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Response of Sorghum Lines and Hybrids from the United States to Long Smut and Grain Mold

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Abstract

Long smut and grain mold are fungal diseases that impact sorghum yield and quality. Long smut infection is most severe in the drier regions of Africa and Asia; whereas, grain mold is the most important disease of sorghum worldwide. In this study, 30 sorghum lines/hybrids were evaluate at the Agronomic Research Stations in Nioro, Senegal, West Africa. Seven lines/hybrids exhibited less than 10% long smut incidence, including AgriPro 2838, and AP 920 that were free of the disease, while NECS 2 had the lowest grain mold severity. The two hybrids AgriPro 2838 and AP 920 may possess genes for long smut resistance and could be utilized in breeding programs for long smut resistance.

Keywords: Sorghum bicolor; Sporisorium ehrenbergii; long smut; Grain mold; Grain molding fungi.

1. Introduction

Long smut, incited by *Sporisorium ehrenbergii* Vánky (syn. *Tolyposporium ehrenbergii* (Kühn) Patouillard) has been shown to be most severe in areas of Africa and Asia with drought conditions or low rainfall, high temperature, and low soil moisture [1-5]. Yield losses of up to 60 % have been documented [6-8]. A Field survey conducted by Teferi and Wubshet [9]. noted that 88.6% of fields in South Tigray, Ethiopia, were infected with long smut. Pathogenesis of this disease begins when air borne teliospores of the pathogen enter the host during boot stage, germinate to produce sporidia which in turn infect individual spikelets [1, 5, 8]. Symptoms are characterized as elongated, cylindrical, and slightly curved spore sacs (sori) which are evident at heading 11 – 14 days after infection [5, 8]. Dispersal of the disease can occur within fields and long distant by air-borne teliospores, insects, contaminated soil and seeds [1, 8]. Although the pathogen survives in the soil as teliospores or teliospores sticking together to form balls, infection of the host due to contaminated seed or soil does not occur; as a result, using chemical treatment as seed dressing may not effectively control the disease [1, 5, 8]. However, [10], reported that chemical seed treatment with Apron Star 42WS coupled with foliar application of neem seed oil was shown to reduce both the incidence and severity of both covered and long smut of sorghum. Nevertheless, the use of host plant resistance offers the best strategy for controlling long smut [1, 5, 6]. Sorghum lines with high level of resistance to the disease have been documented [2, 7, 11-14]. In the U.S. long smut is not present, as a result, there is limited information on the reactions of U.S. sorghum lines to the disease [13, 15].

Grain mold, a fungal disease of sorghum reduces both the yield and quality and is most severe in regions where wet and humid conditions are prevalent later in the growing season when mature grains are still on the field [16, 17]. This disease complex, associated with several fungal species, including *Fusarium thapsinum* Klittick, Leslie, Nelson *et al*., Manasas; *Fusarium semitectum* Berk. & Ravenel; *Curvularia lunata* (Wakk.) Boedijn; *Alternaria alternata* (Fr.: Fr.) Keissl.; and *Phoma sorghina* (Sacc.) Boerema, Dorenbosch, & Van Kesteren, is considered to be the most important biotic constraint to sorghum production and profitability [16, 18, 19]. In addition, some of the *Fusarium* species associated with the disease have the capacity to produce mycotoxins on the host either during the grain development or post- harvest during storage [20-24]. Generally, Grain mold symptoms may be manifested as seed discoloration and smaller seed size [14, 18, 25]. Yield losses due to grain mold on highly susceptible sorghum lines can reach 100 % [26]. 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 [18, 19]. The use of genetically resistant sources offers the most practical method for controlling the disease complex [14, 18, 27, 28]. Thus, studies have documented resistance to grain mold either under natural infected field trials or by inoculating the lines with either individual or mixture of fungal species [28-32].

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In this communication, we report the reactions of selected lines and hybrids from the U.S. to long smut and grain mold infection at Nioro, Senegal, West Africa.

