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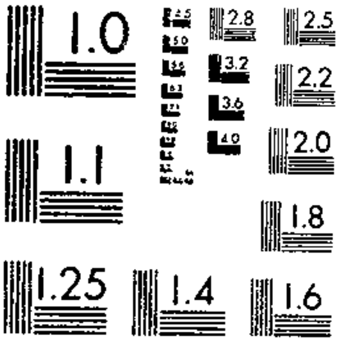

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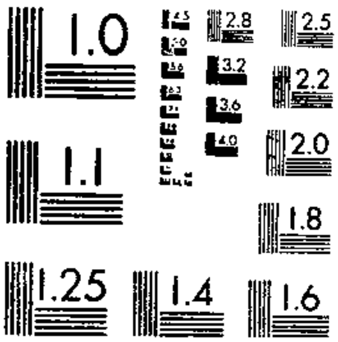

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Anthracnose and Red Rot of Sorghum[1]

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CONTENTS

ANTHRACNOSE and red rot, caused by *Colletotrichum graminicolum* (Ces.) G. W. Wils., are two phases of a major disease of sorghum in the sirup-producing areas of the southern United States. Shortly after the initiation of a research program to improve sorgo (sweet sorghums) as a source of sugar and sirup, it became apparent that this disease could be a limiting factor in the intensive production of the crop in the Gulf coastal areas. In 1941 investigations on anthracnose and red rot were initiated at the United States Sugar Plant Field Laboratory at Meridian, Miss. This bulletin reports the results of the investigations.

HISTORY OF THE DISEASE

Anthracnose of sorghum was first described in the United States from Texas in 1911 (*10*).[2] Subsequently, reports and descriptions of the disease were made from various points in the United States (*8, p. 160; 18; 19; 26*). The red rot aspects of the disease on sorgo caused by *Colletotrichum graminicolum* were first described by Lohman and Stokes (*16*). They reported severe damage to sorgo in Mississippi. What was apparently the same disease was described a year earlier on broomcorn in Illinois (*11*) where severe damage was reported. Considerable damage to Sudan grass in the South Atlantic States has also been reported (*15*).

[1] Submitted for publication May 1, 1951.
[2] Italic numbers in parentheses refer to Literature Cited, p. 20.

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The disease has been reported from most of the areas of the world in which sorgo is produced (*2, 3, 4, 7, 9, 17, 20, 21, 22, 23, 24, 25, 28, 30*). For the most part these reports refer only to the leaf aspects of the disease. Aside from the reports in the United States, the red rot phase of *C. graminicolum* has been reported from New South Wales (*22*), Java (*29*), and probably Burma (*28*). It is thus seen that the stalk-rot phase of the disease is relatively little known.

DESCRIPTION OF THE DISEASE

There are two aspects of the disease on sorgo: The leaf-spotting phase and the stalk-rotting phase. In their development and injury to the plant the two phases often appear as two separate diseases, and in the literature it is usual to find discussions of one with no mention of the other. Both phases of the disease are caused by the same organism, and their epidemiological relationship makes it desirable that they be treated as one disease. However, for convenience in presentation, the two phases will be described separately.

LEAF ANTHRACNOSE

Infection by *Colletotrichum graminicolum* on the leaves appears as small, circular to elliptical, discolored spots ranging in size from one-sixteenth to one-fourth inch in diameter (fig. 1). The spots are tan, reddish orange, or reddish purple to blackish purple, depending upon the variety. As the spots grow older the center becomes grayish to dark-straw-colored and numerous acervuli with prominent setae appear. Under proper conditions of moisture the fungus

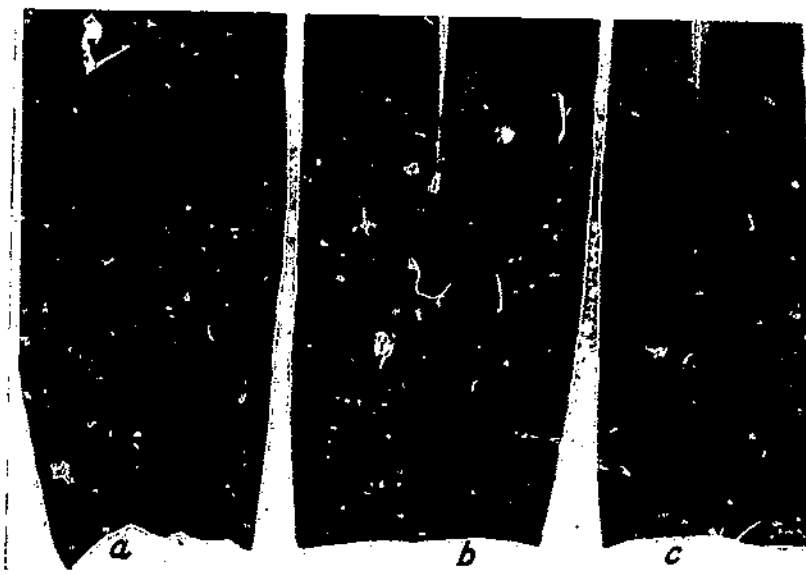

FIGURE 1.—Leaf of (*A*) Collier infected by anthracnose compared with uninfected leaves of (*B*) MN 1034 and (*C*) MN 809 W. S.

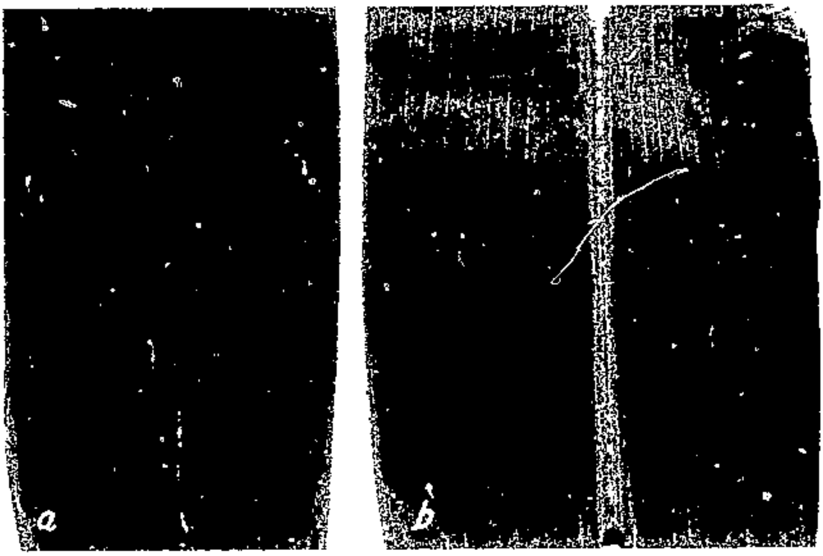

FIGURE 2.—*Colletotrichum graminicolum* on midrib and leaf of sorghum, developing after clipping the ends of the leaves under a spore suspension. *A*, Collier; *B*, MN 1054.

