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Research Article
Screening of Sorghum Lines Against Long Smut and Grain Mold Pathogens

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Abstract

Background and Objective: Long smut infection is severe in the drier regions of Africa and Asia, whereas, grain mold is the most important widespread complex disease where sorghum is grown worldwide. Both fungal diseases cause significant losses in grain yield and quality. Long smut has not yet been observed in the United States but there is no guarantee that the disease may never reach the shores. The current study was undertaken to screen selected sorghum lines and hybrids from the U.S. in Bambey, Senegal, West Africa to identify resistance sources. **Materials and Methods:** In this study, a total of 21 sorghum lines and hybrids from the United States and two Senegalese lines CE 151-262 and CE 196-7-2-1 were evaluated for resistance to long smut and grain mold at the Agronomic Research Station, Bambey, Senegal, West Africa, in 2011-2012 growing seasons. Seeds from sorghum lines and hybrids were planted in a randomized complete block design and replicated thrice. Differences in means among sorghum genotypes were determined at the 5% probability level based on pairwise comparison of least-square means with t-tests. **Results:** The study showed that sorghum hybrids AP 920 and AgriPro 2838 recorded zero long smut infection, while Triumph 459 was the most susceptible hybrid. All other lines and hybrids had long smut incidence ranging from 2.8-76.3%. None of the lines and hybrids showed resistance to natural grain mold infestation. **Conclusion:** The two Senegalese lines CE 151-262 and CE 196-7-2-1, exhibited lower grain mold scores than resistant checks SC719-11E and RTx2911. This study also indicated that AP 920 and AgriPro 2838 are resistant to long smut and could be used as resistance hybrids in West Africa.

Key words: *Sorghum bicolor*, *Sporisorium ehrenbergii*, long smut, grain mold, grain molding fungi

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Long smut of sorghum (*Sorghum bicolor* (L.) Moench) incited by *Sporisorium ehrenbergii* Vánky (syn. *Tolyposporium ehrenbergii* (Kühn) Patouillard) is an important disease in Africa and Asia, especially in areas with low rainfall, low soil moisture and high temperature[1-3]. The disease was shown to be most severe during drought years in Nigeria[4]. Yield losses ranging from 20-60% have been reported[3,5]. Teferi and Wubshet[6] noted 88.6% field infection in South Tigray, Ethiopia with long smut. The pathogen infects the host when air borne teliospores enter into the boot, germinate to produce sporidia which in turn infect individual spikelets[2,4,5]. Infection occurs only during the booting stage to anthesis and no later[2,4]. Symptoms, evident at heading 11-14 days after infection include elongated, cylindrical and slightly curved spore sacs (sori)[2,5]. The disease can be spread within fields and to distant areas by air-borne teliospores, insects and to new areas by contaminated soil and seeds[2,4,5,7]. Teliospores of *S. ehrenbergii* often adhere together to form balls which can survive for many years in the soil and serve as primary source of inoculum[2,5].

Although the pathogen survives in the soil as teliospores, infection of the host due to contaminated seed or soil does not play a role in the development of the disease, because infection occurs only at booting stage of the host[8]. As a result, the use of chemical as seed dressing will not be an effective method to control the disease[2,4]. The most effective method of long smut control is the use of host plant resistance[2,4,7]. So far, no sorghum genotype that is immune to the disease has been identified[9]. However, a number of sorghum lines with high level of resistance to the disease have been reported[1,3,8]. Long smut has not yet been observed in sorghum fields in the U.S.; as a result, little information was available on the reactions of the U.S. sorghum lines[10].

Globally, grain mold is the most important fungal disease of sorghum. The disease impacts both the yield and quality and is most severe in areas where moist conditions occur later in the growing season when mature grains are not harvested on time[11-13]. Yield losses due to grain mold on highly susceptible sorghum lines can reach 100%[14]. This disease complex is associated with several fungal species, including *Fusarium thapsinum* Klittick, Leslie, Nelson *et al*., Manassas; *Fusarium semitectum* Berk. and Ravenel; *Curvularia lunata* (Wakk.) Boedijn, *Colletotrichum graminicola* (Ces.) G. W. Wilson; *Alternaria alternata* (Fr.: Fr.) Keissl. and *Phoma sorghina* (Sacc.) Boerema, Dorenbosch and Van Kesteren[11,15-17]. Worldwide, *F. thapsinum*, *F. nygamy* and *C. lunata* are considered the most important grain molding fungi[11]. However, the aforementioned species are not usually the most frequently recovered species on moldy grains in some sorghum growing regions of the U.S.[17]. Some of the *Fusarium* species associated with this disease complex are mycotoxigenic either during the grain development or post- harvest during storage[14,15,18-20]. Grain mold symptoms may be manifested as seed discoloration and smaller seed size[3,14]. Planting cultivars that mature during periods of dry weather and chemical treatment to enhance seed germination and vigor and the use of cultivars with colored grain high in tannins are often used to reduce the disease infection[12,13,15,16,21]. The use of genetically resistant sources offers the most practical method for controlling the disease complex[3,12,13,22]. A number of studies have reported resistance to grain mold either under natural infected field trials or by inoculating the lines with either individual or mixture of fungal species[16,17,23]. Considering the importance of sorghum long smut and grain mold, the current study was undertaken to screen selected sorghum lines and hybrids from the U.S. in Bambey, Senegal, West Africa to identify resistance sources.

