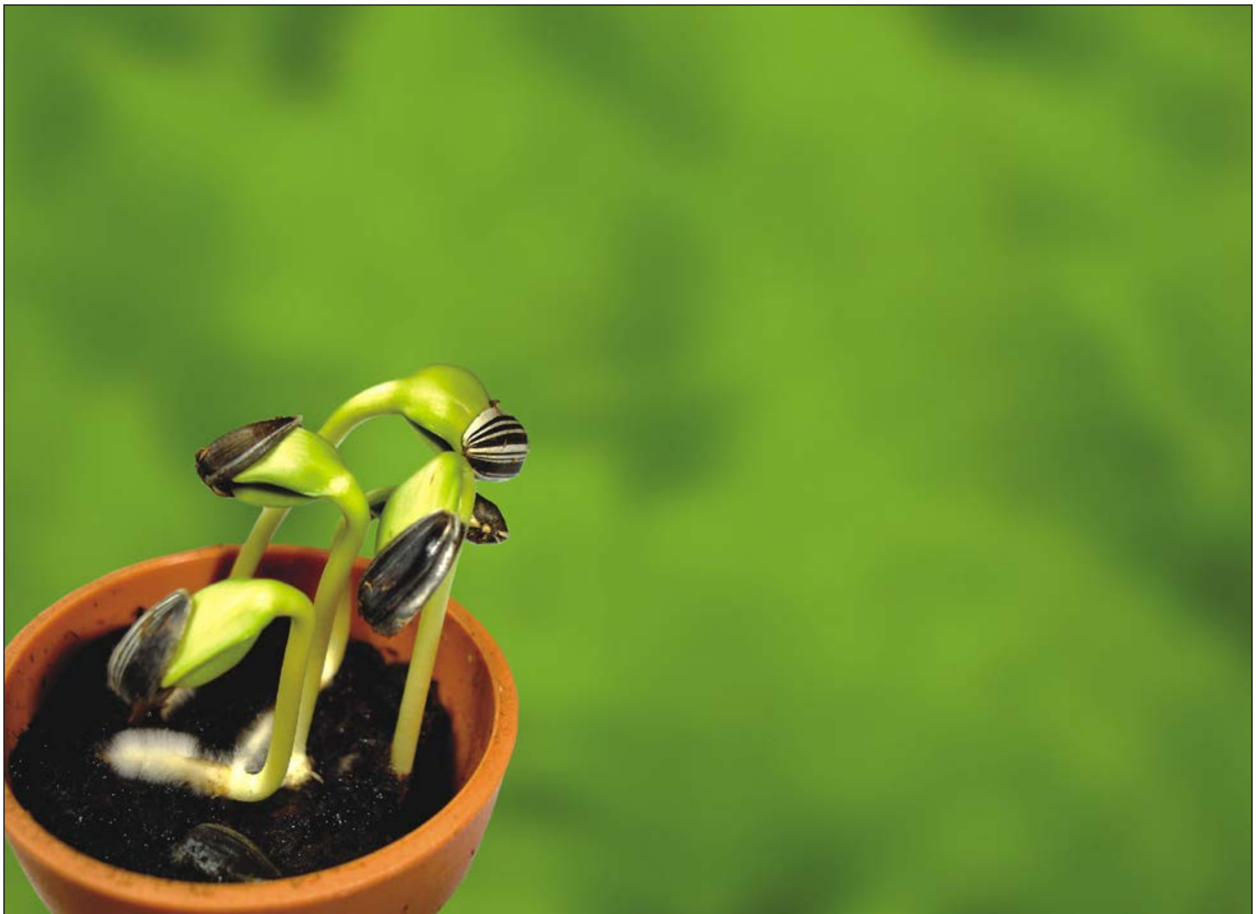

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Physical Kernel Properties Associated with Grain Mold Resistance in Sorghum (*Sorghum bicolor* (L.) Moench)