sporulates freely to produce the pinkish spore masses characteristic of anthracnose diseases. Midrib infection commonly occurs as elliptical to elongate discolored areas. These frequently coalesce so that the whole length of the midrib is discolored (fig. 2). The fungus fruits freely on midrib lesions. The discoloration of the midrib also varies with the variety, ranging from tan to reddish orange and from varying shades of reddish purple to almost black. Light tan color reaction in sorgo is governed by factors recessive to the reddish purple color factors (7).

Leaf infection may occur at any stage of plant development, from seedlings in the 3- or 4-leaf stage to mature plants. Under natural conditions the first infection usually appears at midsummer when the plants are 4 to 5 feet tall, and in some cases the earlier maturing varieties may be in the late flowering stage before infection appears. Infection of very young plants, however, readily occurs under natural conditions, as suckers from the stubble of early harvested varieties rapidly become infected at a very early stage. Infection is also readily obtained by artificial inoculation of seedlings in the 4- or 5-leaf stage. Thus the leaf tissues are susceptible from a very early stage until maturity.

Artificial infection of young leaves is readily obtained, and the spots develop first near the distal end of the leaf. The proximal half, as well as the leaf sheath, remains more or less resistant to invasion until the leaves are fully grown, after which these parts may be totally invaded. The very aggressive development of the disease, frequently leading to total leaf destruction, usually begins at the jointing stage. Typically, with the initial infection occurring on the older leaves about mid-July, the disease progresses rapidly on very susceptible varieties, spreading up the plant so that the foliage may be completely involved by flowering time. On less susceptible varieties the point of total leaf destruction may be delayed until the ripe or even postripe stage. All degrees of susceptibility, ranging from the very susceptible class characterized by complete leaf destruction at or before flowering time to the practically immune class in which no definite leaf spotting ever develops, have been observed among the several thousand sorghum selections studied. Midrib infection is likewise obtainable at any stage of plant growth, although, as with the leaf spot, the more aggressive development occurs on older plants. Various degrees of resistance to midrib infection occur, according to variety (fig. 2).

RED ROT

Red rot is primarily a disease of the maturing plant, although infection and limited development of red rot may be obtained at any time after the jointing stage. Early cases of infection by *Colletotrichum graminicolum* show no external symptoms; however, when the stalks are split lengthwise the internal tissues may be seen to be water-soaked and variously discolored. Discoloration type seems to be largely a varietal characteristic and may vary from yellowish tan through reddish orange and from reddish purple to blackish purple. The discolored areas may be solid but are frequently mottled with light-colored to whitish areas. The discoloration may be continuous through the infected internodes or may consist of many apparently isolated spots. On certain varieties the invaded tissues may have a water-soaked translucent appearance, with only an occasional show of color. The last-named symptom is unusual but is especially characteristic of the variety White African. The nodal tissue is rarely discolored, although it may be invaded by the fungus. Young lesions on the more susceptible varieties appear as elliptic pockets or bars immediately beneath the epidermal tissue, especially in the upper internodes of the plant (fig. 3). They have white to light-colored interiors with dark-colored margins. The lightly colored areas are more abundantly invaded with mycelium than the more highly colored areas.

It would appear that, as the fungus invades the plant, the plant is stimulated to produce pigments that limit mycelium development. When very susceptible varieties are invaded it appears that areas 1 cm. or more in diameter may be invaded by the mycelium before the color reaction can set in to limit its development. Thus are developed the lightly colored pockets with an abundance of mycelium, surrounded by highly colored areas practically devoid of mycelium. Once stimulated, the reaction producing the pigment appears to continue at some distance from the point of invasion; large discolored areas practically devoid of mycelium may be found. In many varieties in which the discoloration is uniform instead of mottled, mycelium

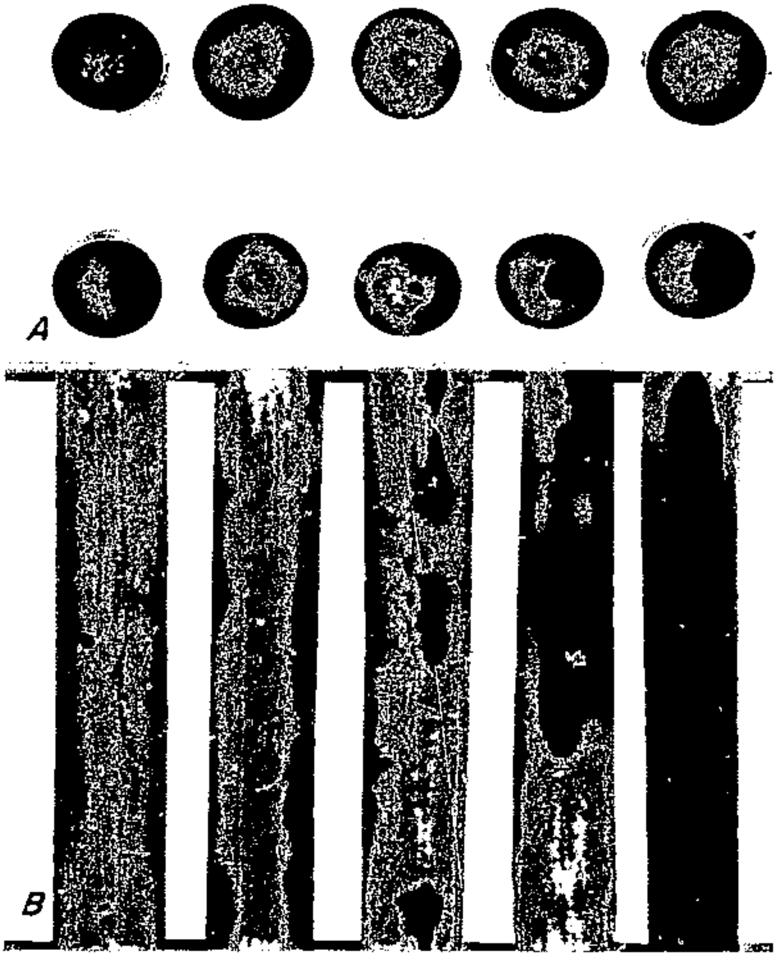

FIGURE 3.—Sections of Hodo stalk showing bars or lesions immediately beneath the epidermal tissue: A, cross section; B, longitudinal section.

is exceedingly difficult to find, although large areas of tissue are involved. It would appear that the tissue of these varieties responds rapidly to infection and thus the invasion is more limited. In such varieties, although discoloration is extensive, tissue damage is less extensive than in others with the mottled appearance.

