Development of Leaf Anthracnose and its Effect on Yield and Grain Weight of Sorghum in West Africa

Melville D. Thomas, Ibrahim Sissoko, and **Mamadou Sacko,** International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), B.P. 320, Bamako, Mali, West Africa

ABSTRACT

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Leaf anthracnose *(Colletotrichum graminicola)* development and its effect on yield and grain weight were studied for three seasons between 1990 and 1992 on two inbred sorghum cultivars exposed to natural inoculum in Mali, West Africa. Infection on the susceptible, medium-maturing (70 to 80 days to 50% flowering) cultivar IS 18696 (race caudatum) increased gradually until anthesis, then increased rapidly so that most leaves were killed at physiological maturity. Development of the disease on the moderately resistant early-maturing (<70 days to 50% flowering) cultivar IS 25105 (race guineense) was slower even after anthesis than on IS 18696, and leaves were not killed at physiological maturity. Mean disease severities for 15 plants on a 1 to 6 scale at about 50% flowering for IS 18696 were 3.1, 4.0, and 3.4 in 1990, 1991, and 1992, respectively. In contrast, disease severities for IS 25105 at 50% flowering were 2.1 in 1990 and 1991, and less than 3.3 at 11 days after 50% flowering in 1992. Areas under the disease progress curve (AUDPC) for the three years were 61, 127, and 121 for IS 18696, and 47, 112, and 122 for IS 25105. Yield loss calculated from fungicide-treated and unsprayed plots was as high as 67% in 1990, 55% in 1991, and 57% in 1992 for the susceptible cultivar IS 18696. The disease had no effect on yield for the moderately resistant cultivar IS 25105 in 1990 and 1991, and caused only 4% loss in 1992. Kernel weight losses were between 18 and 36% for IS 18696 and 15% for IS 25105 in 1991 only.

Anthracnose of sorghum (*Sorghum bicolor* (L.) Moench), caused by *Colletotrichum graminicola* (Ces.) G.W. Wilson, is a serious disease in West Africa and in other production regions (2,13,14). Many local land races and introduced genotypes in the Northern Guinean (1,000 to 1,200 mm of annual rainfall) zones of semiarid West Africa are susceptible to the foliar stage of the disease (2). Serious epidemics occur in farmers' fields and in research plots. In many instances, leaves are completely blighted and plants die before grain filling is completed. Although sorghum anthracnose was first reported in Togo in 1902 (11), very little information is available on its prevalence and severity for most West African countries. Anthracnose causes severe foliar damage on sorghum in Nigeria (12). Neya and Kabore (8) reported that infection by *C. graminicola* resulted in 46% loss in yield on a local susceptible cultivar in Burkina Faso. The leaf blight phase of the disease limits production in other regions of the world. In the United States, estimated losses in grain yield resulting from infection exceeded 50% (5), and actual losses in yield and 100 seed weight were 30 and 13%, respectively (1). In Puerto Rico, *C. graminicola* reduced grain yield per head by 70% (9). In India, percent loss in grain yield due to anthracnose was reported between 1.2 and 16.4% (7).

The development of leaf diseases in relation to the growth stages of crops is important for understanding the impact of the disease on yield. *C. graminicola* destroys sorghum plants rapidly as they approach maturity, and losses have been recorded from fields only 2 weeks after a relatively low disease incidence (3). This paper reports on field experiments designed to study the progress of leaf anthracnose relative to flowering and grain filling stages of sorghum and to assess the effect of the disease on yield and grain weight.

Present address of M. D. Thomas: PMB 743, Freetown, Sierra Leone, West Africa. Present address of M. Sacko: Protection des vegetaux, B.P. 1560, Bamako, Mali, West Africa.