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ABSTRACT

Grain mold is a major disease of sorghum that effects grain production and quality. The disease is very important in improved cultivars with short and medium duration which flower and mature earlier in the rainy season, when soil moisture levels are generally more favorable for grain filling which potentially give higher yields. However, the earlier flowering often results in exposure of developing grain exposed wet conditions in which it can deteriorate rapidly. To overcome this problem, it is essential to identify grain mold resistant hybrids. Sorghum (*Sorghum bicolor* (L.) moench) cultivars exhibiting contrasting reactions to the grain mold complex and there is always bias with visual scoring systems to score disease severity. Identification of kernel properties associated with resistance to grain mold would useful in screening of breeding material; thus, grain density and germination percentage are two import kernel properties to appraise the grain mold resistance. Twenty five hybrids were selected based on their visual rating for grain mold resistance from replicated trials at two locations in India during 2004 and 2005 rainy seasons and grouped into resistant hybrids and susceptible hybrids. Grain mold resistant hybrids exhibited more grain density (1.19 g mL^{-1}) compared to mold susceptible hybrids (1.10 g mL^{-1}). Germination percentage indicating the seed viability and germination decreased with extent of grain mold incidence. Grain density is an important physical parameter to resist the entry of fungi into the grain. The grains which contain hard endosperm will offer more resistance and also show the high germination percentage.

Key words: Grain density, germination percent, grain mold, sorghum, field grade score

INTRODUCTION

Sorghum is one of the most important cereal crops widely grown for food, feed, fodder/forage and fuel in semi-arid tropics of Asia, Africa, the America and Australia. 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 (Ashok kumar *et al*., 2008). 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 post rainy season sorghum accounts for the remaining area (Ashok kumar *et al*., 2008). 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 (Thakur *et al.*, 2006). Sorghum cultivars with white grain per carp (used as food in India) are particularly more vulnerable to grain mold than those with brown and red grain pericarp. Current commercial hybrids are bred for earliness in India so that they escape drought. However, maturity coincides with heavy rains that greatly increase the risk of infection by grain molds (Ambekar *et al.*, 2011). Grain mold can be broadly defined as pre-physiological grain deterioration caused by fungal species interacting pathogenically and/or saprophytically with developing grain. Grain weathering, on the other hand, is a postphysiological maturity problem observed as grain discoloration and tissue damage by saprophytic fungal colonization due to wet weather (Thakur *et al.*, 2007). Several species of the genera *Fusarium, Curvularia, Alternaria, Phoma, Bipolaris* and *Colletotrichum* have been reported to be associated with grain mold (Thakur *et al.*, 2003). The disease is associated with losses in seed mass (Somani and Indira, 1999), grain density (Ibrahim *et al.*, 1985) and germination (Maiti *et al.*, 1985). Other types of damage that arise from grain mold relate to storage quality (Hodges *et al.*, 1999), food and feed processing quality and market value. Several mold-causal fungi are producers of potent mycotoxins that are harmful to human and animal health and productivity. Evaluation of sorghum genotypes based on visual (panicle grain mold resistance and threshed grain mold resistance) scores has led to the identification of several grain mold resistant genotypes (Bandyopadhyay and Mughogho, 1988; Ghorade *et al.*, 1997; Audilakshmi *et al.*, 1999; Reddy *et al.*, 2000; Palakshappa *et al.*, 2003). Sorghum hybrids are predominantly cultivated during the rainy season in India. Development of Sorghum cultivars with resistance to grain mold have greater importance under such conditions. Assessment of severity in fungal infection in crops and its effect on seed and nutritional qualities is often difficult. Many methods can be used to determine the fungal infection. Rana *et al.* (1977) reported that tan plant type having grains with lower water absorption capacity and higher grain hardness could contribute to mold resistant cultivars. Hence, the present study was undertaken to estimate the physical kernel properties i.e., grain density and germination percentage selected mold susceptible and resistant hybrids.

