Field Evaluation of Anthracnose Resistance for Sorghum Germplasm from the Sikasso Region of Mali

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Abstract: Sorghum anthracnose is a highly variable pathogen and occurs in most sorghum producing regions worldwide. The disease can be managed using resistant varieties, but additional sources of resistance are needed for sorghum improvement. Germplasm collections are an important resource for the identification of host plant resistance and the 132 sorghum landraces from the Sikasso region of Mali were inoculated with *Colletotrichum sublineolum* and evaluated for foliar anthracnose resistance in Isabela, Puerto Rico during the 2004 and 2005 growing seasons. A resistant response was observed for 109 accessions. For the 23 susceptible accessions, infection severity was low with a mean infected leaf area of 5.6%. Only one accession was rated as highly susceptible. Anthracnose resistant germplasm was more frequently associated with the southern administrative districts that experience higher annual rainfall. More than 80% of the accessions from the Bougouni and Sikasso districts showed a resistant response. The lowest mean infection severity, 1.5%, was observed for accessions from the Sikasso district. In comparison, 71% of the accessions from the drier, northern Koutiala district showed a resistant response, with a mean infection severity of 8.8% for the susceptible accessions from this district. Nearly all landraces from the Sikasso region were classified as race guinea and the guinea landraces that were further classified as margaritiferum were all rated as resistant. Results indicate that the Sikasso region of Mali could be an important source of anthracnose resistant germplasm and that ecogeographic origin and race classification could be used to select germplasm for additional disease evaluations.

Keywords: Genetic resources, *Sorghum bicolor*, Sorghum diseases, West African germplasm.

INTRODUCTION

Colletotrichum sublineolum P. Henn., Kabát & Bubák is the fungal pathogen responsible for sorghum (*Sorghum bicolor* (L.) Moench) anthracnose [1]. The disease was first reported in Togo, West Africa in 1902 and in the United States in 1912 [2, 3]. The disease occurs worldwide, but is more typically associated with warm, humid climatic conditions that favor development and spread of the disease [3-6]. The disease has been frequently reported in Africa, Brazil, and India [6-14]. In the United States, the disease is more commonly observed in the southeastern states [2, 4, 15, 16] and resistant hybrids are recommended for this region. Anthracnose infection can be observed on all above ground tissues of the sorghum plant, but foliar infection is more commonly observed on susceptible varieties [3]. Symptoms generally appear 30 to 40 days after seedling emergence, but infection can occur at every stage of plant development. Typical symptoms of foliar infection appear as circular spots or elongated lesions with purple, red, tan, or black margins depending on host plant pigmentation. Black, asexual fruiting bodies, acervuli, appear in the center of the lesions during sporulation. Coalescence of lesions is typically observed on susceptible varieties and may result in leaf senescence and plant death. The disease can spread rapidly infecting most of the leaves of susceptible varieties. Plant death within 30 days after the presence of visual disease symptoms has been observed for highly susceptible sorghum varieties in Puerto Rico.

Grain yield losses from 41 to 67% were observed for an experimental evaluation conducted in Mali, West Africa with yield losses associated with a reduction in grain weight and the formation of fewer grains due to grain abortion from panicle infection [9]. The disease can be successfully managed through the use of resistant varieties. However, the pathogen is considered highly variable for virulence, which limits the long-term durability of resistant sources [3]. As a result, new sources of resistance are needed for sorghum improvement. With more than 43,000 sorghum accessions, the United States Department of Agriculture, Agricultural Research Service, National Plant Germplasm System (USDA-ARS, NPGS) sorghum collection [17] is a valuable resource for the identification of anthracnose resistant germplasm [18-20]. An anthracnose evaluation of a germplasm subset from the Mali sorghum collection maintained by the NPGS indicated that anthracnose resistant germplasm could be frequently identified from the collection [21]; however, it is unknown if anthracnose resistant landraces are frequently associated with ecogeographical regions of Mali.