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MATERIALS AND METHODS

Experimental design. The experiment was conducted for 3 years at ICRISAT's West Africa Sorghum Improvement Program research facilities at Samanko, 16 km from Bamako, Mali. In 1990, 1991, and 1992, two red-grained inbred sorghum cultivars, IS 18696 (race caudatum) and IS 25105 (race guineense), were sown on 7, 11, and 10 July, respectively. IS 18696 is of medium maturity (70 to 80 days to reach 50% flowering) and susceptible to leaf anthracnose. IS 25105 is early maturing (<70 days to reach 50% flowering) and is considered moderately resistant to the disease because severe symptoms appear only at maturity. A split-plot design with four replicates was used, with fungicide treatments as main plots and cultivars in 4-m-long three-row subplots. Rows were spaced at 0.75 m, and hills of plants within rows were spaced 0.4 m. Plants were thinned to two per hill. There were five main plot treatments, consisting of four fungicide treatments and a control. Fungicide treatments in main plots were benomyl (Dupont, Geneva, Switzerland) and Peltar (25% methylthiophanate + 50% maneb; PROCIDA, Marseille, France), each applied separately beginning at about 6 weeks after sowing. Each fungicide was applied either three or five times (six times in 1992) at 7- to 10-day intervals. Plants in control plots were sprayed with water. The fungicides were sprayed to runoff at concentrations of active ingredients of 400 g ha^{-1} for benomyl and 3 kg ha^{-1} for Peltar. In order to reduce the effect of interplot interference, main plots and blocks (replicates) were separated by three rows of the tall local pearl millet (*Pennisetum glaucum* (L) R. Br.), cultivar Sanko. The millet was sown 10 to 14 days prior to sorghum. Fertilizers were applied as NPK (15:15:15) at 100 kg ha^{-1} during land preparation and as urea (45% N) at 100 kg ha^{-1} 30 and 50 days after sowing.

Disease assessment and grain weight. Fifteen plants per subplot were tagged arbitrarily, and disease severity was assessed for each of the plants at about 1 week intervals, between 53 and 74, 61 and 96, and 72 and 99 days after sowing (DAS) in 1990, 1991, and 1992, respectively. Disease severity was assessed on a scale of 1 to 6, where 1 = no symptoms, 2 = up to 5%, 3 = 6 to 25%, 4 = 26 to 50%, 5 = 51 to 75%, and 6 = more than 75% of leaf area infected. The mean disease severity ratings for the subplots (15 plants) were used in the analysis of variance. Disease severity was plotted over time to illustrate disease progress curves. Area under the disease progress curve (AUDPC) was calculated according to Shaner and Finney (10). The panicles from the 15 tagged

plants rated for disease severity in each subplot were harvested within 10 days after physiological maturity. The lots of 15 panicles were sun-dried, threshed, and kept separate. The total grain weight of each lot of 15 panicles and the weight of 1,000 grains from each lot were recorded. Adjustments for percent moisture content were not made. Percent loss in grain weight was calculated $100(H - D)/H$, where H is the weight of grain from plants sprayed five or six times with benomyl or Peltar, and D is the weight of grain from unsprayed plants. Rainfall for Samanko was recorded daily, and temperature and relative humidity for Bamako were obtained from the meteorology division. Statistical procedures for analysis of variance (GENSTAT 5, release 2.2; Rothamsted Experimental Station, Harpenden, United Kingdom) were applied to the data (4).