In the very susceptible varieties the internode tissue dries and shrinks. This is especially marked for the upper internodes and peduncle. The stalks break over readily, usually in the lower third region (fig. 1). Surface lesions are common on very susceptible varieties. These are elliptic to elongate, measuring up to one-fourth inch in length, and by coalescence eventually form large irregular discolorations. In these lesions, acervuli, which sporulate abundantly under favorable conditions, occur in large numbers (fig. 5).

FIGURE 4.—Effects of red rot on Hodo sorgo. Note the severe breaking of stalks in this field of Hodo in the dough stage.

FIGURE 5. Surface lesions of *Colletotrichum graminicolum* on stalks of Hodo sorgo.

THE CAUSAL ORGANISM

Cultural and morphological studies and detailed pathogenicity studies, including cross inoculations, have been made on several hundred isolates of *Colletotrichum* from 19 grass species, mostly sorgo, Johnson grass, Sudan grass, sugarcane, *Erianthus* spp., and broomcorn.

A wide variety of cultural types was found. On malt agar the mycelial mat ranged from a thin felty to a thick, loose cottony growth; occasionally a very loose woolly mat was found. At times aerial mycelium was very scant, with or without numerous pinkish masses of conidia. The color of the aerial growth ranged from almost white through various degrees of gray and greenish black to almost black. Occasionally a pink or orange isolate was found. Pigmentation of the subsurface growth ranged from practically none to typically smoky, but frequently greenish black. Occasionally a yellowish-orange pigmentation was produced. Sectoring, especially patch variation, was common.

Conidia production was extremely variable. Some cultures produced an abundance of conidia, either in pinkish masses under the aerial growth or singly scattered throughout the mycelium. In other cultures conidia were extremely scarce. The conidia were typically falcate with pointed ends, although the degree of curvature and pointedness varied markedly. Comparative measurements of conidia have not been made, but differences in size among isolates were apparent. These differences, however, appeared not to be related to the isolate sources.

A similar range of cultural types was obtained on potato dextrose and oatmeal agars. Growth and sporulation were usually more luxuriant on potato dextrose agar. Pigmentation was usually retarded on oatmeal agar. Examples of the various cultural types are shown in figures 6, 7, and 8.

The wide variation of cultural types was common to all isolate sources from which a sufficient number of isolates were available. It was impossible to identify positively any single isolate with a host source on the basis of cultural characters. On the other hand, given a sufficient number of cultures it was possible to distinguish on a group basis those isolates that originated from sugarcane (fig. 6, *A*) from those that originated from sorgo (fig. 6, *B*), Johnson grass (fig. 7, *A*), Sudan grass (fig. 7, *B*), *Erianthus* spp. (fig. 8, *A*), and broomcorn (fig. 8, *B*). Groups of isolates from hosts other than sugarcane were indistinguishable among themselves. The chief distinguishing character separating the sugarcane group from the other grass groups was the greater homogeneity of the former. Isolates from the other grass species were insufficient in number for extensive group comparisons.

Isolates from sorgo, Johnson grass, Sudan grass, broomcorn, and *Erianthus* spp. were for the most part highly pathogenic to sorgo. Those originating from the other grass hosts were nonpathogenic or only slightly pathogenic (*12*).

Since the discovery of a perfect stage of *Colletotrichum falcatum* Went as *Physalospora tucumanensis* Speg. (*5*), intensive searches for an ascigerous stage of *C. falcatum* and of *C. graminicolum* have been