To further evaluate the Mali germplasm collection, sorghum landraces were selected from the Sikasso region for field evaluation of anthracnose resistance. The objectives of this study were: 1) determine the frequency of anthracnose resistant germplasm from the Sikasso region; 2) determine if resistance was associated with ecogeographical origin within

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the Sikasso region; 3) determine if resistance was associated with phenotypic characteristics used to evaluate sorghum germplasm; and 4) to identify germplasm with anthracnose resistance for genetic characterization and sorghum improvement.

MATERIALS AND METHODOLOGY

The 132 accessions selected from the Sikasso region of Mali for the anthracnose evaluation were identified from the NPGS sorghum collection using available passport information [17] and seed samples were obtained from the USDA-ARS Genetic Resources Conservation Unit, Griffin, Georgia. Six anthracnose resistant control genotypes, NSL 365745, PI 148097, PI 276787, RTx2536, SC326-6, and SC748-6, and seven susceptible control genotypes, PI 257599, PI 276842, PI 561472, PI 564163 (BTx623), PI 609251, PI 609634, and PI 609746, were included in the evaluation. PI 609251 was also included in the evaluation as a non-inoculated control genotype. The first anthracnose evaluation was planted on 6 July 2004 and the second evaluation was planted on 7 March 2005 at the USDA-ARS Tropical Agriculture Research Station, Isabela, Puerto Rico. The 146 sorghum accessions were planted in single rows using a partially balanced lattice design with three replications. Rows were 1.8 m in length with 0.9 m row spacing. Anthracnose susceptible genotypes were planted as border rows around each experimental field. Fertilizer was applied at a rate of 560 kg ha^{-1} (15-5-10 NPK) during planting. Lorsban 15G (Chlorpyrifos) granular insecticide (Dow AgroSciences, Indianapolis, IN) was applied at a rate of 8 kg ha^{-1} at planting to prevent seed loss from fire ants. Supplemental irrigation was applied after planting for stand establishment and three times before anthracnose inoculation for the evaluation conducted in 2004 and five times before inoculation for the evaluation conducted in 2005. No irrigation was applied after inoculation. Weeds were controlled with mechanical tillage.

Anthracnose infected sorghum leaves were randomly collected from research plots in Isabela, Puerto Rico before the evaluation to represent the pathotypes at the location and were used for preparation of inoculum. Preparation of anthracnose cultures, field inoculation, and disease evaluation were as described by Erpelding and Prom [19]. Plants were inoculated 32 days after planting in 2004 and 34 days after planting in 2005 using anthracnose colonized sorghum seed. Anthracnose infection response was evaluated at 22, 36, 60, and 80 days after inoculation in 2004. A tropical storm delayed the third evaluation and the third and final evaluations were conducted after the plants recovered. In 2005, field evaluations were conducted at 35, 48, and 63 days after inoculation. Anthracnose infection response was evaluated using a 1-5 rating scale based on disease response observed on inoculated leaves and disease progression on non-inoculated leaves [21]. Resistant accessions were rated as 1 or 2, moderately susceptible accessions as 3, susceptible accessions as 4, and highly susceptible accessions with acervuli development observed on the flag leaf were rated as 5. The percentage of infected leaf area or disease severity was estimated during the final evaluation for the susceptible accessions and was based on a visual estimate of infection severity for the susceptible plants in each row. Statistical analysis of the data was conducted using the disease severity from the final rating using the Statistix software package (Analytical Software, Tallahassee, FL).