MATERIALS AND METHODS

Experimental material: The experimental material was obtained from ICRISAT, Patancheru, India. It included eight A-lines (ICSA 369, ICSA 370, ICSA 371, ICSA 400, ICSA 384, ICSA 382, ICSA 52 and ICSA 101), their respective B-lines, 21 R-lines (IS 41720, IS 41397, IS 41675, IS18758C-618-2, IS 18758C-618-3, IS 30469C-140-2, IS 30469C-1508-2, ICSV 96105, ICSV 96094, IS 84, SPV 462, ICSR 89013, ICSR 91011, ICSR 89018, ICSR 89058, PVK 801, GD 65028, GD 65055, ICSR 92001, ICSR 91019 and ICSR 91029) and six checks (Bulk Y, IS25017, IS 20, IS 14384, PVK 801 and CSH 16). The eight A-lines (5 of which were grain mold resistant) and 21 testers (9 of which were grain mold resistant) were crossed in Line Tester mating design during the 2003-2004 and 2004-2005 post rainy seasons (October to February) at ICRISAT, Patancheru, India. The 203 genotypes including 168 hybrids, 8 B-lines, 21 R-lines and 6 checks were evaluated in a randomized complete block design with two replications at ICRISAT and at College of Agriculture, Acharya N.G. Ranga Agricultural University, Rajendranagar, India during the 2004 and 2005 rainy (June to September) seasons. Each genotype was grown in two rows of 4 m length with a spacing of 60 cm between rows and 15 cm between plants in a row. Recommended agronomic practices were followed to grow a good crop. From these trials, 25 hybrids were selected for grain analysis. Among the 25 hybrids, 15 hybrids (10 with white grain color and 5 with red grain color) were grain mold resistant and 10 hybrids (5 with white grain color and 5 with red grain color) were grain mold susceptible based on the visual rating for field grade score. Harvested grain of 48 genotypes that include 25 hybrids, their 22 parents and a susceptible check, Bulk Y, was used for estimating grain density and germination percent.

Field screening technique for grain molds: The screening technique of Bandyopadhyay and Mughogho (1988) was used to increase grain mold pressure. Sprinkler irrigation was provided twice a day on rain-free days for 1 h each during morning and evening from flowering to physiological maturity to create high humidity (>90% relative humidity) that is conducive for the development of mold on the developing grains. Ten uniformly flowered panicles were tagged in each replication for recording the data.

Field grade score: Ten panicles from each replication of each test entry were scored visually for mold severity on the panicle surface at harvest, using a progressive 1 to 9 scale where 1 = no mold, 2 = 1-5%, 3 = 6-10%, 4 = 11-20%, 5 = 21-30%, 6 = 31-40%, 7 = 41-50%, 8 = 51-75% and 9 = >75% molded grains on a panicle.

Grain density: The method used by Pendleton *et al.* (2005) was utilized to determine the density of the grain. Grain sample of 20 g from each genotype was taken in duplicate. These samples were put with 70 mL of water into a 100 mL glass graduated cylinder. The amount of water displaced by the grain was used as the volume of the grain. The weight of the grain was divided by volume of the grain to determine the density of the grain in g mL^{-1}.

Germination percentage (GER %): One hundred grains from each of the ten panicles from each replicate that was scored for TGS, were incubated in petri dishes lined with wet filter paper for 4 d at 30°C number of germinated seed was counted (Audilakshmi *et al.*, 1999).

RESULTS AND DISCUSSION

One of the common problems associated with visual appraisal is the difficulty to compare the results from workers using different assessment procedures and scales. Though commonly used in resistance screening, visual appraisal alone does not always provide a satisfactory means of assaying fungal infection (ICRISAT, 1991). Grain density and germination percentage are the two important physical traits which are directly associated with resistance to measure grain mold resistance. Physical kernel attributes may become more important factors in resistance to grain mold after physiological maturity (Castor and Frederiksen, 1980). Sorghum kernels with more corneous endosperm were more resistant to grain mold than those with floury endosperm (Ibrahim *et al.*, 1985; Jambunathan *et al.*, 1992; Mukuru, 1992). These observations led to conclude that grain mold resistance associated with kernel hardness. Grain hardness is measured by different instruments by different workers and it is laborious. An attempt was made to identify the relation of grain hardness with grain density in resistant and susceptible cultivars indicated the positive association. In the present study (Table 1), resistant hybrids recorded higher density (1.19 g mL^{-1}) compared to susceptible hybrids (1.10 g mL^{-1}). Among hybrids, ICSA 52×ICSV 96105 (1.23 and 3.0 g mL^{-1}) and ICSA 101×ICSR 89058 (1.21 and 3.63 g mL^{-1}) recorded high grain

Table 1: Mean performance of hybrids and parents for grain density (g mL^{-1}) and germination percentage over two years