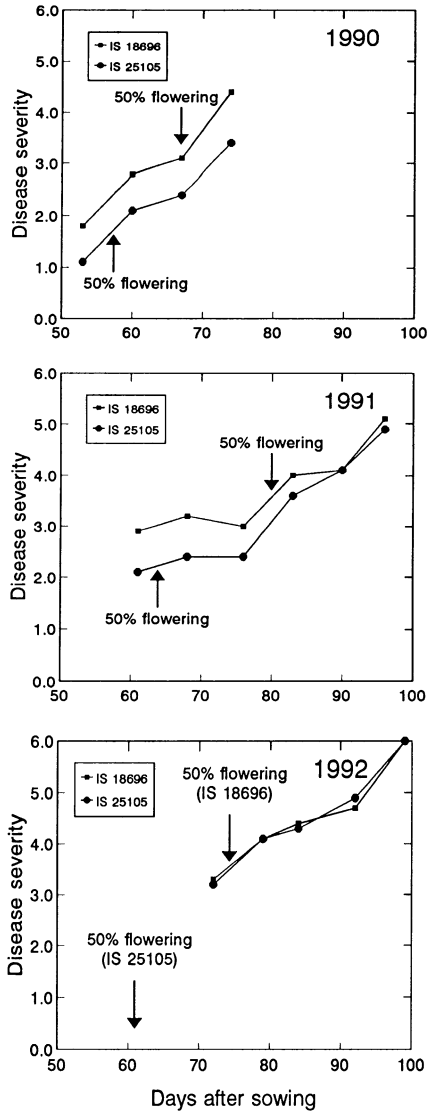

Fig. 1. Disease progress curves for the susceptible caudatum sorghum cultivar IS 18696 and the moderately resistant guineense sorghum cultivar IS 25105 infected by natural inoculum of the leaf anthracnose fungus *Colletotrichum graminicola* in 1990, 1991, and 1992. Disease severity is the mean from 15 plants, based on a rating scale of 1 to 6, where 1 = no symptoms, 2 = up to 5%, 3 = 6 to 25%, 4 = 25 to 50%, 5 = 51 to 75%, and 6 = more than 75% leaf area infected. Times to 50% flowering in days after sowing for IS 18696 and IS 25105, respectively, were 68 and 57 in 1990, 81 and 62 in 1991, and 76 and 61 in 1992. For a given day, all disease severity ratings between both cultivars were not significant except for the following, which were highly significant ($P < 0.01$): days 67 and 74 in 1990; days 61, 68, and 76 in 1991.

RESULTS

Symptom expression and disease development in unsprayed plants. Leaf anthracnose symptoms on IS 18696 were first evident as midrib infection at about 4 weeks after sowing. As the disease developed, the leaf lamina and midrib became severely infected, and abundant acervuli appeared on these tissues. All leaves were severely infected, and top leaves were killed before grain reached physiological maturity. Grain abortion was evident, and acervuli were observed on poorly formed grains. In contrast, midrib infection was rare on the moderately resistant cultivar IS 25105. Fewer acervuli were observed, and these were mostly restricted to the lower leaves late in the season. Infection on the top four leaves became severe only toward physiological maturity and did not result in leaf death during grain formation. Grain abortion did not occur, and acervuli were not apparent on grains.

In 1990, infection increased gradually until 67 DAS on the susceptible cultivar, IS 18696. Average time to 50% flowering

Table 1. Effect of leaf anthracnose on grain yield of sorghum for the susceptible caudatum cultivar IS 18696 and the moderately resistant guineense cultivar IS 25105

	Grain yield (g)[y]					
Fungicide	1990		1991		1992	
treatment[z]	18696	25105	18696	25105	18696	25105
Benomyl-3 sprays	64	312	169	293	194	372
Peltar-3 sprays	64	380	125	290	261	351
Benomyl-5 sprays	203	284	144	281	373	449
Peltar-5 sprays	259	324	181	187	270	452
Unsprayed	85	347	81	287	159	433
LSD (treatments)	94		112		146	
LSD (cultivars)	33		78		43	

[y] Grain yield is the mean from 15 panicles. Least significant difference (LSD) at $P < 0.01$.
[z] Six instead of five sprays in 1992.

Table 2. Effect of leaf anthracnose on grain weight of sorghum for the susceptible cultivar IS 18696 and the moderately resistant guineense cultivar IS 25105

	Grain weight (g)[y]					
Fungicide	1990		1991		1992	
treatment[z]	18696	25105	18696	25105	18696	25105
Benomyl-3 sprays	6.9	18.8	11.8	17.2	12.7	21.7
Peltar-3 sprays	6.7	20.4	12.9	17.7	14.0	21.2
Benomyl-5 sprays	9.9	19.6	10.6	19.3	16.5	21.5
Peltar-5 sprays	10.8	19.5	14.6	19.5	14.8	21.2
Unsprayed	7.8	20.1	11.9	16.5	10.5	21.2
LSD (treatments)	2.35		4.64		3.12	
LSD (cultivars)	1.06		5.21		1.68	

[y] Mean weight of 1,000 grains sampled from 15 panicles. Least significant difference (LSD) at $P < 0.01$.
[z] Six instead of five sprays in 1992.

Table 3. Area under the disease progress curve (AUDPC) for susceptible caudatum sorghum cultivar (IS 18696) and moderately resistant guineense sorghum cultivar (IS 25105) infected by natural inoculum of the leaf anthracnose fungus *Colletotrichum graminicola*

	AUDPC[y]					
Fungicide	1990		1991		1992	
treatment[z]	18696	25105	18696	25105	18696	25105
Benomyl-3 sprays	73	49	102	87	74	51
Peltar-3 sprays	68	45	95	98	90	89
Benomyl-5 sprays	46	40	98	84	85	89
Peltar-5 sprays	44	35	91	87	85	90
Unsprayed	61	47	127	112	121	122
LSD (treatments)	4		13		18	
LSD (cultivars)	3		3		4	

[y] AUDPC after Shaner and Finney (10). Lease significant difference (LSD) at $P < 0.01$.
[z] Six instead of five sprays in 1992.

for this cultivar was 68 DAS. New lesions appeared rapidly after flowering, and by 74 DAS, average disease severity rating was 4.4. Disease development was slower for the moderately resistant cultivar, IS 25105. Average time to 50% flowering was 57 DAS, and 17 days later at 74 DAS, average disease severity did not exceed 3.3. Similar trends were observed in 1991 and 1992 (Fig. 1). Average monthly relative humidity and temperature did not vary much during the period of disease assessment within or between years. In contrast, total rainfall from day of sowing to onset of disease assessment was 428 mm in 1990, 543 mm in 1991, and 578 mm in 1992. During disease assessment, the crop received additional rain of 139, 241, and 14 mm in 1990, 1991, and 1992, respectively.

