Improved sorghum hybrids with grain mold resistance

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Introduction

Sorghum (*Sorghum bicolor*) is the fifth most important cereal crop globally after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*) and barley (*Hordeum vulgare*) with multiple uses as food, feed, fodder and fuel. It has a great potential in the gluten-free food market. Globally it is grown on over 43 million ha predominantly in tropical Africa and India. It is also grown in temperate areas (Americas, Europe and Australia) as a feed crop. In the tropics, sorghum is faced with a hostile environment, where unreliable rainfall, poor soils, pests, diseases and parasitic weeds constantly exert harsh selection pressure. India has the largest area (8.5 million ha) under sorghum and 45% of this area is in rainy season while postrainy season sorghum accounts for the remaining area.

Grain mold is a major disease of sorghum that affects grain production and quality. The disease is particularly important on improved, short- and medium-duration sorghum cultivars that mature during the rainy season in humid, tropical and subtropical climates. Photoperiod-sensitive cultivars that mature after the rains often escape grain mold infection. Sorghum cultivars with white grain pericarp (used as food in India) are particularly more vulnerable to grain mold than those with brown and red grain pericarp (Thakur et al. 2006). Annual global losses due to grain molds have been estimated at US$130 million. At present, grain mold is tackled by developing host plant resistance and modifying the cultural practices with some success.

In sorghum, heterosis for grain yields in hybrids is well established. However, there is a yield gap of about 3 t ha^{-1} between the potential grain yield and yield in farmers' fields (1.1 t ha^{-1}) in India (AICSIP 1994). This reduction in the realized grain yields in farmers' fields is due to several biotic and abiotic constraints. Grain mold is one of the important biotic constraints of sorghum in rainy season attributed with severe reduction in grain yield and quality (Bandyopadhyay et al. 1988). It is caused by several non-specialized fungi like *Fusarium monliforme, F. pallidoroseum, Curvularia lunata* and *Phoma sorghina* (Bandyopadhyay et al. 1988, 1998).

Research efforts for grain mold resistance at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and other places (USA and India) have met with partial success in breeding cultivars with high levels of grain mold resistance and higher grain yields. In this paper, we present the strategy adapted and performance of some recently developed sorghum hybrids and parents in ICRISAT sorghum improvement program for resistance to grain mold and high grain yields.

Materials and methods

Nine white grain sorghum hybrids along with their parents – five B-lines (three grain mold resistant and two high grain yielding) and seven R-lines (three grain mold resistant and four high grain yielding) – developed by ICRISAT, Patancheru, India and four controls [296 B – a high-yielding B-line; CSH 16 – a popular hybrid developed by National Research Centre for Sorghum (NRCS), Hyderabad; IS 14384 – a grain mold resistant landrace; and Bulk Y – a grain mold susceptible cultivar] were evaluated at ICRISAT, Patancheru (altitude 545 m above mean sea level, latitude 17.53° N and longitude 78.27° E) in 2006 and 2007 rainy seasons. The material was planted in a randomized complete block design (RCBD) with three replications in Alfisols at ICRISAT, Patancheru to evaluate agronomic traits. The same set was planted in grain mold screening nursery in the same environment in RCBD with three replications. For grain mold infection, sprinkler irrigation method without artificial inoculation was used from the time of flowering to maintain high humidity and conidial-mycelial suspension (Castor 1977) during the grain-filling period. Recommended agronomic practices were followed to raise a good crop. During the non-rainy days, sprinklers were operated for one hour in the morning and one hour in the evening to create favorable conditions for fungal development. The data were recorded for time to 50% flowering, plant height, plant aspect score for agronomic desirability (on a 1 to 5 scale, where 1 = more desirable and 5 = least desirable) and grain yield in agronomic block. Panicle grain mold rating (PGMR) score was recorded in the screening block at grain maturity stage on a 1 to 9 scale, where 1 = <10% and 9 = >90% mold infected grains (Bandyopadhyay et al. 1988). The data were analyzed using GENSTAT (Edition 10) to test the significant differences among the genotypes, for mean performance to select the high-yielding genotypes with grain mold resistance and estimate correlations among the characteristics.