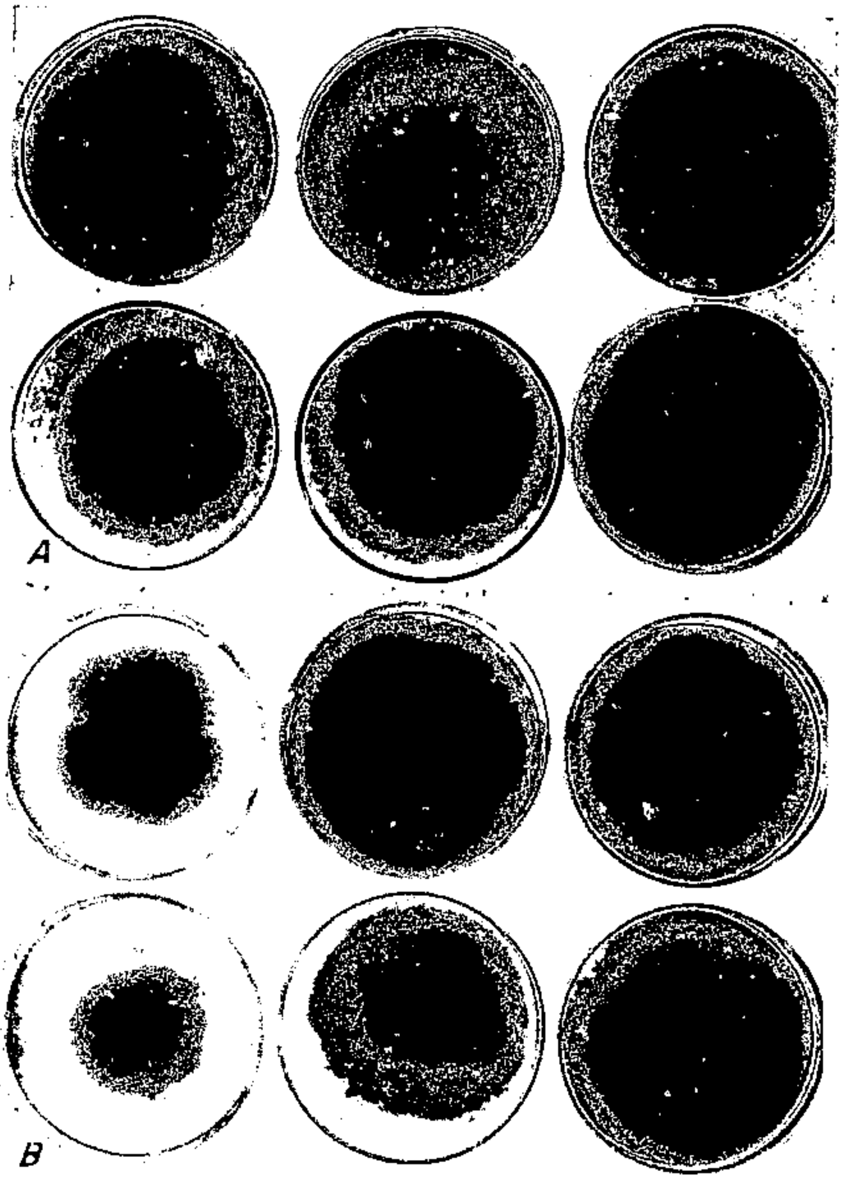

FIGURE 6. Cultural types of *Colletotrichum*: *A*, Isolates from sugarcane; *B*, isolates from sorgo.

made in the vicinity of Meridian, Miss., but with no success. The *P. tucumanensis* stage was obtained for a small percentage of isolates of *C. falcatum* grown on autoclaved sorgo leaves. *C. graminicolum* failed to produce an ascigerous stage under the same conditions.

The results from studies of cultural characteristics and pathogenicity of several hundred isolates of *Colletotrichum*, although insuffi-

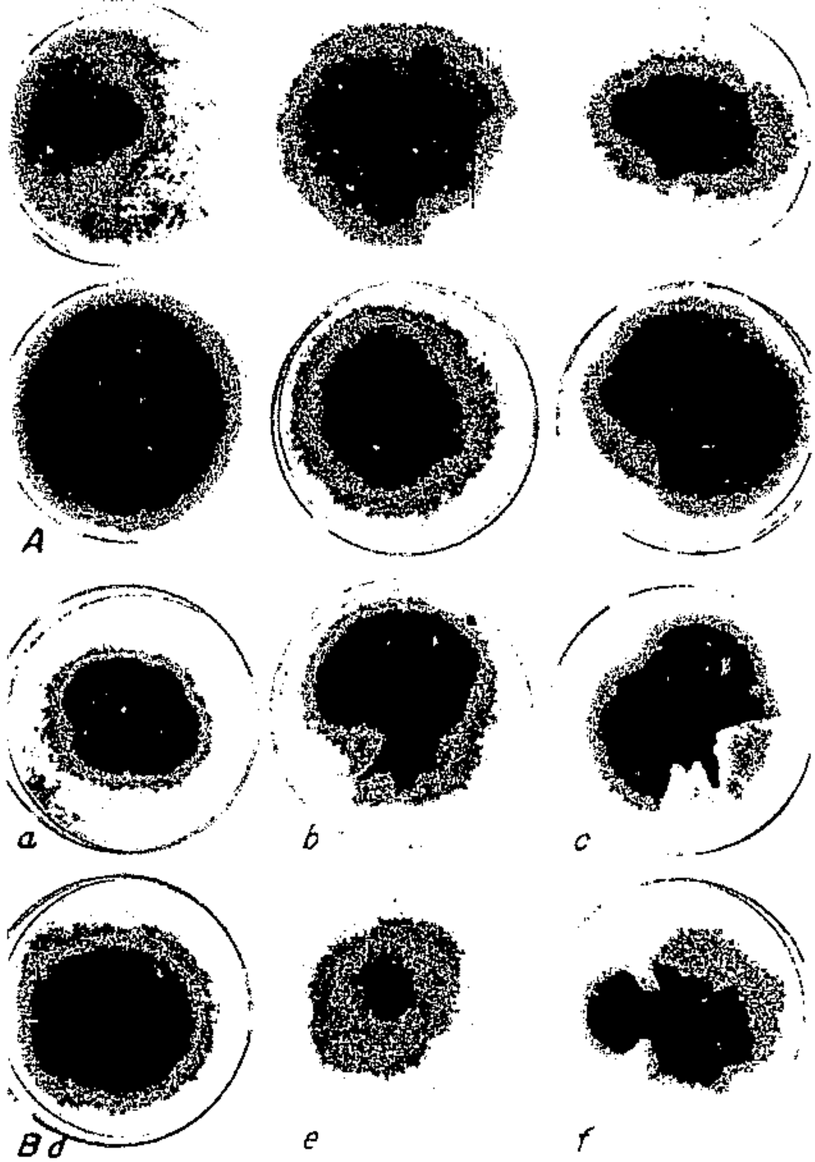

FIGURE 7.—Cultural types of *Colletotrichum*. *A*, All isolates from Johnson grass; *B*, isolates *a*, *b*, *c*, *d*, and *e* from Sudan grass, and isolate *f* from *Echinochloa* sp.

cient for a critical taxonomic disposition of the fungi involved, strongly indicate that *C. graminicolum*, as presently constituted to include the many forms of *Colletotrichum* on grasses formerly referred to as *C. lineola* Corda and *C. cereale* Manns (*31*), consists of more than one pathogenic race. Isolates from sorgo, Johnson grass, Sudan grass, broomcorn, and *Erianthus* appear to form one or more