MATERIALS AND METHODS

The field evaluation was conducted at the Agronomic Research Stations in Bambey (14°42'N, 16°28'W). Soil type was slightly leached, tropical ferruginous, 7% clay with pH 7.0. Seeds from 21 sorghum lines and hybrids from the United States and two Senegalese lines CE 151-262 and CE 196-7-2-1 were planted in a randomized complete block design and replicated trice. Inoculum preparation and disease assessment for long smut were as previously described by Prom *et al*.[10]. Briefly, a mixture of teliospores from sori of different previously planted sorghum plants were collected and suspended in water to prepare the inoculum. At ambient room temperature after several hours, the suspension was filtered through a nylon mesh and used for inoculation. Four plants/plot were inoculated at the boot stage. Ten milliliters of inoculum was applied between the flag leave and panicle using a pipette. The number of infected plants/plot (both inoculated and non-inoculated) were counted at maturity and expressed as percent incidence. Disease incidence was further categorized into four classes: 0 = Resistant, 1-10% was considered as low, 11-30% as moderate and >30% as high disease infection. Based on a scale of 1-5 as previously described by Thakur *et al*.[24] and Isakeit *et al*.[25], grain mold severity was assessed on naturally-infected threshed seeds where, 1 = No mold observed on the panicle, 2 = 1-9%, 3 = 10-24%, 4 = 25-49% and 5 = 50% or more of the panicle molded. The weather parameters measured were based on

Table 1: Weather parameters for Bambey, Senegal, West Africa during the growing seasons between July to October for 2011 and 2012

	Mean				
Year	Precip[1]	Tmin[2]	Tmax[3]	% RH min[4]	% RH max[5]
2011	146.1	23.9	34.2	54.5	96.6
2012	150.6	24.2	34.1	58.6	98.2

[1]Precip: Total precipitation in mm, [2]Tmin: Minimum temperature (°C), [3]Tmax: Maximum temperature (°C), [4]% RH min: Percent minimum relative humidity; [5]% RH max: Percent maximum relative humidity

means from July to October of each growing season for minimum temperature, maximum temperature, percent minimum relative humidity and percent maximum relative humidity (Table 1).

Statistical analysis: Long smut incidence and grain mold severity data were combined over 2 years and analyzed using the command PROC GLM (SAS Institute, SAS version 9.3, Cary, NC). Differences in means among sorghum genotypes were determined at the 5% probability level based on pairwise comparisons of least-square means with t-tests.

RESULTS AND DISCUSSION

Long smut and grain mold are important fungal diseases that can cause significant economic losses due to their impact on yield and seed quality. The weather conditions in Bambey, Senegal, during the 2011 and 2012 growing seasons were similar (Table 1).

Long smut of sorghum is most devastating in areas with drought conditions, where losses can reach up to 60%[1,2,4,10]. In this study, sorghum hybrids AP 920 and AgriPro 2838 recorded zero long smut infection, whereas, Triumph 459 exhibited 93.4% infection (Table 2). Sorghum lines SC719-11E and SC748-5 exhibited 2.8 and 6.7% infection, respectively. Anaso[26] reported that the line SC748-5 was highly resistant to long smut in Nigeria. However, SC748-5 has been shown to be resistant to moderately resistant in Bambey and Nioro, Senegal, respectively[3]. All other lines/hybrids exhibited disease incidence ranging from 17.6% (Mycogen P S 1482) to 76.3% (CE 196-7-2-1). Earlier studies conducted in other growing regions have identified a number of sorghum genotypes like Hegari, Redlan, Spur Feterita, Impi fodder cultivar, C45, AUS6, NK125, NK263, Cr 51-16, SC630-11E, QL3 (India) and SC326-6[1,4,8] with high levels of resistance to long smut. Hybrids B9612, R9645, Novartis 2030/C from the United States also were shown to exhibit resistance to long smut[3,10].