Results and discussion

The ANOVA showed significant differences among the hybrids and years for all the traits (Table 1). Significant differences were observed for hybrid × years interactions for time to 50% flowering, plant height and grain yield. The mean performance of hybrids and parents is presented in Table 2. Time to 50% flowering in the three hybrids – ICSA 384 × ICSR 91011, ICSA 52 × ICSV 96105 and ICSA 101 × ICSR 89058 was similar to CSH 16, while the parents ICSV 96105, ICSB 52, ICSB 101 and IS 41675 were significantly earlier by two to four days than 296 B (69 days). Among the hybrids, ICSA 101 × IS 41675 (2.8 m), ICSA 52 × ICSV 96105 (2.8 m), ICSA 101 × ICSR 89058 (2.4 m) and ICSA 382 × GD 65055 (2.4 m) were significantly taller than CSH 16 (2.2 m) indicating their superiority for fodder yield. All the parents tested were significantly taller than 296 B (1.4 m). The agronomic desirability of three hybrids (ICSA 101 × PVK 801, ICSA 101 × ICSR 89058 and ICSA 384 × ICSR 91011) was similar to CSH 16 (score 1.5); among the parents, ICSB 400 and ICSR 89058 were similar to 296 B (score 1.8). Among the hybrids, ICSA 101 × PVK 801 (6.0 t ha^{-1}) recorded significantly higher (18%) grain yield than CSH 16 (4.7 t ha^{-1}). Grain yield in the two hybrids ICSA 101 × ICSR 89058 (4.6 t ha^{-1}) and ICSA 400 × GD 65028 (4.8 t ha^{-1}) was similar to CSH 16. Among the parents, ICSR 89058, PVK 801, IS 41675, ICSB 400, ICSR 91011 and ICSB 52 recorded significantly higher grain yield (ranging from 17 to 67%) than 296 B (2.3 t ha^{-1}). All the hybrids and parents tested recorded significantly better PGMR than respective controls CSH 16 (PGMR 4.7) and 296 B (PGMR 8.2) indicating their resistance to grain mold infection (Table 2).

The correlations among the traits are presented in Table 3. As expected, hybrids that matured early during rainy season and dwarf cultivars showed high grain mold infection that resulted in low grain yields. In tall and late maturing lines, grain mold severity tended to decrease. Agronomic desirability score showed negative correlation with grain yield indicating that selection criteria should be grain yield followed by agronomic desirability. The entries with high grain yield were tall indicating their suitability for dual use (food and fodder).

Some of the hybrids possessing average grain yields in agronomic block showed low grain mold incidence than others in screening block indicating their ability to better withstand grain mold infection. They are handy in areas where grain mold is a severe problem. The hybrid ICSA 101 × PVK 801 was the best among the nine hybrids tested; it produced higher grain yield and had better grain mold tolerance than other test hybrids. It recorded significantly higher (18%) grain yield (6.0 t ha^{-1}) and lesser (25%) grain mold incidence (PGMR 3.5) than CSH 16 with similar agronomic desirability. Another hybrid ICSA 101 × ICSR 89058 was similar to CSH 16 (4.7 t ha^{-1}) for grain yield and agronomic desirability; but it had significantly higher grain mold tolerance (27%) compared to CSH 16. Validation of these results through multilocational testing is needed for commercial use. Promising hybrid parents like ICSR 89058, PVK 801, IS 41675, ICSB 400, ICSR 91011 and ICSB 52 with higher grain yield and grain mold tolerance identified in this study can be used in future hybrid breeding programs.

Table 1. Mean sum of squares (ANOVA) of sorghum hybrids in grain mold 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})	Panicle grain mold rating (PGMR)
Replication	2	9.49	0.10	0.11	0.29
Hybrids (H)	24	107.84**	1.12**	7.55**	23.11**
Year (Y)	1	530.16**	3.39**	414.72**	16.67**
H × Y	24	18.83**	0.05*	3.44**	6.06**
Error	98	2.35	0.03	0.37	0.12
Total	149				

1. * = Significant at 5% level; ** = Significant at 1% level.