RESULTS

The anthracnose infection response for the 132 sorghum accessions from the Sikasso region of Mali is presented in Table **1**. In 2004, a resistant response was observed for 123 accessions. Eight accessions showed variation for infection response across replications and were rated as susceptible. Only one accession, PI 610058, showed a susceptible response across replications. Mean infected leaf area was 10.2% for the nine susceptible accessions observed in 2004. For the 2005 anthracnose evaluation, 109 accessions showed a resistant response. Eight of the 23 accessions rated as susceptible showed a susceptible response across replications, with one accession, PI 585820, rated as highly susceptible. Mean infected leaf area was 6.4% for the 23 accessions rated as susceptible in 2005. The nine accessions rated as susceptible in 2004 were also rated as susceptible in 2005, and four accessions that showed variation across replications in 2004 showed a susceptible response across replications in 2005. Mean infected leaf area was similar between the two growing seasons for the nine susceptible accessions; although, a higher percentage of infected leaf area, 14.4%, was observed in 2005. For the two growing seasons, mean infection severity for the susceptible accessions was 5.6%. All accessions showed the hypersensitive response within 7 days after inoculation, which appeared as red spots or reddening of inoculated leaves. Senescence of leaf margins was observed for approximately 40% of the accessions 30 days after inoculation. Acervuli development was observed approximately 30 days after inoculation for 18 of the 23 susceptible accessions. The majority of the susceptible accessions also showed development of acervuli in the leaf midrib. For the susceptible accessions, acervuli development was generally associated with inoculated leaf tissue and senescence of these leaves was observed during the final evaluation. Although infection severity was greater for inoculated leaves, most of the susceptible accessions showed little disease progression on non-inoculated leaves, which resulted in the low infection severity recorded for these accessions.

The Sikasso region of Mali is comprised of seven administrative districts and sorghum landraces from the Bougouni, Koutiala, and Sikasso districts are maintained in the NPGS sorghum collection (Table **1**). Germplasm from the Bougouni district showed a greater frequency of anthracnose resistance, with 88% of the sorghum accessions showing a resistant response. More than 55% of the accessions included in the anthracnose evaluation were from this district. Mean infected leaf area was 6.8% for the nine susceptible accessions from the Bougouni district. The lowest frequency of resistant germplasm was observed for the Koutiala district, with 71% of the accessions from this region showing a resistant response. The highest infection severity was also observed for sorghum germplasm from the Koutiala district. Mean infected leaf area was approximately 8.8% for the nine susceptible accessions observed from this district. Additionally, the only accession rated as highly susceptible, with infection observed on the flag leaf, was collected from the Koutiala district. The lowest infection severity was observed for the five susceptible accessions identified from the

Table 1. Anthracnose Disease Response for 132 Sorghum Accessions from the Sikasso Region of Mali and 13 Control Genotypes Inoculated with *C. sublineolum* and Evaluated under Field Conditions in Isabela, Puerto Rico during the 2004 and 2005 Growing Seasons

Accession[A]	2004		2005		District[D]	Working Group[E]
	Disease Rating[B]	Disease Severity[C]	Disease Rating	Disease Severity		
PI 585773	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610077	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610089	2	0.0 a	2	0.0 a	Bougouni	Breeding Line
PI 610090	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610070	2	0.0 a	2	0.0 a	Bougouni	Breeding Line
PI 610071	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585778	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585779	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610083	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610084	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610085	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610094	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610095	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610096	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585770	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610076	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610091	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610092	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585774	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585775	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585776	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610078	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585781	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585782	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610099	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585785	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610100	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610101	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610068	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610105	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585769	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585780	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610093	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585771	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585772	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610055	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610056	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610057	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585759	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum

(Table 1) contd…..

Accession[A]	2004		2005		District[D]	Working Group[E]
	Disease Rating[B]	Disease Severity[C]	Disease Rating	Disease Severity		
PI 585777	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610079	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610081	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610080	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585762	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585763	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610060	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610086	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610087	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610088	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585784	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585783	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585768	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585767	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610066	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610067	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610072	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610073	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610074	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610075	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 585786	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 585787	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 610102	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610097	2	0.0 a	2	0.0 a	Bougouni	Margaritiferum
PI 610098	2	0.0 a	2	0.0 a	Bougouni	Guineense
PI 609108	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609111	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609112	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585816	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585831	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585832	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609124	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585830	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609125	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609126	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585814	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609110	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585813	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609109	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 610113	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 610114	2	0.0 a	2	0.0 a	Koutiala	Guineense

(Table 1) contd…..