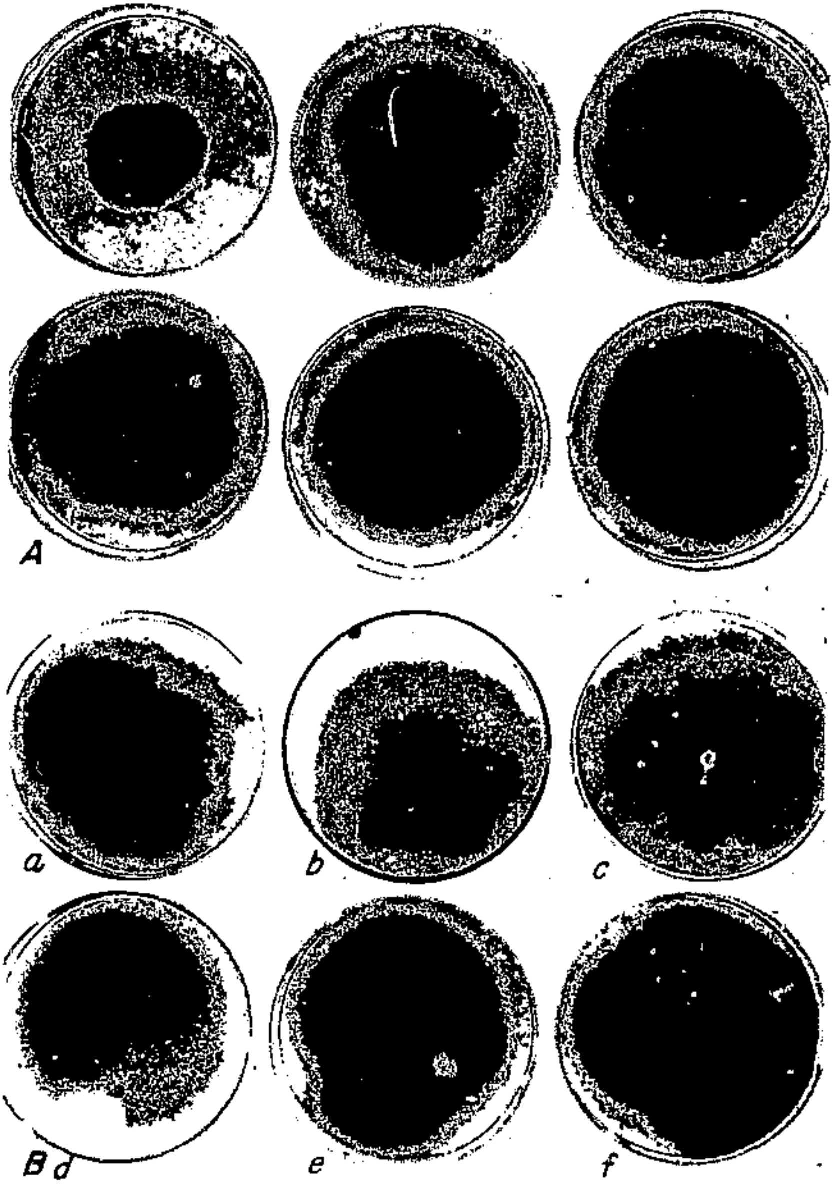

FIGURE 8.—Cultural types in *Colletotrichum*: *A*, All isolates from *Erianthus* spp.; *B*, isolates *a* and *d* from broomcorn, isolates *b* and *c* from Johnson grass, and isolates *e* and *f* from Kentucky bluegrass.

races with high pathogenicity to sorgo as a common character, whereas those from 11 other grass species appear to belong to one or more other races that are nonpathogenic to sorgo.

Observations by other investigators in keeping with those of the writers strongly support this idea of strain difference in *C. graminicolum*. In India (*7, 9*) a destructive disease of corn has been reported to be caused by *C. graminicolum*. Bruehl and Dickson (*3*) found that anthracnose of cereals and grasses was produced only by isolates of *C. graminicolum* from the same or closely related species. Important losses to oats and other small grains have also been reported. The Indian workers report that the fungus involved in the corn disease also infected sorghum, oats, and rye, in addition to several other grass species. In limited trials the isolates from sorgo used in the present study did not infect oats, rye, or corn.

LIFE HISTORY OF *COLLETOTRICHUM GRAMINICOLUM* IN RELATION TO PATHOGENICITY

Colletotrichum graminicolum probably lives over from season to season in trash from the previous crop or susceptible weeds. Sporulation of the fungus has been observed on sorgo stalks and stubbles after overwintering in the field. When ground up in a hammer mill and spread in experimental plots, infected plant material, shocked in the field through the winter, has been found highly effective in establishing epidemics of anthracnose in our disease nurseries. Severe epidemics usually follow this practice within a few weeks, if weather conditions are favorable. Weed hosts (principally Johnson grass) of *C. graminicolum* may also serve as a means of overwintering. That this may occur was strongly indicated by experience with a planting in 1948 in which a severe epidemic of anthracnose developed on land that had no history of sorgo culture in recent years. *C. graminicolum* has been found on sorgo seed; thus, infected seed may serve as a source of inoculum (*6, 17*).

Infection from trash or other sources of inoculum first occurs on the more mature leaves, and under proper conditions it spreads rapidly from them to other leaves. Infection commonly occurs through uninjured tissue. Fruiting bodies appeared within 8 to 10 days after infection.

As the plants approach maturity stalk infection becomes apparent on the more susceptible varieties. The stalk lesions are more prevalent on the peduncle and internodes of the upper half of the plant. Red rot develops by the extension of the cortical lesions to involve the inner stalk tissue. In many varieties cortical lesions are rare or absent. In such varieties the infection apparently occurs by penetration through the cortex near the base of the internodes without forming surface lesions. Red rot developing from such infection is usually restricted to the more pithy portions of the stalk. The more juicy cortical and subcortical layers are rarely involved. This type of red rot causes relatively little damage. It is frequently very difficult to find mycelium by microscopic examination, and isolation of the fungus by tissue plating is difficult. Success in isolating the fungus is more readily obtained by plating the uncolored tissues on the border of the discolored area at the base of the internode.

The spread of red rot up and down the stalk from the point of infection has been studied by artificial inoculation. In very susceptible varieties red rot may spread into five or more internodes from a single point of inoculation. The spread is in both directions, mostly upward. In more resistant varieties the invasion may be limited to fewer internodes; occasionally in highly resistant material it may be limited to the inoculated internodes.

LOSSES CAUSED BY THE DISEASE

One of the principal forms of damage caused by *Colletotrichum graminicolum* is the reduction of sugar solids that accompanies early leaf destruction. The measure of this loss has been difficult because of the problem of maintaining disease-free controls for comparison with infected material. Over a period of several years, however, general observation indicates that this loss may be considerable. Varieties such as Collier, Rex, and C. P. Special commonly yield juice with solids reaching 20° Brix or more in seasons free or practically free of disease, while under conditions of severe leaf destruction Brix readings of 12° to 14°, and in many cases 10° or less, are the rule. That these observations are substantially correct was brought out by juice-quality determinations on material with varying amounts of leaf destruction from replicated plots in 1947 and 1949.

In the 1947 test replicated plots of Rex and Collier, separated by untreated buffers, were inoculated at different intervals so that various degrees of defoliation were obtained. Although the uninoculated controls became infected and suffered severe leaf destruction, a differential with respect to earliness of leaf destruction was maintained between the controls and inoculated plots. Results of this test are shown in table 1.