	Grain density (g mL^{-1})			Germination percentage			
Resistant hybrids	Patancheru 2004	Patancheru 2005	Pooled	Patancheru 2004	Patancheru 2005	Pooled	Field grade score
ICSA 400×IS41675	1.20	1.17	1.18	87.00	85.00	86.00	2.63
ICSA 400×ICSR 91011	1.17	1.14	1.16	92.00	89.00	90.50	3.25
ICSA 382×ICSR 91011	1.16	1.17	1.17	91.00	89.00	90.00	3.00
ICSA 101×ICSR 89058	1.23	1.20	1.21	96.00	85.00	90.50	3.63
ICSA 101×PVK 801	1.20	1.18	1.19	94.00	91.00	92.50	2.63
ICSA 52×IS 41675	1.21	1.17	1.19	87.00	88.00	87.50	4.50
ICSA 52×ICSV 96105	1.25	1.21	1.23	88.00	87.00	87.50	3.0
ICSA 384×IS30469C-1508-2	1.19	1.17	1.18	88.00	82.00	85.00	3.88
ICSA 382×IS30469C-140-2	1.19	1.14	1.16	92.00	82.00	87.00	3.50
ICSA 400×ICSR 89058	1.19	1.18	1.18	88.00	87.00	87.50	4.0
ICSA 400×GD 65028	1.20	1.18	1.19	97.00	91.00	94.00	2.13
ICSA 384×GD 65028	1.20	1.17	1.19	94.00	89.00	91.50	2.00
ICSA 382×GD 65028	1.20	1.18	1.19	96.00	87.00	91.50	2.13
ICSA 101×GD 65028	1.20	1.18	1.19	90.00	94.00	92.00	2.25
ICSA 371×GD 65055	1.20	1.19	1.19	91.00	92.00	91.50	2.13
Mean	1.20	1.17	1.19	91.40	87.87	89.63	
Susceptible hybrids							
ICSA 384×IS 18758C-618-3	1.12	1.12	1.12	60.00	73.00	66.50	8.63
ICSA 52×IS 84	1.06	1.07	1.06	42.00	46.00	44.00	9.0
ICSA 52×ICSR 91011	1.08	1.10	1.09	68.00	83.00	75.50	7.38
ICSA 52×ICSR 92001	1.07	1.08	1.07	56.00	85.00	70.50	7.75
ICSA 384×ICSR 91019	1.09	1.08	1.09	61.00	61.00	61.00	7.38
ICSA 369×IS 84	1.11	1.12	1.11	66.00	65.00	65.50	7.13
ICSA 369×IS 18758C-618-3	1.11	1.11	1.11	82.00	75.00	78.50	5.38
ICSA 370×IS 84	1.10	1.12	1.11	72.00	62.00	67.00	6.63
ICSA 371×IS 84	1.11	1.10	1.11	71.00	65.00	68.00	6.88
ICSA 370×IS 18758C-618-2	1.12	1.13	1.12	83.00	72.00	77.50	4.38
Mean	1.10	1.10	1.10	66.10	68.70	67.40	
Bulk Y (Susceptible check)	1.00	1.01	1.01	39.0	25.0	32.0	9.0

density values, low field grade scores and considered as grain mold resistant. Similar results were reported by Shinde *et al.* (2004). Grain germination was closely related to grain molds, that resistant genotypes could be identified from germination tests (Denis *et al.*, 1977). Seed viability and germination were shown to decrease with increasing infection by mold-causing fungi (Mahalinga *et al.*, 1988; Singh and Agarwal, 1989; Forbes *et al.*, 1989). In the present study resistant hybrids recorded high germination (89.63%) compared to susceptible hybrids (67.40%). The hybrids viz., ICSA 400×GD 65028 (94.00 and 2.13%), ICSA 101×PVK 801 (92.50 and 2.63%) and ICSA 371×GD 65055 (91.50 and 2.13%) recorded high germination percentages, low field grade scores and considered as grain mold resistant. Similar results were observed by Audilakshmi *et al.* (1999), Bhongle *et al.* (2001) and Shinde *et al.* (2004).

CONCLUSION

Research workers generally depend on visual examination of sorghum grains for selection of grain mold resistant entries. However, these scores sometimes may not give accurate results because; it is difficult to judge the difference in the case of closely resembled samples. Grain density and germination percentage are two important and useful tools to measure grain mold resistance. The data obtained from twenty five hybrids for Grain density and germination percentage revealed and reconfirmed the earlier findings that the resistant hybrids contain high grain density and germination percentage compared to susceptible hybrids.

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