Accession[A]	2004		2005		District[D]	Working Group[E]
	Disease Rating[B]	Disease Severity[C]	Disease Rating	Disease Severity		
PI 610109	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 610110	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585818	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585819	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609113	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 609114	2	0.0 a	2	0.0 a	Koutiala	Guineense
PI 585791	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610107	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610119	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585799	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610121	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610122	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585796	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585797	2	0.0 a	2	0.0 a	Sikasso	Margaritiferum
PI 585798	2	0.0 a	2	0.0 a	Sikasso	Margaritiferum
PI 610124	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610123	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610125	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610126	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585792	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585793	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610115	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610120	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585794	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 585795	2	0.0 a	2	0.0 a	Sikasso	Margaritiferum
PI 610133	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610134	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610116	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610117	2	0.0 a	2	0.0 a	Sikasso	Guineense
PI 610112	2	0.0 a	2\2\4	0.1 a	Koutiala	Guineense
PI 610108	2	0.0 a	2\2\4	3.0 ab	Sikasso	Guineense
PI 610118	2	0.0 a	2\2\4	1.7 a	Sikasso	Breeding Line
PI 585800	2	0.0 a	2\2\4	0.2 a	Sikasso	Guineense
PI 610106	2	0.0 a	2\2\4	0.3 a	Sikasso	Guineense
PI 610069	2	0.0 a	2\4\4	0.4 a	Bougouni	Guineense
PI 585761	2	0.0 a	2\4\4	0.7 a	Bougouni	Guineense
PI 585815	2	0.0 a	2\4\4	0.2 a	Koutiala	Guineense
PI 585812	2	0.0 a	2\4\4	0.3 a	Koutiala	Guineense
PI 610111	2	0.0 a	2\4\4	0.3 a	Koutiala	Guineense
PI 585810	2	0.0 a	2\4\4	1.8 a	Sikasso	Guineense
PI 610082	2	0.0 a	4	0.7 a	Bougouni	Guineense

(Table 1) contd…..

Accession[A]	2004		2005		District[D]	Working Group[E]
	Disease Rating[B]	Disease Severity[C]	Disease Rating	Disease Severity		
PI 585817	2	0.0 a	4	7.0 abc	Koutiala	Guineense
PI 585811	2	0.0 a	4	1.0 a	Koutiala	Guineense
PI 585833	2\2\4	10.0 cd	2\2\5	10.0 bc	Koutiala	Guineense
PI 585760	2\2\4	7.0 bc	2\4\4	0.7 a	Bougouni	Guineense
PI 610059	2\2\4	7.0 bc	4	12.0 c	Bougouni	Guineense
PI 610065	2\2\4	3.0 ab	4	13.0 cd	Bougouni	Guineense
PI 612845	2\4\4	13.0 de	2\4\4	0.4 a	Bougouni	Caudatum
PI 585821	2\4\4	13.0 de	2\4\4	20.0 de	Koutiala	Guineense
PI 610064	2\4\4	20.0 f	4	20.0 de	Bougouni	Guineense
PI 585820	2\4\4	2.0 ab	4\5\5	40.0 g	Koutiala	Guineense
PI 610058	4	17.0 ef	4	13.0 cd	Bougouni	Guineense
NSL 365745	2	0.0 a	2	0.0 a		
RTx2536	2	0.0 a	2	0.0 a		
SC326-6	2	0.0 a	2	0.0 a		
SC748-6	2	0.0 a	2	0.0 a		
PI 276787	2	0.0 a	2\4\4	0.2 a		
PI 148097	2	0.0 a	4	0.4 a		
PI 257599	5	67.0 i	4\5\5	43.0 g		
PI 276842	5	57.0 h	4\4\5	27.0 ef		
PI 561472	5	37.0 g	5	30.0 f		
PI 564163	5	83.0 k	5	30.0 f		
PI 609251	5	97.0 l	5	80.0 i		
PI 609251(ni)	5	93.0 l	5	80.0 i		
PI 609634	5	87.0 k	5	63.0 h		
PI 609746	5	77.0 j	5	43.0 g		

[A]NPGS plant introduction number [17] for the 132 sorghum accessions. Sorghum accessions are arranged by anthracnose infection response from resistant (rating=2) to susceptible (rating=4 or 5). Six resistant control genotypes, NSL 365745, PI 148097, PI 276787, RTx2536, SC326-6, and SC748-6, and seven susceptible control genotypes, PI 257599, PI 276842, PI 561472, PI 564163 (BTx623), PI 609251, PI 609634, and PI 609746, were included in the anthracnose evaluation. PI 609251 was also included as a non-inoculated (ni) control.