TABLE 1.—*Effects of inoculation by C. graminicolum on leaf damage and on juice quality of Collier and Rex sorgo in 1947*

Variety and inoculation date[1]	Foliage damage on			Juice quality on August 27			Red rot index[2]
	July 31	Aug. 15	Aug. 27	Brix	Sucrose	Apparent purity	
Collier:	*Percent*	*Percent*	*Percent*	*Degrees*	*Percent*		
Check	10	38	100	15.9	11.1	72	6.0
June 19	69	81	100	12.9	8.1	63	8.0
July 1	65	86	100	11.6	7.7	67	11.0
July 11	35	81	100	13.0	9.2	69	8.0
July 18	38	62	100	13.1	9.2	70	7.0
July 28	20	63	100	13.8	10.0	72	9.0
August 6	10	60	100	15.6	11.7	71	10.0
Rex:							
Check	0	28	70	15.1	11.2	73	1.6
July 1	55	79	100	9.8	5.3	51	1.6
July 11	60	79	100	10.9	7.2	59	3.6
July 18	10	60	100	14.4	10.7	75	3.1
July 28	5	45	80	16.6	11.6	71	7.8

[1] Leaf-whorl inoculations were made June 19 and July 1, 11, and 18. Inoculations on July 28 and August 6 were made in the stalk. (See section on varietal reaction, p. 11.)

[2] See section on varietal reaction, p. 11.

In the 1949 test 15 plots of Collier sorgo were planted in a cornfield on newly cleared land so that the plots were separated by about 100 feet. This degree of isolation proved sufficient to prevent excessive infection of control plots. Five plots were inoculated in the leaf whorl with a hypodermic needle during the last week of June; 5 plots were inoculated by spreading infected sorgo trash about the plots during the first week of July; the remaining 5 plots were not inoculated. On July 20 leaf-infection data were recorded for each plot. On August 10, when the plants were in the dough stage, samples were taken for juice analyses. Table 2 gives the data on leaf destruction and juice quality for the 3 treatments.

TABLE 2.—*Effect of inoculation by C. graminicolum on leaf damage and on juice quality of Collier sorgo in 1949*

Treatment	Leaf damage on—		Juice quality on Aug. 10		
	July 20	Aug. 10	Brix	Sucrose	Apparent purity
	Percent	*Percent*	*Degrees*	*Percent*	
Needle-inoculated	90	100	11.7	6.6	56
Trash-inoculated	(1)	45	18.2	13.8	76
Not inoculated	0	(1)	18.2	13.8	76

[1] Trace.

The depressing effects of early defoliation on solids, as determined by Brix hydrometer readings, sucrose content, and purity of the juice, are strikingly brought out by comparing the needle-inoculated plots with the control plots. Although an appreciable amount of infection developed in the trash-inoculated plots, it came so late in the development of the plants that little or no effect on juice quality was noted. This effect of time of defoliation on juice quality is well illustrated in table 1. The very close parallel between the defoliation data of approximately one month before harvest and the values for total solids, sucrose, and purity at harvest in this test is rather striking, even though by harvesttime (August 27) nearly all plots were 100 percent defoliated and total solids and sucrose were, in general, low. It is thus seen that for the maximum damage severe defoliation must occur about 4 weeks before maturity, as progressively later defoliation has correspondingly less effect on juice quality.

In the 1947 test invert sugar determinations were made on the check plots and on plots that had received the earliest inoculation treatment. The percentages of invert sugars in solids, for controls and for inoculated plants, were 10.2 and 19.0, respectively, for Collier and 7.5 and 28.1 for Rex. It is thus seen that premature leaf destruction resulted not only in a lower percentage of total solids but in a lowering of the purity because of an increase in invert sugars in the defoliated plants. Thus, defoliation caused by *Colletotrichum graminicolum* may be important in sorgo production for sirup, because reduction of total solids reduces the yield of sirup per ton of stalks. With respect to sugar production, not only was the total content of solids reduced, but recoverable sucrose was further reduced because of lowered purity.

No direct information has been obtained on the effects of red rot on juice quality. It is apparent, however, from frequent observations and from the limited data in table 1, that up to the ripe stage a considerable amount of red rot may occur without greatly affecting the total solids and purity of the juice. General observation, however, indicates that when sorgo is kept beyond the ripe stage the normal loss in total solids and purity may be aggravated by severe red rot. From the standpoint of sirup production, red rot may be of considerable importance. Badly damaged sorgo yields a sirup of inferior quality because of the difficulty of obtaining proper clarification. Such sirup usually is dark red.

Aside from the losses suffered as a result of reductions in total solids (Brix) and purity of the juice and lowered quality of sirup, breakage of stalks from severe red rot damage renders harvest operations difficult or practically impossible. Losses in sirup production due to red rot may be avoided to a great extent, for many varieties at least, by harvesting in the early-dough stage. Certain popular sirup varieties (Hodo and Honey), however, may suffer considerably even if harvested early.

VARIETAL REACTION TO ANTHRACNOSE AND RED ROT

Approximately 50 named varieties of sorgo, several unnamed domestic varieties of sorgo, several grain sorghum varieties, several broomcorn varieties, and several hundred sorghum introductions from Africa and India have been rated for their response to both leaf anthracnose and red rot. In many cases these ratings have been based on inoculated and uninoculated plants. Inoculation to study leaf anthracnose reaction was accomplished by introducing a spore suspension of *Colletotrichum graminicolum* into the leaf whorl with a hypodermic needle. The plants were usually inoculated when about 3 feet tall. Stalk inoculation was made at heading to flowering time by introducing a spore suspension into approximately the median internode (*13*).

The readings on leaf infection were made on a scale of 0 to 4. For the early reading: 0 equals no effect from inoculation; 1, numerous small pin-point necrotic spots on inoculated leaves; 2, necrotic spots larger than 1 mm. (up to 2) in diameter; 3, definite leaf spots up to 5 mm. with sporulation; and 4, the same as 3 but with more extensive necrosis, coalescence of spots, and leaf destruction. For the harvesting reading, 0 to 4 represent different degrees of leaf destruction, an insignificant amount equaling 0 and total leaf destruction equaling 4. Intermediate degrees of leaf destruction were represented by 1, 2, and 3.