2. Materials and Methods

The field evaluation was conducted at the Agronomic Research Stations in Nioro (13° 45′ N, 15° 47′ W), Senegal, West Africa. At Nioro, the soil type is slightly leached, tropical ferruginous with clay content (7 to 10%) and acidic (pH 5.4). Seeds from each sorghum line were planted in a RCBD and replicated three times. Long smut inoculum preparation, inoculation protocol, and disease assessment were conducted as previously described by Prom *et al*. [13], where 10 ml of a mixture of teliospores was applied between the flag leave and panicle using a pipette. Percent incidence was based on the number of infected plants per plot (both inoculated and non-inoculated). Long smut incidence was further categorized into four classes: 0 = resistant; 1 to 10% was considered as low, 11 to 30% as moderate and > 30% as high. Grain mold was assessed on naturally-infected threshed seeds using a 1 to 5 scale, where 1 = no mold observed on the panicle; 2 = 1 to 9 % of the panicle molded; 3 = 10 to 24% of the panicle molded; 4 = 25 to 49% of the panicle molded; and 5 = 50% or more of the panicle molded [30, 33]. Days to flowering (Julian days) were recorded. Plant height measured in centimeters from the base of the plant to the tip of the panicle. The weather parameters minimum temperature, maximum temperature, percent minimum relative humidity, and percent maximum relative humidity were recorded for the months of July to October during the growing season (Table 1).

3. DatA Analysis

The data were combined over two years and analyzed using the command PROC GLM (SAS Institute, SAS version 9.4, Cary, NC). Differences in means among sorghum lines were determined at the 5% probability level based on pairwise comparisons of least-square means with *t*-tests.

4. Results and Discussion

In this study, 30 sorghum lines and hybrids were evaluated for resistance to long smut and grain mold. Other parameters such as weather conditions, days to flowering and plant height were also recorded. The mean minimum temperature, maximum temperature, percent minimum relative humidity, and percent maximum relative humidity were similar in both years, while mean total precipitation was slightly higher in 2012 than 2011 (Table 1). Days to flowering (DF) ranged from 51 for SC719-11E and hybrid Pioneer 84G11 to 83 DF for RTx2536 (Table 2).

Analysis of variance showed that the main effects of plant height ($P<0.0001$), long smut incidence ($P<0.05$), and grain mold severity ($P<0.0001$) were significant, indicating difference in response by the sorghum lines. The Senegalese line CE196-7-2-1 was the tallest measuring 180.8 cm, followed by Mycogen P.S. 1506 and CE151-262, while Ap 920 (100 cm) was the shortest line.

Sources of long smut resistance

Seven lines/hybrids out of the 30 sorghum germplasm exhibited less than 10% long smut incidence, including RTx2536, AgriPro 2838, and AP 920 that were free of the disease (Table 2). NECS4 recorded the highest long smut incidence (86%), this level was significantly higher than the incidence noted on 14 sorghum lines/hybrids evaluated in this study. [34] also noted that these hybrids AgriPro 2838 and AP 920 were not infected with long smut when evaluated in Bambey, Senegal. In this trial, RTx2536 was free of long smut infection; however, previous studies have shown RTx2536 and other sorghum lines to be susceptible to long smut in one location and not in another location in Senegal [13, 14]. Hence, the physiologic races of *S. ehrenbergii* that have been reported [35, 36], could also be operating in different locations in Senegal. Several studies have identified a number of sorghum genotypes with high levels of resistance to long smut Hegari, Redlan, Spur Feterita, Impi fodder cultivar, C45, AUS6, NK125, NK263, Cr 51-16, SC630-11E, QL3 (India), and SC326-6 [1, 2, 11, 12]. Also, hybrids B9612, R9645, and Novartis 2030/C from the United States were shown to exhibit high levels of resistance to long smut [13, 14]. Although, long smut has not yet been observed on growing sorghum in the U.S., infected seeds and panicles were found in sorghum seed packages from Africa and India [15]. With the ease of travel, there is a chance that long smut may be introduced into the U.S. via contaminated soil or seeds in the near future.