[B]Anthracnose disease rating is based on a 1-5 scale [21]. Resistant plants are rated as 2, susceptible plants as 4, and highly susceptible plants showing infection in the flag leaf are rated as 5. Data from the three replications is presented when variation was observed across replications.

[C]Mean anthracnose disease severity is based on the percentage of infected leaf area for the susceptible plants within a row averaged across replications. Numbers followed by the same letters are not significantly different ($LSD_{0.05}$).

[D]Administrative districts for the Sikasso region of Mali were sorghum landraces were collected.

[E]Phenotypic working groups used for the classification of sorghum accessions from the Sikasso region.

Sikasso district, with a mean infected leaf area of 1.5%. Acervuli development on inoculated leaves was only observed for the accessions from the Sikasso district during the 2005 evaluation. Approximately 21% of the accessions evaluated were from this district.

Nearly all the accessions from the Sikasso region were classified as race guinea with the exception of PI 612845, which was classified as race caudatum. The race guinea accessions from the Sikasso region were further classified into two working groups, guineense and margaritiferum (Table **1**). All the margaritiferum sorghum landraces showed an anthracnose resistant response; whereas, 78% of the guineense sorghum landraces showed a resistant response. The majority of the margaritiferum sorghum landraces, 90%, were collected from the Bougouni district and no margaritiferum landraces were present in the germplasm collection from the Koutiala district. Approximately 80% of the guineense landraces from the Bougouni and Sikasso districts showed a resistant response.

For the 13 control genotypes included in the anthracnose evaluation, the observed infection response was as expected (Table **1**). A resistant response was observed for the six resistant control genotypes. However, PI 148097 and PI 276787 showed a low frequency of acervuli development on inoculated leaves in the 2005 evaluation, with infection severity less than 0.5% on inoculated leaves. The seven an-

thracnose susceptible control genotypes showed a highly susceptible response for the two evaluations. Infection severity was greater in 2004 for the susceptible controls, with a mean infected leaf area of 75% compared to a mean infected leaf area of 50% in 2005. The non-inoculated plots of PI 609251 showed a similar infection severity as the inoculated plots within an experiment. All susceptible accessions showed acervuli development within 30 days after inoculation and were rated as susceptible or highly susceptible.

DISCUSSION AND CONCLUSION

More than 82% of the 132 sorghum accessions from the Sikasso region of Mali showed a resistant response suggesting that sorghum germplasm from the Sikasso region could be an important source of anthracnose resistance for crop improvement. Additionally, infection severity for 15 of the 23 susceptible accessions was less than 10%, which may suggest some mechanism of horizontal resistance is also present in the germplasm from this region. More accessions showed a susceptible response in 2005 suggesting more favorable conditions for anthracnose disease development. However, infection severity was similar between the two growing seasons for the susceptible accessions. In contrast, infection severity was greater in 2004 as compared to 2005 for the susceptible control genotypes included in the evaluation. Several studies have shown variation in anthracnose infection response due to environmental variation [6, 13, 22]. Hess *et al*. [13] observed significant genotype by environment interactions for anthracnose disease severity and suggested evaluations should be conducted over a range of environments. Results of this study would also suggest environmental variation influenced anthracnose disease response and screening germplasm over growing seasons would aid in the selection of anthracnose resistant accessions. Variation in virulence within the pathogen population may also contribute to the variation in disease response observed between growing seasons [7, 12, 14, 16]; although, all accessions showing a susceptible response in 2004 were also susceptible in 2005 and no variation in disease response was observed for the control genotypes included in the evaluation. Pande *et al*. [7] indicated that the degree of pathogenicity could vary based on host-pathogen interaction and this would suggest that an environmental interaction could also influence pathogenicity resulting in variation in disease response between growing seasons.