Red rot readings were made on stalks split longitudinally at the ripe stage. Each affected internode up to 6 (the most severely affected ones were considered when there were more than 6) was given a rating of 0 to 3, with 0 indicating no red rot, 3 indicating 90 percent or more of the internode rotted, and 1 and 2 indicating intermediate degrees of red rot. From these figures on individual internodes for 5 to 10 plants for each plot or variety, a red rot index was developed by adding all the ratings and dividing by the number of stalks. The average number of infected internodes per stalk was also recorded as part of the red rot rating. With these two figures given, one can, by inspection, determine the average severity of the rot per internode.

Data on 38 sweet sorghum (sorgo) varieties, 5 unnamed juicy selections, 5 grain sorghums, and 3 broomcorn varieties are given in table 3.

TABLE 3.—*Reaction of sorghum varieties to anthracnose and red rot*

Variety	Anthracnose rating		Red rot rating			
			Not inoculated		Inoculated	
	3 weeks after inoculation	At harvest	Red rot index	Average number internodes per stalk [1]	Red rot index	Average number internodes per stalk [1]
Albaugh	2	4	16	6.0		
Ames Amber	2	4	9	4.4		
Atlas	2	1	0	0	5.0	2.0
Chinese Amber	4	4	12	4.6		
Clubhead	4	4	14	5.4		
Colman (M)	3	4	1	.8	7.4	3.3
Cowper	3	4	5	2.4		
Early Folger 9097	1	4	6	2.8		
Early Folger 16154	2	4	7	3.0		
Early Sumac	3	4	7	3.3		
Gooseneck	2	4	10	4.4		
Honey	3	4	18	6.0		
Honey Drip	3	4	14	5.2		
Indiana Amber	3	4	13	5.6		
Jones	4	4	18	6.0		
Kansas Orange	4	4	16	6.0		
Leoti	4	4	2	1.0	11.2	5.0
Mazo Amber	4	4	10	3.6		
McLean	3	4	0	0	16.0	6.0
Minnesota Amber	4	4	18	5.8		
Orange	4	4	16	6.0		
Planter	1	0	0	0	2.0	1.0
Rex	4	4	8	6.0	13.0	5.0
Red Amber	3	4	18	6.0		
Rox Orange	4	4	18	6.0		
Saccaline	4	4	18	6.0		
Sugar Drip	4	4	16	6.0		
Sourless	4	4	18	6.0		
Straightneck	4	4	11	5.3		
Silver Top	3	4	15	5.8		
Sumac	3	4	7	4.2		
Texas Seeded Ribbon	3	4	15	5.6		
Waconia Amber	4	4	18	6.0		
White African	3	4	9	4.8		
S. A. 107	3	3	2	2	4.4	2.0
S. A. 108	3	3	2	1.6	5.4	2.6
S. A. 119 9	2	4	1	.8	4.6	2.2
S. A. 173	3	4	0	0	5.4	2.6
S. A. 169	4	4	18	6.0		
Collier	4	4	14	5.4		
Colman (Y)	3	4	14	5.6		
Georgia Blue Ribbon	2	4	17	6.0		
Hodo	2	4	18	6.0		
Iceberg	3	4	18	6.0		
C. P. Special	4	4	18	6.0		
Norkan	4	4	13	5.0		
Club Kafir	2		0	0	2.5	1.2
Early Kalo	2	4	3	2.0		
Hegari	1	1	1	.8	4.8	2.3
Pink Kafir	1	1	6	2.6		
Western Blackhull Kafir	1	1	0	0	3.2	1.2

[1] Showing red rot.

The final readings on anthracnose show that only Atlas and Planter of the sweet sorghum varieties (sirup or sugar types) had any strong degree of resistance to the leaf phase of the disease; however, difference among varieties was in evidence in the rapidity with which severe leaf destruction developed. These differences are reflected in a comparison of the earlier readings. Of the grain-type sorghums listed, Early Kalo was the only susceptible variety. All of the broomcorn varieties were highly susceptible.

Much greater variation occurred with respect to red rot infection. For the most part, ratings were obtained for both inoculated and uninoculated plants except where red rot was very severe in uninoculated plants. Although many of these varieties were highly susceptible, 10 of the sweet types, including the unnamed selections, were highly resistant to red rot from natural infection. Six of these likewise limited spread of red rot to a considerable degree after inoculation. Two varieties, Leoti and McLean, were striking in their strong resist-

TABLE 4.—*Reactions of select sorghum importations and 4 domestic varieties to anthracnose and red rot*

Selection number or variety	Leaf anthracnose ratings [1]	Red rot rating [1]			
		Not inoculated		Inoculated	
		Red rot index	Average number internodes per stalk [2]	Red rot index	Average number internodes per stalk [2]
1551	0	0	0	5	2.0
1646	0	.1	.1	1	1.8
1034 [3]	0	3.0	2.8	6	2.8
1060	.5	1.0	1.0	3	1.6
1059	.5	6.0	2.6	6	2.6
1277	.7	0	0	7	3.5
1049	1.0	0	0	3	1.0
1057	1.0	2.0	1.2	6	2.6
2467	1.0	7.0	1.2	15	6.0
2795	1.0	12.0	5.5	17	5.8
2794	1.3	16.0	6.0		
1399	1.7	0	0	11	1.8
1053	2.0	0	0	5	2.0
1809	2.0	2.0	1.2	10	1.5
1541	3.0	11.0	5.1	18	6.0
1029	3.7	8.0	3.9	8	3.2
1194	1.0	0	0		
1756	1.0	17.0	5.7	18	6.0
White African	3.7	6.0	3.8	15	5.8
Rex	1.0	10.0	1.6		-
Collier	1.0	14.0	6.0		--
Hodo	1.0	17.0	6.8		--

[1] 3-year averages in most cases.
[2] Showing red rot.
[3] Since this bulletin was prepared, MN 1034 has been released under the name "Sart."

ance to natural infection and their high degree of susceptibility when inoculated. The variety Planter was outstanding in its resistance to red rot under both conditions. The grain sorghums were little affected by red rot under both conditions of testing. Natural infection was sufficient to cause severe damage to the three broomcorn varieties.

There seems to be no consistent relation between reaction to anthracnose and stalk rot, and also between stalk rot following inoculation and stalk rot from natural infection. Abbott (*1*) found that, with sugarcane, susceptibility and resistance to leaf infection (principally midrib) were not related to these characters of the stalk. The lack of relationship in reaction to different aspects of the disease is more strikingly brought out by a consideration of the results for the African and Indian importations. More than a thousand introductions have been studied, with 2 to 3 years of data being available for many of them. Data for a few of the introductions are given in table 4 to illustrate the range of behavior of this material.