4.1. Sources of Grain Mold Resistance

Grain mold is a major biotic constraint to sorghum productivity and profitability. The results of this work showed that the susceptible check RTx2536, NECS 5, NECS 7, NC 6B50, Golden Acres 3696, and Pioneer 85G46 exhibited the highest grain mold severity, while NECS 2 had the lowest severity (Table 2). Over the years, several studies have reported grain mold resistant sources obtained either under natural infected field trials or by inoculation with grain molding fungi [28-32]. [30] identified IS 2815, IS 21599, IS 10288, IS 3436, IS 10646, IS 10475, and IS 23585 as possessing genes for resistance to grain mold. Accessions PI570011, PI570022, PI569992, PI569882, PI571312, PI570759, and PI267548 from Sudan were reported as possessing high levels of resistance to grain mold when inoculated with *F. thapsinum* [28]. Similarly, when sorghum accessions from Ethiopia and Mali were challenged with *F. thapsinum*, accessions PI525954, PI276841, and PI276840 had lower mean grain mold severities and higher germination rates than the two grain mold resistant checks Sureno and SC719 included in the study [32].

5. Conclusion

This study has identified two hybrids AgriPro 2838 and AP 920 that may possess genes for long smut resistance and one line NECS 2 with low level of grain mold severity. Nevertheless, additional evaluations in multi-locations and determining the action and nature of the resistance gene(s) is paramount before these lines can be utilized in long smut and grain mold resistance breeding programs.

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Table-1. Weather parameters for Nioro, 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	186.0	23.7	33.8	63.5	92.8
2012	213.5	23.1	33.2	61.6	96.3

[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

Table-2. Reaction of sorghum lines and hybrids from the United States to long smut and grain mold infection1

Line/Hybrids	Days to 50% Flowering	Plant height (cm)	% Long smut[2]	Grain Mold severity[3]
RTx2536	83	121.3bcdef	0.0d	5.0a
RTx430	82	103.7ef	28.8bcd	3.5bcde
AgriPro 2838	76	117.0bcdef	0.0d	4.3abc
NECS 2	76	-	40.0abcd	2.7e
Mycogen P S 1506	75	138.0b	46.7abcd	4.0abcd
BTx623	75	123.7bcde	40.3abcd	4.0abcd
Triumph 474	73	128.3bcd	25.0bcd	4.2abc
Mycogen P S 1482	72	102.7ef	4.7cd	4.5ab
SC748	70	102.0ef	3.3d	3.3cde
Triumph 459	69	115.7cdef	36.7abcd	3.4bcde
CE 196-7-2-1	68	180.8a	46.5abcd	3.2de
Tx2911	68	100.8ef	40.1abcd	4.0abcd
NECS 1	67	-	69.6ab	3.3cde
CE 151-262	67	134.4b	38.3abcd	4.1abc
AgriPro 9850	66	110.3cdef	23.9bcd	3.5bcde
Nov.K35-45/CN9239	66	101.3ef	14.2bcd	4.8a
NECS 6	63	-	66.3ab	3.7bcde
As.S.C.A355Lxp3505	63	112.0cdef	4.6d	4.2abc
NC 6B50	61	106.3def	13.3bcd	5.0a
NECS 3	59	-	72.1ab	3.4bcde
AP 920	58	100.3f	0.0d	4.7ab
NECS 5	57	-	66.7ab	5.0a
NECS 4	55	-	86.2a	4.7ab
NECS 7	52	-	52.7abcd	5.0a
PS 220	52	-	49.5abcd	3.7bcde
Golden Acres 3696	52	-	22.2bcd	5.0a
DKS 53-67	52	-	45.4abcd	4.7ab
Pioneer 85G46	52	-	61.1abc	5.0a
SC 719-11E	51	132.0bc	9.5cd	4.3abc
Pioneer 84G11	51	-	23.8bcd	4.3abc

[1]Sorghum germplasm with checks were planted at the Nioro Research Station during the 2011 and 2012 growing seasons.

[4]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.

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