In this study, none of the lines/hybrids showed resistance to grain mold under naturally infected field studies in Bambey, Senegal (Table 2). Seven of the 24 line/hybrids were

Table 2: Reaction of selected US sorghum germplasm to grain mold and long smut infection in Bambey, Senegal, West Africa[1]

Line	Long smut % incidence	Grain mold
Golden Acres 3696	22.3[bcde2]	5.0[a]
RTx2536	20.0[cde]	5.0[a]
NC 6B50	20.0[cde]	5.0[a]
Pioneer 85G46	61.0[abc]	5.0[a]
Nov K35-45/CN 9239	27.8[bcde]	4.8[a]
AgriPro 2838	0.0[e]	4.7[ab]
SC719-11E	2.8[e]	4.7[ab]
Mycogen P S 1506	75.0[a]	4.5[ab]
Pioneer 84G11	24.0[bcde]	4.3[abc]
AP 920	0.0e	4.3[abc]
DKS 5367	47.0[abcde]	4.3[abc]
Triumph 474	29.9[abcde]	4.3[abc]
A S A 355L x P3505	30.8[abcde]	4.3[abc]
TX2911	36.2[abcde]	4.2[abc]
Mycogen P S 1482	17.6[cde]	4.0[abcd]
RTx430	59.6[abc]	4.0[abcd]
Triumph 459	93.4[a]	3.9[abcd]
BTx623	57.6[abc]	3.7[bcde]
PS 220	49.7[abcd]	3.7[bcde]
AgriPro 9850	27.3[bcde]	3.5[cde]
SC748-5	6.7[e]	3.3[cde]
CE 196-7-2-1	76.3[a]	3.2[de]
CE 151-262	65.8[ab]	3.0[e]

[1]Sorghum hybrids and lines were planted at the Bambey Research Station during the 2011 and 2012 growing seasons. [2]Means within a column followed by the same letter(s) are not significantly different at the 5% probability level based on pairwise comparisons of least-square means with t-tests

moderately susceptible while the rest were susceptible, including the checks SC719-11E and TX 2911. The two Senegalese lines CE 151-262 and CE 196-7-2-1, exhibited lower grain mold scores than the checks SC719-11E and Tx2911 that have been shown to be resistant in studies in Puerto Rico and the U.S.[23,27]. Nevertheless, grain mold resistant sources have been identified in other sorghum growing regions[17,22-24,27,28]. For instance, four coloured seeded (IS 14375, IS 14387, IS 18144 and IS 18528) and white-seeded (IS 21443, IS 24495 and IS 25017) lines grown under sprinkler irrigation in India exhibited high levels of grain mold resistance[29]. Several other identified resistant sources (IS 2815, IS 21599, IS 10288, IS 3436, IS 10646, IS 10475 and IS 23585) are currently been used to develop restorer lines, varieties and hybrids parents for breeding programs in India[24]. Kumar *et al.*[28] identified 9 hybrids, including ICSA 101×PVK 801, ICSA 382×GD 65055 and ICSA 400×GD 65028 as possessing resistance to grain mold in India. Prom and Erpelding[22] identified accessions PI570011, PI570022, PI569992, PI569882, PI571312, PI570759 and PI267548 from Sudan as resistance sources to grain mold. When challenged with *F. thapsinum*, accessions PI525954, PI276841 and PI276840 had lower mean grain mold severities and higher germination rates when compared with the resistant checks Sureno and SC719[23].

CONCLUSION

It is concluded that, sorghum hybrids AP 920 and AgriPro 2838 exhibited zero long smut infection, indicating that these hybrids could be used in long smut resistance breeding programs. Identification of highly grain mold resistant sources will require addition screening of diverse sorghum germplasm.

SIGNIFICANCE STATEMENTS

This study provides sorghum breeders in the U.S. with two sorghum hybrids AP 920 and AgriPro 2838 which may possess genes for long smut resistance that can be introgressed into elite and well adapted sorghum lines. Thus, if long smut is observed in this country, these lines can be planted and thereby prevent yield and quality losses. Also, the lack of highly resistant grain mold line in the current study warrants further evaluation of sorghum germplasm from other sources to identify stable grain mold resistance sources for sorghum growing regions in Senegal, West Africa.

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