The data on domestic varieties and imported collections of sorghum suggest that characters are available to obtain resistance to every aspect of the anthracnose and red rot disease.

In a study involving three African selections (MN 778, MN 822, and MN 960) and two domestic varieties (Collier and Leoti) resistance of the near-immunity type (figs. 9, 10, and 11) to leaf infection was determined by a single factor dominant over susceptibility (*14*). This resistance, therefore, should be readily recovered in crosses involving susceptible and resistant individuals. No information is available on the inheritance of the intermediate types of resistance.

FIGURE 9.—Reaction of different varieties and their F_1's on anthracnose development after needle inoculation in the leaf whorl: *A*, MN 778; *B*, F_1 (MN 778 × MN 822); and *C*, MN 822.

FIGURE 10.—Reaction of different varieties and their F_1's on anthracnose development after needle inoculation in the leaf whorl: *A*, Collier (MN 451); *B*, F_1 (Collier × MN 960); and *C*, MN 960.

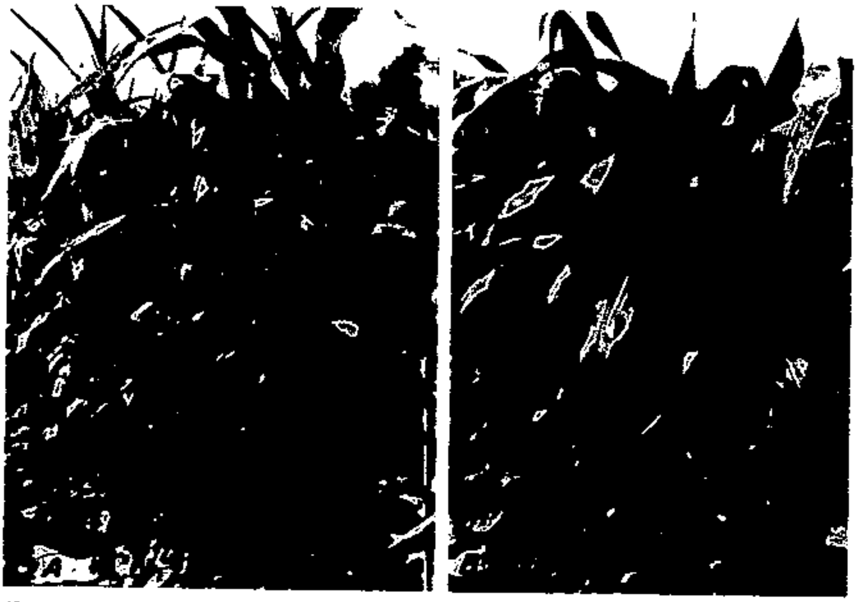

FIGURE 11.—Effects of artificial inoculation with *Colletotrichum graminicolum* on (*A*) susceptible Collier and (*B*) resistant MN 1034.

The inheritance of resistance to red rot is apparently more complex. So far, no plant has been found that is completely resistant to red rot when artificially inoculated, although certain varieties have a sufficient degree of resistance to be of much practical value if this resistance could be incorporated with other desirable characters. Many varieties and selections have been found that are capable of escaping natural infection and subsequent red rot development. This character, however, appears to be relatively unstable and dependent upon such factors as temperature in relation to maturity date and the inoculum potential from the time of heading to maturity. In 1949 the maturity of most varieties was from 2 to 3 weeks earlier than usual. Some normally late-maturing varieties that usually escaped red rot to a large extent had more red rot in 1949 than in previous years. From a practical standpoint it is highly probable that many of the varieties with intermediate reaction to red rot would remain relatively undamaged by the disease if leaf resistance were introduced in these varieties. A fairly high inoculum potential is required to cause very much damage from red rot in moderately resistant varieties. The inoculum potential, in a field where there is only a small amount of leaf anthracnose, would probably be so low as to allow a moderately susceptible variety to escape severe damage from red rot.

CONTROL

The use of resistant varieties offers the best means of reducing losses from anthracnose and red rot. Clean cultural practices to keep out susceptible weeds and preferably rotation to avoid residues of infected sorghum and weeds should reduce the inoculum potential and prevent the severe early infections that bring out important losses. Treatment of seed to control seed-borne inoculum would also be advisable. Loss from red rot in sorgo grown for sirup may be largely prevented by early harvesting. It has been shown that sorgo can be harvested in the early-dough stage with no appreciable loss in yield or quality of sirup (*27*). Harvesting the more tolerant varieties at this stage almost eliminates loss from red rot. This approach to control with the extremely susceptible varieties may not always be successful. If it is apparent that red rot is becoming severe, a field may be harvested even earlier. Although this early harvest may result in lower yields of sirup per ton of stalks, such a course usually prevents a greater loss resulting from the lower crop yield and the poor quality of sirup if harvest is delayed until a more mature stage.

SUMMARY

Anthracnose and red rot of sorgo are phases of the most important disease affecting this crop over a large part of the area of sorgo production.

Leaf spot (anthracnose), which frequently results in complete leaf destruction, and stalk rot (red rot), characterized by various patterns of discoloration but almost always with some hue of red, are characteristic phases of the disease.

The leaves may be infected at any stage of growth, but are more aggressively attacked when full-grown. Red rot affects primarily the mature stalks. A reduction in percentage of total sugars, an increase in invert sugars, and lodging are the most important forms of damage caused by the disease.

The disease is caused by a race of *Colletotrichum graminicolum* (Ces.) G. W. Wils. that has been shown to be pathogenic to sorgo,

grain sorghum, broomcorn, Sudan grass, Johnson grass, and *Erianthus* spp.

The fungus lives over on field residues of susceptible crops and weeds and on the seed.

Resistance to anthracnose and red rot is rare among domestic sorgo varieties but more common in grain sorghums. Broomcorn is especially susceptible. A high degree of resistance to leaf anthracnose has been found quite common among sorghums introduced from Africa. In crosses, the resistance of certain of the African introductions has been shown to be inherited as a single factor dominant over susceptibility. Resistance to red rot has been found in varying degrees, and it appears to be less fixed than that for leaf anthracnose. Resistance to stalk rot is of two types—resistance to infection and resistance to spread after infection.

Resistant varieties offer the most effective means of control. In the absence of resistance, clean culture, crop rotation, and seed treatment should reduce the probability of occurrence of severe damage. Red rot losses can be largely avoided if moderately susceptible varieties are harvested in the early-dough stage.

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