.3
ICSA 425 × M 35-1-16	1.4	1.7	72	1.8	2.0	1.8	39.1
ICSA 433 × ICSV 700	1.7	2.7	76	2.5	1.5	2.8	55.7
ICSA 433 × ICSV 702	2.2	2.2	75	2.5	1.7	2.8	56.6
ICSA 433 × M 35-1-19	2.1	2.9	75	2.5	1.8	3.2	50.4
ICSA 434 × ICSV 700	1.8	2.2	75	3.1	1.8	5.1	37.3
ICSA 434 × M 35-1-19	1.3	2.4	72	3.1	2.0	6.1	52.7
ICSA 438 × ICSV 702	1.3	1.5	73	2.2	1.7	3.9	51.7
ICSA 444 × ICSV 702	1.4	1.8	74	2.4	2.0	4.7	54.6
ICSA 444 × M 35-1-36	1.7	2.2	70	3.3	2.5	5.0	58.6
ICSA 445 × ICSV 700	1.3	1.8	75	3.2	2.0	4.7	52.9
ICSA 445 × ICSV 702	1.7	1.9	73	2.2	1.3	5.2	47.2
ICSA 445 × M 35-1-16	1.2	2.2	70	3.1	2.2	5.0	61.7
ICSA 452 × SFCR 125	1.3	2.8	73	2.4	2.2	4.3	57.6
ICSA 458 × M 35-1-19	1.3	2.1	71	3.2	2.3	5.1	59.1
ICSB 425	2.0	1.7	73	1.6	2.5	2.2	30.6
ICSB 433	2.2	2.5	74	1.8	2.2	2.8	48.7
ICSB 434	2.3	2.5	75	1.8	1.7	2.3	56.6
ICSB 438	1.6	2.3	72	1.4	2.0	3.0	31.2
ICSB 444	2.5	2.2	73	1.5	1.3	3.1	47.9
ICSB 445	2.7	2.4	73	1.4	1.5	2.9	58.4
ICSB 452	1.8	3.2	73	1.8	2.2	3.3	63.1
ICSR 90011	3.2	4.2	73	1.9	1.7	3.8	59.2
ICSV 700	1.8	1.7	79	3.2	2.3	2.5	33.5
ICSV 702	2.3	1.5	79	2.0	2.0	2.0	27.9
M 35-1-16	1.5	2.3	72	3.0	2.3	3.0	51.7
M 35-1-19	1.8	2.0	72	2.9	2.8	2.5	53.1
M 35-1-36	2.0	2.2	72	3.0	3.0	3.3	48.8
SFCR 125	1.7	1.5	75	2.8	3.0	2.4	54.8
Controls							
IS 18551	1.5	1.0	76	3.1	3.0	0.9	40.7
296 B	2.5	4.5	73	1.5	1.0	2.9	78.1
CSH 16	2.3	4.0	70	2.2	1.2	5.3	80.6
Mean	1.86	2.31	73	2.38	2.03	3.44	51.10
SE±	0.26	0.33	0.79	0.07	0.27	0.34	6.87
CV (%)	24.56	24.89	1.87	5.35	23.32	17.01	23.28
CD (5%)	0.71	1.02	1.58	0.20	0.83	0.35	20.42

1. Seedling vigor scored on a 1 to 5 scale, where 1 = more vigorous and 5 = least vigorous.
2. Leaf glossiness scored on a 1 to 5 scale, where 1 = more glossy and 5 = least glossy.
3. Agronomic desirability scored on a 1 to 5 scale, where 1 = more desirable and 5 = least desirable.

improvement program include ICSV 705, PS 30715-1, ICSV 708 and PS 35805 (Reddy et al. 1997). Of late, the thrust is on development and diversification of hybrid parents with high grain yield and shoot fly resistance as per se performance is the key in developing heterotic hybrids in sorghum. From this study, two hybrids with high grain yields and shoot fly resistance have been identified which need validation through large-scale testing for commercialization. Also, some promising hybrid parents were identified with high grain yield and shoot fly resistance that can be used in future sorghum improvement programs.

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