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

Hybrid/Parent	Time to 50% flowering (days)	Plant height (m)	Plant aspect score[1]	Grain yield (t ha^{-1})	Panicle grain mold rating[2]
Hybrids					
ICSA 101 × PVK 801	67	2.3	1.5	6.0	3.5
ICSA 101 × ICSR 89058	66	2.4	1.5	4.6	3.3
ICSA 101 × IS 41675	67	2.8	2.2	4.1	2.5
ICSA 101 × GD 65028	67	2.3	2.2	4.3	2.2
ICSA 101 × GD 65055	68	2.2	1.8	3.7	1.5
ICSA 382 × GD 65055	67	2.4	2.0	4.3	1.5
ICSA 384 × ICSR 91011	64	2.1	1.5	3.9	3.3
ICSA 52 × ICSV 96105	66	2.8	2.0	5.0	3.2
ICSA 400 × GD 65028	69	2.2	1.8	4.8	1.5
B-lines					
ICSB 52	66	1.7	2.2	3.1	6.0
ICSB 101	67	1.9	2.3	2.8	6.5
ICSB 382	68	2.0	2.8	2.6	4.2
ICSB 384	69	1.9	2.7	1.8	4.0
ICSB 400	69	1.5	1.8	3.6	3.2
R-lines					
PVK 801	68	1.9	2.0	4.2	2.5
ICSR 89058	68	1.9	1.7	4.5	4.0
ICSR 91011	71	2.0	2.3	3.2	4.0
IS 41675	67	2.8	2.5	3.8	3.5
GD 65028	77	2.1	2.5	2.1	2.2
GD 65055	73	2.0	2.2	2.0	5.0
ICSV 96105	65	2.3	2.8	2.4	3.0
Controls					
Bulk Y	53	1.4	3.0	1.8	8.8
IS 14384	73	3.1	2.7	3.5	1.2
CSH 16	65	2.2	1.5	4.7	4.7
296 B	69	1.4	1.8	2.3	8.2
Mean	68	2.14	2.13	3.56	3.73
SE±	0.89	0.10	0.28	0.35	0.20
CV (%)	2.27	8.30	22.36	17.02	9.41
CD (5%)	2.48	0.29	0.77	0.99	0.57

1. Agronomic desirability scored on a 1 to 5 scale, where 1 = more desirable and 5 = least desirable.
2. Panicle grain mold rating scored on a 1 to 9 scale, where 1 = <10% and 9 = >90% mold infected grain.

Table 3. Correlation coefficients of sorghum hybrids in grain mold resistant hybrids and parents trial in 2006 and 2007 rainy seasons at ICRISAT, Patancheru, India[1].

Trait	Time to 50% flowering (days)	Plant height (m)	Plant agronomic aspect score	Grain yield (t ha^{-1})
Plant height (m)	0.228			
Plant agronomic aspect score	–0.056	0.025		
Grain yield (t ha^{-1})	–0.061	0.468*	–0.707**	
Panicle grain mold rating	–0.471*	–0.666**	0.165	–0.481*

1. * = Significant at 5% level; ** = Significant at 1% level.

The host-pathogen-environment interaction is highly complex and variable in sorghum grain mold and no single control method has been found effective. Adjusting sowing dates to avoid warm and humid conditions during flowering to grain maturity reduces grain mold severity, but it is not realistic in most environments due to the constraint of limited growing season. Several other methods, such as application of chemical fungicides and bio-control agents have been shown to provide some degree of protection under experimental conditions, but their effectiveness and economic feasibility in on-farm situations have not been demonstrated. Host plant resistance therefore forms a major component of grain mold management, and it could be complemented with other practices to help reduce the disease severity (Thakur et al. 2006). ICRISAT pioneered development of greenhouse and field screening techniques for grain mold. Bandyopadhyay et al. (1988) identified 156 grain mold tolerant/resistant lines in screening of 13,000 photoperiod-insensitive sorghum germplasm lines. Resistance has been found mostly in colored grain sorghums, with and without tannins, and also in very few white-grain sorghums (Bandyopadhyay et al. 1988, 1998, Thakur et al. 2006). Using the grain mold resistant white-grained germplasm sources, some hybrid parents and varieties were developed (Bandyopadhyay et al. 1988). PVK 801 is one such example developed by Marathwada Agricultural University, Parbhani in partnership with ICRISAT which is quite popular in rainy season in India. White-grain sorghums are preferred for food purposes in India. From this study some promising white-grain hybrids and hybrid parents with grain mold resistance were identified that can be used in future breeding programs.

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