Effect on yield. For all 3 years, grain yield and kernel weight for the susceptible cultivar, IS 18696, were lower from unsprayed plots than from plots sprayed five or six times with fungicides (Tables 1 and 2). In 1990, yield of unsprayed IS 18696 was 58 and 67% less than that of plants sprayed five times with benomyl or Peltar, respectively. Comparable reductions in yield in 1991 and 1992 were 44 and 55%, and 57 and 41%, respectively. Reductions in grain weight were 21 and 28% in 1990, 18% in 1991 (for plots treated with Peltar), and 36 and 29% in 1992. In contrast, differences in yield for the different treatments for the moderately resistant cultivar IS 25105 were small and nonsignificant for all 3 years. Also, in 1990 and 1991, yields for IS 25105 from unsprayed plots were slightly higher than those from plots sprayed five or six times (Table 1). The same trend for this cultivar occurred for grain weight, except in 1991 when loss was 15% (Table 2).

Final disease ratings, which were between 3.4 and 6.0, were taken at 6, 15, and 23 days after 50% flowering for IS 18696, and 17, 34, and 38 days after 50% flowering for IS 25105 in 1990, 1991, and 1992, respectively. Since IS 25105 flowered on average 15 days earlier than IS 18696 for the 3 years, grain formation was probably well underway in IS 25105 before the epidemic became severe.

AUDPC values. AUDPC values for the susceptible cultivar IS 18696 in unsprayed plants were 61, 127, and 121 in 1990, 1991, and 1992, respectively. Comparable AUDPC values for the moderately resistant cultivar IS 25105 were 47, 112, and 122 (Table 3). In general, the differences in AUDPC between unsprayed plants and plants sprayed five or six times with either benomyl or Peltar were significant. The three spray treatments were included in order to have three levels of disease severities (three sprays, five or six sprays, and unsprayed) to which yield could be related. However, yield and AUDPC data for plants that received three sprays were similar to either the five and six sprays or the unsprayed treatment.

DISCUSSION

Disease assessment for the susceptible cultivar IS 18696 commenced on average 13 days before 50% flowering and continued during part of grain formation, especially in 1991 and 1992. For example, assessment continued for 6, 15, and 23 days after 50% flowering in 1990, 1991, and 1992, respectively. In general, sorghum seeds mature in 30 to 56 days after flowering (6,15). We suggest that severe foliar infection during grain formation and direct infection of florets contribute to reduction in yield and grain weight in IS 18696 (Tables 1 and 2). Losses between 41 and 67% in yield and between 18 and 36% in grain weight for the cultivar IS 18696 are in agreement with previous reports on yield loss for sorghum due to anthracnose (9,13). The data are also in agreement with a report from Puerto Rico that ascribes yield loss to formation of fewer grains (9). A positive linear relationship between grain weight loss and seed weight loss has been reported (1).

Unlike IS 18696, disease development in the moderately resistant cultivar IS 25105 reached severe levels (disease severity >4.0) 28 and 18 days after 50% flowering in 1991 and 1992, respectively. In 1990, final disease severity, assessed 17 days after 50% flowering, was 3.4 (Fig. 1). This probably explains why there was little or no effect of the disease on yield and grain weight (Tables 1 and 2). It is likely that early maturity of this cultivar allowed it to escape infection during its early growth stages. AUDPC in unsprayed plots for IS 25105 was relatively high in 1992. This was probably related to reduced rainfall late in the season as compared with 1990 and 1991. However, in 1992 as in the two previous years, the disease reached epidemic levels in this cultivar only at maturity. It is not clear to what extent weather parameters influenced the development of the disease in IS 25105.

The results of this study demonstrate the extent to which leaf anthracnose is serious in West Africa. The disease caused grain abortion and as much as 67% loss in yield in the caudatum cultivar IS 18696. Future studies should include more cultivars and locations. This would permit more inferences on the relation of weather and disease development and on the relation of yield loss to disease development.

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