Several studies have indicated that higher annual rainfall will contribute to greater anthracnose disease severity [5, 6, 10, 12, 13, 22]. The Sikasso region of Mali receives more than 800 mm of annual rainfall [13]. The majority of the Bougouni and Sikasso districts experience over 1,100 mm of annual rainfall and the southern regions of these districts may receive nearly 1,500 mm of annual rainfall. For the northern Koutiala district, annual rainfall ranges from 800 to 1,100 mm. Since climatic conditions are favorable in the Sikasso region for anthracnose disease development, selection pressure may have contributed to the higher frequency of anthracnose resistant germplasm observed from this region. Anthracnose resistant landraces were more frequent from the Bougouni and Sikasso districts as compared to the Koutiala district. For the Koutiala district, the lower annual rainfall may have contributed to the lower frequency of anthracnose resistant germplasm and the greater disease severity observed for the susceptible accessions. However, the majority of the accessions from the Sikasso region showed anthracnose resistance suggesting annual rainfall is sufficient throughout the region to favor selection for resistance. Ngugi *et al*. [6] observed greater anthracnose disease severity in the higher rainfall and more humid ecological zones of western Kenya. Néya and Le Normand [10] also observed greater disease severity at locations experiencing higher rainfall in Burkina Faso. This would suggest an ecogeographic association between anthracnose disease response and annual rainfall as observed in this study. Latitude and longitude data are lacking for the sorghum germplasm from the Sikasso region in order to more effectively evaluate an association between ecogeographic origin and anthracnose resistance. Nevertheless, the Sikasso region is an important source of anthracnose resistant germplasm and additional sorghum landraces should be acquired from this region.

Phenotypic evaluation data for sorghum germplasm may also aid in the selection of accessions for anthracnose field evaluation and could also be used to select landraces for acquisition. In this study, all 31 margaritiferum landraces and most of the guineense landraces showed resistance to anthracnose, which would suggest that landraces classified as race guinea may be more frequently associated with anthracnose resistance. Potentially, this association with anthracnose resistance may correspond to annual rainfall, since no margaritiferum landraces were included in the germplasm collection from the Koutiala district. This may suggest that in the Sikasso region the margaritiferum sorghum landraces are grown more frequently in areas of higher annual rainfall resulting in greater disease selection pressure. If the observed association between resistance and phenotypic classification would instead correspond to annual rainfall, phenotypic data would still be important for germplasm selection when passport information is lacking to determine ecogeographic origin. For example, race guinea accessions are typically associated with regions of higher annual rainfall and this race classification could be used to select sorghum landraces for anthracnose field evaluation.

Presently, it is unknown if the sorghum landraces from the Sikasso region harbor genetic diversity for anthracnose resistance. However, the pathogen is considered highly variable for virulence within and between regions [4, 7, 12, 14, 15] and pathotype variation may occur in the Sikasso region that could favor genetic diversity for resistance in the sorghum landraces. Disease evaluation of this germplasm at other locations would aid in evaluating genetic diversity for resistance. Erpelding and Prom [21] showed that germplasm from Mali conferring resistance to anthracnose pathotypes in Puerto Rico frequently conferred resistance to pathotypes in Texas, which could suggest that resistant germplasm from Mali may provide resistance to anthracnose pathotypes occurring in North America.

In summary, this study identified 109 sorghum accessions with resistance to anthracnose pathotypes in Isabela, Puerto Rico for further characterization and research is underway to evaluation genetic diversity for anthracnose resistance within the Mali sorghum collection to aid in the transfer of resistance to improved sorghum breeding lines. Disease severity was low for the majority of the susceptible accessions from the Sikasso region of Mali suggesting some

mechanism of resistance and these accessions may also have potential for sorghum improvement. Anthracnose resistant germplasm also showed an association with annual rainfall and phenotypic race classification indicating that ecogoegraphical origin and evaluation information can be used to select sorghum germplasm for disease evaluation and could be used to identify regions associated with anthracnose resistance for additional germplasm acquisition.

DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendations or endorsement by the U.S. Department of Agriculture.

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